Description of three Ecopath with Ecosim ecosystem models developed for the Bay of Fundy, Western Scotian Shelf and NAFO Division 4X

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ABSTRACT

The work described in this report is part of the Maritimes Region Ecosystem Research Initiative (ERI), a national program to enhance scientific research that was designed to contribute to progress on the ecosystem-based management (EBM) in Canada. This report documents the input data, and the development and balancing of three detailed mass balance trophic models (using the Ecopath with Ecosim (EwE) software) to represent the Bay of Fundy, western Scotian Shelf and the total area encompassing the first two systems, the 4X area, in the late 1990s (1995-2000).

RÉSUMÉ

Le travail décrit dans le présent rapport a été accompli dans le cadre des Initiatives de recherche sur les écosystèmes (IRE) de la Région des Maritimes. Il s’agit d’un programme national visant à améliorer la recherche scientifique et conçu pour favoriser la progression de la gestion écosystémique au Canada. Ce rapport présente des données d’entrée et traite de l’établissement et de l’équilibrage – à l’aide du logiciel Ecopath with Ecosim (EwE) – de 3 modèles détaillés de bilan massique sur les relations trophiques pour représenter la baie de Fundy, la partie occidentale du plateau néo-écossais ainsi que l’ensemble de la région englobant les 2 premiers systèmes (la zone 4X) à la fin des années 1990 (de 1995 à 2000).

INTRODUCTION

The work described in this report is part of the Maritimes Region Ecosystem Research Initiative (ERI), a national program to enhance scientific research that was designed to contribute to progress on the ecosystem-based management (EBM) in Canada. EBM requires knowledge about the structure and functioning of ecosystems and their sensitivity to human activities. Ecosystem models play an important role in EBM and the interest in the development of such models is not new. The multispecies model of Andersen and Ursin (1977) is an example of a relatively early attempt to approach fisheries in an ecosystem context. These types of models allow for the use of very different sources of information and for dealing with the many aspects of an ecosystem in a unified framework (Christensen et al. 2005). Ecosystem models can be used as a tool 1) to provide a framework to identify potential changes in complex systems that cannot be identified with single-species models, such as counterintuitive changes in abundance when species interactions outweigh the effects of fishing impact or climate change, 2) to emphasize the need to improve knowledge about specific parts of the system, 3) to "test" the compatibility of data sets and 4) to serve as a useful basis for the exploration of scientific hypothesis about system structure, dynamics and functioning (Walters and Martel 2004; Bundy and Fanning 2005; Araújo et al. 2006). The Ecopath with Ecosim (EwE) software (Christensen et al. 2005) is currently the most used and tested ecosystem modelling tool for addressing ecosystem-level responses to changes in fishing harvest strategies and to the influences of climate (Christensen and Walters 2005; Plagányi and Butterworth 2004) and is the tool used herein.

Ecopath with Ecosim models have been developed for many of the shelf ecosystems in the NW Atlantic (e.g., Bundy 2001, 2004, Link et al. 2008), but there are no models for the Canadian waters of the Gulf of Maine Area, that is NAFO Divisions 4X/5Yb (Figure 1). Here for the first time, three trophic models were built using the Ecopath with Ecosim (EwE) software to represent the Bay of Fundy, western Scotian Shelf and the total area encompassing the first two systems, the 4X area (Figure 1), in the late 1990s (1995–2000). The objective of this report is to describe the EwE software and document the data sources, data modifications and assumptions made during parameterisation of the models.

THE BAY OF FUNDY AND WESTERN SCOTIAN SHELF ECOSYSTEMS

The Bay of Fundy and western Scotian Shelf (Figure 1) are located within the Northwest Atlantic Fisheries Organization (NAFO) Divisions 4X and 5Yb. In single species stock assessments (e.g, cod and haddock), they are usually treated as one ecosystem but in fact their dynamics are quite different. The western Scotian Shelf is a wide continental shelf area influenced by currents from Labrador and the Gulf of St. Lawrence and is considered part of the Scotian Shelf Large Marine Ecosystem (LME). This LME is limited in the north by the Laurentian Channel in the south by the Fundian Channel and has a complex topography consisting of shallow banks and basins (Sherman and Hempel 2008 and references therein). The western part of this LME is characterized by warmer waters compared to the eastern part (Zwanenburg et al. 2002). It has a similar demersal fish fauna (Mahon and Smith 1989, Shackell and Frank 2003, Zwanenburg et al. 2002), but higher growth rates and productivity than the east (Frank et al. 2006). The main characteristic of the Bay of Fundy is the magnitude of its tides, which generate intense vertical mixing caused by bottom turbulence and generate high levels of marine productivity and is considered part of the Northeast U.S. Large Marine Ecosystem (LME) (Sherman and Hempel 2008 and references therein).

The boundaries used in this study to define the western Scotian Shelf and Bay of Fundy were based on DFO summer research survey strata and thus do not exactly reflect the boundaries as described above. The western Scotian Shelf is defined here by an area of about 43,645 km^2 that includes NAFO Divisions 4Xmnop and DFO summer research survey strata 470 to 483 (Fig. 1). The Bay of Fundy is defined by an area of about 29,935 km^2 that includes NAFO Divisions 4Xqrs/5Yb and DFO summer research survey strata 484 to 495. The maximum depth of the offshore boundary of the modelled areas is 500 m; the inshore boundary reaches to 10 m.

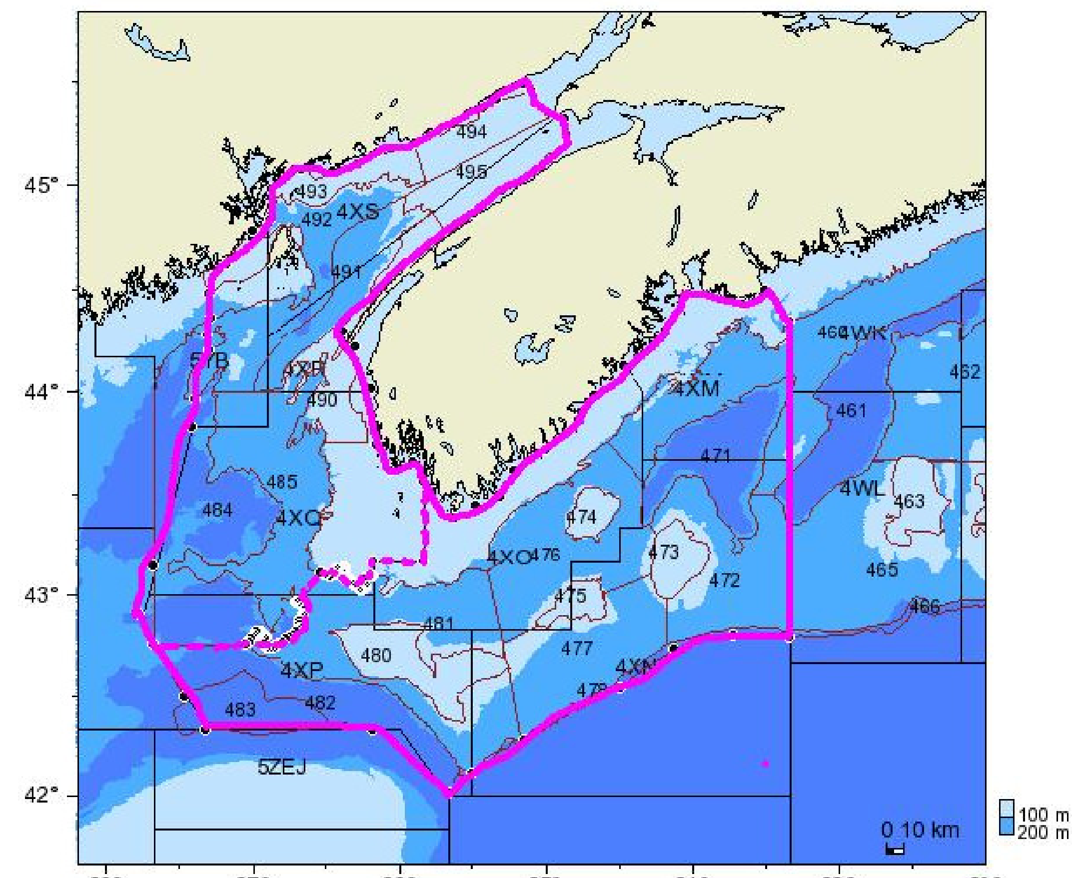

Figure 1. Map of the western Scotian Shelf and Bay of Fundy. Pink lines mark the limits of the model area (4X/5Yb); the dashed pink splits this area into the BoF and WSS; black lines show the limits of the NAFO Subdivisions and red lines the DFO summer survey strata. Note that NAFO Divisions 4Qq and 4Xp are shared by the western Scotian Shelf and Bay of Fundy.

METHODS

MODELLING FRAMEWORK

Ecopath with Ecosim (EwE) is a modelling framework (Christensen et al. 2005) representing the whole biological ecosystem, from phytoplankton to top predators. It is built on assumptions of mass balance and a system of linear equations describing the average flows of mass and energy between the functional groups. Functional groups can represent a group of similar species, single species or they can be split into stanzas representing different life-stages. In the Ecopath module, a base-model for the system is parameterized for a specific period of time (a snapshot). Ecosim is the time-dynamic module of the framework that uses parameters from the Ecopath base model as starting point for the dynamic simulations. A description of the two modules is given below.

The "mass balance" term in EwE means that the model parameters are under the physical constraint that the total flow of mass into a functional group must equal the total flow out of that group. Each functional group is represented by two master equations representing the energy flow between functional groups and the energy balance within functional groups. For species represented by aggregated biomass pools, i.e., with no size/age structure representation, the flow to and from each functional is described by the first Ecopath master equation:

$$P_i = Y_i + B_i \cdot M2_i + E_i + BA_i + P_i \cdot (1 - EE_i) \qquad \text{Eq. 1.}$$

where P_i is the total production; Y_i is the total fishery catch; B_i the biomass; $M2_i$ is the predation mortality rate; E_i the net migration rate (emigration - immigration), BA_i is the biomass accumulation rate and EE_i is the "ecotrophic efficiency" of *i,* with $P_i \cdot (1\text{-}EE_i)$ being the other (non-predation) natural mortality term. Ecotrophic efficiency is the proportion of the production that is accounted for by fishing, predation, immigration and population growth. It is estimated as:

$$EE_i = \frac{Y_i + B_i \cdot M2_i + E_i + BA_i}{P_i} \qquad \text{Eq. 2.}$$

The Ecopath master equation can be expressed as:

$$B_i \cdot (P/B)_i - (P/B)_i \cdot B_i \cdot (1 - EE_i) - Y_i - E_i - BA_i - \sum_{j=1}^{n} B_j \cdot (Q/B)_j \cdot DC_{ji} = 0 \qquad \text{Eq. 3.}$$

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

In the second master equation of Ecopath, the energy balance within each species or group is ensured using the equation:

$$Q_i = P_i + R_i + Q_i \cdot GS_i \qquad \text{Eq. 4.}$$

where R_i and GS_i are the respiration and the proportion of food that is not assimilated and the other parameters are defined above.

In most cases, at least three of the four basic parameters, namely *B, P/B, Q/B* and *EE* are required for the model parameterization. The fourth is then estimated by Ecopath. If all four basic parameters are entered, Ecopath then estimates either the *BA* or *E*. Besides the three basic parameters, the user needs to provide, when appropriate, estimates of *Y*, *E* (default is zero), BA_i (default is zero), *DC* and the GS_i (default is 0.2).

Ecopath can be used to estimate *B* or *P/B*, when an estimated value of *EE* for a group is entered. However, the user should ideally enter estimates for the first two parameters and let the program estimate *EE,* since it is difficult to measure, and provides a diagnostic for the model (see below). In cases where one of the other parameters is missing, an estimate for *EE* is entered based on assumptions about the level of predation and/or fishing mortality on a functional group. For example, in an exploited system, small pelagic fish generally are either eaten or fished and just a small proportion die of another causes. So, species that are heavily consumed or exploited will have *EE* values close to one (0.90-0.99), whereas top predators such as sharks and marine mammals will have much lower values. If *Q/B* for a group is missing, it can be estimated if estimates for the gross food conversion efficiency, *P/Q*, and *P/B* are provided.

As noted above, the EwE model also allows the user to represent fully age/size-structured functional groups, to represent ontogenetic changes in diet and changes in vulnerability to predation and fishing. In these cases, the user must enter the estimates of total mortality (*Z*), *B*, *Q/B* and *BA* for one stage, the leading stanza, and *Z* for the additional ones. In addition, estimates for the growth parameter *K* of the von Bertalanffy growth function, the starting age in months of each stage and the ratio between the average weight at maturity and the asymptotic weight must be entered. The *B* of the other stage(s) is then estimated by Ecopath. Based on these input parameters, the EwE multi-stanza routine caculates biomass and *Q/B* of the other stanzas, based on the following assumptions (Christensen et al. 2005):

- “body growth for the species as a whole follows a von Bertalanffy growth curve with weight proportional to length-cubed;
- the species population as a whole has had relatively stable mortality and relative recruitment rate for at least a few years, and so has reached a stable age-size distribution;
- *Q/B* estimates for non-leading stanzas are estimated based on the assumption that feeding rates vary with age as the 2/3 power of body weight (a “hidden” assumption in the von Bertalanffy growth model)”.

Under the stable age distribution assumption, the relative numbers at age are given by:

$$N_{t+1} = N_t \cdot \exp(-Z - BA / B) \qquad \text{Eq. 5.}$$

where exp(-Z-BA/B) is the population growth rate-corrected survivorship and t age in months; and N = 1 for t = 0.

The relative biomass or any stanza s (b_s) is given by:

$$b_s = \frac{\sum_{t.in.s} N_t \cdot W_t}{\sum_{all.t} N_t \cdot W_t} \qquad \text{Eq. 6.}$$

Where $W_t = (1- \exp(-K_t))^3$, Eq. 7., is the von Bertalanffy's prediction of relative body weight at age t.

The population biomass (B) is then estimated as:

$$B = \frac{B_{leading}}{b_{leading}} \qquad \text{Eq. 8.}$$

Where $B_{leading}$ and $b_{leading}$ are the absolute and the relative biomass of the leading stanza. The absolute biomass for any non-leading stanzas (B_s) is then estimated as:

$$B_s = B \cdot b_s \qquad \text{Eq. 9.}$$

The Q/B estimates for non-leading stanzas are calculated with a similar approach.

Ecosim is the time dynamic version of Ecopath, based on the set of linear equations used in Ecopath. It can be used to simulate the ecosystem effects of fishing mortality and environmental forcing over time. The dynamics of the functional groups represented by aggregated biomass pools are described by equations of the form:

$$dB_i / dt = g_i \cdot \sum_j Q_{ji} - \sum_j Q_{ij} + I_i - (M_i + F_i + e_i) \cdot B_i \qquad \text{Eq. 10.}$$

where dB_i/dt represents the growth rate of group (i) during the time interval dt in terms of its biomass, B_i, g_i is the net growth efficiency (production/consumption ratio), M_i the non-predation ($(P/B)_i B_i(1-EE_i)$) natural mortality rate, F_i is fishing mortality rate, e_i is emigration rate, I_i is immigration rate, (and $e_i \cdot B_i - I_i$ is the net migration rate). The first summation term represents total consumption by group (i), and the second summation term represents total consumption (predation) by all predators on the same group (i).

For groups represented by two or more stanzas, the stanza information (N_s and W_s) from Ecopath is used to initialize a fully size-age structured simulation, which is performed in monthly time steps. The numbers and weights at ages are updated for ages up to 90% of maximum body weight, and the older ages are accounted in a plus group. Here, in contrast to the non-stanza functional group where growth is simply represented as the difference between production and losses (Eq 10), growth is parameterized in accordance with the von Bertallanfy growth equation curvature parameter provided (K), where growth rates are dependent on body size and food consumption. Fecundity is assumed to be proportional to body weight, starting at the weight at maturity, which then affects egg production and recruitment of age 0 fish. Monthly changes in relative body weight within each stanza are predicted from the growth equation:

$$W_{t+1} = W_t + e_t q_t - mW_t \qquad \text{Eq. 11.}$$

where e_t is the size-dependent growth efficiency for a given time interval and stanza, q_t is food consumption rate of age t individuals predicted from the foraging-arena equation (see below) at a predation rate proportional to $W_t^{2/3}$ and m is a metabolic rate for the species which is equal to 3 times the monthly von Bertalanffy curve metabolic coefficient K under the assumption that metabolism scales linearly with body body size and consumption rate scales with body size to the 2/3 power (Essington et al. 2001; Christensen et al. 2005; Walters et al. 2008).

In EwE, predation and energy transfer is modelled using a "foraging arena hypothesis" where only part of the prey population prey (i) is vulnerable to predation by predator (j) at any one time. This approach assumes that the total prey biomass is composed of two biomass pools: one (V_{ij}) that is vulnerable to predation by j and another pool, (B_i – V_{ij}) that is invulnerable or safe from predator j. The prey exchange between the pools occurs at instantaneous rates v_{ij} and v'_{ij}. The flow rate to the vulnerable pool is given by $v_{ij} \cdot (B_i - V_{ij})$, while the flow rate to the safe pool is $v'_{ij} \cdot V_{ij}$. It is assumed that within V_{ij}, the predator-prey interactions are described by the Lotka-Volterra (mass action) model:

$$Q_{ij} = a_{ij} \cdot V_{ij} \cdot B_j \qquad \text{Eq. 12.}$$

where Q_{ij} is the consumption of i by j, a_{ij} is the effective search rate for predator j feeding on prey i and B_j is the predator biomass.

The rate of change in V_{ij} is predicted from:

$$dV_{ij}/dt = v_{ij} \cdot (B_i - V_{ij}) - v'_{ij} \cdot V_{ij} - a_{ij} \cdot V_{ij} \cdot B_j \qquad \text{Eq. 13.}$$

This equation is solved for V_{ij}, under the assumption that it stays close to the moving equilibrium defined by setting $dV_{ij}/dt = 0$, as:

$$V_{ij} = \frac{v_{ij} \cdot B_i}{v_{ij} + v'_{ij} + a_{ij} \cdot B_j} \qquad \text{Eq. 14.}$$

Eq. (14) is then substituted into Eq. (12), producing the foraging arena equation (Walters et al. 1997):

$$Q_{ij} = \frac{a_{ij} \cdot v_{ij} \cdot B_i \cdot B_j}{v_{ij} + v'_{ij} + a_{ij} \cdot B_j} \qquad \text{Eq. 15.}$$

In most cases there are no field or laboratory estimates for a_{ij}, v_{ij} and v'_{ij}. The approach used in EwE is to solve the Eq. 15 for a_{ij}, given baseline estimates of Q_{ij}, B_i and B_j and an estimate of v_{ij}, while assuming that $v_{ij} = v'_{ij}$. The "vulnerability", v_{ij}, is the maximum mortality that can be inflicted on prey i in the presence of infinite biomass of predator j. It is estimated as $v_{ij} = k_{ij} \cdot Q_{ijbase} / B_{ibase}$, where Q_{ijbase} is the Ecopath baseline estimate of the consumption of the species i by species j and B_{ibase} is the baseline biomass of i. The parameter k_{ij}, determines the maximum Q_{ij}, and is essentially a scaling factor. This parameter is a user-defined input to Ecosim and can vary from 1 to ∞, with a default value of 2. Low values cause bottom-up control, whereas high values result in top-down Lotka-Volterra predator-prey dynamics, with extreme cases leading to dynamic instability (predator-prey cycles) and loss of biodiversity through the overexploitation of some functional groups by their predators. In addition to these behavioural/ecological aspects, the k_{ij}, parameter also reflects how abundant the predator species is relative to its virgin abundance. Hence, if a predator's abundance at the baseline situation is far below its carrying capacity, a very high k_{ij} (e.g. 100+) for its prey means that the predator is capable of inflicting much higher mortality than the baseline estimate, increasing its consumption and thus recovering more quickly. So, for low consumer biomasses, the foraging arena functional relationship approaches the mass-action flow (Lotka-Volterra), while for for high consumer biomass, it approaches a maximum 'donor controlled' flow rate. Assuming the same k_{ij} (e.g. 2) values for all species in the model is equivalent to assuming that all species are currently at the same point on their consumption curves (Plagányi and Butterworth 2004). Hence it is advised to estimate the vulnerabilities by fitting the model estimates (e.g. biomass, catch) to observed time series data (Christensen et al. 2005; Plagányi and Butterworth 2004; Walters and Martel 2004) and exploring the potential parameter space. An example is given in Figure 2 to illustrate the effects on the mortality rate M_{ij}, when the prey biomass B_i is held constant while varying the predator biomass B_j.

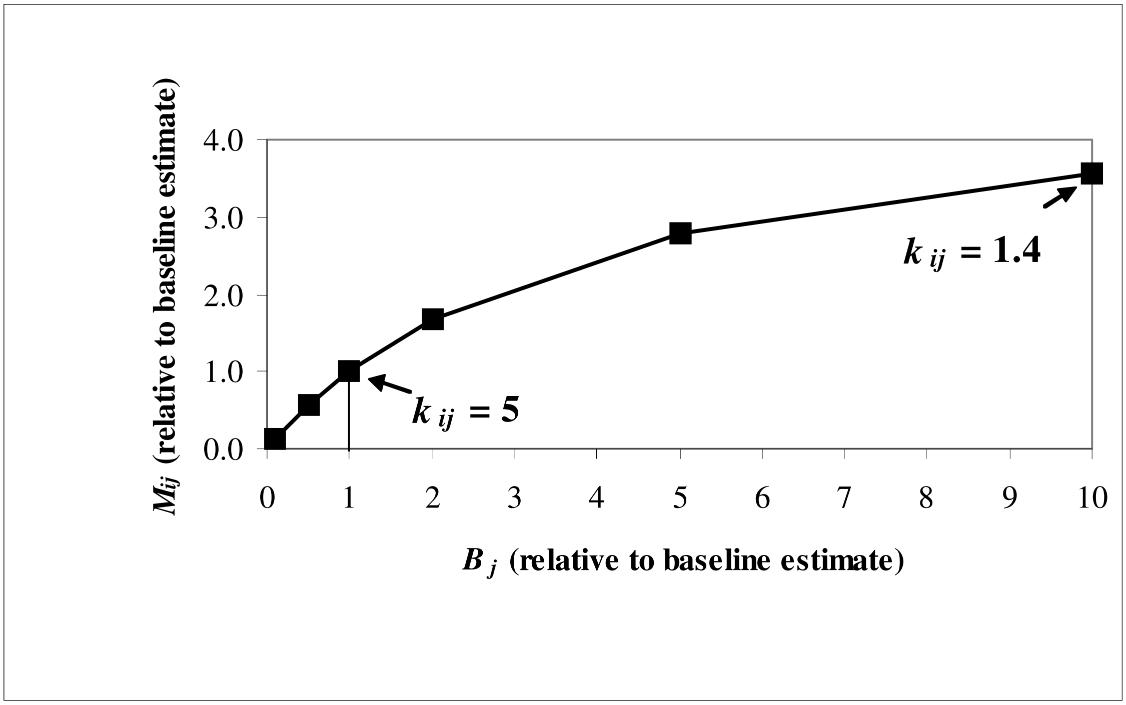

Figure 2. Estimates of predation mortality (M_{ij}) relative to the baseline estimate when predator biomass (B_j) is varied while prey biomass (B_i) is held constant. k_{ij} is the ratio between the hypothetical maximum predation mortality, also called vulnerability (v_{ij}), and the estimated M_{ij} at a given time. v_{ij} was set as 5 times the baseline M_{ij} (k_{ij} = 5 when relative B_j = 1). In this procedure, the equation is solved for the search parameter (a_{ij}), given the baseline estimates of Q_{ij}, B_i, B_j and the chosen k_{ij}.

The basic foraging arena equation has been extended to include the prey relative feeding time, T_i, the predator relative feeding time, T_j, seasonal or long term forcing effects, S_{ij}, mediation forcing effects, M_{ij}, and the effects of handling time as a limit to consumption rate, D_j. A full description of these parameters is given in Walters and Martel (2004) and Christensen et al. (2005). The extended foraging arena equation (Christensen et al. 2005) is then defined as:

$$Q_{ij} = \frac{a_{ij} \cdot v_{ij} \cdot B_i \cdot B_j \cdot T_i \cdot T_j \cdot S_{ij} \cdot M_{ij} / D_j}{v_{ij} + v_{ij} \cdot T_i \cdot M_{ij} + a_{ij} \cdot M_{ij} \cdot B_j \cdot S_{ij} \cdot T_j / D_j} \qquad \text{Eq. 16.}$$

The additional parameters are set with the Ecosim default values but can be changed to, for example, explore different types of functional responses or improve model estimates. See Christensen et al. (2005) for further details.

MODEL STRUCTURE

A total of 63 functional groups was initially used to represent the ecosystems models developed here. These include, one primary producer group, one microflora group, 4 zooplankton groups, 13 invertebrate groups, 20 fish groups, one seabird group and 3 marine mammal groups. Most fish groups (e.g. cod) are represented by two or more life stanzas to account for ontogenetic shifts in habitat use, feeding behaviour and diet, predation mortality and selective fishing impacts. In addition to the living groups, 2 non-living groups are included, detritus and discards. The list is presented in Box 1.

Box 1. Structure of the 4X, Western Scotian Shelf and Bay of Fundy Models

Marine Mammals and Seabirds

1	Whales
2	Toothed cetaceans
3	Seals
4	Seabirds

Fish Groups

5	Sharks
6	Large pelagics
7	Cod <1
8	Cod 1-3
9	Cod 4-6
10	Cod 7+
11	S Hake <25
12	S Hake 25-31
13	S Hake 31+
14	Halibut <46
15	Halibut 46-81
16	Halibut 82+
17	Pollock <49
18	Pollock 49+
19	D piscivores <40
20	D piscivores 40+
21	L benthivores <41
22	L bentivores 41+
23	Skates <49
24	Skates 49+
25	Dogfish <73
26	Dogfish 73+
27	Redfish <22
28	Redfish 22+
29	A plaice <26
30	A plaice 26+
31	Flounders <30
32	Flounders 30+

Fish Groups cont.

33	Haddock <33
34	Haddock 33+
35	L sculpin <25
36	L sculpin 25+
37	Herring <4
38	Herring 4+
39	Other pelagic
40	Mackerel
41	Mesopelagic
42	Small-medium benthivores

Invertebrate Groups

43	Squids
44	Lobster
45	Large crabs
46	Small crabs
47	Shrimps
48	Scallop
49	Bivalves
50	Other molluscs
51	Other arthropoda
52	Echinoderms
53	Sessile benthic groups
54	Worms
55	Meiofauna

Plankton and Bacteria

56	Gelatinous zoop
57	Macrozoop
58	Mesozoop
59	Microzoop
60	Microflora
61	Phytoplankton

Detritus

62	Discards
63	Detritus

ESTIMATION OF INPUT PARAMETERS

Input parameters for the 3 ecosystems models were in many cases, especially for fish species, derived from local data. The next sub-sections give a general description of the main sources of data, methods and assumptions used to estimate the input parameters. The parameters were derived from a variety of sources, which are described in specific sections of the functional groups.

Biomass

1. For most fish groups and squids, biomass estimates were derived either from (i) summer bottom trawl survey and corrected for size-specific catchability models or overall (average) catchability coefficients reported by Harley et al. (2001) and Harley and Myers (2001), or (ii) from population models.

A summer stratified random bottom trawl research survey has been conducted over the Scotian Shelf in July since 1970, initially on the RV A.T. Cameron using a Yankee 36 gear. After 1981 the vessel changed (Lady Hammond, then the CCGS Alfred Needler) and the gear changed to a Western IIA gear. Conversion factors estimated by Fanning (1985) were applied to adjust for changes in vessel fishing power between the two periods when deriving the time series of biomass to be used in dynamic simulations in Ecosim (Appendix 1A).

The area covered by the DFO summer survey excludes inshore areas below100 m (50 fathom). However, the waters off southwest Nova Scotia, which are important for several groundfish species such as cod, are included in the total area modelled in this study, but are below 100 m (Figure 1). We used a second standardized groundfish survey, conducted in 4X by the Individual Transferable Quota (ITQ) mobile gear < 65' fleet since 1995, to include abundance estimates of fish species in these shallower waters. Sampling since 1996 has been considered appropriate for abundance estimates (Showell et al. 2010). The ITQ survey catch data from the inshore and offshore areas were used to estimate an average correction factor, using data from 1996 to 2009, to "adjust" the RV biomass estimates for area effects (inshore/offshore). For many species the biomass estimates only changed by a small amount because the inshore area is small compared to the offshore and because the ITQ average catch rates for the inshore and offshore areas were similar. One of the exceptions is sea raven, for which the average catch rate in inshore areas was about 3 times higher than offshore. Details of the procedure are given in Appendix 1B.

2. Biomass data for benthic invertebrate groups, except for lobster, scallops, shrimps and large crabs, were derived from grab sample data reported in 3 sources: Peer et al. (1980), Theroux and Wigley (1998) and Wildish et al. (1989). The period covered by these studies includes the years from 1957-1965 (Theroux and Wigley 1998), 1978 (Peer et al. 1980) and 1983-1985 (Wildish et al. 1989). The raw data used here to estimate the average biomasses were directly available only from the Peer et al. (1980) report. The

data used in the Theroux and Wigley (1998) report and Wildish et al. (1989) were provided by Steve Fromm (The National Oceanic and Atmospheric Administration, NOAA, USA) and D. Wildish (David J.Wildish, Fisheries & Oceans Canada, Canada) respectively. The wet weight biomass ($g \bullet m^{-2}$) for each functional group (worms, small crabs, etc..) from each grab sample site was summed for all grab samples in the areas over all years and divided by the total number of grab samples. Bootstrap confidence intervals for the estimates derived from the grab samples were estimated for each functional group (Haddon 2001). Lobster and scallops biomass estimates were derived from population models (see Section 44. Lobster and 48. Scallop below) and large crabs biomass was based on the summer bottom trawl survey (see Section 45-46. Large and small-medium crabs).

3. Seabirds biomass estimates were derived from data reported by Huettmann (2000) and provided by Dave Fifield (Canadian Wildlife Service, Environment Canada). Biomass for the cetaceans groups were derived from Palka (2000, 2006) and Bundy (2004, Appendix 3). Grey seals estimates were provided by Kurtis Trzcinski (DFO, pers. comm.) and are derived from the modelling of grey seal-cod interactions in the eastern Scotian Shelf and western Scotian Shelf populations (Trzcinski et al. 2009) and the estimate for harbour seals was derived from seals numbers reported in the Bay of Fundy by Fowler and Stobo (2005).

4. Biomass samples for the meso, macro and gelatinous zooplankton were provided by Catherine Johnson (DFO, pers. comm.), and microzooplankton, was based on Link et al. (2006) – see Section 56–59. Zooplankton and Micronekton. Biomass and productivity for phytoplankton were estimated from satellite estimates of surface chlorophyll, and estimated for the microflora followed the key assumptions made by Link et al. (2006) – see Section 60-61. Microflora and Phytoplankton.

Growth and maturity parameters for stanza groups

The following methods were used for growth and maturity parameters for fish groups:
1. For species that are routinely sampled, growth parameters were estimated with local size-at-age data for the period modelled here. Estimates (or proxies) of size/age at maturity for such species, generally reported in DFO stock assessment reports, were used.
2. For species for which this information was not available, growth and/or maturity parameters were based on (a) local data from a different time period or (b) derived from empirical equations. Size at maturity and growth parameters were estimated from Froese and Binohlan (2000):

$$\log(L_\infty) = 0.044 + 0.9841 \cdot \log(L_{\max}) \qquad \text{Eq. 17.}$$

$$\log(L_m) = 0.8979 \cdot \log(L_\infty) - 0.0782 \qquad \text{Eq. 18.}$$

where L_∞, $L_{\max}$ and L_m are the asymptotic size of the von Bertalanfy growth equation, the maximum size observed in the research trawl data and the estimated size at maturity respectively. The estimate of K was then obtained from L_∞ estimated from equation (17) and an estimate of the so-called Ø'pamarater (Pauly et al. 1998a):

$$\Phi = \log(K) + 2 \cdot \log(L_\infty) \qquad \text{Eq. 19.}$$

Parameters used in Eq. 19 were estimated from published studies or local data sets. Growth parameters for fish groups used in this study are presented in Appendix 2

Production to Biomass ratio (P/B) and mortality parameters

Allen (1971) has demonstrated that, for the populations under equilibrium conditions and for specific individual growth and population survivorship models, the biomass-weighted average population production to biomass ratio (*P/B*) equals the biomass-weighted average total mortality (see Appendix 3 for further details). As the relatively large individuals (recruits and mature) account for most of the population biomass, the adult average Z is generally a close approximation for the population *P/B* under equilibrium conditions. If the population is growing or decreasing, *P/B* can be then estimated as the sum of Z and the relative average biomass population growth rate (*BA/B*).

The equivalence between *P/B* and Z is only valid for the entire population under equilibrium conditions, and thus only for non multi-stanza groups. Some common approaches to estimating *P/B*, Z or M are given below: see "Description of input data for each Ecopath group", Sections 1 – 61 for further details for individual groups.

Proxies for *P/B* ratios of benthic invertebrates, were either taken from published studies, or were based on Brey's multiple linear model (version 4) of (Brey 1999, 2001):

log(P/B) =	7.947	Intercept	Variables
+	-2.294	* log(M)	M = Mean Indiv. Body Mass (kJ)
+	-2409.856	* 1/(T+273)	T = Bottom Water Temperature (°C)
+	0.168	* 1/D	D = Water Depth (m); Intertidal = 1m, Minimum = 1m
+	0.194	* SubT	Subtidal? Yes:1; No: 0
+	0.180	* In-Epi	Infauna =1 or Epifauna = 0
+	0.277	* MoEpi	Motile Epifauna? Yes:1; No: 0
+	0.174	* Taxon1	Annelida or Crustacea? Yes: 1; No: 0
+	-0.188	* Taxon2	Echinodermata? Yes: 1; No: 0
+	0.330	* Taxon3	Insecta? Yes: 1; No: 0
+	-0.062	* Habitat1	Habitat = Lake? Yes: 1; No: 0
+	582.851	* log(M)*1/(T+273)	Composite Variable log(M) * 1/T

Eq. 20.

Ambient temperature was assumed to be equal to the average summer bottom temperature of 7.1 °C, as recorded during the RV surveys, 1995-2000 - see below. Weight conversions were obtained from Brey's conversions database, which are contained in the same spreadsheet used for the *P/B* estimation (Brey 2001).

Daily production rate for mesozooplankton was estimated from an empirical equation (Huntley and Lopez 1992), which estimates production from biomass and seawater temperature (T):

$$P = B \cdot 0.0445e^{0.111T} \qquad \text{Eq. 21.}$$

For many species groups, especially commercially exploited fish species, estimates of mortality were derived from standard stock assessment methods, such as catch curves and virtual population analyses (VPA) (Ricker 1975; Pauly 1983). For cases cases where a total mortality estimate was not directly available or uncertainties in available estimates were considered too large, natural mortality was estimated using the methods of Pauly (1980) and/or Hoenig (1983).

The method of Pauly (1980) is based on the equation:

$$M = K^{0.65} \cdot L_\infty^{-0.279} \cdot T_c^{\ 0.463} \qquad \text{Eq. 22.}$$

where, M is the natural mortality (year^{-1}), K (year^{-1}) is the curvature parameter of the von Bertalanffy growth function, L_∞ is the asymptotic length (cm) in the same function, and T_c is the mean water temperature, in °C. The life-history routine in FishBase (Froese and Pauly 2009 http://www.fishbase.org) was used to estimate M and its confidence limits.

Hoenig (1983) estimated total mortality as:

$$\ln(Z) = 1.46 - 1.01 \cdot \ln(Age_{\max}) \text{ for fish groups} \qquad \text{Eq. 23.}$$

$$\ln(Z) = 0.941 - 0.873 \cdot \ln(Age_{\max}) \text{ for marine mammals} \qquad \text{Eq. 24.}$$

For functional groups represented in the model by two or more life stages (stanzas), estimates of total mortality are required to be entered for each stanza. To obtain a proxy for the biomass-weighted average Z estimate for the young/juvenile (not fully recruited) stanzas of fish functional groups, simple population dynamic models with monthly time steps were used. Equations 25 and 26 estimate length and weight at age, numbers and biomass at age (Eqs. 27 and 28), and, through an iterative process using these results, Eq. 22 and Eq. 29 estimate average mortality per stanza. In these models, the size, Lt and body weight, $Wt,$ at age were based on the von Bertalanffy growth and weight-length equations:

$$L_t = L_\infty \cdot (1 - \exp(-Kt)) \qquad \text{Eq. 25.}$$

$$W_t = a \cdot L_t^{\ b} \qquad \text{Eq. 26.}$$

$$N_{t+1} = N_t \cdot \exp(-M_t) \qquad \text{Eq. 27.}$$

and

$$B_t = N_t \cdot W_t \qquad \text{Eq. 28.}$$

The natural mortality rate at a given age was then estimated using the model proposed by Beyer (Beyer 1989; Beyer et al. 1999) in which predation mortality is inversely proportional to length L_t:

$$M_t = M_\infty \cdot \frac{L_\infty}{L_t} \qquad \text{Eq. 29.}$$

where M_t is the natural mortality at age (t) and M_∞ is the natural morality (predation) of an infinitely old fish.

Finally it was assumed that natural mortality estimated from the Pauly's empirical equation (Eq 22) is a proxy for the population biomass-weighted average natural mortality, enabling Eq 29 to be iteratively solved for M_∞. The mortality for a given fish stanza was then estimated as the biomass-weighted average natural mortality within that stanza *s* as:

$$\overline{M}_s = \frac{\sum M_t \cdot B_t}{\sum B_t} \qquad \text{Eq. 30.}$$

A note on the non-equivalency of Z and P/B in the multi-stanza groups:

The non-equivalency of *Z* and *P/B* in the multi-stanza groups leads to nonsensical results for Ecopath estimates that used *P/B* in its production meaning. For example, one Ecopath diagnostic is the ratio of production to consumption (*P/Q*), which is "expected" to be between 0.1 and 0.3 (Christensen et al. 2005). Ecopath automatically computes *P/Q* for the functional groups. However, for the multiple-stanza groups it uses the stanzas' input *Z* estimates, instead of the actual *P/B*, to estimate *P/Q,* which gives meaningless results, since the equivalence between *Z* and *P/B* is only valid for the population averages. Hence, in order to check this diagnostic correctly, the *P/B* and *P/Q* ratios of multiple-stanzas groups were estimated separately in a spreadsheet using the Allen's curve method (Eq 31) to estimate the *P/B* for each stanza of multi-stanza functional groups. The Allen's curve method (Allen 1950) is an approximation of the equations derived by Allen (1970, see Appendix 3), in which *P/B* is estimated over small age (e.g. monthly) intervals *Δt*, by the equation:

$$\overline{P/B}_{\Delta t} \cong \frac{\sum \overline{N}_{\Delta t} \cdot \Delta W_{\Delta t}}{\sum \overline{B}_{\Delta t}} \qquad \text{Eq. 31.}$$

where $\overline{N}_{\Delta t}$ represents the average numbers in the age interval Δt, $\Delta W_{\Delta t}$ the weight increase and and $\overline{B}_{\Delta t}$ the average biomass. Numbers and weights at ages were derived from equations 5 and 7.

To illustrate this, the estimates for cod in the 4X model are presented in Table 1. The *P/Q* parameters estimated separately (*P/Q**) are within (or close to) the "expected" range of 0.1 – 0.3 for fish populations. Note that the average population *Z* is higher than the *P/B* because of a negative *BA* term.

Table 1. Ecopath multi-stanza representation for 4X cod. Parameters in italics are estimated by the Ecopath multi-stanza routine; *P/B* and *P/Q** values were estimated in a spreadsheet and the population averages are weighted by biomass.

Group name	B ($t.km^{-2}$)	Z ($year^{-1}$)	Q/B ($year^{-1}$)	P/Q^{EwE}	P/B ($year^{-1}$)	P/Q^{*}
Cod <1	*0.004*	1.48	*12.26*	*0.12*	4.21	0.34
Cod 1-3	*0.223*	0.39	*3.43*	*0.11*	0.91	0.27
Cod 4-6	*0.272*	0.82	*2.12*	*0.39*	0.40	0.19
Cod 7+	0.076	0.82	1.56	*0.53*	0.19	0.12
Pop Av.	0.575	0.66	2.62	0.25	0.60	0.23

Consumption to biomass ratio (Q/B)

Estimates of *Q/B* were derived from the following sources:

1. Where data permitted, *Q/B* was estimated for finfish species from the application of a gastric evacuation model to food habits data collected from the Scotian Shelf (Cook and Bundy 2010, Laurinolli et al. 2004). As stated above, the consistency of the estimates were checked by using the relationship between production and consumption (*P/Q*), which are expected to fall within a given range, normally from 0.1 to 0.3 (Christensen et al. 2005).

2. In cases of finfish species for which stomach data were not unavailable or insufficient, or the estimated *Q/B* ratio from the gastric model produced an abnormal *P/Q* ratio, the empirical model of Palomares and Pauly (1998) was used:

$$\log(Q/B) = 5.847 + 0.280 \cdot \log Z - 0.152 \cdot \log W_{\infty} - 1.360 \cdot T + 0.062 \cdot A + 0.510 \cdot h + 0.390 \cdot d$$

Eq. 32.

where, W_{∞} is the asymptotic weight in grams, Z is the total mortality rate, T is an expression for the mean annual temperature of the water body (see Ambient temperature below), which is estimated as T = 1000/Kelvin (Kelvin = °C + 273.15), A is the caudal fin aspect ratio, h is a dummy variable expressing food type (1 for herbivores, and 0 for detritivores and carnivores), and d is a dummy variable also expressing food type (1 for detritivores, and 0 for herbivores and carnivores).

3. For most marine mammals, the parameter was estimated using the daily individual ration equations for cetaceans and pinnipeds from Innes et al. (1987):

$$R = 0.1 \cdot W^{0.8} \text{ (cetaceans)} \qquad \text{Eq. 33.}$$

and

$$R = 0.068 \cdot W^{0.78} \text{ (pinnipeds)} \qquad \text{Eq. 34.}$$

where W is the mean body mass in kg.

4. For all other cases, *Q/B* was based on information in the scientific literature for similar ecosystems or derived from known or educated guesses values of *P/Q* and the estimated *P/B* (*Q/B= P/B÷P/Q*).

Ambient temperature

Ambient temperature used in the empirical equations described above was assumed to be equal to the average summer temperature bottom temperature as recorded during the RV surveys 1995 – 2000 (7.1 °C). This is in the range and close to the average of reported average preferred temperatures (Scott 1982; Lucey and Nye 2010) for several of the main commercial fish and invertebrate species found in the ecosystems studied. This value is also close to the long-term average (= 6.72 °C; 1960-2008) sea surface temperature in the area derived from the The International Comprehensive Ocean–Atmosphere Data Set (ICOADS; Diaz et al. 2002) and hence seems to represent a reasonable proxy for the annual average temperature in the 4X region.

Diet

Summer fish diet was estimated as the biomass weighted diet based on strata estimates, using data housed in the PED Food Habits Database (data were available for NAFO Division 4X (BoF and WSS) from 1999 and 2008 (excluding 2003-04) for the main fish species from the DFO summer research surveys (Cook and Bundy 2010, Laurinolli et al. 2004)). Diet data for fish collected from USA spring and fall surveys in an overlapping portion of NAFO Division 4X for same time interval were used to account for seasonal variation in feeding habits (Link and Almeida 2000, Smith and Link 2010). A simple mean of the spring, summer and fall diets was estimated. For all other cases, diet data from the literature for similar systems or generic knowledge about feeding habits were used to estimate the percent diet composition for the functional groups. Details for input diet composition of each functional group are given in Appendix 4.

For most species, food preferences in the balanced 4X model were used to estimate the percent diet composition in the WSS and BoF models since there are insufficient samples to account for seasonal variation in diets separately in the these two systems. The procedure is carried out by: importing the prey preferences from another model, assuming the predator's preference for a given prey will remain constant in these systems. Predator's food preference is described in Ecopath by the forage ratio (S_i) as suggested by Chesson (1983, cited in Christensen et al. 2000). This index is is given by:

$$S_i = (r_i / P_i)/(\sum_{n=1}^{n} r_n / P_n) \qquad \text{Eq. 35.}$$

where r_i is the relative abundance of a prey in a predator's diet and P_i is the prey's relative abundance in the ecosystem, and n is the number of groups in the system. The standardized forage ratio as originally presented takes values between 0 (avoidance) and 1 (exclusive feeding). In Ecopath the forage ratio has been linearly transformed to vary between -1 and 1, so that -1, 0 and 1 can be interpreted as the estimates of the Ivlev (Ivlev 1961) electivity index (Christensen et al. 2000).

Landings

Commercial landings data by area and species were extracted from the Virtual Data Centre (Fisheries and Oceans Canada, Population Ecology Division database). Extraction of the data for NAFO Division 4X was straightforward since the landings data have been recorded at this scale since the 1950s. However, extracting the landings data for the western Scotian Shelf and the Bay of Fundy separately was more problematic since the data are not recorded at this spatial scale: instead the 4X landings data had to be separated into the BoF and WSS on the basis of positional information, which varies over time. There are 3 classes of landings information available: between 1968 and 1985 landings at the NAFO sub-unit levels are available only for the main commercial species; between 1986 and 1995 landings are available at the NAFO sub-unit level for all species with latitude and longitude information starting in 1991, but with limited coverage; and since 1995/1996 latitude and longitude data are available for most, though not all, fisheries. Appendix 5 further details how the landings data for the BoF and WSS were estimated.

Discards

Gavaris et al. (2010) estimated the discards from Canadian commercial fisheries in NAFO Divisions 4V, 4W, 4X, 5Y and 5Z between the years 2002 and 2006. Due to the broad geographic scale at which the estimation procedure was conducted, discard estimates for the present study were available at the level of the 4X/5Y NAFO Division only. The estimated discards were based on the formula total discards = total all species landings (observed discards / observed all species landings) and were computed by fishery, year and area. As no such detailed and comprehensive study exists for the years modelled here, the species discards rate by type of fisheries reported by Gavaris et al. (2002) were used along with the estimates of landings by the same type of fisheries for the period between 1995 and 2000, which were calculated for the 4X/5Yb to represent the 4X model and 4Xmnop and 4Xqrs5Yb to represent the Western Scotian Shelf and Bay of Fundy models respectively. This method was applied for all functional groups except for dogfish, sharks, and odontocetes for which additional or other sources of information was available. When necessary, additional details are given in the sections that describe each functional group.

DESCRIPTION OF INPUT DATA FOR EACH ECOPATH GROUP

1, 2. WHALES AND TOOTHED CETACEANS

BACKGROUND

Many cetacean species use the Western Scotian Shelf and Bay of Fundy as summer feeding grounds (Palka 2000, 2006; Waring et al. 2002, 2009). Species commonly recorded in the area and that compose the cetaceans groups in the models are listed in the Table 2. Note that Fin and Sei whales are not always distinguished in the marine mammal surveys, and are classified together as “fin or sei whale”.

Table 2. List of cetaceans species regularly sighted in the 4X ecosystems according to Palka (2000, 2006) and Waring et al. (2002, 2009).

Stock	Group	Species	Common Name
Western North Atlantic Stock	Whales	*Balaenoptera physalus*	Fin W.
Gulf of Maine Stock	Whales	*Megaptera novaeangliae*	Humpback W.
Canadian East Coast Stock	Whales	*Balaenoptera acutorostrata*	Minke W.
Western Atlantic Stock	Whales	*Eubalaena glacialis*	Right W.
Nova Scotia Stock	Whales	*Balaenoptera borealis*	Sei W.
Western North Atlantic Stock	Odontocetes	*Ziphius cavirostris and Mesoplodon spp.*	Beaked W.
Western North Atlantic Offshore Stock	Odontocetes	*Tursiops truncatus*	Bottlenose Dolphin, offshore
Western North Atlantic Stock	Odontocetes	*Delphinus delphis*	Common D.
Western North Atlantic Stock	Odontocetes	*Grampus griseus*	Risso's D.
Gulf of Maine/Bay of Fundy Stock	Odontocetes	*Phocoena phocoena*	Harbor porpoise
Western North Atlantic Stock	Odontocetes	*Globicephala melas*	Pilot W.
Western North Atlantic Stock	Odontocetes	*Lagenorhynchus acutus*	Whitesided D.

CATCH

There is no catch of cetaceans in the study area for either study period as Canada ceased commercial whaling in 1972 (Bundy 2004).

By-catch

The Canadian (Bay of Fundy) by-catch of harbour porpoise for the 1996-1998 period represented less than 0.1% of the population size (DFO 1998). Based on data reported in DFO (1998) and Waring et al. (2009), an average of 58 harbor porpoises were killed per annum from 1994 to 2001in the Bay of Fundy, by the Bay of Fundy sink gillnet fisheries and herring weirs. Assuming an average body weight of 31 kg (average of male and females from Trites and Pauly (1998)), gives an average of 1.79 tonnes for the Bay of Fundy area (0.0006 $t.km^{-2}$), which is equivalent to about 0.13% of the average biomass of harbor porpoise in this area (see below). This mortality rate (0.13% of the average biomass) was applied to the western Scotian Shelf and 4X models for the estimation of harbor porpoise incidental catch mortality under the assumption that the area by-catch mortality rates in these areas are similar to the BoF rate.

Additional estimates of incidental catch in the 4X area between 2002 and 2006, which included records of white-sided dolphin, unidentified dolphins and unidentified toothed whale, were reported by Gavaris et al. (2010). The estimates obtained by applying the discards rates from Gavaris et al. (2010) to the same type of fisheries for the 1995 to 2000 period were then summed to those detailed above (see Table 3).

BIOMASS

There are no separate abundance estimates for the western Scotian Shelf and Bay of Fundy. However, Palka (2006) provided summer abundance estimates for the northern Gulf of Maine and Scotian strata, which have a high degree of overlap with the Bay of Fundy and the western Scotian Shelf respectively. With the exception of harbour porpoise (*Phocoena phocoena*), the cetacean abundance estimates from the 1999, 2002 and 2004 surveys detailed in Palka (2006; Table 4) were used to estimate the biomass inputs for the cetaceans groups. The 2002 results for the Bay of Fundy were not used since the aerial survey did not complete the planned track lines in the northern Gulf of Maine (Palka 2006). The assumption was made that the Scotian stratum densities were representative of the western Scotian Shelf. For the Bay of Fundy, it was assumed that the upper part of the area, which is characterised by strong tidal flushing and represents about 11% of the total Bay of Fundy, would be an area of 0 densities. So the density estimates from the northern Gulf of Maine stratum were multiplied by 0.89 to account for this assumption.

Abundance estimates for harbour porpoise were based on data reported in Palka (2000, 2006), which include survey data for 1991, 1992, 1995, 1999 surveys of the Bay of Fundy (lower and upper strata in Palka 2000) and 1999, 2002 and 2004 summer surveys for the western Scotian Shelf (Scotian stratum in Palka 2006).

These abundance estimates were multiplied by the specific average body mass reported by (Trites and Pauly 1998), except for fin whales for which 37 t was used based on catch records (N. Friday, NFMS, Seattle, pers. comm. 2005), and then pro-rated by a “seasonal abundance correction factor” of each species in the two ecosystems to give average annual estimates of biomass. For species whose average body mass is reported by sex, an average of male and female was taken to represent the species. The abundance factor was estimated using average abundance estimates for summer, fall, winter and spring reported for the Gulf of Maine and Georges Bank (Kenney et al. 1997) as the annual average divided by the summer estimate, assuming that the seasonal variation in the species abundance for the period reported by Kenney et al. (1997) in these ecosystems would be similar to what occurs in the Bay of Fundy and western Scotian Shelf. This procedure was not applied to the sei whale or common and white-side dolphins since their residence time did not seem to be well represented based on the seasonal variation observed for the Gulf of Maine and/or Georges Banks area. Instead, the residence time was tentatively estimated on “semi-quantitative” information about the time spent in the different areas occupied by these species as reported in Waring et al. (2002, 2009). The biomass estimates and the data used to derive these parameters are presented in Table 5.

Table 3. Estimated abundance, longevity, mortality and consumption used to derive the inputs parameters for the two cetacean functional groups represented in the 4X ecosystem models. Data sources are described in the main text.

	Numbers (km^{-2})							**Biomass ($t.km^{-2}$)**		
Common Name	BoF	WSS	Longevity (years)	Mean Mass (t)	Z ($year^{-1}$)	Q/B ($year^{-1}$)	Seasonal abundance factor	BoF	WSS	4X average
Fin or Sei Whale	0.005425	0.002023		26.91	0.06	4.66	0.55	0.071350	0.029990	0.046817
Fin W.	0.008923	0.007704	98	37.00	0.05	4.10	0.55	0.161392	0.157036	0.158808
Humpback W.	0.005476	0.013617	75	30.41	0.06	4.63	0.37	0.054758	0.153483	0.113318
Minke W.	0.051359	0.015193	47	6.57	0.09	6.29	0.69	0.207175	0.069074	0.125259
Right W.	0.009734	0.000000		23.38		4.88	0.61	0.123103	0.000000	0.050083
Sei W.	0.004766	0.001109	69	16.81	0.06	5.21	0.55	0.039164	0.010270	0.022025
Unidentified whale	0.004969	0.009727		26.55			0.55	0.055857	0.123241	0.095827
Beaked W.	0.000000	0.003035		0.83		9.52	0.65	0.000000	0.001641	0.000974
Bottlenose Dolphin, offshore	0.000000	0.007762	47	0.19	0.09	12.81	0.56	0.000000	0.000817	0.000485
Common D.	0.000000	0.035308		0.08		15.19	0.40	0.000000	0.001132	0.000671
Risso's D.	0.000000	0.137127		0.22		12.37	0.71	0.000000	0.021717	0.012882
Harbor porpoise	2.299376	0.227087	13	0.03	0.27	18.36	0.67	0.047892	0.004730	0.022290
Pilot W.	0.000000	0.055248	42	0.85	0.10	9.47	0.65	0.000000	0.030487	0.018084
Sperm W.	0.000000	0.000000	69	18.52	0.06	5.11	0.43	0.000000	0.000000	0.000000
Whitesided D.	0.290205	0.655948		0.09		14.79	0.40	0.009424	0.024008	0.018075
Unidentified D.	0.000000	0.030386		0.15			0.52	0.000000	0.002291	0.001359

BIOMASS ACCUMULATION

As reported by Waring et al. (2002), current data and recent analysis suggest that the Gulf of Maine humpback whale stock is steadily increasing in size. This is considered consistent with an estimated average trend of 3.1% for the North Atlantic population in the period between 1979 and 1993 although there are no feeding-area-specific estimates. Analysis of population index calculated from the individual sightings database for the years 1990-2003 suggests a positive trend in numbers for the Western Atlantic right whale population, with average growth rate of about 2% (Waring et al. 2009). There are insufficient data to determine population trends for the remaining cetacean species included in the model. An average, weighted by biomass, *BA* was estimated for each model for the baleen whales and the *BA* for the odontocetes was considered to be zero.

PRODUCTION:BIOMASS

The production to biomass ratio (*P/B*) was estimated as the sum of total mortality (Z) and biomass accumulation. The Z estimates were obtained by applying Hoenig's empirical equation for marine mammals (Eq. 24). Maximum age estimates were taken from the longevity estimates reported by (Trites and Pauly 1998). A biomass-weighted average *Z* was estimated for the 4X, WSS and BoF models and summed with the corresponding annual average *BA* rate to give the *P/B* estimate.

CONSUMPTION:BIOMASS

The *Q/B* ratios were estimated using the daily individual ration equation (Eq. 33). The daily rations were multiplied by 365 to give annual estimates of *Q/B* and then a biomass-weighted average was estimated for each model.

DIET

Diet information for the cetaceans groups was based on literature information that includes both site-specific and generic information on food habits. A description of the food habits, data sources and assumptions used to estimate the diet data is given below for each of the main species. The species diets and weight group diet estimates are detailed in Appendix A4, Tables 1-3 for 4X, BoF and WSS respectively. A biomass-weighted average diet was estimated for each model.

Mysticeti

Fin whale – This is a euryphagous and versatile feeder, preying on krill, small invertebrates and schooling fish (capelin, sand lance, herring and lanternfish) and squids (Pauly et al. 1995, Overholtz and Link 2007). The generic diet reported by Kenney et al.(1997) was composed of 90% fish and 10% zooplankton. The generic diet reported by Pauly et al. (1998b) was composed of 80% large zooplankton, 15% fish and 5% squids. According to Bundy (2004 and references therein), observation and diet data for fin and sei whales on the Scotian Shelf indicated that these species feed predominately on zooplankton (euphausiids and copepods). Read and Brownstein (2003) assumed that herring would account for 17% of the fin whale diet in the Gulf of Maine in the 1990's. Overholtz and Link (2007) assumed that mammals had smaller percentages of herring in their diets during the late 1970s and early 1980s in the Gulf of Maine–Georges Bank complex when herring abundance was low, and much higher percentages in recent years, although recent diet percentages for herring would not exceed 40–70% because many alternative prey are abundant (e.g. krill and other pelagic fish species). Their approach to deal with the high level of uncertainty resulted in a very wide range of assumed values for the proportion of herring in the diets of marine mammals. For example, the proportion of herring in the diet of fin whale was allowed to range from 25% to 76% in 2002, when it was assumed that the proportion would be at its highest values. We assumed that the diet of this species would be 80% of krill (macrozooplankton) since this species seems to be a very important prey item in the area (This study; Brown et al. 1981). The remaining part of the diet was allocated to the small-medium pelagic species (herring, other pelagic, mackerel, squids) according to their relative abundance in the areas modelled.

Sei whale – The generic diet reported Kenney et al. (1997) was composed exclusively of zooplankton. The generic diet reported by Pauly et al. (1998b) was composed of 80% large zooplankton, 15% fish and 5% squids, the same proportions used to represent the fin whale diet in that study. As already noted above, diet data for fin and sei whales on the Scotian Shelf indicated that these species feed predominately on zooplankton (euphausiids and copepods). We assumed that the diet of this species was composed of 80% of macrozooplankton. The remaining part of the diet was allocated to the small-medium pelagic species (herring, other pelagic, mackerel, squids) according to their relative abundance in the areas modelled.

Humpback whale - Euphausiids and small schooling fish (capelin, clupeids, osmerids, gadids, ammodytids) (Hain et al. 1981; Pauly et al. 1995 and references therein) are the main prey of humpback whales. The generic diet reported by Kenney et al. (1997) was composed of 95% fish and 5% zooplankton. The generic diet reported by Pauly et al. (1998b) was composed of 55% large zooplankton and 45% fish (15% small pelagic and 30% miscellaneous fish). Read and Brownstein (2003) assumed that herring would account for 17% of the Humpback whale diet in the Gulf of Maine in the 1990's. Observations of humpback whale feeding behaviour in the Western North Atlantic (West Quoddy Head, Mt. Desert Rock, Stellwagen Bank, the waters east and southeast of Cape Cod, and southeast of Block Island) (Hain et al. 1981) indicated that American sand lance was a frequent prey, being identified in 50% of feeding events in the Stellwagen Bank in 1978 and in 75% of observations in 1979. According to that study, herring seemed to be the target of the humpbacks in the West Quoddy Head area (Bay of Fundy) close inshore and in coves. We assumed that the percent diet for this was composed of 55% of macrozooplankton. The remaining part of the diet was allocated to fish groups (small-medium pelagic and gadids) according to their relative abundance in the areas modelled.

Minke whale – this is an euryphagous species, feeding on krill, small fish such as capelin, sand lance and age 0 groups of herring, cod, haddock and pollock (Haug et al. 1994, Pauly et al. 1998b). The generic diet reported by Kenney et al.(1997) was composed of 95% fish and 5% zooplankton. The generic diet reported by Pauly et al. (1998b) was composed of 65% of large zooplankton and 35% of fish (30% of small pelagic and 5% of miscellaneous fish). Read and Brownstein (2003) assumed that herring would account for about 34% of the minke whale diet in the Gulf of Maine in the 1990's. We assumed that their diet was composed of 65% macrozooplankton. 30% was assumed to be composed of small-medium pelagic species (e. g., herring, mackerel) and 5% gadid species. The allocation of prey to the differents functional groups reflected their relative abundance in the areas modelled.

Right whale – this species feeds primarily on copepods and secondarily on euphausiids (Murinson and Gaskin 1989; Pauly et al. 1998b). The percent diet composition for this species was allocated 50% to macrozooplankton (mostly euphausiids) and 50% to mesozooplankton (mostly copepods).

Odontocetes

The diets of the main odontocetes species are composed mainly of small schooling fish and squids. The importance of these items varies according to species and region. Fish prey lengths are generally below 40 cm and in most cases smaller than 30 cm. Several studies indicate that the average prey size of dolphins never exceeds 30 cm (Recchia and Read 1989, Craddock et al. 2009, Gannon et al. 1998, 1997, Meynier et al. 2008). Craddock et al. (2009) report that the white-sided dolphin exhibits size-selective predation with an average fish prey size of about 20 cm. The average sizes, size ranges and standard deviations reported by Craddock et al. (2009) Gannon et al. (1998, 1997) Meynier et al. (2008) (see Table 4) and the NORMDIST• function of Excel were used as a guide for allocating the proportions of the different sizes of prey species in the diet of these odontocetes species in the model.

Harbor porpoise – this species preys on a variety of fish. In the Bay of Fundy and Gulf of Maine, the preferred prey seem to be herring and silver hake, but also can include an important proportion of hakes (*Urophycis* spp.) and cod (Recchia and Read 1989; Gannon et al. 1998). The percent diet composition for this species was estimated by averaging the results from these two studies.

White-sided Dolphin – This species feeds on schooling fish and squids. The main prey items in the Northwest Atlantic are silver hake, herring, haddock and red hake (Craddock et al. 2009), with the fish items comprising almost 90% of the diet. The generic diet reported Kenney et al. (1997) was composed of 90% fish and 10% of squids. The generic diet reported by Pauly et al. (1998b) was composed of 65% of fish, 25% of squids and 10% of benthic invertebrates. According to Craddock et al. 2009, the white-sided dolphins probably do not dive to the bottom to forage. The relatively large proportion of

• The NORMDIST function returns the normal cumulative distribution for the specified mean and standard deviation.

benthic animals such as the octopus *Bathypolypus bairdii* could be discarded catch or related to the fact that some animals could be forced off the bottom by otter trawls. To account for these facts, part of the diet was composed of discards. The percent diet composition for this species was estimated by averaging the results from incidentally caught dolphins reported in Craddock et al. (2009).

Common Dolphin - This species feeds on schooling fish and squids. Overholtz and Waring (1991) analyzed the stomach contents of 4 dolphins caught in the Mid-Atlantic Bight and found 100% mackerel. Meynier et al. (2008) analysed stomach contents from common dolphins stranded along the French coast between 1999 and 2002. The main prey items were sardine, horse mackerel, anchovy, sprat and squids, with all fish prey items accounting for about 95% of the diet. The generic diet reported Kenney et al. (1997) was composed of 85% of fish and 15% of squids. The generic diet reported by Pauly et al. (1998b) was composed of 70% of fish and 30% of squids. Since the common dolphin diet is similar to the white-sided dolphin diet described above, the latter was used to represent the common dolphin diet.

Risso's Dolphins - This species seems to feed exclusively on squids (Pauly et al. 1995; Kenney et al. 1997).

Pilot whales - Gannon et al. (1997) reported the trace, non-trace and modified mass proportions in the diets for this species collected off the northeastern United States. The modified mass was considered the best approach, since this method tries to correct bias related to trace and non-trace (recent feeding) diet data. The proportions for the modified mass were 82.9% for all squids and 17.2% for mackerel. Fish prey items included, besides mackerel, herring, silver hake and even spiny dogfish. Overholtz and Waring (1991) reported 71% for mackerel and 29% of squids in the diets of pilot whale in the Mid-Atlantic Bight, but the high proportion of mackerel in this study could be reflect of recent feeding. The generic diet reported by Kenney et al. (1997) was composed of 10% of fish and 90% of squids. The generic diet reported by Pauly et al. (1998b) was composed of 25% of fish and 75% of squids. The diet proportions reported by Gannon et al. (1997) were used to represent the diet of this species, which included almost exclusively squids (about 83%) and mackerel (about 17%), but also included small amounts for herring, spiny dogfish and silver hake.

Table 4. Reported sizes for some of the main fish prey items of harbor porpoise, white sided-dolphin, common dolphin and pilot whales.

Predator	Prey	Av size	SD	Range	Study
Harbor porpoise	*C. harengus*	25.4	3.6	15.9 - 33.9	Gannon et al. 1998
	G. morhua	24.1	13.3		
	M. bilinearis	16.4	9.6	3 - 40.5	
	P. virens	19.5	10.1		
	S. scombrus	22.4	5.3		
	Sebastes spp.	3.7	0.3		
	Urophycis spp.	15.9	14.6		
	Main prey items	28	9	13-40	Fontaine et al. 1994
White-sided dolphin	*G. morhua*	7.6		6.7–8.9	Craddock et al. 2009
	M. aeglefinus	20.3		8.7–32.7	
	C. harengus	25.37		9.7–31.9	
	U. chuss	17.7		0.6–48.9	
	M. bilinearis	19.57		5.0–46.4	
Common dolphin	*Trachurus* spp.	11.7	3.5	4.8–32.9	Meynier et al. 2008
	Sardina pilchardus	19.2	3.2	6.4–26.0	
	Sprattus sprattus	11.4	2.1	5.9–17.4	
	Engraulis encrasicolus	12.1	2.6	3.3–19.4	
	Micromesistius poutassou	12.2	4.2	0.8–24.1	
	Trisopterus spp.	8	3.6	1.7–20.3	
	M. merluccius	18.6	4.9	9.0–29.8	
	S. scombrus	29	7.7	16.9–38.4	
Pilot whale	*S. scombrus*	34.9	3	26.5-37.5	Gannon et al. 1997
	S. scombrus	38.2	2.7	31.1-42.1	

BASIC INPUTS SUMMARY

Table 5. Basic input parameters for cetaceans. *B*=biomass, *P/B* = production:biomass ratio, *Q/B* = consumption:biomass ratio, *D*=discards, *D/B* = discard:biomass ratio.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	D ($t.km^{-2}$)	D/B ($year^{-1}$)
4X Mysticeti	0.612137	0.071	4.94		
4X Odontocetes	0.074818	0.180	14.50	0.002995	0.04
WSS Mysticeti	0.543095	0.071	4.72		
WSS Odontocetes	0.086823	0.120	12.33	0.000456	0.01
BoF Mysticeti	0.712799	0.072	5.11		
BoF Odontocetes	0.057317	0.270	17.77	0.006567	0.11

3. SEALS

BACKGROUND

This group is composed of the grey seal (*Halichoerus grypus*) and the harbour seal (*Phoca vitulina*). The grey seal is mainly a continental shelf species, preferring areas with water depths less than 200 m deep. The Northwestern Atlantic herd is considered to form a single genetic population, but for management purposes is divided into three components based on the location of the main breeding colonies: Sable Island, on the eastern Scotian Shelf, Eastern shore, which includes two breeding colonies in the eastern Scotian Shelf and another in the western Scotian Shelf, and Gulf, which breeds in the Gulf of St. Lawrence on drifting pack ice and small islands. It is estimated that 81% of the pups are born on Sable Island, 15% in the Gulf and 4% along the Nova Scotia's eastern shore, but this distribution has changed overtime. The species is considered by the fishing industry to be having a negative effect on the recovery of some fish stocks and to be damaging fishing gear. So far the evidence of the impact on fish species is not conclusive and there is no data on the degree of gear damage (DFO2008a).

The harbour seal of the western North Atlantic are distributed from the eastern Canadian Arctic and Greenland south to southern New England and New York and occasionally to the Carolinas. The species is a year-round inhabitant of the coastal waters of eastern Canada and Maine. The stock structure of the western North Atlantic population is unknown, but harbour seals found along the eastern USA and Canadian coasts are considered to be part of the same population (Waring et al. 2002 and references therein).

See Tables 6-8 for a summary of input parameter estimates.

BIOMASS

Most of the grey seals that occur in 4X actually inhabit the eastern Scotian Shelf and make seasonal movements onto the western Scotian Shelf to feed. Biomass estimates for the 4X grey seals component were derived from the modelling of grey seal-cod interactions in the eastern Scotian Shelf and western Scotian Shelf populations (Trzcinski et al. 2009) and provided by K. Trzcinski (DFO, pers. comm.). It is currently unknown what proportion of the grey seals present in 4X occur in the Bay of Fundy so a value of 5% was assumed, based on expert advice (K. Trzcinski, DFO, pers. comm.). Fowler and Stobo (2005) reported an estimate of 5554 harbour seals in the Bay of Fundy. This seems to be the only published abundance estimate for this species in the Bay of Fundy/western Scotian Shelf area. This value was used to estimate the biomass of harbour seals in the Bay of Fundy, by multiplying it by the average body mass reported in (Trites and Pauly 1998). It was then assumed that the biomass of this species in the western Scotian Shelf would be 5% of the BoF estimate.

BIOMASS ACCUMULATION

According to the grey seal model, the population has increased exponentially since the 1970s until about 1997 when the rate of increase started to slow (Bowen et al. 2003; Bowen et al. 2007). The average population growth for the period 1995-2000 was about 8.8%. The annual growth rate for the harbour seal population was estimated for the period between 1981 and 2001 to be about 6.6% (Waring et al. 2009). An average, weighted by biomass, of these values was calculated for each model.

PRODUCTION:BIOMASS

The *P/B* estimate for grey and harbour seals was derived from estimates of total mortality. The total grey seal mortality was derived from the population model data reported in Trzcinski et al. (2009). The total mortality of harbour seal was estimated using Hoenig's empirical model for marine mammals (Eq. 24). The maximum age estimate was taken from Trites and Pauly (1998). A biomass-weighted average *Z* was estimated for each model and summed with the corresponding average *BA* to give the *P/B* estimate.

CONSUMPTION:BIOMASS

The consumption of grey seals was derived from the seal model reported by Trzcinski et al. (2009) and the estimate for harbour seal was derived using the daily individual ration equation (Eq. 34) and the mean body weight in kg reported by Trites and Pauly (1998). This daily ration was multiplied by 365 to give annual estimates of *Q/B* for harbour seal. A biomass-weighted average *Q/B* was estimated for each model.

DIET

There are no diet data for grey seals for the model area during the study period. Instead diet was derived from estimates of grey seal diet data provided by Don Bowen (DFO, pers. comm.) for the eastern Scotian Shelf, based on quantitative fatty acid signature analysis data (see also Iverson et al. 2004) for the years between 1991 and 2004 and scat data for the years between 1991 and 2010. The samples were collected from grey seals captured on Sable Island which is located on the eastern Scotian Shelf. A simple average of the two data sets was estimated. The most important prey items in that area, as determined by these types of analyses, are sand lance and redfish (Bowen et al. 1993; Bowen and Harrison 1994; Bowen et al. 2006). Both species are quite abundant in the eastern Scotian Shelf bottom trawl survey samples but only redfish occur in high numbers in the Bay of Fundy/western Scotian Shelf area samples. Two studies (Bowen et al. 1993; Bowen and Harrison 1994) suggested a relationship between prey abundance and distribution and their importance as prey items. For example herring and mackerel seemed to be much more important in inshore areas while sand lance and silver hake were more important offshore at Sable Island. One exception for this is haddock, which is very abundant but has been so far found in small amounts in all diets studies reported for this region. The predation on small-medium pelagic species was adjusted to account for differences in the relative abundance of the several types of small pelagic species between the eastern Scotian Shelf and the 4X area. This greatly increased the proportion of herring compared to the original data set. For functional groups represented by 2 or more stanzas, the proportions of each stanza in the seals diet were tentatively estimated based on the prey length frequency distribution presented in Bowen et al. (1993) and Bowen and Harrison (1994). The data is presented in Table A4.4.

BASIC INPUT SUMMARY

Table 6. 4X model: basic input parameters for seals. *B*=biomass, Z = total mortality, P*/B* = production:biomass ratio, *Q/B* = consumption to biomass ratio, *BA* = biomass accumulation,

	Grey	Harbour	Total
B (tons)	3882.6	724.3	4606.9
B (t.km^{-2})	0.052	0.010	0.063
Z (/yr)	0.049	0.134	0.063
P/B (/yr)	0.137	0.200	0.147
Q/B (/yr)	6.851	9.955	7.339
BA (/yr)	0.088	0.066	0.084
Longevity (yr)		29.5	
Body mass (kg)		63.6	

Table 7. WSS model: basic input parameters for seals. See Table 6 for abbreviations.

	Grey	Harbour	Total
B (tons)	3688.5	34.5	3723.0
B (t.km^{-2})	0.085	0.001	0.085
Z (/yr)	0.049	0.134	0.050
P/B (/yr)	0.137	0.200	0.138
Q/B (/yr)	6.851	9.955	6.879
BA (/yr)	0.088	0.066	0.088
Longevity (yr)		29.5	
Body mass (kg)		63.6	

Table 8. BoF model: basic input parameters for seals. See Table 6 for abbreviations.

	Grey	Harbour	Total
B (tons)	194.1	689.8	883.9
B (t.km^{-2})	0.006	0.023	0.030
Z (/yr)	0.049	0.134	0.115
P/B (/yr)	0.137	0.200	0.186
Q/B (/yr)	6.851	9.955	9.273
BA (/yr)	0.088	0.066	0.071
Longevity (yr)		29.5	
Body mass (kg)		63.6	

4. SEABIRDS

BACKGROUND

Quantitative estimates of abundance, biomass and consumption of seabirds on the eastern and western Scotian Shelf were provided by a specially commissioned report for an earlier DFO project (Huettmann 2000). The abundance estimates (Table 9) were derived from the PIROP (Programme Intégré des Récherches sur les Oiseaux Pélagiques) database, which is "the largest and most detailed data set on seabird abundance and distribution for the study area" (Huettmann 2000; Bundy 2004). One of the original objectives of Huettmann's study was to provide temporal estimates for two time blocks (1966-1979; 1980-1992) but the sample sizes were too small and so he used the whole time period (1966-1992). The western Scotian Shelf area defined by Huettmann (2000) includes both the Bay of Fundy and the western Scotian Shelf. Although new data has been collected since Huettmann's analysis, coverage of the BoF in the new surveys (2006-2009) on which to base spatial distribution analysis for the two systems is very low (Dave Fifield, Canadian Wildlife Service, Environment Canada, pers. comm.). Instead, the abundance data was partitioned into the BoF and WSS (as defined in this study) based on the abundance ratio between the two systems as derived from the original data (Figure 3) used in Huettmann (2000), which was provided by David Fifield. See Table 11 for a summary of input parameters.

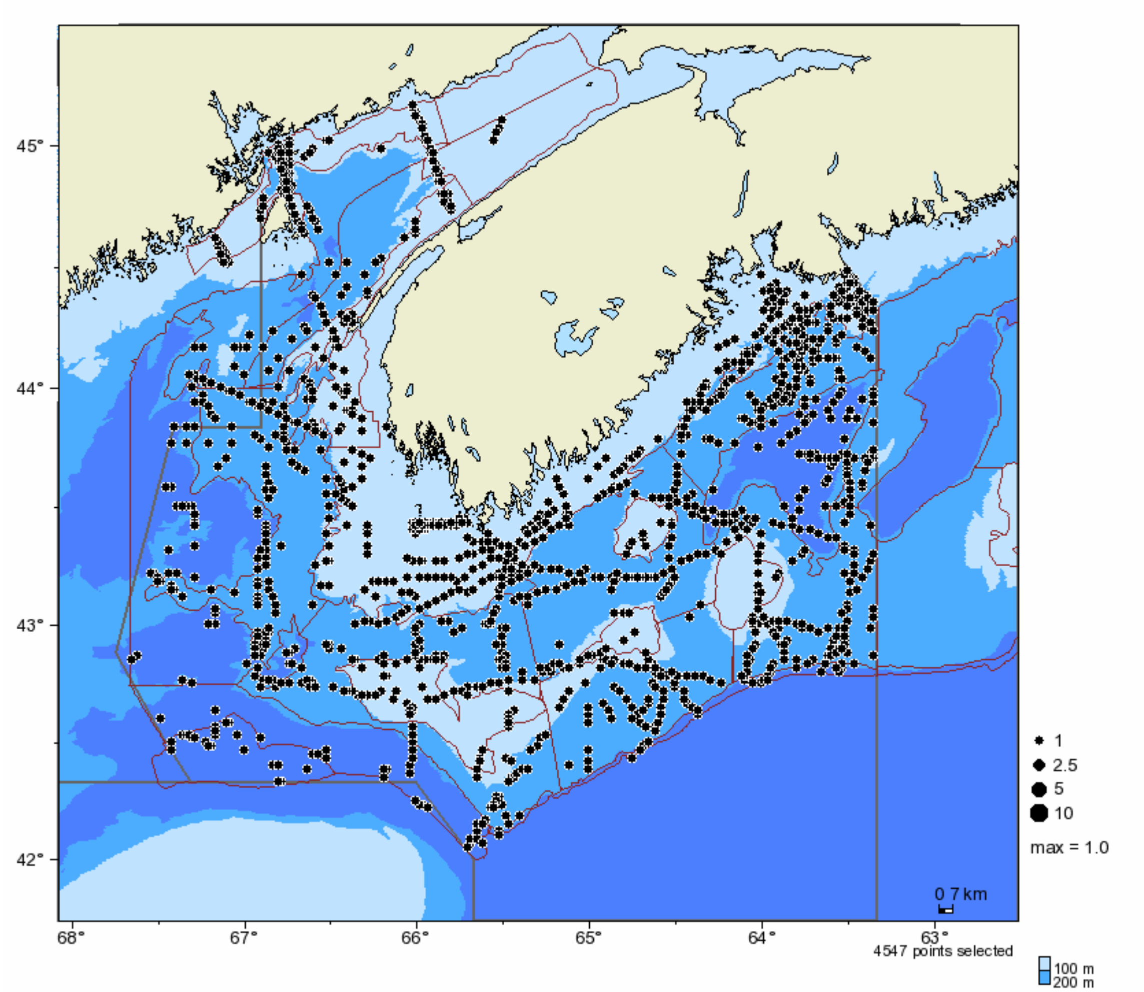

Figure 3. Seabirds sightings in the 1966-1979 and 1980-1992 periods for the 4X models area. Data provided by (Dave Fifield, Canadian Wildlife Service, Environment Canada, per. com.).

BIOMASS

A total annual average estimate of 649 t was estimated for the 4X area, 305 t for the BoF and 344 t for the WSS (Table 9) models.

Table 9. Seabirds biomass estimates derived from the PIROP (Programme Intégré des Récherches sur les Oiseaux Pélagiques) data reported by Huettmann (2000).

	Ecosystem					
	WSS		**BoF**		**4X**	
Species/Biomass	**t.km^{-2}**	**tonnes**	**t.km^{-2}**	**tonnes**	**t.km^{-2}**	**tonnes**
Black-legged Kittiwake	0.000235	10	0.001382	41	0.000702	52
Dovekie	0.000149	7	0.000521	16	0.000300	22
Great Black-backed Gull	0.001572	69	0.001892	57	0.001702	125
Greater Shearwater	0.002015	88	0.002498	75	0.002212	163
Herring Gull	0.001674	73	0.002385	71	0.001963	144
Leach's Storm-Petrel	0.000041	2	0.000067	2	0.000051	4
Northern Fulmar	0.000558	24	0.000299	9	0.000453	33
Sooty Shearwater	0.000355	15	0.000415	12	0.000379	28
Thick-billed Murre	0.000743	32	0.000213	6	0.000527	39
Wilsons Storm-Petrel	0.000082	4	0.000033	1	0.000062	5
Other Seabirds	0.000447	20	0.000489	15	0.000464	34
	0.007872	344	0.010192	305	0.008815	649

PRODUCTION:BIOMASS

The production to biomass ratio (*P/B* = 0.25 year^{-1}) estimate was based on reported values for other ecosystem models (Bundy 2004; Link et al. 2006).

CONSUMPTION:BIOMASS

The annual consumption to biomass ratio (*Q/B* year^{-1}) estimates for the western Scotian Shelf and eastern Scotian Shelf reported by Huettmann (2000) were quite similar, 125.1 and 127.3 year^{-1} respectively. However, the uncertainties related to methodological issues and poor understanding of how prey consumption of seabirds relates to “predator-prey relationships”, specially when they are at sea, are quite large (Huettmann 2000). For example, *Q/B* estimates derived from estimates of total consumption and biomass for several species of seabirds in the Northwest Atlantic (NAFO Areas 2J3KLMNOPs) reported by ICES (2000, Table 4.6) varies from 66 to 264 year^{-1}, with a mean of 129 year^{-1}, which is close to the value reported by Huettmann and used here.

DIET

The percent diet composition was estimated based on information that includes both site-specific studies and studies from other systems in the Northwest Atlantic (Brown 1981; ICES 2000; Huettmann 2000). Based on information reported in these studies a generic diet matrix for the 10 most important species was constructed (Table 10). Then the proportion taking into account both the relative abudance of the seabirds species and prey items in each system. The 4X diet is a biomass-weighted average of WSS and Bof diets (Table A4.5).

Table 10. Generic diet compostion of the most abundant bird species in the 4X area.

Prey/Predator	B-L. Kittiwake	Dovekie	G. B-B Gull	G. Shearwater	Herring Gull	Leach's S-Petrel	Northern Fulmar	S. Shearwater	T-B Murre	Wilsons' S.-Petrel
Small pelagic[1]	84	-	64	42	57	3	70	2	31	20
Gadoids	-	-	-	-	1	-	-	-	2	-
Small demersal fish	-	-	1	-	-	-	-	-	66	-
Squids	-	-	-	17	10	-	20	-	-	-
Myctophid	-	-	-	-	-	28	-	-	-	-
Euphausiid	-	-	-	35	-	5	-	84	-	-
Amphipods	-	-	-	-	-	15	-	-	-	-
Euphausiid and Fish	-	-	-	4	-	-	-	14	-	-
Zooplankton	-	100	-	-	-	-	-	-	-	80
Invertebrates	4	-	1	3	-	50	-	1	-	-
Discards	-	-	-	-	-	-	10	-	-	-
Seabirds	-	-	5	-	-	-	-	-	-	-
Others[2]	13	-	31	-	33	-	-	-	1	-
	100	100	100	100	100	100	100	100	100	100

1 – “Small pelagic” fish includes capelin, herring, sand lance and prey items decribed as “fatfish”.
2 – “Others” category includes prey types that are normally captured on land or in nearshore areas. This item is represented as import in the Ecopath models diet

BASIC INPUT SUMMARY

Table 11. Basic input parameters for seabirds. *B*=biomass, *P/B* = production:biomass ratio, *Q/B* = consumption to biomass ratio, *D* = discards, *D/B* = discard:biomass ratio.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	D ($t.km^{-2}$)	D/B ($year^{-1}$)
4X	0.008815	0.25	125.10	0.000024	0.003
WSS	0.007872	0.25	125.10	0.000030	0.004
BoF	0.010192	0.25	125.10	0.000010	0.001

5. SHARKS

BACKGROUND

This functional group is composed mainly of the porbeagle shark (*Lamna nasus*), blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*). The porbeagle shark is the only species for which there is a direct commercial fishery in Canadian shelf and adjacent oceanic waters (Campana et al. 2009). Despite its low importance in landings data, the blue shark is the most frequently caught large shark in Canadian waters and most catches are discarded (Campana et al. 2006). See Table 12 for a summary of input parameters.

BIOMASS

The biomass was estimated using the fishing mortality and total catches (landings + discards) as *B = C/F*, where "*F"* was derived from the porbeagle population model in the Northwest Atlantic (Gibson and Campana 2005; Campana et al. 2010). This estimate accounts for the seasonal behaviour of sharks since the annual estimate is calculated from an annual "*F*" and seasonal catch. The details for fishing mortality and discards estimates are given below.

BIOMASS ACCUMULATION

The porbeagle population declined during the 1990's, with an average relative biomass accumulation rate (*BA/B*) of about -0.075 $year^{-1}$. This decline is similar to the standardized catch rate trend for blue shark (about -5% per year) between 1995 and 2003 in Atlantic Canada (Campana et al. 2006).

PRODUCTION:BIOMASS

The *P/B* for sharks was based on fishing mortality, natural mortality and biomass accumulation (*BA/B*) for the porbeagle population in the Northwest Atlantic (Gibson and Campana 2005; Campana et al. 2010). The fishing mortality was estimated by dividing the total catches for the population by the biomass (*C/B*) estimates, provided by Steven

Campana (DFO, pers. comm.), which resulted in an average *F* of about 0.10 $year^{-1}$ for the period between 1995 and 2000. Natural mortality was assumed to be 0.15 $year^{-1}$, which is intermediate to that of immature and mature porbeagles (Campana et al. 2002, 2008). Hence the *P/B* (=*Z*+*BA/B*) of the porbeable population during the 1990's was estimated to be 0.18 $year^{-1}$. This estimate was used as input for the shark *P/B* in all models.

CONSUMPTION:BIOMASS

There are no direct estimates of *Q/B* for sharks in the 4X region. Wetherbee and Cortés (2004) summarized the literature information on food consumption of several shark species, including blue shark and shortfin mako. Based on the reported values by Wetherbee and Cortés (2004, Table 8.1), average annual *Q/B*s of 3.18 and 6.38 $year^{-1}$ for adult and juvenile sharks respectively were estimated. The mid-point between these two estimates (4.78 $year^{-1}$) was used as the input for the 4X models, which resulted in a *P/Q* of 0.037.

CATCHES

Estimates of discards in the 4X/5Y region for the period 2002 to 2006 show that about 86% of the total shark discards (203 tonnes) occurred in the swordfish longline fishery and that blue sharks accounted for 74% of the discarded sharks, followed by porbeable at 13% and shortfin mako at 11% (Gavaris et al. 2010). Other species such as thresher and tiger shark occurred in small amounts. Campana et al. (2009) estimated that discard mortality for blue shark would represent 35% of the blue shark discarded in the pelagic longline fishery. Since there are no specific estimates for sharks discards in the 4X/5Y for the period modelled in this study, the total discards mortalities were estimated by first applying the discards/total landings ratio by fishery estimated by Gavaris et al. (2010) to the landings data for the 1995-2000 period, then applying the average discard mortality rate estimated by Campana et al. (2009).

DIET

Diet estimates (Table A4.6) were based on the food habit studies of Joyce et al. (2002) and Maccord and Campana (2003) for the porbeagle and blue shark respectively. A weighted average of the two studies was calculated, with a larger weighting factor given to the porbeagle data (3:1) since the blue shark information reported by Maccord and Campana (2003) referred to percentage in numbers. Since the diet data was collected over a broad area, predation on prey items that are not common in the model area, such as mesopelagic species, was allocated to other pelagic prey items. The predation on small pelagic species, including squids, was also adjusted to account for differences in the relative abundance of the several types of small pelagic species in the models. Percentages of small and large herring were assumed to be 20% and 80% respectively of total herring consumed. The data is presented in Table A4.6.

BASIC INPUT SUMMARY

Table 12. Basic input parameters for sharks. *B*=biomass, *P/B* = production:biomass ratio, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)
4X	0.026025	0.18	4.78	0.002091	0.000575	0.00267	0.10
BoF	0.012304	0.18	4.78	0.000973	0.000287	0.00126	0.10
WSS	0.035437	0.18	4.78	0.002858	0.000772	0.00363	0.10

6. LARGE PELAGICS

BACKGROUND

The large pelagic group is composed of highly migratory species such as swordfish (*Xiphias gladus*), bluefin tuna (*Thunnus thynnus*), yellowfin tuna (*T. albacares*), albacore tuna (T. *alalunga*), bigeye tuna (*T. obesus*). See Table 13 for a summary of input parameter estimates.

BIOMASS

Since these species are not captured in the DFO Summer Trawl Survey, and in the absence of other information, biomass was estimated using the relationship $\overline{B} = \frac{C}{F}$, where $\overline{B}$ is the average biomass in the year and *C* the average annual catches in the area studied and *F* is a proxy for instantaneous fishing mortality rate estimated from the stock $\frac{C}{B}$ ratio in the 1995-2000. Catch to biomass ratios were available for the main species in this group, i.e., swordfish and bluefin tuna. For bluefin tuna a ratio of 0.16 $year^{-1}$ was derived from biomass and catch data for ages 7+, which are the main ages caught in Canadian waters, using estimates for the North-western Atlantic bluefin tuna population (ICCAT 2008; Tables 3 and 4, pages 47 – 48, and Table 2, Appendix 9, pages 164 – 166). For swordfish a ratio of 0.30 $year^{-1}$ was derived from the North Atlantic population biomass and catch data (ICCAT 2009; Tables 1 and 11). A simple average of the two estimates, 0.23 $year^{-1}$, was used to derive the biomass for the 4X and WSS model since overall landings for the two species have been fairly similar over the years. However, since blue fin tuna is by far the dominant species of the group landings in the BoF area, its exploitation ratio was used to derive the group biomass in this area.

BIOMASS ACCUMULATION

No *BA* term was included for this group, since the combined biomass series for the main species in the 1995-2000 period were fairly stable.

PRODUCTION:BIOMASS

The *P/B* for the large pelagic group was based on estimates of natural mortality rates as used in stock assessment, 0.14 and 0.2 year^{-1} for bluefin tuna and swordfish respectively (ICCAT 2008, 2009), plus the exploitation rates as estimated above.

CONSUMPTION:BIOMASS

There are no direct estimates of *Q/B* for this group in the 4X region. This parameter was based on literature estimates for swordfish, bluefin and yellowfin tuna (estimates reported in Bundy 2004). The landings-weighted average for the entire 4X was 4.23 year^{-1}, which was used in all models.

DIET

Percent diet composition for this group (Table A4.7) was based on (i) percent frequency of occurrence data of prey items of swordfish in a broad area located in eastern Canada oceanic waters (Sean Smith, DFO, pers. comm.) and (ii) on diet composition (percent weight) for bluefin tuna in New England (United States) waters reported by Chase (2002, Table 2). According to Scott and Scott (1988, and references therein), swordfish are probably opportunistic, eating what is available. Prey items observed in old studies included at least 31 species. The main items for Canadian waters were Atlantic mackerel, barracudinas (Paralepidae), silver hake, redfish, herring, and lanternfishes (Myctophidae) and shortfin squid, *Illex illecebrosus*. Herring were not observed in the recent swordfish stomach data. This is due to the fact that the stomachs were collected from fish caught on oceanic waters outside the area modelled in this study where the small pelagic fish species assemblage is different from the assemblage observed on the continental shelf part of the 4X Division (Sean Smith, DFO, pers. comm.). Hence, prey items observed in swordfish contents were then allocated to the same or similar species/functional groups according to their relative importance in the areas modelled, under the assumption that swordfish will eat what is available in a given area. On the other hand the bluefin tuna diet data reported by Chase (2002) was obtained from five feeding grounds on the New England continental shelf. Although species composition in these areas are different from the 4X division, most prey items reported are also common in the continental shelf of the 4X division. The main prey was herring, which is agreement with diet information for many piscivorous fish species collected in the NAFO Division 4X. The average size, size range and standard deviation for herring reported by Chase (2002, Table 5) and the NORMDIST[•] function of Excel were used as a guide for allocating the proportions of the different sizes of prey species in the diet of the large pelagics in the model. A simple average of the two diets was estimated and used as input for the 4X model. The data is presented in Table A4.7.

[•] The NORMDIST function returns the normal cumulative distribution for the specified mean and standard deviation.

BASIC INPUT SUMMARY

Table 13. Basic input parameters for the large pelagic fish group. *B*=biomass, *P/B* = production:biomass ratio, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)
4X	0.023573	0.40	4.23	0.005068	0.000469	0.005537	0.23
WSS	0.035586	0.40	4.23	0.007570	0.000788	0.008358	0.23
BoF	0.008688	0.30	4.23	0.001419	0.000004	0.001423	0.16

7 – 10. ATLANTIC COD

BACKGROUND

Atlantic cod, *Gadus morhua*, on the western Scotian Shelf and Bay of Fundy are treated as a single population for stock assessment purposes. The 4X cod begin to recruit to the fishery at age 2 and at age 3 most individuals begin to spawn. The spawning stock is considered to be formed of 4 year old fish and older, since the contribution of younger fish is considered to be minimal. Spawning occurs in the fall along the coast of Nova Scotia and in spring primarily on Browns Bank, which is closed to fishing from 1st February to 15th June. The condition factor of the 4X cod does not seem to have decreased over time (DFO 2009a, Clark and Emberley 2009.). Diet of young cod is composed mainly of invertebrates and changes gradually to a more piscivorous diet as it grows. Stomach data from the PED Food Habits Database for this region suggest that at least 50% of the diet is composed of fish and squids for cod above 50 cm.

There are clear growth differences between cod in WSS and BoF, with the latter having larger sizes-at-age. It is recognised that there are separate spawning components and that there is not a broad mixing of cod throughout the 4X area. However, since landings data have not been consistently collected with the appropriate spatial data to separate them into the WSS and BoF, it has not been considered feasible to conduct separate stock assessments for the two areas. Thus the stock assessment is carried out treating the spawning components that occur in the area as a single population (DFO 2009a, Clark and Emberley 2009).

In a recent cod assessment, Clark and Emberley (2009) considered several VPA model formulations to assess the 4X cod stock and address the issues related to the strong residuals patterns in the VPA model for this stock. The current accepted model uses a knife-edge increase in M in 1996. Due to issues related to the change of the research vessel, which occurred in 1982, the period used for model calibration starts in 1983. There are concerns about accuracy of landings data prior to the 1990s, but it is considered that the issues are not of sufficient magnitude to render the modelling unreliable. Results from the accepted model indicate that natural or unexplained mortality for age 4+ cod had increased from 0.2 to about 0.7 $year^{-1}$ in 1996 and remains at this level. The spawning stock biomass was estimated to be 9000 t in 2008, the lowest value in the series that started in 1948. Despite the reduction in the TAC to 5000 t and the fact that landings have remained below that level from 2005 to 2008, the adult biomass-weighted average fishing mortality (~0.40 $year^{-1}$) was still above the target adopted for this stock, which is 0.2 $year^{-1}$.

It has been suggested that the high *M* or unexplained mortality estimated in the accepted VPA is related to the exponential increase in the gray seal population, which could be preying upon large cod and also contributing to the increased levels of parasite infection (Clark and Emberley 2009). However, recent assessment of cod-seal interaction in the area have been unsuccessful in explaining the high adult cod mortality rate, since diet data suggest that seal predation occurs only on cod sizes that are normally younger than 4 years old (Bowen et al. 1993; Bowen and Harrison 1994; Trzcinski et al. 2009). Part of the high mortality could be also related to unreported fishing mortality; however it is not believed that this is a major factor.

Based on the biological and fisheries features described above, the cod group is represented by 4 stanzas or age groups: <1 year, 1-3, 4-6 and 7+. The size limits between these stanzas for the 4X cod in the period between 1995 and 2000 are about 22, 62 and 89 cm. These size classes were used as limits for the diet data separation into the four stanzas for all 3 models. Table 14 provides a summary of input parameter estimates.

BIOMASS

The biomass for the 3 models was estimated using catchability estimates from generic cod models (Harley et al. 2001). The 4X q-adjusted RV summer biomass estimates derived from the 50% quantile model, and extrapolated to the entire area, were in most cases below the VPA biomass estimates (Figure 4). The average q-adjusted RV biomass for 1995-2000 was 30630 t, while the average VPA for the same period was 39470 t. The uncertainty of the predictive distributions for catchability-at-length derived from the Harley and Myers (2001) models were large and reflect the variability among the stocks used in the meta-analysis. The 25% quantile catchability model of Harley and Myers (2001) gives catchablity estimates that are closer to the ones derived from the 4X VPA analyses, producing an average biomass of 40822 t for 1995-2000. This was used to derive the biomasses for the Ecopath models. Still, the estimates derived from survey data tend to be systematically lower prior to the early 1990s, reflecting the fact that the survey data do not show a decline as steep as the VPA estimates, even when a correction factor of 1.2 (Fanning 1985) was applied to the period prior to the research vessel changes.

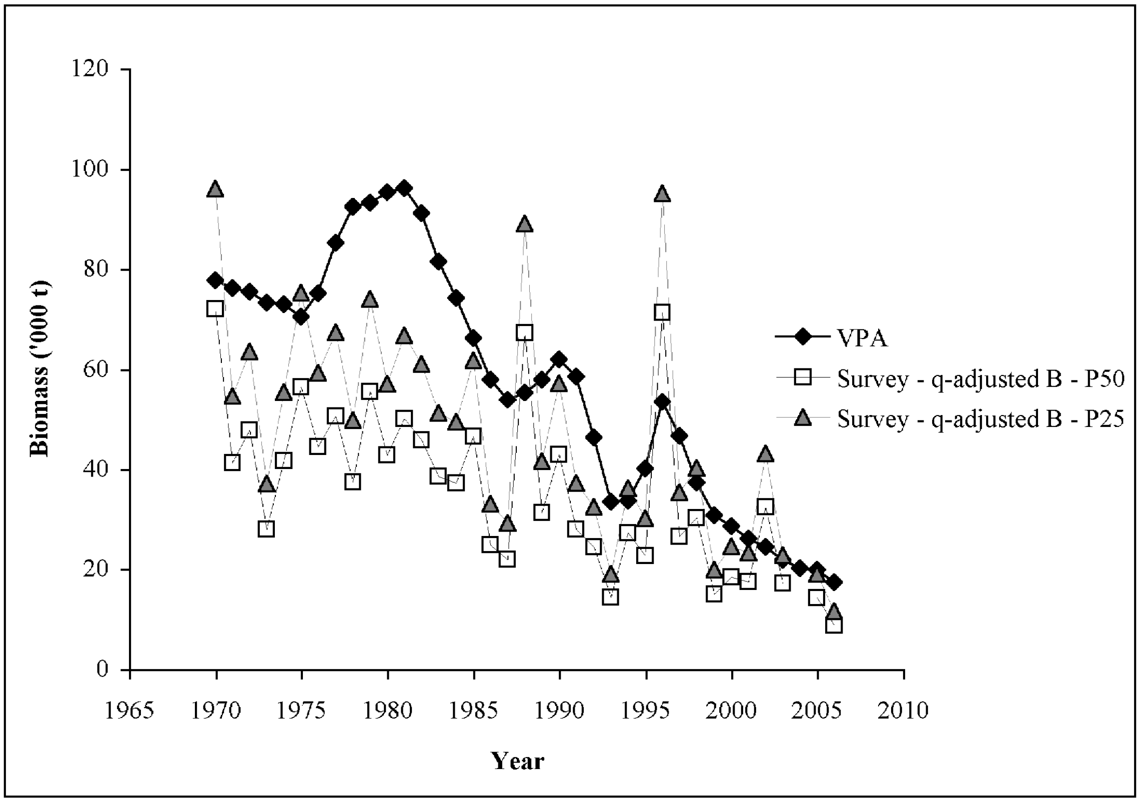

Figure 4. Comparison of total biomass of cod derived from VPA analysis (Clark and Emberley 2009) and from survey data applied to the generic cod catchability models of Harley et al. (2001).

BIOMASS ACCUMULATION

Despite some oscillation, the VPA biomass series shows that the 4X cod biomass was decreasing during the 1990s at an average rate of -5% per year. As the survey series are much more variable the general trend is not so clear. However, there is an overall decreasing trend from the 1990s to the end of the period in the 4X survey data. The decline seems to be stronger for the WSS component than for the BoF one, and the average biomass accumulation estimates for the two systems were -5 and -2.6% respectively.

MORTALITY

Average total mortality rates of cod for 1995-2000 were estimated from catch curve analysis of trawl survey data for cod age 4 and above. The estimates were 0.82 (95% CI: 0.67-0.97), 0.86 (95% CI: 0.58-1.15) and 0.77 year^{-1} (95% CI: 0.55-0.99) for the 4X, BoF and WSS areas respectively. These high estimates are in agreement with the VPA total mortality estimates for cod between age 4 and 12 years, which biomass-weighted average was 1.03 year^{-1} for the same period. Since the confidence intervals of the WSS and BoF estimates overlap, the same mortality rate (0.82 $year^{-1}$) was used as input for the cod 4+ stanzas total mortality. The mortality for the two small cod stanzas (below age 4) were estimated with the size-based approach (Eqs. 25 – 29) used for fish that are not fully recruited and are presented below (Table 14).

CONSUMPTION:BIOMASS

A *Q/B* of 1.56 $year^{-1}$ was estimated for the cod 7+ stanza from the gastric evacuation model using stomach content data from NAFO Division 4X. This estimate was used as input for the cod 7+ stanza, which resulted in reasonable average *Q/B* and *P/Q* ratios for the other size stanzas (Table 1).

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 1368 stomach samples taken on Summer RV Canadian surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). To increase sample size, the 4-6 and 7+ years stanzas diet data were combined to produce a common percent diet composition. The data is presented in Table A4.8.

BASIC INPUT SUMMARY

Table 14. Basic input parameters for Atlantic cod. Numbers in italic are estimated by the Ecopath multi-stanzas routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length.

Model	Group name	B (t.km^{-2})	Z (year^{-1})	Q/B (year^{-1})	L (t.km^{-2})	D (t.km^{-2})	C (t.km^{-2})	C/B (year^{-1})	K (year^{-1})	BA (year^{-1})	Wmat /Winf
4X	<1	*0.00354*	1.48	*10.53*		0.000286	0.000286	0.08	0.14	-0.05	0.04
	1-3	*0.223368*	0.39	*2.95*	0.024145		0.024145	0.11			
	4-6	*0.271913*	0.82	*1.82*	0.081950		0.08195	0.3			
	7+	0.076371	0.82	1.34	0.010009		0.010009	0.13			
	Pop.	0.575192	0.66	2.25	0.11610	0.000286	0.11639	0.2			
WSS	<1	*0.002037*	1.58	*11.66*		0.00022	0.00022	0.11	0.11	-0.05	0.02
	1-3	*0.136926*	0.39	*3.13*	0.01883		0.01883	0.14			
	4-6	*0.181344*	0.82	*1.89*	0.078909		0.078909	0.44			
	7+	0.056807	0.82	1.34	0.011601		0.011601	0.2			
	Pop.	0.377114	0.67	2.31	0.109340	0.00022	0.10956	0.29			
BoF	<1	*0.008006*	1.53	*9.66*		0.000387	0.000387	0.05	0.17	-0.026	0.06
	1-3	*0.424321*	0.4	*2.8*	0.029548		0.029548	0.07			
	4-6	*0.446612*	0.82	*1.76*	0.087424		0.087424	0.2			
	7+	0.104896	0.82	1.34	0.008993		0.008993	0.09			
	Pop.	0.983835	0.64	2.23	0.125965	0.000387	0.126352	0.13			

11 – 13. SILVER HAKE

BACKGROUND

Silver hake (*Merluccius bilinearis*) is found from Cape Hatteras to the Grand Banks and the Gulf of St. Lawrence. The species is found on the Scotian Shelf mainly between 7 and 10^{o} C and makes incursions to shallow waters during the summer. The maximum reported age is 12 years and maturity occurs at age 2, which corresponds to a size of about 25 cm in the 4X area. It is supposed that the silver hake found in the Bay of Fundy area represent a part of the Gulf of Maine and Northern Georges Bank stock (Showell et al. 2005). However, in contrast to other groundfish species such as cod, silver hake do not appear to exhibit large growth differences in the BoF and WSS.

The diet of small silver hake is composed mainly of invertebrates but rapidly changes to fish and squids as they grow. Based on local data from the PED Food Habits Database, the diet of fish above 30 cm was estimated to be composed of at least 50% of fish and squids and there is a high degree of cannibalism for species above this size. Based on this information, the silver hake functional group was split into 3 stanzas: <2, 2-3 and 4+ years. See Table 15 for a summary of the input data.

BIOMASS

Harley et al. (2001) recommended the generic pelagic gadoid model for the estimation of catchability adjusted silver hake biomass from bottom trawl survey data. However, this produced very high biomass estimates resulting in a considerable amount of unexplained mortality. As noted before, the uncertainty of the predictive distributions for catchability-at-length derived from the Harley and Myers (2001) models are large and reflect the variability among the stocks used in the meta-analysis. Bundy (2004) explored this same issue and derived a biomass estimate of 103853 t from the last VPA analysis for the silver hake 4VWX stock for 1995-2000 (derived from Showell and Fanning 1999). This estimate is much lower than the estimate for 4X area (298543 t) derived above from the pelagic gadoid model. This suggests that the catchability of silver hake is much higher than indicated by the pelagic gadoid model and is likely more consistent with catchabilities implied by the generic demersal gadoids model (Harley et al. 2001). Hence, the demersal gadoids model was used for the estimation of silver hake biomass inputs. Note that there is a high degree of uncertainty associated with this estimate.

BIOMASS ACCUMULATION

There is no clear trend in the biomass series during the 1990s for this group, thus *BA* was set to zero.

MORTALITY

Average total mortality rates of adult silver hake were estimated from catch curve analysis of raw trawl survey data for specimens age 2 and above. The estimate for the

BoF area was based on the years 1991-2000 because the data in this area is more variable with fewer observed age groups while the 4X and WSS estimates were based on data for the years 1995-2000. The estimates were: 4X - 1.00 (95% CI: 0.71-1.30); BoF - 1.28 (95% CI: 0.52-2.03) and WSS - 0.98 year^{-1} (95% CI: 0.69-1.27). These estimates are consistent with the total mortality estimates derived from VPA analysis for the 4VWX silver hake stock in the 1990s (Showell and Fanning 1999). Since the confidence intervals of the WSS and BoF estimates overlap, the same mortality rate (1.00 year^{-1}) was used as input for the total mortality of 2+ silver hake. Also, numbers at age for adult silver hake may be underestimated in the BoF area since, based on RV survey data, adult fish do not normally occupy this area during the summer, when the survey takes place (a higher proportion of silver hake 25+ cm was estimated based on fall RV surveys carried out between 1979 to 1984). The mortality for the juvenile stanza (below age 2) was estimated with the size-based approach (Eqs. 25 – 29) used for fish that are not fully recruited and are presented below in the basic inputs summary.

CONSUMPTION:BIOMASS

A *Q/B* of 11.35 year^{-1} for the silver hake 4+ stanza was estimated from the gastric evacuation model while the estimate for all sizes groups was 8.29 year^{-1}. Pauly (1989) reported consumption estimates of 3.85 and 4.26 year $^{-1}$ for silver hake in US waters. In the eastern Scotian Shelf, the *Q/B* based on evacuation model for the large silver hake (about 30 cm +) was 6.21 (PED Food Habits Database). The estimate derived from the empirical model (Palomares and Pauly 1998) was 4.1 year^{-1}. Using the highest values in the range reported above cause a large impact on the small silver hake stanzas (below age 2) because of the high level of cannibalism by this species. On the other hand, using the estimated derived from the empirical equation as input for the large stanza, reduces the impact on small silver hakes and results in *P/Q* ratios that seem to be consistent with the observed growth rates for this population. The estimated derived from the empirical model was thus used for the large silver hake stanza.

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 968 stomach samples taken on Summer RV Canadian surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010. More than half of the stomach samples were for the small silver hake stanza (fish under 25 cm). The data is presented in Table A4.9.

BASIC INPUTS SUMMARY

Table 15. Basic input parameters for silver hake. Numbers in italic are estimated by the Ecopath multi-stanzas routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length.

Model	Group name	B (t.km^{-2})	Z (year^{-1})	Q/B (year^{-1})	L (t.km^{-2})	D (t.km^{-2})	C (t.km^{-2})	C/B (year^{-1})	K (year^{-1})	BA (year^{-1})	Wmat /Winf
4X	<2	*0.093434*	0.87	*8.63*	0.005438	0.000096	0.005534	0.06	0.46		0.22
	2-3	*0.134770*	1	*5.16*	0.023001		0.023001	0.17			
	4+	0.043039	1	4.10	0.008442		0.008442	0.20			
	Pop.	0.271243	0.96	6.19	0.036881	0.000096	0.036978	0.14			
WSS	<2	*0.126573*	0.87	*8.63*	0.008614	0.00008	0.008696	0.07	0.46		0.22
	2-3	*0.182570*	1	*5.16*	0.036431		0.036431	0.20			
	4+	0.058304	1	4.1	0.013372		0.013372	0.23			
	Pop.	0.367447	0.96	6.19	0.058417	0.00008	0.058498	0.16			
BoF	<2	*0.047270*	0.87	*8.63*	0.000809	0.000116	0.000925	0.02	0.46		0.22
	2-3	*0.068182*	1	*5.16*	0.003422		0.003422	0.05			
	4+	0.021774	1	4.10	0.001256		0.001256	0.06			
	Pop.	0.137226	0.96	6.19	0.005487	0.000116	0.005603	0.04			

14 – 16. HALIBUT

BACKGROUND

The halibut functional group includes the Atlantic halibut, *Hippoglossus hippoglossus*, and Greenland halibut, or turbot, *Reinhardtius hippoglossoides*, which occurs sporadically and in very low numbers in the 4X area.

The distribution of the Atlantic halibut in the western Atlantic ranges from southwestern Greenland and Labrador in Canada to Virginia in the USA. The center of species abundance is along the southern edge of the Grand Bank and on the Scotian Shelf from Browns Bank to Banquereau Bank. Preferred depths range between 200 and 500 m, and the species is normally associated with bottom temperatures around 5 C° (DFO 2001, 2009b). Tagging experiments indicated that the species move over large distances, with smaller fish moving further than the larger fish (DFO 2001, 2009b). The management unit includes NAFO Divisions 3NOPs4VWX5Zc (Trumble et al. 1993; DFO 2001, 2009b). The landings for this stock peaked in the mid 1980s, decreased to an all-time minimum in the mid 1990s and have shown an increasing trend since then. Current catch rate analyses and model results indicate an increase in population size in the past 4 years (DFO 2009b).

The size at 50% maturity of females and males of Atlantic halibut are 120 cm and 80 cm respectively (DFO 2009b). Fishing regulations stipulate a minimum landing size of 82 cm, requiring all Atlantic halibut below this size to be released. Data from the PED Food Habits Database for the area indicate that for fish above 46 cm, fish items represent at least 50% of the diet composition. Based on this information, the group was split into 3 stanzas: <46 cm, 46-81 cm and 82+ cm. See Table 16 for summary of input parameters.

BIOMASS

Biomass estimates were derived from the Atlantic halibut population model for NAFO Division 3NOPs4VWX5Zc, provided by K. Trzcinski (DFO, pers. comm., Trzcinski et al. 2011). The average exploitation rate ($F=C/B$) for the legal-sized halibut in the 1995-2000 years was 0.17 year^{-1}. This estimate was used to derive the halibut leading stanza biomass from catch estimates in the areas modelled. The biomass was estimated using the fishing mortality and total catches as $B = C/F$, were "*F*" is the exploitation rate derived from the population model mentioned above.

BIOMASS ACCUMULATION

Halibut model results do not show a clear biomass trend in the 1990s (Trzcinski et al. 2011), and the *BA* was set to zero.

MORTALITY

Natural mortality in the Atlantic halibut stock assessment is assumed to be 0.1 $year^{-1}$ and the 1995-2000 exploitation rate of the exploitable biomass was estimated to be 0.17 $year^{-1}$. The resultant total mortality of 0.27 $year^{-1}$ was used as the input mortality for the adult halibut stanza. The mortalities for the juvenile stanza were estimated with the size-based approach (Eqs. 25 – 29) used for fish that are not fully recruited and are presented below in the basic inputs summary.

CONSUMPTION:BIOMASS

A *Q/B* of 1.61 $year^{-1}$ was estimated from the gastric evacuation model for the large Atlantic halibut stanza, produceding reasonable production to consumption ratio estimates for all stanzas when input to the EwE multistanza routine.

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 268 stomach samples from Summer RV Canadian surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). Due to low sample sizes, US strata 36, which extends into the Gulf of Maine was included in the US data. Data for the two large stanzas were combined to increase sample size. The data is presented in Table A4.10.

Table 16. Basic input parameters for halibut. Numbers in italic are estimated by the Ecopath multi-stanza routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length

Model	Group name	B (t.km^{--2})	Z (year^{-1})	Q/B (year^{-1})	L (t.km^{--2})	D (t.km^{--2})	C (t.km^{--2})	C/B (year^{-1})	K (year^{-1})	BA (year^{-1})	Wmat /Winf
4X	<46	*0.00135*	0.57	*5.09*	0.000029	0.000153	0.000182	0.14	0.14		0.24
	46-81	*0.00523*	0.27	*2.59*	0.000250	0.000153	0.000403	0.08			
	82+	0.017291	0.27	1.61	0.002993		0.002993	0.17			
	Pop.	0.023863	0.29	2.02	0.003272	0.000306	0.003578	0.15			
WSS	<46	*0.001821*	0.57	*5.09*	0.000039	0.00019	0.000229	0.13	0.14		0.24
	46-81	*0.007065*	0.27	*2.59*	0.000338	0.00019	0.000528	0.07			
	82+	0.023379	0.27	1.61	0.004047		0.004047	0.17			
	Pop.	0.032265	0.29	2.02	0.004424	0.000380	0.004804	0.15			
BoF	<46	*0.000656*	0.57	*5.09*	0.000014	0.000103	0.000117	0.18	0.14		0.24
	46-81	*0.002544*	0.27	*2.59*	0.000122	0.000103	0.000225	0.09			
	82+	0.008418	0.27	1.61	0.001457		0.001457	0.17			
	Pop.	0.011618	0.29	2.02	0.001593	0.000206	0.001799	0.15			

17 – 18. POLLOCK

BACKGROUND

The distribution of pollock (*Pollachius virens*) in the western Atlantic ranges from southern Labrador to Cape Hatteras, although the main fishing areas are the Scotian Shelf, Georges Bank and the Gulf of Maine (Stone et al. 2006). According to current management, there are two stock components, one slow-growing component that includes NAFO divisions 4V and 4W and the units 4Xm and 4Xn, and one fast-growing component that includes the units 4Xopqrs and the Canadian parts of subarea 5 (5Yb + 5Zc) (Stone et al. 2006). Growth differences are also observed in BoF and WSS pollock, with larger sizes at age observed in the BoF (Virtual Data Centre, Fisheries and Oceans Canada, Population Ecology Division database).

Pollock younger than 2 years are closely associated with nearshore habitats and they mature between 3 and 5 years old depending on the area (Stone et al. 2006). Data from the PED Food Habits Database for the 4X area indicate that it is a piscivorous species, with fish and squids accounting for more than 50% of the diet of specimens above 43-48 cm. The commercial and main spawning ages comprise mainly the 4+ age groups. Based on these observations, the group was split into two stanzas: <4 and 4+ years old. The corresponding size for pollock age split in the 4X area is about 49 cm. See Table 17 for summary of input parameters.

BIOMASS

Harley et al. (2001) recommended the generic pelagic gadoids model for the estimation of q-adjusted pollock biomass from bottom trawl survey data. However, this produces a large biomass that results in a very low fishing mortality (c.f. silve hake above), much lower than the estimates derived for this stock from the VPA analysis (Stone et al. 2006, 2009). The alternate generic demersal gadoids model (Harley et al. 2001) gives much lower biomass estimates than the pelagic model, but because of the large inter annual variation in the pollock survey data, results in low fishing mortality compared to the VPA estimates. Hence, the alternative adopted was to use the unadjusted survey data to derive separated estimates for the 4X (Figure 5), BoF and WSS models.

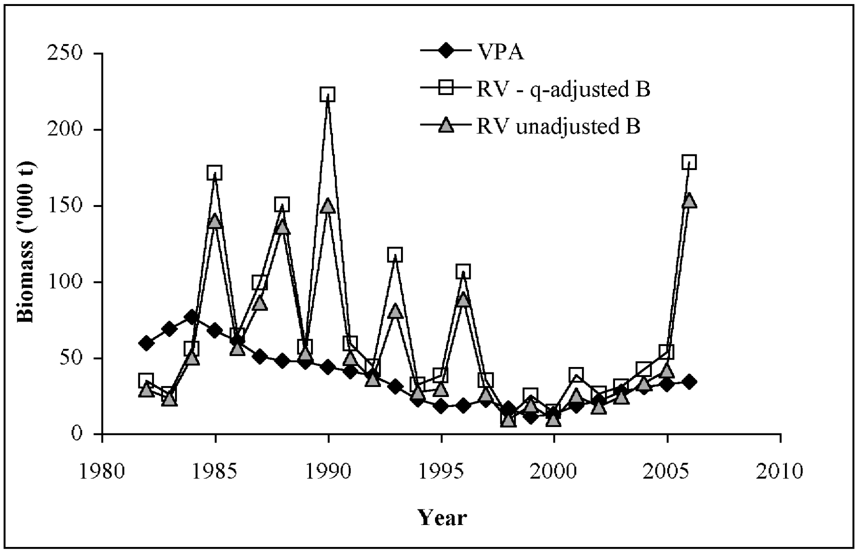

Figure 5. Estimates of biomass for pollock. The VPA series refers to the 4Xopqrs5Yb5Zc component. The survey data series refer to the entire 4X area: q-adjusted with the demersal gadoid model of Harley et al. (2001) and the non-adjusted series.

BIOMASS ACCUMULATION

The VPA biomass series shows a decreasing trend at the end of the 1990s, with an average *BA* rate of -0.07 year^{-1}. This value was used in all models.

MORTALITY

Average total mortality rates of pollock for 1995-2000 were estimated from catch curve analysis of trawl survey data for pollock age 4 and above. The estimates were 1.09 (95% CI: 0.83-1.35), 0.97 (95% CI: 0.77-1.18) and 1.08 year^{-1} (95% CI: 0.81-1.35) for the 4X, BoF and WSS areas respectively. These high estimates are in agreement with the VPA estimate of total mortality (biomass-weighted average) of 0.85 year^{-1} for pollock between age 4 and 13 years for the same period. Since there were no significant differences between the WSS and BoF estimates, which were similar to the VPA estimate, the same mortality rate (0.85 year^{-1}) was used as input for the pollock 4+ stanza total mortality. The mortality for the small pollock stanza was estimated with the size-based approach (Eqs. 25 – 29) used for fish that are not fully recruited and are presented below in the basic inputs summary.

CONSUMPTION:BIOMASS

A *Q/B* of 3.67 year^{-1} was estimated using the gastric evacuation model for all available pollock length sizes. This is comparable to the estimate of 3.59 year^{-1} for the eastern Scotian Shelf (Bundy 2004), but lower than the estimate of 4.76 year^{-1} for George's Bank (Pauly 1989). The estimate of 3.67 year^{-1} was used for the adult pollock stanza in all models.

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 769 stomach samples taken on Summer RV Canadian surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). Due to low sample sizes, US strata 36, which extends into the Gulf of Maine was included in the US data. The data is presented in Table A4.11.

Table 17. Basic input parameters for pollock. Numbers in italic are estimated by the Ecopath multi-stanzas routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length

Model	Group name	B (t.km^{-2})	Z (year^{-1})	Q/B (year^{-1})	L (t.km^{-2})	D (t.km^{-2})	C (t.km^{-2})	C/B (year^{-1})	K (year^{-1})	BA (year^{-1})	Wmat /Winf
4X	<4	*0.282278*	0.47	*6.42*	0.004407	0.000290	0.004697	0.02	0.16	-0.07	0.13
	4+	0.372317	0.85	3.67	0.092313		0.092313	0.25			
	Pop.	0.654595	0.69	4.86	0.096720	0.000290	0.097010	0.15			
WSS	<4	*0.176199*	0.49	*6.32*	0.002707	0.000220	0.002931	0.02	0.18	-0.07	0.15
	4+	0.212481	0.85	3.67	0.056690		0.056690	0.27			
	Pop.	0.388680	0.69	4.87	0.059397	0.000220	0.059621	0.15			
BoF	<4	*0.487613*	0.48	*6.31*	0.006887	0.000385	0.007272	0.01	0.18	-0.07	0.13
	4+	0.594982	0.85	3.67	0.144251		0.144251	0.24			
	Pop.	1.082595	0.68	4.86	0.151138	0.000385	0.151523	0.14			

19 – 20. DEMERSAL PISCIVORES

BACKGROUND

This group is comprised of white hake (*Urophycis tenuis*), cusk (*Brosme brosme*), sea raven (*Hemitripterus americanus*) and monkfish (*Lophius americanus*), all demersal, highly piscivores species. White hake is the main species in the group accounting for more than 50% of the biomass. It is distributed from the southern Grand Banks to the mid-Atlantic Bight, mainly at depths between 50 to 400 m and associated with temperatures between 6 °C and 10 °C. Current assessment considers three components in the NAFO Divisions 4Vn, 4VsW and 4X/5, the latter accounting for most of white hake landings (Bundy and Simon 2005).

Fifty percent maturity of white hake occurs at about 42.5 cm on the Scotian Shelf and 45.5 cm in the Bay of Fundy, lengths that correspond to ages of 3.2 and 3.5 respectively (Bundy and Simon 2005). The diet composition for fish above 40-43 cm is mainly composed of fish. Based on this information, the group was split into small (<40 cm) and large (40+ cm) stanzas. See Table 18 for summary of input parameters.

BIOMASS

Biomass was estimated from the summer DFO RV Groundfish survey data, adjusted for catchability. Harley et al. (2001) recommended the generic demersal gadoids model for the estimation of biomasses for all species in this group. They also suggested increasing the "effective size" and hence the catchability of some species such as sea raven to account for different morphology and behaviour. The suggested correction factor could be as high as 1.5. Instead a correction factor of 1.25 was used to increase the effective size of monkfish and sea raven. None of the species included in this group are currently assessed through the use of VPA analysis and hence there are no analytical results for comparison.

BIOMASS ACCUMULATION

The group as a whole have a decreasing biomass trend in the 1990s, with a steeper decline in the BoF series. The average biomass accumulation rates were -0.12, -0.02 and -0.16 for the 4X, WSS and BoF models respectively. Thus the 4X trend is driven by the trend in BoF.

MORTALITY

Average total mortality rates for white hake were estimated from length-based catch curve analysis (Pauly 1983) of trawl survey and commercial landings data. The estimates derived from the research data were 0.67 (95% CI: 0.57-0.77), 0.69 (95% CI: 0.54-0.84) and 0.75 year^{-1} (95% CI: 0.65-0.84) for the 4X, BoF and WSS areas respectively. On the other hand the estimate based on the commercial length frequency data for the entire 4X area was 0.57 year^{-1} (95% CI: 0.51-0.64) for lengths between 61 and 121 cm. These estimates should be seen as relative rather absolute values. The lower estimate derived from the commercial data could be indication that the research survey underestimate the abundance of large fish. However, as the confidence intervals overlap and currently there is no apparent reason to give preference to either survey or commercial data, the mid point (0.62 $year^{-1}$) between the two 4X estimates was used as input for the adult stanza in all models. The mortality for the small stanza was estimated with the size-based approach (Eqs. 25 – 29) used for fish that are not fully recruited and are presented below in the basic inputs summary.

CONSUMPTION:BIOMASS

A *Q/B* of 4.03 $year^{-1}$ was estimated from the gastric evacuation models and stomach content data for all available size classes. This estimate was used for the adult stanza and resulted in reasonable *P/Q* ratio for the other stanza of this group when input to the multi-stanza routine.

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 1506 stomach samples from the Canadian Summer RV surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). The data is presented in Table A4.12.

BASIC INPUTS SUMMARY

Table 18. Basic input parameters for the demersal piscivores. Numbers in italic are estimated by the Ecopath multi-stanzas routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length

Model	Group name	B (t.km^{--2})	Z (year^{-1})	Q/B (year^{-1})	L (t.km^{--2})	D (t.km^{--2})	C (t.km^{--2})	C/B (year^{-1})	K (year^{-1})	BA (year^{-1})	Wmat /Winf
4X	<40	*0.058105*	0.44	*8.91*		0.002805	0.002805	0.05	0.075	-0.12	0.02
	40+	0.266410	0.62	4.03	0.058946		0.058946	0.22			
	Pop.	0.324515	0.59	4.90	0.058946	0.002805	0.061751	0.19			
WSS	<40	*0.045107*	0.44	*8.28*		0.002211	0.002211	0.05	0.09	-0.02	0.03
	40+	0.116670	0.62	4.03	0.060988		0.060988	0.52			
	Pop.	0.161777	0.57	5.22	0.060988	0.002211	0.063199	0.39			
BoF	<40	*0.076082*	0.43	*9.44*		0.003672	0.003672	0.05	0.06	-0.16	0.01
	40+	0.475011	0.62	4.03	0.055968		0.055968	0.12			
	Pop.	0.551093	0.59	4.78	0.055968	0.003672	0.059640	0.11			

21 – 22. LARGE BENTHIVORES

BACKGROUND

This is a generic group composed of several demersal benthivore species with reported maximum sizes above 50 cm. The main species in the group are red hake (*Urophycis chuss*), ocean pout (*Macrozoarces americanus*), striped Atlantic wolffish (*Anarhichas lupus*) and lumpfish (*Cyclopterus lumpus*).

The group is split into small and large stanzas based on the average size at maturity of the main species. The sizes at maturity were derived from equations 17 and 18 and maximum sizes observed in survey data. The estimated sizes at maturity fall in the range of reported values for these species (Gunnarson et al. 2006; Scott and Scott 1988; Steimle et al. 1999) and varied from 30 cm for lumpfish to about 56 cm for the striped Atlantic wolfish, with a biomass-weighted average of about 40 cm in the 4X area. This estimate was used as the split size limit for all models. See Table 19 for summary of input parameters.

BIOMASS

Biomass was estimated from the summer DFO RV Groundfish survey data, adjusted for catchability. Harley et al. (2001) recommended the ling model for the estimation of biomasses for species like the striped Atlantic wolffish and ocean pout. They also considered the possibility of using the demersal gadoids model, but considered that the higher catchabillity estimates for fish below 80 cm would not be reasonable. However the ling model gives very high biomass estimates for these species, resulting in high level of unexplained mortality for this functional group. Hence, the demersal gadoids model was used for all species in this group and the inputs are considered conservative estimates.

BIOMASS ACCUMULATION

RV biomass series do not show a clear biomass trend in the 1990s, and then the *BA* was set to zero.

MORTALITY

Average total mortality rates for the main species in the group were estimated from length-based catch curve analysis (Pauly 1983) of trawl survey of the entire 4X area. The estimates ranged from 0.25 year^{-1} for striped wolffish to 1.10 year^{-1} for red hake. The biomass-weighted average was 0.64 year^{-1}. This estimate was used as input for the adult mortality in all models. The mortality for the small stanza was estimated with the size-based approach (Eqs. 25 – 29) used for fish that are not fully recruited and are presented below in the basic inputs summary.

CONSUMPTION:BIOMASS

A *Q/B* of 1.92 year^{-1} was estimated from the gastric evacuation models and stomach content data for the large adult stanza. This resulted in reasonable *P/Q* ratios for the other stanza of this group when input to the multi-stanza routine.

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 870 stomach samples taken on Canadian Summer RV surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). Due to low sample sizes, US strata 36, which extends into the Gulf of Maine was included in the US data. The data is presented in Table A4.13.

Table 19. Basic input parameters for the large benthivores. Numbers in italic are estimated by the Ecopath multi-stanzas routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length.

Model	Group name	B (t.km^{-2})	Z (year^{-1})	Q/B (year^{-1})	C (t.km^{-2})	C (t.km^{-2})	C (t.km^{-2})	C/B (year^{-1})	K (year^{-1})	BA (year^{-1})	Wmat /Winf
4X	<40	*0.070525*	0.34	*3.25*		0.000385	0.000385	0.005	0.14		0.15
	40+	0.064762	0.64	1.92	0.004406		0.004406	0.068			
	Pop.	0.135287	0.48	2.61	0.004406	0.000385	0.004791	0.035			
WSS	<40	*0.056127*	0.35	*3.31*		0.000393	0.000393	0.007	0.14		0.15
	40+	0.061880	0.64	1.92	0.005522		0.005522	0.089			
	Pop.	0.118007	0.50	2.58	0.005522	0.000393	0.005915	0.050			
BoF	<40	*0.090155*	0.34	*3.21*		0.000373	0.000373	0.004	0.14		0.15
	40+	0.068777	0.64	1.92	0.002779		0.002779	0.040			
	Pop.	0.158932	0.47	2.65	0.002779	0.000373	0.003152	0.020			

23–24. SKATES

BACKGROUND

This group includes thorny skate (*Raja ocelleta*), winter skate (*R. radiata*), smooth Skate (*R. senta*), little skate (*R. erinacea*) and barndoor skate (*R. laevis*). They are all relatively slow-growing, late-maturing and long-lived species. The fastest growing species is the little skate, which matures at about 7 years of age, whereas the other species can take more than 10 years to reach maturity. The temperature preference of these species is variable, but most fall within 1 to 10 °C. The biomass of skates in the 4X area has declined from the late 1970s to the early 1990s and seems to be relatively stable since then. The group was split into small (below 49 cm) and large (49+ cm), based on the mode of the research trawl length frequency data for the period modelled here. This size is close to the average size at maturity of the smallest species, little and smooth skates. See Table 20 for summary of input parameters.

BIOMASS

Biomass was estimated from the summer DFO RV Groundfish survey data, adjusted for catchability. Harley et al. (2001) recommended using the flatfish model to estimate skate biomass, adjusting for the catchability of skates to the RV bottom trawl survey data.

BIOMASS ACCUMULATION

RV biomass series oscillates and does not show a clear biomass trend in the 1990s, and the *BA* was set to zero.

PRODUCTION:BIOMASS

Total mortality rate for this group was estimated from length-based catch curve analysis (Pauly 1983) of trawl survey in the 4X area for winter and thorny skates. The biomass-weighted average was 0.26 year^{-1}. The same estimate was obtained with the empirical equation of Hoenig (1983) and maximum age estimates for winter, thorny, little and smooth skates. This estimate was used as input for the adult mortality in all models. The mortality for the small stanza was estimated with the size-based approach (Eqs. 25 – 29) used for fish that are not fully recruited and are presented below in the basic inputs summary.

CONSUMPTION:BIOMASS

A *Q/B* of 1.90 year^{-1} was estimated from the gastric evacuation models and stomach content data for the large adult stanza. This resulted in reasonable *P/Q* ratios for the other stanza of this group when input to the multi-stanza routine.

CATCHES

Landings for this group are relatively small (see Table 20). The discards estimates are quite uncertain and the size composition has not been reported by Gavaris et al. (2010). Therefore, it was assumed the discards were composed of 50% small skates and 50% large skates.

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 638 stomach samples from Canadian Summer RV surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). The data is presented in Table A4.14.

BASIC INPUTS SUMMARY

Table 20. Basic input parameters for skates. Numbers in italic are estimated by the Ecopath multi-stanzas routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length.

Model	Group name	B (t.km^{-2})	Z (year^{-1})	Q/B (year^{-1})	L (t.km^{-2})	D (t.km^{-2})	C (t.km^{-2})	C/B (year^{-1})	K (year^{-1})	BA (year^{-1})	Wmat /Winf
4X	<49	*0.090172*	0.31	*3.29*		0.006547	0.006547	0.07	0.13		0.40
	49+	0.073658	0.26	1.90	0.000799	0.006547	0.007345	0.10			
	Pop.	0.163830	0.29	2.67	0.000799	0.013094	0.013892	0.08			
WSS	<49	*0.087530*	0.31	*3.29*		0.007955	0.007955	0.09	0.13		0.40
	49+	0.071500	0.26	1.90	0.000849	0.007955	0.008804	0.12			
	Pop.	0.159030	0.29	2.67	0.000849	0.015910	0.016760	0.11			
BoF	<49	*0.093854*	0.31	*3.29*		0.004492	0.004492	0.05	0.13		0.40
	49+	0.076665	0.26	1.90	0.000726	0.004492	0.005218	0.07			
	Pop.	0.170519	0.29	2.67	0.000726	0.008984	0.009711	0.06			

25–26. SPINY DOGFISH

BACKGROUND

Spiny dogfish (*Squalus acanthias*) in the northwest Atlantic have many characteristics of a metapopulation, which can be divided in several groups, such as the southern Gulf of St. Lawrence, around Newfoundland, the eastern and central Scotian Shelf, Bay of Fundy and SW Nova Scotia, Massachusetts and North Carolina (Campana et al. 2007). There is some mixing between groups, particularly in the Gulf of Maine and Bay of Fundy, but it seems that the other Canadian groups remain largely separate, with seasonal migration occurring mainly or exclusively between inshore and offshore sites (Campana et al. 2007). Compagno (1984) states that dogfish migrations are governed by temperature changes. On the Scotian Shelf they are mainly associated with temperatures between 6 and 11ºC at depths of 50-200 m. Large females have been reported in high numbers in the nearshore area of the Scotian Shelf, likely to allow maximal growth of their embryos in warmer coastal waters (Stehlik 2007 and references therein). It is known that their embryos grow faster at higher temperatures (Jones and Ugland 2001; Stehlik 2007).

Spiny dogfish is a relatively small shark species. The length at 50% maturity for males and females in Atlantic Canada is about 64 and 82 cm TL respectively, with an average of 73 cm. These sizes correspond to ages 10 for male and age 16 for females (Campana et al. 2007). The diet data for the 4X area indicate that the amount of fish and squid consumed by dogfish increases with length, and that fish and squid represent more than 50% of the diet for specimens above 70 cm (Cook and Bundy 2010). Commercial catch at length data from longline and gillnet samples suggest that fish of 74 cm and above are fully recruited to the fisheries. Based on this information, the dogfish functional group was split into juveniles (below 73 cm) and adults (73+ cm). See Table 21 for a summary of input parameters.

BIOMASS

Harley et al. (2001) recommended the demersal gadoids equation for the estimation of dogfish biomass from the DFO RV Groundfish Survey data, which is consistent with estimates of dogfish catchability from Edwards (1968) and Sparholt (1990). According to Campana et al. (2007) the summer DFO RV Groundfish Survey does not sample the population well since the large females remain on the Scotian Shelf throughout the year but move well inshore (out of RV surveys reach) during the summer. In addition, the survey may not capture the entire population residing in the model area due to mixing between groups, which may affect estimates. Thus the biomass estimate for dogfish derived from the summer data, particularly for the large specimens, is likely a conservative estimate.

BIOMASS ACCUMULATION

The summer survey data is quite variable and does not show a clear trend for dogfish biomass in the late 1990's. Nor does the Canadian spring index (Campana et al. 2007), which includes data from other areas in addition to 4X and is considered to be a better indicator of total adult biomass. Consequently the *BA* was considered to be zero.

PRODUCTION:BIOMASS

Presently there is no viable population model for dogfish in Atlantic Canada (Campana et al. 2007). The natural mortality rate of dogfish estimated with the Hoenig's (1983) equation (Eq. 23 in this report) and the maximum reported age for Atlantic Canada (31 years) was 0.13 year^{-1}. Since the DFO summer survey likely underestimates the abundance of mature females in the survey area, length-based catch curves based on this data would overestimate the total mortality. In fact the total mortality estimated using length-based catch curve method (Pauly 1983) and summer abundance for the 1995-2000 period was 0.29 year^{-1}. On the other hand, the total mortality based on the average numbers at size estimated from summer, spring and fall DFO RV Groundfish Surveys for the 1979-1984 period was 0.15 year^{-1}. In the absence of reliable specific estimates for the period modelled here, the total mortalities of the small and large dogfish were assumed to be 0.13 year^{-1} and 0.15 year^{-1} respectively.

CONSUMPTION:BIOMASS

Q/B's of 1.81 and 3.20 year^{-1} for the small and large stanzas respectively were estimated from the gastric evacuation model with stomach content data, with an average of 2.41 year^{-1} for all available length sizes. The estimate for the small group was used as input for the large stanza in the Ecopath multi-stanze routine, since this produced a population average *Q/B* of 2.49 year^{-1}, similar to the average estimated from the gastric model. It results in a population average *P/Q* of 0.06, which is in the range of reported values for dogfish by Wetherbee and Cortés (2004).

CATCHES

According to Campana et al. (2007) there is a substantial amount of bycatch of dogfish by Canadian fisheries. However, not all discarded dogfish die and mortality can vary from 0% to 55% of total dogfish discarded depending on the type of fishery (Campana et al. 2007). Discard estimates for dogfish in the 4X/5Y divisions were provided by Steve Campana (DFO, pers. comm.) and discard mortality estimates were obtained from Campana et al. (2007). Based on the data sources above, it was estimated that discard mortality represented about 73% of the total dogfish landings in 4X/5Y between 1995 and 2000, although the total amount of dogfish discarded was about 2.3 times the total landings of this species.

In order to estimate deaths due to discarding for the Bay of Fundy and western Scotian Shelf separately, the discards/total landings ratio by fishery type estimated for 4X/5Y was applied to the Bay of Fundy and western Scotian Shelf landings data. The amount of discarded mortality was then allocated to the small and large dogfish stanzas based on the size distribution of both commercial landings (longline and gillnet fisheries) and research survey data. The latter was included to provide a proxy for size distribution of dogfish in otter trawl landings, since this information was not available. The proportions of discards in each stanza were estimated using the fishery specific discard mortality as a weighting factor.

DIETS

Diet data for the 1995-2000 4X model were estimated from a total of 1128 stomach samples from Canadian Summer RV surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). Due to low sample sizes, US strata 36, which extends into the Gulf of Maine, was included in the US data. The data is presented in Table A4.15.

BASIC INPUTS SUMMARY

Table 21. Basic input parameters for dogfish. Numbers in italic are estimated by the Ecopath multi-stanzas routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length.

Model	Group name	B ($t.km^{-2}$)	Z ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)	K ($year^{-1}$)	BA ($year^{-1}$)	Wmat /Winf
4X	<73 cm	*1.687615*	0.13	*3.07*	0.002279	0.003367	0.005646	0.003	0.06		0.29
	73+ cm	1.472669	0.15	1.81	0.010973	0.006327	0.017299	0.012			
	Pop.	3.160284	0.14	2.49	0.013252	0.009694	0.022945	0.007			
WSS	<73 cm	*0.944005*	0.13	*3.07*	0.000624	0.002919	0.003544	0.004	0.06		0.29
	73+ cm	0.823770	0.15	1.81	0.003006	0.005131	0.008137	0.010			
	Pop.	1.767775	0.14	2.49	0.003630	0.008050	0.011680	0.007			
BoF	<73 cm	*2.723528*	0.13	*3.07*	0.004691	0.004053	0.008744	0.003	0.06		0.29
	73+ cm	2.376642	0.15	1.81	0.022588	0.008037	0.030625	0.013			
	Pop.	5.100170	0.14	2.49	0.027279	0.012090	0.039369	0.008			

27–28. REDFISH

The redfish functional group includes redfish, *Sebastes* spp., which account for most of the biomass, and rosefish, *Helicolenus dactylopterus*. They are all slow growing and long lived species, with maximum sizes not exceeding 60 cm and maximum reported ages of about 70 years or more. The Northwest Atlantic redfish is a complex of three species: *S. mentella*, *S. fasciatus* and *S. marinus*. As they are difficult to distinguish, they are not categorized by species in the fishery and are managed as a group. Their distribution ranges from the Gulf of Maine north to Baffin Island. The complex is managed under nine management areas in the Northwest Atlantic. *S. fasciatus* is the dominant species in the Gulf of Maine and the basins and continental slope of the western Scotian Shelf, which make part of Unit 3, NAFO 4WdehklX, and NAFO subarea 5 (DFO 2008b).

The average length at maturity is about 24 to 26 for females and 16 to 17 for males on the continental slope of 4WX, and the minimum legal size is 22 cm (Branton 1999; DFO 2008b). This minimum landing size was used to differentiate between the small and large redfish stanzas. See Table 22 for summary of input parameters.

BIOMASS

Biomass was estimated from the summer DFO RV Groundfish survey data, adjusted for catchability. Harley et al. (2001) recommended the bulk or average catchablilty estimate (0.27) from Edwards (1968) for the estimation of redfish biomass, since no meta-analysis was attempted for this group of species, due to issues related to survey coverage. For rosefish they recommended the demersal gadoids model. Brodziack et al. (2004) reported average catchablity estimates of 0.34-0.36, derived from stock assessment of redfish in the Gulf of Main-Georges Bank region. Here, the demersal gadoids model of Harley et al. (2001) was used to estimate the q-adjusted biomass first applying a factor of 1.25 to increase the fish “effective” size. The resultant average catchability for the 4X area is 0.43, which is above the reported range for the US stocks.

BIOMASS ACCUMULATION

There was no clear trend for this group.

MORTALITY

Since 1995, the summer survey coverage was extended to include the Scotian Shelf slope to cover redfish habitat at the shelf edge (Branton 1999). These extra strata were included for the estimation of mortality rate, since the estimate based on the regular survey strata data seemed to underestimate the abundance of large specimens and overestimate the mortality. Total mortality rate estimated from length-based catch curve analysis (Pauly 1983) for years 1995 to 2000 was 0.23 $year^{-1}$. This estimate was used as input for the adult mortality in all models. The mortality for the small stanza was estimated with the size-based approach (Eqs. 25 – 29) used for fish that are not fully recruited and are presented below in the basic inputs summary.

CONSUMPTION:BIOMASS

A *Q/B* of 3.44 year^{-1} was estimated from the gastric evacuation models and stomach content data for the large adult stanza. This estimate was used as input for the adult stanza, and resulted in *P/Q* values lower than 0.1 for the two stanzas.

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 693 stomach samples from the Canadian Summer RV Canadian surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). The data is presented in Table A4.16.

Table 22. Basic input parameters for redfish. Numbers in italic are estimated by the Ecopath multi-stanzas routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length.

Model	Group name	B (t.km^{-2})	Z (year^{-1})	Q/B (year^{-1})	L (t.km^{-2})	D (t.km^{-2})	C (t.km^{-2})	C/B (year^{-1})	K (year^{-1})	BA (year^{-1})	Wmat /Winf
4X	<22	*0.730325*	0.27	*7.16*		0.000270	0.000270	0.000	0.06		0.06
	22+	1.523083	0.23	3.44	0.059140		0.059140	0.039			
	Pop.	2.253408	0.24	4.65	0.059140	0.000270	0.059411	0.026			
WSS	<22	*0.930702*	0.27	*7.16*		0.000249	0.000249	0.000	0.06		0.06
	22+	1.940966	0.23	3.44	0.054280		0.054280	0.028			
	Pop.	2.871668	0.24	4.65	0.054280	0.000249	0.054528	0.019			
BoF	<22	*0.451182*	0.27	*7.16*		0.000302	0.000302	0.001	0.06		0.06
	22+	0.940934	0.23	3.44	0.066227		0.066227	0.070			
	Pop.	1.392116	0.24	2.07	0.066227	0.000302	0.066530	0.048			

29–30. AMERICAN PLAICE

American plaice, *Hippoglossoides platessoides*, occurs on both sides of the Atlantic, and is distributed along the Northwest Atlantic continental shelf from southern Labrador to Rhode Island (Scott and Scott 1988; Collette and Klein-MacPhee 2002). Since it has been difficult to obtain reliable statistics on landings separated by species, American plaice is managed as part of a flounder stock complex under the same TAC as yellowtail flounder (*Limanda ferruginea*), witch flounder (*Glyptocephalus cynoglossus*) and winter flounder (*Pseudopleuronectes americanus*). In addition, there were reports from the fishing industry of serious misreporting of the other species of flatfish prior to 1991, which makes old landings data very unreliable (DFO 2002). It is treated here as separate group because it is more piscivorous than the other species, and thus has a different trophic role.

Length at 50% maturity of American plaice has declined from about 34 cm in 1970 to about 26-29 cm in the late 1970s (DFO 2002). The available data do not indicate a further decline in the 1980s and there is no data for later periods in 4X, although there has been a considerable reduction in length of maturity in NAFO Divison 4VW (M. Fowler, DFO, pers. Comm., DFO 2011). The group is split in small (<26 cm) and large stanzas (26+ cm) based on these estimates. See Table 23 for summary of input parameters.

BIOMASS

Biomass was estimated from the summer DFO RV Groundfish survey data, adjusted for catchability. Harley et al. (2001) recommended the generic flatfish model for the estimation of q-adjusted biomass of American plaice.

BIOMASS ACCUMULATION

The biomass series in the BoF and WSS systems both show a clear decreasing trend during the late 1990s and early 2000s. The biomass accumulation for the entire 4X area in this period was about -0.07 year^{-1}. This value was used as input in all 3 models since the trends in WSS and BoF were quite similar.

MORTALITY

Age-length keys for this species were available only for the 1970s and 1980s. Average total mortality based on catch curve analysis of all available data for the 4X area in those years was 0.43 year^{-1} (95% CI: 0.38-0.49) for the ages between 5 and 23 years. Total mortality estimated from length-based catch curve analysis (Pauly 1983) of recent length frequency data and growth parameters derived from past data for the entire 4X area for the length interval 26-55 cm was 0.52 year^{-1} (95% CI: 0.47-0.58), in a period when the stock was in decline. This last estimate was used as input for the adult stanza in all 3 models. The mortality for the small stanza was estimated with the size-based approach

(Eqs. 25 – 29) used for fish that are not fully recruited and are presented below in the basic inputs summary.

CONSUMPTION:BIOMASS

A *Q/B* of 2.41 year^{-1} for the large American plaice stanza was estimated from the gastric evacuation models with stomach content. This estimate was used as input for the adult stanzas, which resulted in reasonable *P/Q* ratios.

CATCHES

There are considerable uncertainties about landings data for flatfish species. As stated above, since it has been difficult to obtain reliable statistics on landings separated by species, American plaice is managed as part of a flounder stock complex under the same TAC with other flatfish species. Unspecified flounders make a large proportion of total flatfish landings in the 4X area, in some years accounting for more than 50% of the total flatfish landings. This problem has diminished and in recent years unspecified flounders account for less then 20% of total flatfish landings (Virtual Data Centre, Fisheries and Oceans Canada, Population Ecology Division database). Fowler and Stobo (1999), adjusted landings data for flounders based on fishing log book information, accounting for about 94% of the unspecified flounder in average for the years 1992-1999, attributing these landings to one of the four flatfish species: Amercian plaice, yellowtail flounder, winter flounder and witch flounder. We used the data presented in Fowler and Stobo (1999, Table 4) to estimate the landings data for flounders while accounting for unspecified flounders in the years 1992-1997. For the remainder years in the series from 1970 to 2008 we applied the average proportions as estimates for the 1992-1997.

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 505 stomach samples from the Canadian Summer RV Canadian surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). The data is presented in Table A4.17.

BASIC INPUTS SUMMARY

Table 23. Basic input parameters for American plaice. Numbers in italic are estimated by the Ecopath multi-stanzas routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length.

Model	Group name	B ($t.km^{-2}$)	Z ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)	K ($year^{-1}$)	BA ($year^{-1}$)	Wmat /Winf
4X	<26	*0.042833*	0.44	*4.70*		0.000009	0.000009	0.000	0.12	-0.07	0.06
	26+	0.101483	0.52	2.41	0.001319		0.005274	0.052			
	Pop.	0.144316	0.50	3.09	0.001319	0.000009	0.005283	0.037			
WSS	<26	*0.047269*	0.44	*4.70*		0.000007	0.000007	0.000	0.12	-0.07	0.06
	26+	0.111993	0.52	2.41	0.000792		0.002305	0.021			
	Pop.	0.159262	0.50	3.09	0.000792	0.000007	0.002312	0.015			
BoF	<26	*0.036653*	0.44	*4.70*		0.000012	0.000012	0.000	0.12	-0.07	0.06
	26+	0.086842	0.52	2.41	0.002088		0.009796	0.113			
	Pop.	0.123495	0.50	3.09	0.002088	0.000012	0.009808	0.079			

31–32. FLOUNDERS

This group includes the yellowtail flounder (*Limanda ferruginea*), witch flounder (*Glyptocephalus cynoglossus*), winter flounder (*Pseudopleuronectes americanus*), fourspot flounder (*Paralichthys oblongus*) and windowpane (*Scophthalmus aquosus*). The last two species are quite rare in the system, occurring only occasionally in the research trawl survey data. Flounders are treated here as separate group from American plaice because of differences in food habits. Winter flounder is distributed from the northwest of Newfoundland to Virginia. Witch flounder occurs on both sides of the Atlantic. In the Northeast Atlantic they are distributed from Cape Hatteras, North Carolina to Labrador, Canada. Yellowtail flounder occurs from the north shore of the Gulf of St. Lawrence, the Labrador side of the Strait of Belle Isle, northern Newfoundland, Newfoundland banks, and southward to the Chesapeake Bay. Among the main species of this group, the adults of winter flounder have the highest preferred temperatures (12 to 15° C; Pereira et al. 1999 and references therein).

Weighted average size at maturity for flounders in the 4X area was estimated to be about 30 cm using equations 17 and 18. This size was used as the limit for the small and large flounders' stanzas. See Table 24 for summary of input parameters.

BIOMASS

The biomass of flounders was estimated from the summer DFO RV Groundfish survey data, adjusted for catchability using the the generic flatfish model of Harley et al. (2001).

BIOMASS ACCUMULATION

There was no apparent trend for this group.

MORTALITY

Age-length keys for the main species in this group (winter, witch and yellowtail flounder) were available only for the 1970s and 1980s. Total mortality rates were estimated from length-based catch curve analysis of recent length frequency data (Pauly's method) and growth parameters derived from past data. Estimates varied from 0.34 to 0.89 year^{-1}, and on average for the entire 4X the total mortality was 0.59 year^{-1}. This estimate was used as input for the adult stanza in all 3 models. The mortality for the small stanza was estimated with the size-based approach used for fish that are not fully recruited and are presented below.

CONSUMPTION:BIOMASS

A *Q/B* of 3.21 year^{-1} was estimated for the large flounders stanza from the gastric evacuation model and stomach content data. This estimate was used as input for the adult stanzas, which resulted in reasonable *P/Q* ratios.

CATCHES

See American palice section above on catches for a description about the produre used to estimate flatfish landings in the 4X area.

DIETS

Diet data for the 1995-2000 4X model were estimated from a total of 1395 stomach samples from the Canadian Summer RV Canadian surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). The data is presented in Table A4.18.

Table 24. Basic input parameters for flounders. Numbers in italic are estimated by the Ecopath multi-stanzas routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length.

Model	Group name	B (t.km^{-2})	Z (year^{-1})	Q/B (year^{-1})	L (t.km^{-2})	D (t.km^{-2})	C (t.km^{-2})	C/B (year^{-1})	K (year^{-1})	BA (year^{-1})	Wmat /Winf
4X	<30	*0.162009*	0.53	*5.83*		0.000372	0.000372	0.002	0.21		0.17
	30+	0.256310	0.59	3.21	0.021106		0.021106	0.082			
	Pop.	0.418319	0.57	4.22	0.021106	0.000372	0.021478	0.051			
WSS	<30	*0.112992*	0.53	*5.83*		0.000291	0.000291	0.003	0.21		0.17
	30+	0.178761	0.59	3.21	0.011794		0.011794	0.066			
	Pop.	0.291753	0.57	4.22	0.011794	0.000291	0.012085	0.041			
BoF	<30	*0.229187*	0.53	*5.83*		0.000489	0.000489	0.002	0.21		0.17
	30+	0.362590	0.59	3.21	0.034383		0.034383	0.095			
	Pop.	0.591777	0.57	4.22	0.034383	0.000489	0.034872	0.059			

33–34. HADDOCK

BACKGROUND

Haddock (*Melanogrammus aeglefinus*) is one of the must abundant groundfish species in the western Scotian Shelf and Bay of Fundy. It feeds mainly on small invertebrates and is most common at depths of 46-228 m. Haddock have different growth rates on the western Scotian Shelf and in the Bay of Fundy, where they grow faster. Considerable declines in weight-at-age have been observed in both areas. The weight-at-age of fish younger than 5 years has declined slightly, but the decline in weight-at-age of older fish has been more dramatic. The commercial weight of a 7-year old haddock is now comparable to the commercial weight-at-age of a 3-year old in the 1970s and early 1980s. The observed changes in growth and recruitment for this stock are not currently understood, but it is an important issue in the marketability of the fish and overall stock productivity (Hurley et al. 2009; Mohn et al. 2010.).

According to Mohn et al. (2010), the distribution of RV summer catches of haddock have changed over the period between 1970 and 2009. Comparatively, the proportions of catches from the different units that make part of the 4X division have changed overtime. In recent years, there has been an increase in the proportion of catch from NAFO sub-divisions 4Xn and 4Xp. The increase in 4Xn was related to the increase in the winter fishery whereas the increase in catch from 4Xp reflected the targeting of larger haddock in deeper waters. These fish were targeted for they reached higher market prices with low bycatches of cod, which limits the amount of effort on haddock. In addition, the expansion of the lobster fishery since 2002 has forced the mobile fleet to go further offshore.

Female age at 50% maturity is about 3 years old and is used to divide the two haddock stanzas: <3 and 3+ years old. This is roughly equivalent to an average size of about 37 cm in the 4X area for the period represented in this study. See Table 25 for summary of input parameters.

BIOMASS

Biomass was estimated from the summer DFO RV Groundfish survey data, adjusted for catchability using the generic haddock catchability model of Harley et al. (2001). The RV summer q-adjusted biomass estimates for the entire 4X are much higher than the VPA biomass estimates for some years (Mohn et al. 2010) (Figure 6). The large differences between the standard VPA and the survey estimates are partially explained by the assumption of constant *M* used in the standard VPA. An alternate VPA, incorporating a random walk *M* (results provided by R.K. Mohn, DFO, pers. comm.) produces higher estimates of biomass than the standard VPA (Figure 6). The q-adjusted survey series corresponds well with the biomass estimates from the “random walk *M*” VPA.

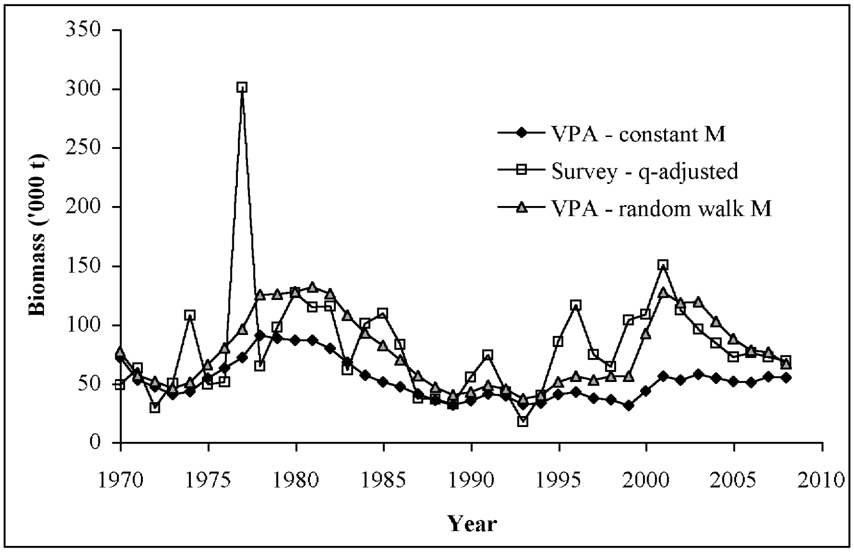

Figure 6. Estimates of biomass for haddock. The survey data series was q-adjusted with the generic haddock model of Harley et al. (2001).

BIOMASS ACCUMULATION

The biomass series in the BoF and WSS systems both show a clear increasing trend during the 1990s. The biomass accumulation for the entire 4X area between 1991 and 2000 was about 0.07 year^{-1}. This value was used as input in all 3 models since the trends in WSS and BoF were comparable.

MORTALITY

Average total mortality rates for 1995-2000 were estimated from catch curve analysis of trawl survey data for fish between 3 and 10 years. The estimates were 0.52 (95% CI: 0.49-0.55), 0.86 (95% CI: 0.65-1.05) and 0.53 year^{-1} (95% CI: 0.48-0.58) for the 4X, BoF and WSS areas respectively. These estimates suggest that the mortality in the BoF is higher than in the WSS area. However, the average mortality rates from the two VPA models reported above (Mohn et al. 2010; R.K. Mohn, DFO, pers. comm.) were around 0.40 year^{-1} for the years 1995-2000, which was a period of low, below average mortality rates according to the VPA estimates. One assumption of the catch curve model is that recruitment rates are constant. However 4X haddock had two strong recruitment events in 1994 and 1995 (age 1 haddock). In fact, the average mortality estimates from catch curve analysis for the period immediately before (1990-1994) were 0.42 (95% CI: 0.34-0.49), 0.47 (95% CI: 0.34-0.61) and 0.40 year^{-1} (95% CI: 0.34-0.46) for the 4X, BoF and WSS areas respectively, which are closer to the VPA estimates for the same period (around 0.45 year^{-1}). Since the confidence intervals of the WSS and BoF estimates overlap, the same mortality rate (0.42 year^{-1}) was used as input for the 3+ stanza total mortality for all 3 models. The mortality for the small stanza was estimated with the size-based approach (Eqs. 25 – 29) used for fish that are not fully recruited (Table 25).

CONSUMPTION:BIOMASS

A *Q/B* of 2.08 $year^{-1}$ was estimated for the large haddock stanza from the gastric evacuation models and stomach content data. This estimate is below the reported values for haddock, which range from 3 to 12.76 $year^{-1}$, but resulted in reasonable *P/Q* ratios for this species.

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 1895 stomach samples from the Canadian Summer RV Canadian surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). The data is presented in Table A4.19.

Table 25. Basic input parameters for haddock. Numbers in italic are estimated by the Ecopath multi-stanzas routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length.

Model	Group name	B ($t.km^{-2}$)	Z ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)	K ($year^{-1}$)	BA ($year^{-1}$)	Wmat /Winf
4X	<3	*0.288628*	0.66	*4.09*	0.000433	0.000111	0.000545	0.002	0.27	0.07	0.16
	3+	0.806943	0.42	2.08	0.089896		0.089896	0.111			
	Pop.	1.095571	0.48	2.61	0.090329	0.000111	0.090440	0.083			
WSS	<3	*0.248877*	0.64	*4.34*	0.000461	0.000117	0.000578	0.002	0.22	0.07	0.16
	3+	0.858958	0.42	2.08	0.095633		0.095633	0.111			
	Pop.	1.107835	0.47	2.59	0.096094	0.000117	0.096211	0.087			
BoF	<3	*0.360567*	0.69	*3.76*	0.000393	0.000104	0.000496	0.001	0.36	0.07	0.16
	3+	0.731107	0.42	2.08	0.081531		0.081531	0.112			
	Pop.	1.091674	0.51	2.63	0.081924	0.000104	0.082028	0.075			

35–36. LONGHORN SCULPIN

BACKGROUND

This species is a common resident of coastal waters, moving into deeper water in winter and returning in spring. It has been reported to occur from shallow waters to 127 m and in temperatures ranging from 0.5 to 19° C. It is suggested that its distribution is determined mainly by depth but temperature is also an important factor. It is a voracious carnivore, consuming a wide range of crabs, shrimps, other invertebrates and several small fishes. It is assumed that predation has little effect on this species because of its spiny defence mechanism, but they are eaten by cod, halibut, sea ravens and monkfish and occur in >1% of sea raven stomachs (Cook and Bundy 2010, A. Cook, DFO, pers. Comm.). The main cause of mortality may be unreported discards (Scott and Scott 1988).

Longhorn sculpin can reach a length of 45.7 cm, although they rarely grow larger than 35cm (Scott and Scott 1988). Little work has been completed on age and growth of this species. However, in southern New England waters they have been observed to be 5.5 cm at age 1, 18cm at age 2, 21 cm at age 3, 25 cm at age 4, 27 cm at age 5, and 30 cm at age 6 (Collette and Klien-MacPhee 2002).

Length-at-maturity estimated from the empirical equations 17 and 18 was 22 cm for WSS and 19 for BoF. The start point for length-based mortality estimates was 24 and 26 cm for WSS and BoF respectively. Overall, fish are not very important in diet, but there is an increasing trend in the proportion of these items as longhorn sculpin grow. Based on these data, the group is represented by two stanzas, below and above 25 cm.

BIOMASS

Biomass was estimated from the summer DFO RV Groundfish survey data, adjusted for catchability. Harley et al. (2001) recommended the generic demersal gadoids model for the estimation of biomass for longhorn sculpin and that the “effective size” should be increased by about 50% to account for different morphology and behaviour. This method was applied in the estimation of biomass for longhorn sculpin.

BIOMASS ACCUMULATION

The biomass series in the BoF and 4X systems both show a clear decreasing trend during the late 1990s and early 2000s. In the WSS the series is quite variable without a clear trend. The biomass accumulation for the entire 4X and BoF areas between those years were about -0.08 and -0.10 $year^{-1}$.

MORTALITY

Longhorn sculpin is a relatively short-lived species. The maximum reported age for this species is 5 years (Scott and Scotth 1988). Very little has been reported on the population dynamics of this species and there is no growth data in the area studied. The growth parameters used were derived from empirical equations 17 and 19 and the maximum size reported in the survey catches and the average Φ' estimated from L_∞ and K values reported in the literature for the family Cottidae (Froese and Pauly 2009 http://www.fishbase.org). Natural mortality derived from the models of Hoenig (1983) and Pauly (1980) (Eqs. 21 and 22) were 0.38 and 0.21 year^{-1} respectively, which, given the uncertainties about this species, are presented here to provide a range of “possible” mortality estimates. Total mortality estimated from length-based catch curve analysis of survey length frequency data (Pauly 1983) for the entire 4X area for the length interval 25-33 cm was 0.71 year^{-1} (95% CI: 0.65-0.77). This estimate was used as input for the adult stanza in all 3 models. The mortality for the small stanza was estimated with the size-based approach (Eqs. 25 – 29) used for fish that are not fully recruited and are presented below (Table 26).

CONSUMPTION:BIOMASS

A *Q/B* of 3.93 year^{-1} for the large sculpin stanza was estimated from the gastric evacuation model and stomach content data. This estimate was used as input for the adult stanzas, which resulted in reasonable *P/Q* ratios for this species.

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 605 stomach samples from the Canadian Summer RV Canadian surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). The data is presented in Table A4.20.

BASIC INPUTS SUMMARY

Table 26. Basic input parameters for longhorn sculpin. Numbers in italic are estimated by the Ecopath multi-stanzas routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length.

Model	Group name	B ($t.km^{-2}$)	Z ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)	K ($year^{-1}$)	BA ($year^{-1}$)	Wmat /Winf
4X	<25	*0.060322*	0.33	*6.65*	0.000840	0.000883	0.001723	0.029	0.12	-0.08	0.15
	25+	0.073649	0.71	3.93	0.001181		0.001181	0.016			
	Pop.	0.133971	0.54	5.15	0.002021	0.000883	0.002904	0.022			
WSS	<25	*0.041529*	0.33	*6.71*	0.000070	0.000690	0.000760	0.018	0.12		0.15
	25+	0.037928	0.71	3.93	0.000099		0.000099	0.003			
	Pop.	0.079457	0.51	5.38	0.000169	0.000690	0.000859	0.011			
BoF	<25	*0.093736*	0.33	*6.64*	0.001961	0.001164	0.003126	0.033	0.12	-0.10	0.15
	25+	0.123412	0.71	3.93	0.002759		0.002759	0.022			
	Pop.	0.217148	0.55	5.10	0.004720	0.001164	0.005885	0.027			

37–38. HERRING.

BACKGROUND

The Atlantic herring, *Clupea harengus*, is one of, if not the most important forage fish in the 4X area. Four spawning components are recognised in 4VWX and management of the fishery is carried out at this level. The largest, the Southwest Nova Scotia/Bay of Fundy spawning component, includes 3 spawning sites, which are located in the area used in this study to represent the Bay of Fundy ecosystem. The main one is located close to the limit used to separate the Bay of Fundy from the western Scotian Shelf. Most of the 4X herring catches are taken in the BoF/South West Nova Scotia area by the summer purse seine fishery. A second component, the SW New Brunswick migrant juveniles, which contributes a significant part of the herring 4X landings, is not considered part of the 4WX population, and the landings from local weirs are not currently included in the VPA analysis of this stock. Two additional spawning components, which have a minor importance relative to the overall stock biomass, include the offshore Scotian Shelf banks and the coastal Nova Scotia components, the former utilizing spawning areas located in the western Scotian Shelf and eastern Scotian Shelf, and the latter shallow coastal areas of Nova Scotia. There seems to be considerable mixing of fish from different stock components outside the spawning period, since herring can migrate long distances throughout the annual cycle of spawning, overwintering and summer feeding (Power et al. 2008). However, the extent of this migration and of this mixing is currently unknown (G. Melvin, DFO, pers. comm.). Thus the only spawning component explicitly considered in this model is the SWNS spawning component.

Age at first maturity is between 3 and 4 years, or between 23 and 28 cm. Commercial ages are mostly composed of age 4+ herring, which are under much higher exploitation rates than the younger fish (Power et al. 2008). So, herring was split in two stanzas to account for the effects of fishing and the onset of maturity, below 4 and 4+ years groups, a split age that corresponds on average to a size of 24 cm approximately. See Table 27 for summary of input parameters

BIOMASS

The 4WX herring stock biomass has been estimated using VPA analysis and acoustic surveys (Power et al. 2006, 2008). The VPA series (most recent results provided by M. Power, DFO, pers.comm) starts in 1965. The acoustic survey series starts in 1997, but due to variation in the coverage area, acoustic biomass estimates prior to 1999 are not considered comparable to the later years. The VPA is calibrated with the German Bank acoustic survey index and they show a similar trend. Despite this, the absolute biomass estimates from the two methods are quite different. For example, the estimated average total VPA biomass for the 1995-2000 years was 185,000 tonnes, which is just 38% of the SW Nova/Bay of Fundy acoustic survey average estimate for the spawning biomass for 1999 and 2000 (485,000 tonnes). The inconsistency between the results could be related to several factors, including double counting of fish by the acoustic survey and/or unaccounted mortality in the VPA model. The lastest VPA results have not been considered for management advice due to these inconsistencies and differences between the commercial catch-at-age data and biological samples that are taken during the acoustic surveys. The acoustic survey biomass is currently used only as a relative index of abundance.

A second issue regarding biomass estimates is the allocation of biomass between the BoF and WSS models. The commercial landings and acoustic survey data suggest that the BoF would have a much higher biomass than the WSS ecosystem. However these data reflect the herring distribution for part of the year, mainly between July and October, when most of the catches are taken. On the other hand the summer research trawl survey data show a widespread distribution across the BoF and WSS systems. The data from these surveys show strong year to year variation that reflects behaviour and availability to the gear and is not considered a good indicator of absolute abundance, but is considered useful for documenting size, maturity and distribution (Power et al. 2008; McQuinn 2009). During the 1990's, the summer trawl survey data show a higher biomass catch rate (kg/set) of herring in the WSS area. However, the higher catch rates reflect the differences in size composition: herring are more abundant in the BoF area, where a large proportion of the catch is composed of small fish whereas the WSS catch is composed mainly of large (24+ cm) herring. This seems to be a common feature since the early 1980's although there is some year to year variation in the size composition of the survey catches from the two areas. In addition to the summer survey, a series of spring and fall surveys were carried out between 1979 and 1984. The data collected in those years suggest a strong seasonal variation in the size composition of herring in the WSS area, with very few small fish in the fall and summer as opposed to the spring data, where they represented more than 50% of the biomass.

It is not well understood how herring use the BoF and WSS. There is evidence that some herring stocks have a more constant or persistent migratory patterns than others and the level of stock mixing is also quite variable depending on the region (Scott and Scott 1998). An example of stock mixing occurs along the coast of sowthwestern New Brunswick and eastern Maine, where juveniles of the Gulf of Maine (5Y) and Nova Scotia (4WX) stocks mix during summer. The degree of mixing is unknown and all New Brunswick weir catches are currently included in the GOM (5Y/5Z) stock analysis. It is possible that part of the stock that is found in the BoF during the fishing and spawning seasons, moves to the WSS or even to US waters.

Considering that neither the VPA nor the acoustic survey biomass estimates are currently accepted as indicators of absolute biomass, the approach adopted here was to use the midpoint between the total VPA and the SW Nova/Bay of Fundy spawning acoustic biomass as the input for the 4X model. An additional assumption made was that 70% of this biomass would be in the BoF and 30% in the WSS system to reflect the fact that most of catches are taken from the BoF area.

MORTALITY

The estimate of total mortality for the adult herring stanza was derived from the VPA results. The biomass-weighted average mortality for the years between 1995 and 2000 was 0.81 $year^{-1}$. Since the VPA model used a natural mortality of 0.2 $year^{-1}$ for all ages, the estimated adult fishing mortality was 0.61 $year^{-1}$. An estimate of 0.63 $year^{-1}$ for total mortality of the small herring stanza, which are not fully recruited to the fisheries, was derived from the size-based approach (Eqs. 25 – 29). In contrast, the VPA estimate of total mortality for the small herring stanza was 0.37 $year^{-1}$. The former was used as input to the model (Table 27), and as a result of these differences, the biomass of the small herring estimated by Ecopath (based on the inputs of adult biomass and the mortality rates to the multi-stanza routine), represents a higher proportion of the total biomass than the VPA estimate for those age groups.

CONSUMPTION:BIOMASS

A *Q/B* of 2.36 $year^{-1}$ was estimated using the gastric evacuation model and stomach content data for all available length sizes. This value was used as the input for the large herring stanza and resulted in reasonable *P/Q* ratios for this species.

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 416 stomach samples from the Canadian Summer RV Canadian surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). The same diet composition was used for the small and large herring stanzas. The data is presented in Table A4.21.

BASIC INPUTS SUMMARY

Table 27. Basic input parameters for herring. Numbers in italic are estimated by the Ecopath multi-stanzas routine. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch, *K* = curvature of the von Bertalanffy growth model, *BA* = biomass accumulation, W_{mat}/W_{inf} = weight at maturity/weigh at infinite length.

Model	Group name	B ($t.km^{-2}$)	Z ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)	K ($year^{-1}$)	BA ($year^{-1}$)	Wmat /Winf
4X	<4	*3.459351*	0.63	*3.93*	0.230954	0.000211	0.231165	0.07	0.28		0.33
	4+	2.250210	0.81	2.36	0.719899		0.719899	0.32			
	Pop.	5.709561	0.70	3.31	0.950853	0.000211	0.951064	0.17			
WSS	<4	*1.749621*	0.63	*3.93*	0.035130	0.000184	0.035314	0.02	0.28		0.33
	4+	1.138079	0.81	2.36	0.109503		0.109503	0.10			
	Pop.	2.887700	0.70	3.31	0.144633	0.000184	0.144817	0.05			
BoF	<4	*5.952089*	0.63	*3.93*	0.516461	0.000249	0.516710	0.09	0.28		0.33
	4+	3.871666	0.81	2.36	1.609840		1.609840	0.42			
	Pop.	9.823755	0.70	3.31	2.126301	0.000249	2.126550	0.22			

39. OTHER PELAGIC

BACKGROUND

The other pelagic group includes several small-medium pelagic species such as Atlantic argentine (*Argentina silus*), American shad (*Alosa sapidissima*), alewife (*Alosa pseudoharengus*), sand lance (*Ammodytes dubius*) and capelin (*Mallotus villosus*). According to research survey data, the main species in the group are Atlantic argentine, American shad, and alewife. The most abundance species on the WSS is argentine, which is bathypelagic. Little is known about seasonal movements but in the summer it occurs on the Scotian Shelf at depths of 180-250 m and temperatures between 7-10°C. Shad and alewife are anadromous and more abundant in the BoF area. Shad is highly migratory and individuals born in Canadian rivers move southwards from Canadian Atlantic and Gulf of Maine waters to the mid Atlantic United States in fall and winter and return in spring. Bottom trawl catches in the Atlantic indicate that this species occurs at bottom temperatures of 3-13°C. Alewife movements and activities at sea are not well documented. When at sea, it is captured most frequently at depths of 56-110 m at a temperature of about 4 °C (range 3-17°C) (Scott and Scott 1988 and references therein).

BIOMASS

Biomass was estimated from the summer DFO RV Groundfish survey data, adjusted for catchability. Harley et al. (2001) recommended herring catchability estimates as a proxy for shad and alewife. The herring catchability estimates reported by Harley et al.(2001) range from 0.015 (from Edwards 1968) to 0.025 (from Sparholt 1990). For argentine the reported estimates range from 0.018 (from Edwards 1968) to 0.049 (inferred from *Trisopterus esmarkii* by Sparholt 1990). A value of 0.025 was used here, which is close to the average of the reported values for the small pelagics with the exception of sand lance. For the latter, the lower value in the reported range above was used. The resultant estimated biomass in the WSS was very high due to the extremely high catches of argentine in the 1995 summer survey (Figure 7). Hence the 1995 value was substituted with the average of the 1994 and 1996 values in the estimation of the average biomass for the WSS.

Landings data for the argentine, shad and alewife suggest a strong seasonal variation in abundance, with the peak abundance between May and July. Similarly, the fall, spring and summer RV survey data for the period between 1979 and 1984 suggest that peak abundance of these species biomass occur in summer. The biomass data for this period was then used to estimate a seasonal scaling factor (average biomass (fall, spring, summer)/summer biomass), which varied from 0.35 to 0.39, to adjust the biomass estimates for the 1995-2000 years, assuming a similar seasonal distribution. See Table 28 for summary of input parameters.

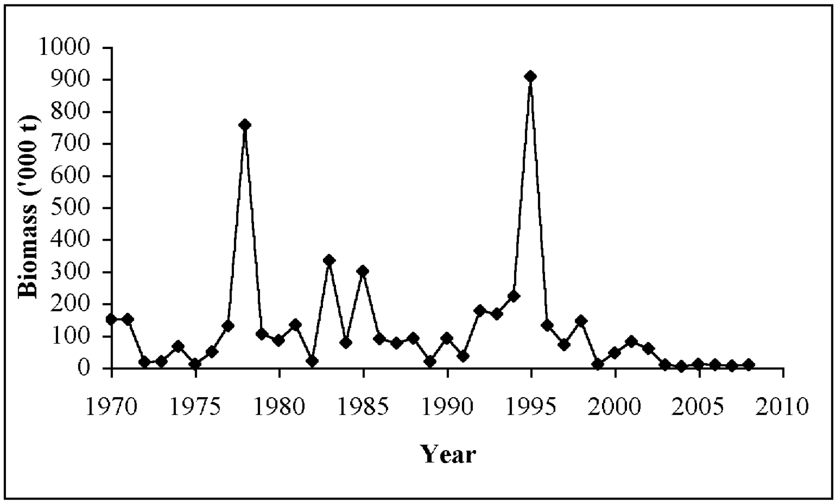

Figure 7. Research survey biomass series of other pelagics in the western Scotian Shelf showing the occurrence of outliers due to extremely high catches for Atlantic argentine in 1977 and 1995.

BIOMASS ACCUMULATION

There is a clear, steep decline in the biomass of small pelagics in the WSS after 1995, related to changes in abundance of Atlantic argentine, with an average *BA* of about -0.18 year^{-1} for the period between 1996 and 2005. The series for the BoF and entire 4X do not show such a steep trend, and the no *BA* terms were added.

PRODUCTION:BIOMASS

Total mortality was estimated based on a length-based catch curve analysis (Pauly 1983) and natural mortality estimates for Atlantic argentine, American shad and alewife. The biomass-weighted average mortalities were 0.56, 0.48 and 0.67 year^{-1} for the 4X, WSS and BoF models respectively. These values were summed with the estimated *BA* rates to produce the *P/B* estimates.

CONSUMPTION:BIOMASS

A *Q/B* of 3.31 year^{-1} was estimated from the gastric evacuation model and stomach content data for Atlantic argentine and used to represent the small pelagics.

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 250 stomach samples of argentine from the Canadian Summer RV Canadian surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). Due to low sample sizes, US strata 36, which extends into the Gulf of Maine, was included in the US data. The data is presented in Table A4.22.

BASIC INPUTS SUMMARY

Table 28. Basic input parameters for the other pelagic group. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)
4X	0.865770	0.56	3.31	0.019708	0.000560	0.020268	0.023
WSS	0.869932	0.30	3.31	0.005803	0.00047	0.006276	0.007
BoF	0.852984	0.67	3.31	0.039981	0.000687	0.040668	0.048

40. ATLANTIC MACKEREL

BACKGROUND

Northwest Atlantic Mackerel (*Scomber scombrus)* is currently assessed as a single stock unit, whose distribution ranges from North Carolina to Labrador (NAFO subareas 2-6). There are two major spawning areas, one located in the Gulf of St. Lawrence and a second in the Gulf of Maine and Georges Bank area. The species is highly migratory and the seasonal distribution is influenced by temperature. Mackerel overwinter at the edge of the continental shelf in deeper and warmer waters. In spring there is a migration to inshore waters. Spawning in US waters occurs in March and April and in Canadian waters takes place during June and July (Scott and Scott 1988; TRAC 2010). Adult mackerel prefer temperatures in the range of 9-12° C and tend to avoid cool areas, like the Bay of Fundy (Scott and Scott 1998). Size at maturity in Canadian waters has been reported be around the minimum legal size of 25 cm in recent years (Grégoire 2009).

The first US/Canada joint mackerel assessment for both spawning areas was recently conducted (TRAC 2010). A VPA model tuned to the US Northeast Fisheries Science Center (NEFSC) spring survey index and two commercial catch per unit effort (CPUE) indices (bottom-trawl and mid-water trawl) shows a steep decline from the population maximum of 2,689,732 tonnes in 1969 to 293,499 tonnes in 1981. From 1981 to 2008 the stock has fluctuated around a mean of 447,154 tonnes. From 2000 to 2008, the VPA estimates suggest that the population biomass declined at an average rate of -13% per year. The VPA results are consistent with the decreasing trend during the past decade in SSB estimates in the Gulf of St. Lawrence, which were derived from the egg surveys carried out in that region (TRAC 2010). However the VPA results are considered quite uncertain. There are striking differences between the NEFSC spring survey and CPUE indices and total landings, the former presenting an increasing trend since the 1980's. The NEFSC spring survey trend is also inconsistent with the DFO survey series (Canadian waters). There were large retrospective patterns in the VPA estimates and the present status of the stock is unclear (TRAC 2010). See Table 29 for summary of input parameters.

BIOMASS

Although biomass estimates for mackerel could be derived from the July RV survey, by July most 4X mackerel are in the inshore waters of the western Scotian Shelf, outside the surveyed area. So, the survey data was used only to give an estimate of the importance of the Bay of Fundy and western Scotian Shelf mackerel abundance relative to the whole 4X region.

In the absence of other information, VPA data (Dr. J. Deroba, NFSC, pers. comm.) were used to estimate mackerel biomass, despite the uncertainties noted above. The total population landings to biomass ratio (used as a proxy for the average population F) and the 4X landings were used to estimate the total 4X biomass as L/F. In this method the assumption made is that the level of exploitation is fairly constant across the species range. The average population exploitation rate, as derived by the population L/B, for the 1995-2000 period was about 0.09. Based on this estimate, the mackerel biomass for the 4X region was estimated to be 39,415 tonnes. The biomass for the BoF and WSS areas was then estimated by scaling the biomass estimate for 4X by the relative biomass of mackerel in the BoF and WSS, as measured by the RV survey (i.e, (BoF/4X and WSS/4X). The final estimates are presented below in Table 29.

BIOMASS ACCUMULATION

Although the VPA biomass series show a declining trend during the 1990s, the strong 1999 year class caused the population biomass to rise in the following 2 years. So the biomass accumulation parameter was set to zero.

PRODUCTION:BIOMASS

The biomass weighted average total mortality for the 1995-2000 years derived from the VPA model estimates was 0.53 year^{-1}. This estimate was used in the 4X, WSS and BoF models.

CONSUMPTION:BIOMASS

A Q/B of 5.08 year^{-1} was estimated using Eq. 32 (Palomares and Pauly 1998).

DIET

Diet data for the 1995-2000 4X model were estimated from a total of 107 stomach samples from the Canadian Summer RV Canadian surveys (PED Food Habits Database) and US Fall and Spring surveys (Link and Almeida 2000, Smith and Link 2010). Due to low sample sizes, US strata 36, which extends into the Gulf of Maine, was included in the US data. The data is presented in Table A4.23.

BASIC INPUTS SUMMARY

Table 29. Basic input parameters for mackerel. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)
4X	0.535679	0.53	5.08	0.048208	0.000276	0.048484	0.09
WSS	0.728954	0.53	5.08	0.078427	0.00024	0.078670	0.11
BoF	0.253889	0.53	5.08	0.00415	0.000324	0.004474	0.02

41 – MESOPELAGIC

BACKGROUND

Small mesopelagic species (Myctophidae) occur in deep water around and off the shelf edge. Many make diurnal vertical migrations, ascending to depths of 30-100 m at night (Scott and Scott 1988). Some are occasionally caught in the summer DFO RV Groundfish survey. *Benthosema* sp. has been reported in small numbers, averaging from 1.3 to 8.1 specimens m^{-2} in the seasonal BIONESS samples collected on the Western Scotian Shelf slope (Sameoto et al. 2002). Some specimens have been recorded in stomach contents of some fish species collected in the studied area and hence are included as a functional group in the models. See Table 30 for summary of input parameters.

BIOMASS

There are no data to estimate the biomass of small mesopelagics. Instead, it was estimated by the model, assuming an ecotrophic efficiency of 0.95.

PRODUCTION:BIOMASS

Natural mortality estimates for *B. glaciale* reported in FishBase (Froese and Pauly 2009) range from 0.7 to 1.75 $year^{-1}$. The latter estimate was obtained from data collected off Nova Scotia (Halliday 1970). The average of reported values, 0.97 $year^{-1}$, was used as input for *P/B* in all 3 models.

CONSUMPTION:BIOMASS

An average annual *Q/B* of 18.9 $year^{-1}$ was estimated from daily consumption rates for *Benthosema glaciale* collected off Nova Scotia (Sameoto 1988).

DIETS

Diet for this group was based on data for *B. glaciale* reported by Sameoto (1988).

BASIC INPUTS SUMMARY

Table 30. Basic input parameters for small mesopelagics. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio, *EE* = ecotrophic efficiency.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE
4X		0.97	18.9	0.95
WSS		0.97	18.9	0.95
BoF		0.97	18.9	0.95

42 – SMALL-MEDIUM BENTHIVORES

BACKGROUND

This is a generic group composed of several demersal benthivore species with reported maximum sizes around 40 cm. The main species in the group are longfin hake (*Phycis chesteri*), fourbeard rockling (*Enchelyopus cimbrius*), mailed sculpin (*Triglops murrayi*), Arctic hookear sculpin (*Artediellus uncinatus*), Atlantic hookear sculpin (*A. atlanticus*), alligatorfish (*Aspidophoroides monopterygius*) marlin-spike grenadier (*Nezumia bairdi*) and snake blenny (*Lumpenus lumpretaeformis*). See Table 31 for summary of input parameters.

BIOMASS

Biomass was estimated from the summer DFO RV Groundfish survey data, adjusted for catchability. Harley et al. (2001) recommended the ling catchability model for the estimation of biomass of species such as alligatorfish and the demersal gadoids model for species like longfin hake. However, the resultant biomass estimates from the ling catchability model for small fish such alligatorfish are unrealistically high. Hence, the biomass of all species was estimated using the demersal gadoids model.

PRODUCTION:BIOMASS

The *P/B* input for this group was based on estimates of natural and total mortality for longfin hake, one of the most important species in this group in terms of biomass. The natural mortality and total mortally derived from the Pauly's methods for natural mortality (Eq. 22) and length-based catch curve (Pauly 1983) were 0.58 and 1.15 $year^{-1}$ respectively, with an average of 0.86 $year^{-1}$. This estimate was used as *P/B* input in all models.

DIET

The PED Food Habits Database holds very little data for this group of species. Therefore the data was complemented with diet information reported by Bowman et al. (2000), which includes samples collected in Canadian and US waters. The data is presented in Table A4.24.

BASIC INPUTS SUMMARY

Table 31. Basic input parameters for small benthivores. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)
4X	0.010189	0.86	4.68		0.000236	0.000236	0.023
WSS	0.012712	0.86	4.68		0.0002	0.0002	0.016
BoF	0.006673	0.86	4.68		0.000293	0.000293	0.044

43 – SQUIDS

BACKGROUND

The dominant species of squid in the 4X region is the northern shortfin squid, *Illex illecebrosus*. This species is highly migratory and has a very short life span of less than one year (Hendrickson 2004). It is distributed from the Labrador to the Florida Straits, but is commercially exploited from Newfoundland to Cape Hatteras. The squid found in this area are considered part of a single stock. According to the proposed migration route, egg masses are transported northeasterly in the Gulf Stream current, with hatching occurring offshore during winter between one and two weeks after spawning. Pre-recruits and recruits then start to migrate onto the continental shelf in spring and by summer the species is found on the continental shelf. By late autumn the mature specimens migrate off the shelf presumably to a winter spawning site. There is also evidence of southward migration, since a tagged squid released in Newfoundland was recaptured off Maryland (Black et al. 1987; Hendrickson and Holmes 2004). The timing of the fisheries for squid generally reflects the migration pattern (Hendrickson and Showell 2004). See Table 32 for summary of input parameters.

BIOMASS

Biomass was estimated from the summer DFO RV Groundfish survey data. Commercial data for the 4X area suggest that the peak abundance lasts for about 3 months at most. However, seasonal RV survey data for the period between 1979 and 1984 suggest that biomass in fall was as high as in summer months. So, it was assumed that the residence time was between 3 and 6 months, with an average of 4.5 months. Link et al. (2006) used a catchability of 0.08, which is an average for several small pelagic fish. This estimate was used along with the residence time of 4.5 months to “adjust” the summer biomass estimate from the RV survey.

PRODUCTION:BIOMASS

Caddy (1996) used a theoretical modelling approach to estimate the natural mortality of short-lived invertebrates. He estimated the non-spawning natural mortality of high fecundity and opportunistic spawners, such as some squid, in the range of 2.8-3.4 $year^{-1}$. Model estimates of natural mortality reported by Hendrickson and Hart (2006) range from 0.01 to 0.14 $week^{-1}$ for non-spawning specimens and from 0.42 to 0.63 $week^{-1}$ for the spawners. Since squid spawn off the shelf, it is assumed here that their mortality, while they are on the shelf, is 3.4 $year^{-1}$ (0.07 $week^{-1}$). This is the maximum value reported by Caddy (1996), which is in the range of the model based estimates reported by Hendrickson and Hart (2006). This value was used as input for *P/B* in all models.

CONSUMPTION:BIOMASS

Maurer and Bowman (1985) estimated seasonal consumption rates for shortfin squid in NAFO subareas 5 and 6. The quarterly *Q/B* ratios estimates ranged from 0.6 to 19.4 per quarter, with a weighted average of 3.3 per quarter, producing an annual *Q/B* of 13.2 $year^{-1}$.

DIETS

Diet data for the shortfin squid were taken from Bowman et al. (2000) (Table B-1a). Most of the data were collected off US waters but some samples from the Scotian Shelf are included. This species is highly cannibalistic, but can also consume a significant proportion of fish. Most of the fish reported were unidentified, though a very small proportion was identified as Gadidae and Rajidae. The fish items in the diet were allocated to the different functional groups according to their relative abundance in the models.

BASIC INPUTS SUMMARY

Table 32. Basic input parameters for squids. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)
4X	0.292252	3.4	13.2	0.001637	0.000019	0.001656	0.006
WSS	0.481841	3.4	13.2	0.001946	0.000016	0.001962	0.004
BoF	0.015837	3.4	13.2	0.001185	0.000022	0.001207	0.076

44 – LOBSTER

BACKGROUND

The American lobster, *Homarus americanus*, is distributed from southern Labrador to Maryland, US. While lobster fishing occurs in all coastal waters within its range, the largest fisheries landings are located around the Gulf of St. Lawrence and Gulf of Maine. The lobster of the Gulf of Maine is currently viewed as a metapopulation, and a recent genetic study (Kenchington et al. 2009) has shown some structure within this area. Although the species is most common in coastal waters, it also occurs in deeper waters, such as some warm water areas of the Gulf of Maine and along the continental shelf edge from Sable Island to North Carolina. There are seasonal movements into shallower waters in the summer and into deeper waters in the winter. In much of the lobsters range the migration takes place over a few kilometres but can be over distances as long as hundreds of kilometres in the Bay of Fundy, Gulf of Maine, Georges Bank and off the coast of New England (DFO 2006, 2007). Studies on lobster movement demonstrate substantial mixing in the Bay of Fundy and along the Maine coast. In the waters off southwestern Nova Scotia and in the Bay of Fundy, the size at 50% maturity is 95 - 105 mm carapace length. They take about 8 years to reach the current legal size of 82.5 mm CL and their maximum age is 50 years or more (Robichaud and Lawton 1997; DFO 2006, 2007; Gendron et al. 2006).

In eastern Canada, American lobster is managed by management unit, referred to as Lobster Fishing Areas (LFA's, Figure 8). LFA 34, located off SW Nova Scotia and straddling the BoF and WSS, accounts for 40% of Canadian landings and more than 20% of the world landings of *Homarus* sp (DFO 2006). Lobster landings increased dramatically over the entire east coast of North America since the 1980s. Lobster were not systematically recorded in the Canadian research surveys before 1999, but US survey data from the Gulf of Maine also show an increase in lobster from the beginning of the 1980s to a maximum at the end of the 1990s (DFO 2006, 2007; Idoine 2005). These large-scale increases in abundance may be due to changes in temperature leading to improved larval and juvenile survival (Koeller 1999; DFO 2007). Effective effort also increased during this period due to changes in vessels, technological and fishing behaviour. While this contributed to the increase landings, its contribution cannot be quantified (DFO 2006, 2007).

The model input estimates were based on data and parameters for the Southwest Nova Scotia (LFA 34), Bay of Fundy (LFA 35 to 38) and offshore lobster (LFA 41). See Table 33 for summary of input parameters.

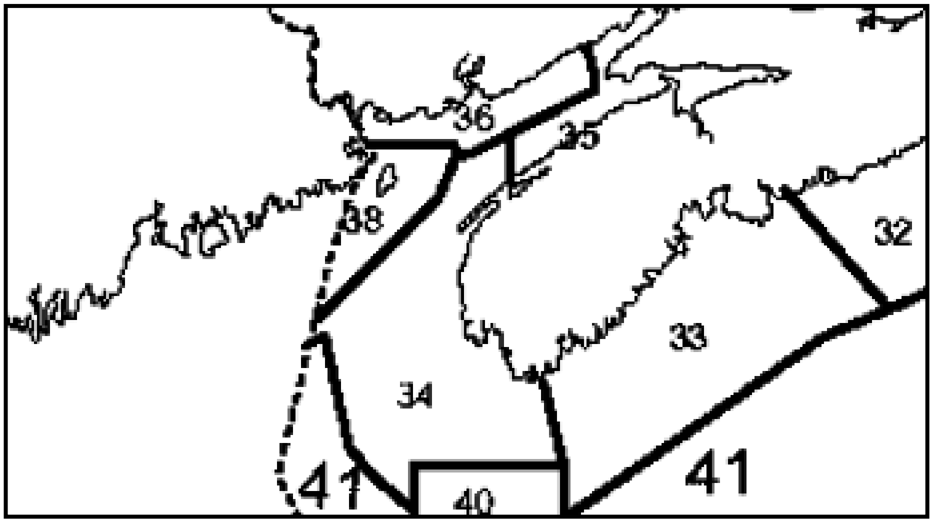

Figure 8. Map of the Western Scotian Shelf (WSS) and Bay of Fundy (BoF) depicting the Lobster Fishing Areas (LFA). Most catches are taken from LFA 34, which includes parts of the BoF and WSS systems.

BIOMASS

Biomass estimates were estimated from the relationship exploitation = landings/biomass. Average exploitation rates were derived from length-based cohort analysis for LFA's 34, 35, 36 and 38 (Lawton et al. 1999; Pezzack et al. 2001; Pezzack et al. 2006; Robichaud and Pezzack 2007) and total landings data for the areas modelled. The same weighted average exploitation rate estimate (0.67 $year^{-1}$) was used in all 3 models since LFA 34, which accounts for most of landings and biomass, is located in between the BoF and WSS model areas. Note that the results from the cohort analysis are considered quite uncertain and have not previously been used to produce biomass estimates (D. Pezzack, DFO, pers. comm.).

BIOMASS ACCUMULATION

Since lobsters were not systematically recorded in the summer DFO RV Groundfish survey before 1999, the biomass accumulation rate was estimated for the period between 1999 and 2008. Lobster biomass increased at annual rate of about 13% in both the WSS and BoF system between 1999 and 2008. This estimate is similar to the RV survey trend for the 1990s and higher than the average increase rate in landings for the period 1995-2000, which was about 5% per year.

PRODUCTION: BIOMASS

The *P/B* ratio was estimate by summing the exploitation rates derived from the cohort analysis and the biomass accumulation estimate. The natural mortality assumed in the cohort analysis was 0.10 $year^{-1}$. Hence the total mortality estimates was 0.78 $year^{-1}$, and *P/B* was 0.91 $year^{-1}$.

CONSUMPTION: BIOMASS

There was no *Q/B* estimate available for lobster. This parameter was estimated based on the assumption that the production to consumption ratio (*P/Q*) of lobster is 0.15.

CATCHES

Except for the offshore LFA 41 in most recent years, there is no latitude and longitude information for lobster landings. All lobster landings from 1947 to 1995 are based on sales slip information from buyers and are summarised by Statistical District. In 1995 landings data started to be collected from individual fishermen sending in monthly catch settlement reports. In all LFA's, the report only provided information on daily catch by port and date of landing. Thus, landings data were reported by LFA or Statistical District. Starting in 1998, LFA 34 fishermen adopted a different system, which required them to provide information by reference to 10 min x 10 min grid system. This system was adopted in other LFA's only after 2003 (Pezzack et al. 2006). Landings for LFA 34 from 2003 to 2009 with latitude and longitude information (provided by D. Pezzack, DFO, pers. comm.) were used to estimate the average proportions of landings removed from the BoF and WSS parts of LFA 34. These average proportions were used to prorate the landings in the 1995-2000 years reported in Pezzack et al. (2006). Landings for the other LFA's were reported by Robichaud and Pezzack (2007) and Pezzack et al. (2001).

DIET

Lobster diet was based on a diet study conducted off southwestern Nova Scotia (Elner and Campbell 1987). Like most studies, cannibalism was low and most of the lobster found in diet was the remains of moulted carapaces. However Hanson (2009) observed that cannibalism could be the largest source of non-human mortality of benthic lobsters in the southern Gulf of St. Lawrence, accounting for about 3.5% of prey biomass during summer. Thus, as Hanson (2009) observed, "Fogarty's (1995) hypothesis that cannibalism might be an important regulatory mechanism for lobster populations appears justified". To represent this fact and the scavenging behaviour, 1% of the diet was composed of lobster and 10% of detritus and discards. The same diet data was used in the 3 models.

BASIC INPUTS SUMMARY

Table 33. Basic input parameters for lobster. *B*=biomass, *Z* = total mortality, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)
4X	0.301295	0.91	6.08	0.203756	0.001526	0.2052825	0.68
WSS	0.142884	0.91	6.08	0.096120	0.001232	0.0973516	0.68
BoF	0.532253	0.91	6.08	0.360686	0.001956	0.362643	0.68

45 – 46. LARGE AND SMALL-MEDIUM CRABS

BACKGROUND

The large crabs group includes species with maximum carapace width that normally exceeds 100 mm, such as Jonah crab (*Cancer borealis*), Rock crab (*Cancer irroratus*), Snow crab (*Chionoecetes opilio*), Deep Sea Red Crab (*Geryon quinquedens*), Toad crab (*Hyas araneus*), Porcupine crab (*Neolithodes grimaldi*) and Northern stone crab (*Lithodes maja*). The most important species caught by the bottom trawl survey is the Jonah crab, accounting for about 68% of the large crabs biomass in the years 1999 and 2000. This species is found in waters off Nova Scotia mainly at depths of 50-300 m and temperatures of 8-14°C (DFO 1996). It has been exploited mainly as a by-catch in the lobster fishery and little in known about its biology in the study area.

The small-medium crabs group includes species such as Lyre Crab (*Hyas coarctatus*), *Catapagurus gracilis* and Hermit crabs (*Pagurus acadianus* and *Pagurus pubescens*). See Table 34 for summary of input parameters.

BIOMASS

Crabs are sampled poorly by the DFO RV Groundfish survey, and in addition, were not routinely recorded before 1999. Instead, the biomass of small-medium crabs was estimated from benthic grab data (Peer et al. 1980; Theroux and Wigley 1998; Wildish et al. 1989) for 4X.

Large and highly mobile Decapoda species are more effectively sampled by mobile gear such as dredges and trawl, than by quantitative grab samplers (Theroux and Wigley 1998). Because catchability to bottom trawl estimates for the large crabs are not available, biomass was estimated in an indirect way from the DFO RV Groundfish survey for 4X. The average ratio between lobster and large crabs in the survey for the years 1999 and 2000 was used to estimate the biomass of large crabs, based on the biomass of lobster, estimated from landings data and an estimate of exploitation rate (see Section 44. Lobsters).

PRODUCTION:BIOMASS

There were no mortality estimates for the large crabs in the WSS and BoF. Mortality rates for legal sized snow crab resident in the southern Gulf of St. Lawrence have been estimated to be within the range of 0.301 to 0.654 year^{-1} respectively. The highest value was used as input for *P/B* for the large crabs group. The *P/B* for the small crabs group was set as the double of the large crabs estimate.

CONSUMPTION:BIOMASS

There was no *Q/B* estimate available for crabs. This parameter was estimated based on the assumption that the production to consumption ratio (*P/Q*) of crabs is 0.15.

DIETS

The diet of the large crabs was based on information from several studies on feeding habits of the two main species, Jonah crab and rock crab (based on relative biomass in the DFO RV Groundfish survey). These two crabs feed on a variety of prey species, are opportunistic feeders and the relative importance of the identified taxa in their diets varies according to locality and substrate (Stehlik 1993; Hudon and Lamarche 1989). Therefore the final diets were adjusted to reflect the differences in the abundances of the preferred prey items in the modelled areas. Among the preferred prey are sea urchins, bivalves, gastropods, crabs, polychaeta, amphipoda and small fish. According to Stehlik (1993), the observed fish in the diets of Jonah and rock crabs in the New York Bight were very small and unlikely to have been bait or discards from fisheries. Therefore these species would be both fish predators and scavengers. Accordingly, part of the fish in diet was allocated to discards.

A large proportion of the small crabs group is composed of hermit crabs (*Pagurus* sp.). According to Schembri (1982), feeding mechanisms in hermit crabs include deposit-feeding, browsing on algae and sedentary colonial invertebrates (which they slice or tear off), suspension-feeding, predation and scavenging. Predators capture small organisms that they may find accidentally or they actively search for prey, which includes burrowing invertebrates. So, a generic hermit crab diet, composed mainly of detritus, worms and meiofauna, was constructed based on the above information and used as input for the small crabs group diet.

BASIC INPUTS SUMMARY

Table 34. Basic input parameters for small (< 100 mm maximum CL) and large crabs (≥ 100 mm). *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch.

Model	Group name	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)
4X	L crabs	0.134617	0.65	4.36	0.016668	0.007250	0.023918	0.18
	S crabs	0.839599	1.31	8.73		0.000633	0.000633	0.0008
WSS	L crabs	0.089533	0.65	4.36	0.011955	0.005849	0.017804	0.20
	S crabs	0.744575	1.31	8.73		0.000495	0.000495	0.0007
BoF	L crabs	0.200347	0.65	4.36	0.023538	0.009294	0.032832	0.16
	S crabs	0.950867	1.31	8.73		0.000836	0.000836	0.0009

47. SHRIMPS

BACKGROUND

This group includes several shrimp and some shrimp-like crustacean species. The taxa that have been identified in the RV Surveys, grab samples and/or local stomach contents data are: *Argis dentata*, *Axius serratus* (shrimp-like), *Crangon septemspinosa*, *Eualus pusiolus*, *Dichelopandalus leptocerus*, *Lebbeus groenlandicus*, *Lebbeus polaris*, *Pandalus borealis*, *P. montagui*, *P. propinquus, Pasiphea multidentata*, *Spirontocaris lilljeborgii* and *S. spinus*. *P. montagui* is the most frequent species among the identified shrimp items in the stomach contents and also the dominant shrimp species caught in RV surveys, followed by *P. borealis* (Cook and Bundy 2010; this study), while the small shrimp *E. pusiolus* and *L. groenlandicus* were the dominant ones in terms of numbers and biomass in the grab samples (Peer et al. 1980, Theroux and Wigley 1998; and Wildish et al.1989) respectively. *P. borealis* is an important commercial species in the eastern Scotian Shelf, but the abundance of commercial shrimp species in the 4X area is very low. An incipient *P. borealis* fishery took place in this region in the late 60s and early 70s when large catches of *Pandalus* sp. were recorded in the RV surveys, but landings fell quickly. *P. borealis* has not been found in commercial quantities on the western Scotian Shelf since then. According to Koeller (2001), the coincidental development of the shrimp fishery in the western Scotian Shelf and the record high catches in the Gulf of Maine in the late 1960s were preceded by a long period of below average temperatures. The subsequent collapse of the Gulf of Maine shrimp fishery and disappearance of the western Scotian Shelf shrimp fishery were preceded by a period of above average temperatures.

Despite the low commercial importance, this functional group seems to play an important role as prey and is found in relatively high proportions in the diets of the juvenile and in some cases also the adult stages of many fish species in the Bay of Fundy and western Scotian shelf such as silver hake, pollock, cod, halibut and skates. See Table 35 for summary of input parameters.

BIOMASS

There are no reliable biomass estimates for this group for the Bay of Fundy and western Scotian shelf; they are not sampled well by the DFO RV Groundfish survey or the grab samplers. Bundy (2004) used a biomass input of 0.201 $t.km^{-2}$ for shrimps in the Eastern Scotian shelf model developed for the late 90s. However, due to the high level of predation on this group, the biomass had to be increased to 13.571 $t.km^{-2}$ in the balanced model. Link et al. (2006) reported a population-model derived biomass estimate for shrimps of 0.1695 $t.km^{-2}$ as input for in Gulf of Maine ecosystem model, another area where an important shrimp fishery exists. These authors also reported a mean density estimate of 0.0171 $t.km^{-2}$ for *Dichelopandalus leptocerus* along the border between the Mid-Atlantic and Southern New England subregions (from 2 m beam trawl catches during summer and fall cruises). This estimate was used as input for the ecosystem models of the regions where there is no important shrimp fishery (Georges Bank, Southern New England, and the Mid-Atlantic Bight).

Biomass estimates derived from benthic grab data (Peer et al. 1980, Theroux and Wigley 1998; and Wildish et al.1989) in the 4X region averaged 0.09 $t.km^{-2}$ (95% CI: 0.011-0.419). The wide bootstrap confidence interval reflects the highly variable catch rates for this group, suggesting a patchy distribution with a high proportion of zero catches. One problem with the grab samples is that they were taken in different periods of time and do not sample the *Pandalus* species well. Canadian surveys and landings, along with US landings and surveys in the Gulf of Maine, suggest a strong temporal variation in the abundance of *Pandalus* species in the Bay of Fundy, Westen Scotian Shelf and Gulf of Maine. Shrimp species were not systematically recorded on the RV surveys before 1999. The average biomass for the 4X area derived for *Pandalus* sp. in the years 1999 and 2000 was 0.0132 $t.km^{-2}$; 0.0146 and 0.0111 $t.km^{-2}$ in the WSS and BoF respectively. Since the uncertainties about the shrimps biomass estimates are very large, their biomass was estimated by the model, as the amount of shrimp required to meet consumption (and fishery) demands, by assuming an ecotrophic efficiency of 0.95.

BIOMASS ACCUMULATION

Shrimp species were not systematically recorded on the RV surveys before 1999, hence there is no information on biomass trends for this group.

PRODUCTION:BIOMASS

A *P/B* ratio of 0.91 $year^{-1}$ (95% CI: 0.79-1.04) was estimated from Eq. 20 (Brey 1995, 1999), using the average weight of shrimps collected by the grab (Peer et al. 1980, Theroux and Wigley 1998; and Wildish et al.1989). Garcia (2007) reported estimates of total mortality (Z) for *P. borealis* between 0.5-2.0 0.7 $year^{-1}$. The highest values occur in areas where fishing is most intense. On the other hand natural mortality for this species is generally considered to be around 0.7 $year^{-1}$ in stock assessment models (Koeller 2006). Hence, the estimate of 0.91 $year^{-1}$, seems reasonable and was used as input in all models.

CONSUMPTION:BIOMASS

This parameter was estimated based on the assumption that the production to consumption ratio (*P/Q*) of scallops is 0.15.

DIET

Diet information for shrimps was based on input data for the same functional group in the eastern Scotian shelf and Georges Bank model developed by Bundy (2004) and Link et al. (2008) respectively.

BASIC INPUTS SUMMARY

Table 35. Basic input parameters for shrimps. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio, *EE* = ecotrophic efficiency, *L*=landings, *D*=discards, *C*=catch.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)
4X		0.91	6.07	0.95	0.000162	0.000008	0.000170
WSS		0.91	6.07	0.95	0.000270	0.000010	0.000280
BoF		0.91	6.07	0.95	0.000004	0.000010	0.000004

48. SCALLOP

BACKGROUND

The sea scallop *Placopecten magellanicus* is distributed over the Atlantic continental shelf of North America from the north shore of the Gulf of St. Lawrence to Cape Hatteras, North Carolina and is the main commercial species of bivalve in the 4X area. The species is concentrated in aggregations or beds that can be sporadic or permanent. High concentration in permanent beds seems to be related to temperature, food supply and physical oceanographic conditions that retain larval stages in the area of the spawning population (Packer et al. 1999; Tremblay and Sinclair 1992).

Growth rates and yields are variable both among different beds and among different areas of large beds and have been shown to be positively correlated to water temperature and food availability, and negatively related to depth and latitude. Laboratory studies have shown that larvae are viable at temperatures of 12-18°C. Adults are reported to exhibit optimal growth rates at temperatures between 10 and 15°C while spawning seems to occur at temperatures ranging from 6.5-16°C. Most sea scallops do not become sexually mature until the spring of their third year (Packer et al. 1999 and references therein)

The 4X aggregations are managed and assessed as discrete populations or stocks that occur within the scallop production areas (SPA). Population assessment models are available for some of these areas. Ecopath model input estimates were based on data and parameters for the SPAs 1A, 1B, 3 and 4, which were provided by Stephen Smith (DFO, pers. comm.). See Table 36 for summary of input parameters.

BIOMASS

Biomass was estimated from the relationship exploitation = landings/biomass. A proxy for the average exploitation rate for all 3 models was derived from the average exploitation rate from population models for scallops in the SPAs 1A, 1B, 3 and 4 in the years 1997-2000. As for other bivalves in the model, the landings estimates were adjusted to include only the weight of soft tissues, by multiplying the total weight by 0.421, the conversion factor for bivalves reported by Laurinolli et al. (2004). Thus the biomass estimate also reflects the soft tissue weight.

BIOMASS ACCUMULATION

The biomass series in the SPAs cited above show a clear increasing trend in the 1997-2000 years. The average biomass accumulation for this period was about 0.06 year^{-1}.

PRODUCTION:BIOMASS

A *P/B* ratio of 0.34 year^{-1} for all three models was estimated as the sum of the average *F* (0.16 year^{-1}), *BA* (0.06 year^{-1}) and *M* (0.12 year^{-1}) derived from the scallop population models.

CONSUMPTION:BIOMASS

This parameter was estimated based on the assumption that the production to consumption ratio (*P/Q*) of scallops is 0.15.

DIET

Sea scallops are suspension or filter feeders. The principal food is phytoplankton, diatoms, and microscopic animals, but detritus particles and associated bacteria also contribute to energy gain during periods of low phytoplankton concentrations (Packer et al. 1999 and references therein). It was assumed that the scallop diet was composed of 40% phytoplankton, 10% of microflora and 50% detritus that is suspended in the seawater.

BASIC INPUTS SUMMARY

Table 36. Basic input parameters for scallop. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch.

Model	B (t.km^{-2})	P/B (year^{-1})	Q/B (year^{-1})	L (t.km^{-2})	D (t.km^{-2})	C (t.km^{-2})	C/B (year^{-1})
4X	0.646857	0.34	*2.28*	0.106389		0.106389	0.16
WSS	0.822489	0.34	*2.28*	0.135275		0.135275	0.16
BoF	0.526394	0.34	*2.28*	0.086576		0.086576	0.16

49. BIVALVES

BACKGROUND

Based on benthic data from Peer et al. (1980), Theroux and Wigley (1998) and Wildish et al. (1989), the 8 most important bivalve species in the 4X region in terms of biomass are: horse mussel (*Modiolus modiolus*), ocean quahog (*Arctica islandica*), *Astarte undata*, *Cyclocardia borealis*, *Astarte crenata subequilatera*, *Cytodaria sliqua*, *Astarte* sp., and *Tridonta borealis*. The relative importance of the main species vary across the area, with the horse mussel having very high biomass in the BoF, whereas in the WSS it is the third ranking species in terms of biomass. See Table 37 for summary of input parameters.

BIOMASS

Total biomass of bivalves was estimated from benthic grab data (Peer et al. 1980; Theroux and Wigley 1998; and Wildish et al.1989). Whole weight was converted to flesh weight by multiplying the estimated biomass by 0.421, the conversion factor for bivalves reported by Laurinolli et al. (2004). The average biomasses and bootstrap confidence intervals for bivalves in the 3 systems were: 63.22 $t.km^{-2}$ (95% CI: 31.29-114.91), 3.81 $t.km^{-2}$ (95% CI: 2.20-6.13), 133.57 $t.km^{-2}$ (95% CI: 64.70-245.38), for the 4X, WSS and BoF models respectively.

PRODUCTION:BIOMASS

A *P/B* of 0.69 $year^{-1}$ (95% CI: 0.61-0.78) for bivalves was estimated using Eq. 20 (Brey 1995, 1999) and average weight from grab data (Peer et al. 1980; Theroux and Wigley 1998; and Wildish et al.1989) for all 3 models.

CONSUMPTION:BIOMASS

This parameter was estimated based on the assumption that the production to consumption ratio (*P/Q*) of bivalves is 0.15.

DIET

Feeding behaviour of bivalves includes suspension and deposit feeding. Suspension or filter feeding includes both detritus and living matter, such as phytoplankton, that are mixed in the sea water. Deposit feeders feed on detritus and other organic particles such as bacteria that are attached to the substrate (Bundy 2004; Packer et al. 1999 and references therein). It was assumed that the free bivalves diet was composed of 50% phytoplankton and 50% detritus, whereas the diet of the sessile species was composed of 100% phytoplankton. Biomass-weighted average diet compositions were then estimated for each of the 3 models.

BASIC INPUTS SUMMARY

Table 37. Basic input parameters for bivalves. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)
4X	63.220230	0.69	4.6	0.010353		0.010353	0.000164
BoF	133.568220	0.69	4.6	0.024011		0.024011	0.000180
WSS	3.813509	0.69	4.6	0.000985		0.000985	0.000258

50. OTHER MOLLUSCS

BACKGROUND

This functional group is composed of the Mollusca classes Gastropoda, Amphineura and Scaphopoda. The main group of species, as observed in the grab samples used in this study, was the gastropods, accounting for about 63% of this functional group biomass. According to Theroux and Wigley (1998) the gastropods are a moderately common component in their study area. However, because of their general small size they account for only a small proportion of the total benthic biomass. See Table 38 for summary of input parameters.

BIOMASS

Total biomass of other molluscs was estimated from benthic grab data (Peer et al. 1980; Theroux and Wigley 1998; Wildish et al. 1989). The average biomasses and bootstrap confidence intervals for other molluscs in the 3 systems were 2.48 $t.km^{-2}$ (95% CI: 1.33-4.40), 2.52 $t.km^{-2}$ (95% CI: 0.65-6.13) and 2.40 $t.km^{-2}$ (95% CI: 1.51-3.92) in the 4X, WSS and BoF models respectively.

PRODUCTION:BIOMASS

A *P/B* of 0.75 $year^{-1}$ (95% CI: 0.66-0.85) was estimated using Eq. 20 (Brey 1995, 1999) for all 3 models.

CONSUMPTION:BIOMASS

This parameter was estimated based on the assumption that the production to consumption ratio (*P/Q*) is 0.15.

DIET

Diet data was based on feeding types of gastropods, the dominant taxon in this functional group. Feeding types represented in the samples were herbivores, predacious and non-predaceous carnivores, and parasites, but the dominant forms were the carnivores and scavengers that feed heavily on bivalve molluscs (Theroux and Wigley 1998). It was assumed that 30% of diet was composed of bivalves, 25% detritus, 25% meiofauna, 10% cannibalism and the remainder equally attributed to predation on other benthic groups.

BASIC INPUTS SUMMARY

Table 38. Basic input parameters for the "other molluscs" functional group. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)	C/B ($year^{-1}$)
4X	2.482815	0.75	*5.02*	0.002360	0.000041	0.002401	0.000967
BoF	2.396828	0.75	*5.02*	0.005757	0.000055	0.005813	0.002425
WSS	2.520127	0.75	*5.02*	0.000030	0.000030	0.000061	0.000024

51. OTHER ARTHROPODA

BACKGROUND

This group is composed of small arthropods that live on, burrow into the benthic interface or swarm off the bottom such as Amphipoda, Mysidacea, Cumacea, Isopoda, Tanaidacea and Pycnogonida. By far, the most abundant taxon in this group and among all macrobenthic organisms is the amphipods. However due to their small size, this functional group represent a small proportion of macrobenthic biomass (Theroux and Wigley 1998). See Table 39 for summary of input parameters.

BIOMASS

Total biomass of other arthropoda was estimated from benthic grab data (Peer et al. 1980; Theroux and Wigley 1998; Wildish et al. 1989). The average biomass and bootstrap confidence intervals were 0.62 $t.km^{-2}$ (95% CI: 0.45-0.85), 0.50 $t.km^{-2}$ (95% CI: 0.34-0.72) and 0.76 $t.km^{-2}$ (95% CI: 0.57-1.02) for the 4X, WSS and BoF models respectively.

PRODUCTION:BIOMASS

A *P/B* of 2.29 $year^{-1}$ (95% CI: 2.03-2.58) was estimated for all 3 models using Eq. 20 (Brey 1995, 1999).

CONSUMPTION:BIOMASS

This parameter was estimated based on the assumption that the production to consumption ratio (*P/Q*) is 0.15.

DIET

Species in this group are mostly detritivores or scavengers, feeding on surface or subsurface deposits or animal remains, with some forms being carnivores (Theroux and Wigley 1998). It was assumed that about 95% of diet was composed of detritus, the remainder equally attributed to cannibalism and predation on meiofauna.

BASIC INPUTS SUMMARY

Table 39. Basic input parameters for the "other gastropoda" functional group. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)
4X	0.620778	2.29	15.25
BoF	0.757541	2.29	15.25
WSS	0.501483	2.29	15.25

52. ECHINODERMS

BACKGROUND

This group includes all echinoderms except the class Crinoidea, which was included in the sessile benthic functional group. Echinoderms are the third largest macrobenthic functional group in 4X in terms of biomass. In the WSS, echinoids have the highest biomass followed by holothurians, and comprise most of the echinoderm biomass. In the BoF three groups, holothurians, followed by echinoids then ophiuroids, account for most of the biomass. See Table 40 for summary of input parameters.

BIOMASS

Total biomass of echinoderms was estimated from benthic grab data (Peer et al. 1980; Theroux and Wigley 1998; Wildish et al. 1989). Total biomass including shell weight was converted to flesh weight using the conversion factor of 0.6, reported by Laurinolli et al. (2004). The average biomass and bootstrap confidence intervals were 12.64 $t.km^{-2}$ (95% CI: 4.56-29.88), 17.58 $t.km^{-2}$ (95% CI: 6.16-38.22), 6.75 $t.km^{-2}$ (95% CI: 3.09-14.36) for the 4X, WSS and BoF models respectively.

PRODUCTION:BIOMASS

A *P/B* of 0.33 $year^{-1}$ (95% CI: 0.27-0.40) was estimated using Eq. 20 (Brey 1995, 1999) for all 3 models.

CONSUMPTION:BIOMASS

This parameter was estimated based on the assumption that the production to consumption ratio (*P/Q*) is 0.15.

DIET

The feeding habits of echinoderms are varied. Of the three dominant groups in terms of biomass, echinoids are carnivorous, herbivorous or omnivorous bottom feeders, holothurians are suspension or deposit feeders and ophiuroids can be carnivores, filter feeders, and scavengers. The distinction in feeding type is not always maintained and when the preferred food types are unavailable, the organisms may revert to other food sources, or in some species, to a different mode of feeding (Theroux and Wigley 1998). The dominant feeding type of the species in the samples used in this study seemed to be mainly either deposit of suspension feeders. It was assumed that about 95% of diet was composed of detritus, the remainder attributed to predation on other benthic groups.

BASIC INPUTS SUMMARY

Table 40. Basic input parameters for the echinoderms functional group. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	L ($t.km^{-2}$)	D ($t.km^{-2}$)	C ($t.km^{-2}$)
4X	12.64	0.33	2.20	0.030260	0.016926	0.030260
WSS	17.58	0.33	2.20	0.005695	0.012980	0.005695
BoF	6.75	0.33	2.20	0.066075	0.022674	0.066075

53. SESSILE BENTHIC GROUPS

BACKGROUND

This is a very generic group composed of the taxa Ascidiacea, Brachiopoda, Bryozoa, Cnidaria, Cirripedia, Crinoidea and Porifera. Porifera accounted for about 33% of the biomass of this group in the samples used to represent the 4X area, whereas the biomasses of Brachiopoda, Bryozoa, Cirripedia and Cnidaria were more or less equivalent, accounting for most of the remaining part of the biomass for the group. In the BoF area, Porifera was the main taxa, while in the WSS the two dominant groups were Cirripedia and Cnidaria, although in all cases the bulk of the biomass is shared among 4 or 5 taxa. See Table 41 for summary of input parameters.

BIOMASS

Total biomass was estimated from benthic grab data (Peer et al. 1980; Theroux and Wigley 1998; Wildish et al. 1989). The average biomass and bootstrap confidence intervals were 26.03 t.km^{-2} (95% CI: 14.26-44.19), 14.30 t.km^{-2} (95% CI: 7.56-25.57), 39.76 t.km^{-2} (95% CI: 23.0-65.0) for the 4X, WSS and BoF models respectively.

PRODUCTION:BIOMASS

Since this group is composed of organisms that form colonies and there was no average individual weight estimates available, the *P/B* ratio was estimated based on average weight for bivalves using the option for sessile animals in the empirical Eq. 20 (Brey 1999). The estimated parameter was 0.32 year^{-1} (95% CI: 0.28-0.38), which is similar to *P/B* ratio for sessile organisms in temperate ecosystems (Stanford and Pitcher 2004; Araújo et al. 2005). This value was used as input in all 3 models.

CONSUMPTION:BIOMASS

This parameter was estimated based on the assumption that the production to consumption ratio (*P/Q*) is 0.15.

DIET

The main feeding type in this group is filter feeding on suspended organic matter and plankton, although some species are carnivores that prey on planktonic crustaceans and other small animals carried by water currents (Theroux and Wigley 1998). It was assumed that about 55% of diet was composed of phytoplankton, 20% of detritus, 15% of microflora and the remainder attributed equally to macro, meso and microzooplankton groups.

BASIC INPUTS SUMMARY

Table 41. Basic input parameters for the sessile benthic functional group. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio, *L*=landings, *D*=discards, *C*=catch.

Model	B (t.km^{-2})	P/B (year^{-1})	Q/B (year^{-1})	L (t.km^{-2})	D (t.km^{-2})	C (t.km^{-2})
4X	26.03	0.32	2.13		0.002943	0.002943
WSS	14.30	0.32	2.13		0.002300	0.002300
BoF	39.76	0.32	2.13		0.003885	0.003885

54. WORMS

BACKGROUND

The dominant taxon in terms of biomass in this generic functional group are the annelids (polychaetes), followed by the taxon Sipuncula (peanut worms) and then by others that represented a small amount of the group's biomass (Chaetoderma, Nematoda, Nemertea, Pogonophora). See Table 42 for summary of input parameters.

BIOMASS

Total biomass was estimated from benthic grab data (Peer et al. 1980; Theroux and Wigley 1998; Wildish et al. 1989). The average biomass and bootstrap confidence intervals were 7.35 t.km^{-2} (95% CI: 5.52-9.81), 4.10 t.km^{-2} (95% CI: 2.98-5.76) and 11.15 t.km^{-2} (95% CI: 8.46-14.6) for the 4X, WSS and BoF models respectively.

PRODUCTION:BIOMASS

A *P/B* of 1.25 year^{-1} (95% CI: 1.13-1.40) was estimated using Eq. 20 (Brey 1999) for all 3 models.

CONSUMPTION:BIOMASS

This parameter was estimated based on the assumption that the production to consumption ratio (*P/Q*) is 0.15.

DIET

Polychaetes are very variable in form, lifestyle and feeding, and include carnivores, suspension feeders, and selective and nonselective deposit feeders (Theroux and Wigley 1998). Most burrow or build tubes and are deposit or filter feeders. Based on the grab sample data, about 30% of the organisms in this functional group were unidentified annelids. The identified species were dominated by the polychaeta *Sternaspis scutata* and the peanut worm *Phascolion strombi*, which are deposit feeders. It was assumed that 80% of diet was composed of detritus and the remainder attributed equally to predation on worms, meiofauna and other arthropods functional group.

BASIC INPUTS SUMMARY

Table 42. Basic input parameters for the worms functional group. Numbers in italic are estimated by Ecopath. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio.

Model	B (t.km^{-2})	P/B (year^{-1})	Q/B (year^{-1})
4X	7.35	1.25	8.33
WSS	4.10	1.25	8.33
BoF	11.15	1.25	8.33

55. MEIOFAUNA

BACKGROUND

Meiofauna are defined as interstitial organisms that are retained on a 40 µm mesh sieve, but pass through a 1 mm sieve (Theroux and Wigley 1998; Mackinson and Daskalov 2007) and hence are not normally present in the benthic samples of Peer et al. (1980), Theroux and Wigley (1998) and Wildish et al. (1989) used in this study. Several taxa make part of this functional group, such as nematodes, harpacticoid copepods, ostracoda and foraminifera. Through grazing on bacteria, bioturbation and mucus production, these organisms play an important role in the transfer of matter and energy to higher trophic levels, which prey upon them, such as benthic crustaceans and bottom fish (Mackinson and Daskalov 2007 and references therein). See Table 43 for summary of input parameters.

BIOMASS

Since the sampling gears used in the studies of Peer et al. (1980), Theroux and Wigley (1998) and Wildish et al. (1989) were not adequate to estimate the abundance of meiofaunal organisms an estimate of 4.10 $t.km^{-2}$ from an Ecopath model for the North Sea (Mackinson and Daskalov 2007) was used as input for all 3 models.

PRODUCTION:BIOMASS

Mackinson and Daskalov (2007) provide a brief review of production to biomass ratios for meiofaunal organisms from several studies, giving estimates from 5 to 35.3 $year^{-1}$ (Mackinson and Daskalov (2007), Table 11.17). The input for this group from the North Sea model (10.8 $year^{-1}$), was used here as input for all 3 models.

CONSUMPTION:BIOMASS

This parameter was estimated based on the assumption that the production to consumption ratio (*P/Q*) is 0.15.

DIET

Meiofaunal organisms seem to feed mostly on detritus and benthic microflora although some are carnivores that prey on other meiofauna (Mackinson and Daskalov 2007 and references therein). The bulk of their diet was thus assumed to be composed of detritus with a small proportion of meiofauna (cannibalism).

BASIC INPUTS SUMMARY

Table 43. Basic input parameters for the meifauna functional group. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio.

Model	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)
4X	4.10	10.8	72.0
WSS	4.10	10.8	72.0
BoF	4.10	10.8	72.0

56–59. ZOOPLANKTON AND MICRONEKTON

BACKGROUND

The zooplankton realm is composed of 4 functional groups: gelatinous, macro, meso and microzooplankton. We used the definition given by Sameoto et al. (2002) for the size criteria.

1. Microzooplankton - animals below 0.2 mm
2. Mesozooplankton - animals between 0.2 mm and 10 mm length (this group is mainly composed of copepods.
3. Macrozooplankton – animals greater than 10 mm. Here, the macrozooplankton (animals between 1 and 4 cm) as defined by Sameoto et al. (2002) and micronekton organisms (animals larger than 4 cm), were combined into one functional group called "macrozooplankton due to data limitations. This functional group includes the crustaceans amphipoda, euphausiacea, mysidacea and similar decapoda captured in plankton nets. Chaetognatha are also included in this group. The dominant taxon in the samples was Euphausids.
4. Gelatinous zooplankton – common groups include members of the Cnidaria (e.g., jellyfish, hydromedusae, hydroids, siphonophores), Ctenophora, Chordata (e.g., larvaceans and salps), and Mollusca (e.g., pteropods).

See Table 44 for summary of input parameters.

BIOMASS

Biomass data for the meso, macro and gelatinous zooplankton were provided by Catherine Johnson (DFO, pers. comm., see Methods Section). The estimate for the mesozooplankton was derived from ring net samples collected from 1998 to 2008, while the estimate for the macrozooplankton and gelatinous zooplankton were derived from BIONESS samples collected from 1999 to 2007, and subsampled with a 10 mm mesh sieve. The spatial cover of the BIONESS samples was very limited and hence the WSS and BoF samples were combined to produce an average biomass estimate for whole area.

The biomass estimates for the meso, macro and gelatinous zooplankton groups were:
- Gelatinous zooplankton - 4X: 0.52 $t.km^{-2}$ (95% CI: 0.17-0.87)
- Macrozooplankton - 4X : 41.31 $t.km^{-2}$ (95% CI: 26.53-56.10)
- Mesozooplankton - 4X: 23.80 $t.km^{-2}$ (95% CI: 21.51-26.09);
WSS: 26.63 $t.km^{-2}$ (95% CI: 23.82-29.45);
BoF: 15.75 $t.km^{-2}$ (95% CI: 12.32-19.17).

There were no biomass estimates for microzooplankton. Link et al. (2006) assumed that the ratio between microzooplankton and phytoplankton biomass in the models developed for the ecosystems off the coast of New England, United States, was approximately 0.16. This ratio was used here to estimate the microzooplankton biomasses, which were 5.39, 4.88 and 5.89 $t.km^{-2}$ for the 4X, WSS and BoF models respectively.

PRODUCTION:BIOMASS

The *P/B* estimated of 72 $year^{-1}$ reported by Link et al. (2006) for microzooplankton was used for this group

An annual average *P/B* ratio of 35.5 $year^{-1}$ was estimated for mesozooplankton from a daily production rate estimated from Eq. 31 (Huntley and Lopez 1992).

For the macrozooplankton, an average *P/B* estimate of 3.04 $year^{-1}$ for euphausiids reported by Bundy (2004) was used as input in the 3 models.

P/B estimates for gelatinous zooplankton for models of ecosystems around the world have been reported to range from 0.79 to 40 $year^{-1}$ (Link et al. 2006; Mackinson and Daskalov 2007; Pauly et al. 2009), with an average of 12.81 $year^{-1}$. A *P/B* of 15.51 $year^{-1}$ was estimated assuming a *P/Q* of 0.25 along with an estimate of *Q/B* of 62.05 $year^{-1}$ (see below).

CONSUMPTION:BIOMASS

The *Q/B* ratios were estimated as follows:

Meso and microzooplankton: estimate based on the assumption that the production to consumption ratio (*P/Q*) is 0.30.

Macrozooplankton: estimate of 19.5 yr^{-1} based on average of estimates for 3 euphausiid species in the in the Gulf of St. Lawrence (Sameoto 1976).

Gelatinous zooplankton – estimate based on a daily *Q/B* ratio of about 17% (=62.05 $year^{-1}$) for ctenophores reported by Reeve and Walter (1976).

DIET

Diet composition for micro, meso and macrozooplankton functional groups were based on inputs for similar functional groups included in the Georges Bank ecosystem model of Link et al. (2008a). The diet for the gelatinous zooplankton was based on the main prey of gelatinous organisms assembled by Pauly et al. (2009) from 21 ecosystem models.

BASIC INPUTS SUMMARY

Table 44. Basic input parameters for zooplankton groups. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio.

Model	Group name	B ($t.km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)
4X	Gelatinous	0.52	15.51	62.05
	Macro	41.31	3.04	19.50
	Meso	23.8	35.50	118.33
	Micro	5.39	72	240.00
WSS	Gelatinous	0.52	15.51	62.05
	Macro	41.31	3.04	19.50
	Meso	26.63	35.50	118.33
	Micro	4.88	72	240.00
BoF	Gelatinous	0.52	15.51	62.05
	Macro	41.31	3.04	19.50
	Meso	15.75	35.50	118.33
	Micro	5.89	72	240.00

60–61. MICROFLORA AND PHYTOPLANKTON

BACKGROUND

A large part of the primary production is “lost” to the pool of dissolved organic matter, either by excretion or by lysis of ungrazed cells. This energy budget is not directly available to herbivores and are utilised by the microflora (bacteria and auto/ heterotrophic nanoflagellates), which form a link between dissolved primary production and production at higher trophic levels (Hoch 1998; Mackinson and Daskalov 2007). To partially account for this process, a microflora functional group was included in the model, which feeds on the detritus group. No distinction was made here between the planktonic and benthic microflora pools. See Table 45 for summary of input parameters.

BIOMASS AND PRODUCTION

Biomass and productivity (*PP*) of phytoplankton were estimated from satellite estimates of surface chlorophyll and algorithms that integrate the surface chlorophyll over different depths provided by Trevor Platt (DFO, pers. comm. see Platt et al. 1991, Longhurst et al. 1995 and Sathyendranath et al. 1995 for methods). Annual estimates for the years between 1998 and 2007 were used to generate the averages for the 3 models. These estimates of production were then divide by the biomass estimates to produce the *P/B* ratios.

There were no local estimates available for the microflora group. We have followed the the key assumptions made by Link et al. 2006, and assumed that the bacterial production is about 10% of total primary production, the gross growth efficiency (*P/Q*) is 0.24 and daily *P/B* is 0.25 (91.3 year^{-1}). The biomass was then estimated from the total production and the *P/B* ratio.

CONSUMPTION:BIOMASS

The *Q/B* of microflora was estimated based on the assumption that the production to consumption ratio (*P/Q*) is 0.24.

DIET

The diet of microflora was composed exclusively of detritus.

BASIC INPUTS SUMMARY

Table 45. Basic input parameters for phytoplankton and microflora functional groups. *B*=biomass, *P/B* = production to biomass ratio, *Q/B* = consumption to biomass ratio.

Model	Group name	B (t.km^{-2})	P/B (year^{-1})	Q/B (year^{-1})
4X	Phyto	33.7	70.7	
	Microflora	2.61	91.25	380.2
WSS	Phyto	30.5	77.6	
	Microflora	2.60	91.25	380.2
BoF	Phyto	36.8	64.8	
	Microflora	2.62	91.25	380.2

BALANCING THE BASELINE MODELS

1. The 4X 1995−2000 model

Twenty-four groups had an *EE* above 1, i.e., they did not have the required level of production to meet consumption and fishery demands based on input parameters. The main problems were caused by excess of predation on juvenile stanzas and functional groups composed of small prey species. The strategy used to balance the model was, in the first instance, to modify the diet matrix since 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, which was highest for the main commercial fish species. These changes were made in an iterative manner, and not all initial changes to diet matrix were kept in the final balanced model, as changes made to balance some groups later in the process reverted some of the initial changes made in the beginning of the process. Some prey species, such as the juveniles of the large benthivores and demersal piscivores groups had to be considerably decreased in the diet of all predators. The basic estimates and diet matrices for the unbalanced and balanced 4X model are presented in Tables 46–49.

The main changes to the 4X model input parameters are summarised in the following paragraphs. The given description does not necessarily reflect the exact sequence of changes, since some final adjustments and parameter corrections were made in later stages.

Sea Birds – The problem was caused by cannibalism and the very high value of *Q/B*. To balance the group, the amount of cannibalism was reduced and the difference attributed to the import group. Since uncertainty of *Q/B* is considered high, it was also reduced to 70% of the initial value, a change that also reduces predation mortality on another prey species.

Lobster – The overall level of predation mortality was relatively high. The proportion of lobsters was reduced in the diets of all predators and the *BA* was reduced from 0.13 to 0.1 $year^{-1}$.

Small crabs – This group was balanced by decreasing its importance in the diets of the other molluscs functional group because this link was quite uncertain, decreasing the biomass of the other mollusc functional group from 2.48 to 2 $t.km^{-2}$ and increasing small crab biomass to 0.97 $t.km^{-2}$. The biomass changes performed were within the estimated confidence intervals. As a result of the changes to the diet composition of other predators, the proportion of small crabs increased in those diets.

Large crabs – The proportion of this group had to be considerably reduced in the diets of all predators and its biomass increased by about 30%.

Squids – Cannibalism was the main cause of mortality. It had to be decreased to about 10% of the initial value. The difference was attributed to squid predation on macrozooplankton. The *Q/B* was reduced from 13.2 to 11.33 $year^{-1}$, the *P/B* increased from 3.4 to 4 $year^{-1}$ and the proportion of squids was reduced in diets of almost all other predators.

Haddock < 3 years – The level of predation by squids and by the small stanza of the demersal piscivores group was reduced.

Longhorn sculpin < 25 cm – The proportion of longhorn sculpin in the diets of all predators was reduced and the *BA* was increased to -0.05 $year^{-1}$.

Cod < 1 year – The proportion of cod had to be reduced in the diets of all predators. Its mortality was increased from 1.48 to 1.55 $year^{-1}$.

Silver hake – This was a problematic group since the Ecopath multi-stanza routine greatly underestimated the biomass estimate for the small stanzas compared to the estimate from the catchability adjusted research survey data. To adjust the biomass estimates for the non-leading stanzas, the total mortality of the two large stanzas was increased to 1.3 $year^{-1}$, within the confidence interval of catch curve estimates, while the mortality for the small stanza was increased to 1.5 $year^{-1}$. It should be noted that the rapid decrease in numbers (and biomass) and apparent high mortality for the large silver hake stanzas could be partially explained by emigration to waters off the shelf. However there is no information available to corroborate this hypothesis. Pollock was one of the main predators of the small silver hake. Its biomass estimate, derived from catchability adjusted research survey data, seemed to be overestimated when compared to the VPA estimate. Reducing the pollock biomass greatly reduced predation on the juveniles of silver hake. The proportion of silver hake was reduced in the diets of all predators.

Demersal piscivores < 40 cm – Ecopath underestimated the biomass of this group compared to the estimate from the catchability adjusted research survey data. Its biomass was increased by increasing the *BA* term from -0.12 to -0.05 $year^{-1}$. The proportion of this group was reduced in the diet of all predators.

Large benthivores < 40 cm – The Ecopath biomass estimate for this stanza was slightly underestimated when compared to the estimate derived from the catchability adjusted research survey data Changes to balance this group included:

1) Its mortality was increased to 0.5 $year^{-1}$.
2) The proportion of this group was reduced in the diets all predators.
3) The biomass of the whole group (small and large stanzas) was increased by 10%.

Herring < 4 years – The proportion of this group was reduced in the diets of all predators and the *Z* increased from 0.63 to 0.64 $year^{-1}$.

Other pelagics – This group was reduced in the diet of all predators. Then the *P/B* was increased from 0.56 to 0.74 $year^{-1}$, which is in the range of *Z* estimates for species in this group.

Mackerel – The proportion of mackerel was reduced in the diets of all predators. Then the *P/B* was increased to 0.58 $year^{-1}$ (+10%).

Small medium-benthivores – This generic prey group has several predators, its *EE* was high but it has little impact on its prey items. The *P/B* was increased to 1.41 year $^{-1}$, which is within the range of the *Z* estimates for species in this group and it was decreased in diets of all predators. Since there are no specific catchability estimates for the species in this group, its biomass was estimated by the model based on an *EE* of 0.95, which increased the biomass from 0.010 to 0.038 $t.km^{-2}$.

Other arthropoda – The main uncertainties are *P/B* and the level of predation. The domininant taxon is the amphipoda for which reported *P/B* estimates from Georges Bank ranged from 2.5 to 4.4 $year^{-1}$ (Collie 1985). Changes made to this group included an increase in its *P/B* to 4.4 $year^{-1}$, the maximum value reported by Collie (1985), an increase in biomass to 0.853 $t.km^{-2}$, which is the upper limit of the estimated confidence level, and a large reduction in its proportion in the diets of all predators, particularly in the diets of its benthic invertabrate predators.

Planktonic and detritus groups – One of the main problems with the planktonic and detritus groups was related to overestimation of their *Q/B* rates, which were estimated from the *P/B* rates and assumptions about *P/Q*. To balance these groups, the *Q/B* of mesozooplankton was reduced to 73 year^{-1}, which was derived from daily estimates of food conversion for *Calanus helgolandicus* (Pafenhofer (1976) in Link et al. (2006)). Then its production was re-estimated from this *Q/B,* assuming that *P/Q* is 0.4. These changes resulted in *P/B* of 29.2 year^{-1}. The *Q/B* of microzooplankton and microflora were re-estimated based on a *P/Q* of 0.5, assuming some autotrophic production for these groups. Their *P/B* was then increased by 15% and they were reduced in the diets of their predators. Their biomasses were then estimated based on *EE* of 0.95.

In addition to the changes described above, other changes to model inputs included:
1 – The *Q/B* (leading parameter) of the large stanza of the demersal piscivores was reduced from 4.03 to 2.50, since this parameter seemed too high for such a large species and also because this group caused high predation mortality on several other species.
2 – The biomass of large dogfish, toothed cetaceans and whales were reduced because (a) there are uncertainties related to the biomass estimates for these groups and (b) these groups were an important source of predation mortality for many other species.
4 – Diets of toothed ceteaceans were further changed to increase the predation on the medium-sized silver hake.
5 – The *Q/B* of dogfish, redfish, silver hake, pollock and cod were reduced.
6 – Predation mortality by squid on several fish species was high due to the very high squid *Q/B* and the relatively high proportions of individual fish species in the squid diet Hence the proportions of fish prey items were greatly reduced in the balanced diet and squids biomass was decreased to 60% of the initial value.
7 –Ecopath overestimates the biomass of small pollock because fish younger than 2 years are closely associated with nearshore habitats and are therefore not well represented in the area modelled (see DFO (2006)). Thus since most small pollock would not be feeding in the model area, about 70% of its diet was directed to import.
8 – The biomass of shrimps estimated by Ecopath assuming an *EE* of 0.95 was very high. Hence shrimps were reduced in the diet of their main predators (silver hake, herring and redfish), making the proportions closer to the minimum proportions observed in the diet estimates calculated from US and Canada dababases. The difference was redirected to the macrozooplankton functional group, since krill is a very important prey for these species. Since the process to balance other groups as desribed above, tended to increase predation on this group, the proportion of shrimps in the diets of all other predators was reduced to values close to initial (unbalanced model) estimates and the difference was directed to macrozooplankton, in cases of shared predators, or to another prey items. The *P/B* of the group was then increased to 3 year^{-1}.
9 – The total mortality for the small longhorn sculpin stanza was increased from 0.33 to 0.60 year^{-1} and mortality of the large stanza reduced from 0.71 to 0.50 year^{-1}. These parameters were changed since they were considered very uncertain and the changes performed made them more similar.
10 – Ecopath overestimated the biomass of the skates small stanza. Hence the total mortality of this group was reduced from 0.31 to 0.20 year^{-1} and the percentages of skates

discards by size groups were changed from 50-50% to 30-70% for small and large skates respectively.

The 4X balanced model food preferences were used to estimate the diets for the WSS and BoF models. Before this procedure was performed, the changes described above that were made to the 4X model input parameters were applied to the WSS and BoF models. For example, biomasses of top predators that were reduced in the 4X were also reduced by an equivalent amount in the other two models. After the first attempt to parametrize the models, 4 and 16 groups had an EE > 1 in the WSS and BoF models respectively. The models were than balanced by changing the diet composition. Larger changes were necessary to balance the BoF model, which had a larger number of functional groups with EE > 1. The basic estimates for the balanced WSS and BoF models are given in Tables 50–51. A comparison of prey selection indices for a selection of prey-predator interactions in the three models are given in Table 52, which shows that these parameters were fairly similar in the final balanced models.

Table 46. Basic parameters for the unbalanced 1995-2000 4X model.

	Group name	TL	B (t.km²)	P/B (year^{-1})	Z (year^{-1})	Q/B (year^{-1})	EE	P/Q	BA (year^{-1})
1	Whales	4.29	0.612	0.071	-	4.940	0.11	0.014	0.008
2	Toothed cetaceans	5.47	0.075	0.180	-	14.500	0.22	0.012	-
3	Seals	4.92	0.063	0.147	-	7.339	0.65	0.020	0.084
4	Sea birds	4.72	0.009	0.250	-	125.100	5.28	0.002	-
5	Sharks	4.96	0.026	0.180	-	4.780	0.15	0.038	-0.075
6	Large pelagic	4.91	0.024	0.400	-	4.240	0.61	0.094	-
7	Cod <1	3.6	0.004	-	1.480	12.262	4.06	0.121	-0.050
8	Cod 1-3	4.34	0.223	-	0.390	3.429	0.74	0.114	-0.050
9	Cod 4-6	4.63	0.272	-	0.820	2.119	0.41	0.387	-0.050
10	Cod 7+	4.63	0.076	-	0.820	1.560	0.16	0.526	-0.050
11	S Hake <25	4.03	0.093	-	0.870	8.628	29.95	0.101	-
12	S Hake 25-31	4.25	0.135	-	1.000	5.163	0.47	0.194	-
13	S Hake 31+	4.98	0.043	-	1.000	4.100	0.84	0.244	-
14	Halibut <46	3.97	0.001	-	0.570	5.093	4.59	0.112	-
15	Halibut 46-81	4.87	0.005	-	0.270	2.585	0.29	0.104	-
16	Halibut 82+	4.87	0.017	-	0.270	1.610	0.64	0.168	-
17	Pollock <49	4.19	0.282	-	0.470	6.420	0.54	0.073	-0.070
18	Pollock 49+	4.56	0.372	-	0.850	3.670	0.29	0.232	-0.070
19	D piscvores <40	4.78	0.058	-	0.440	8.906	16.19	0.049	-0.120
20	D piscvores 40+	4.79	0.266	-	0.620	4.030	0.37	0.154	-0.120
21	L benthivores <40	3.98	0.071	-	0.340	3.251	17.14	0.105	-
22	L bentivores 40+	3.93	0.065	-	0.640	1.920	0.98	0.333	-
23	Skates <49	3.73	0.090	-	0.310	3.294	0.96	0.094	-
24	Skates 49+	4.04	0.074	-	0.260	1.900	0.38	0.137	-
25	Dogfish	4.74	3.160	0.139	-	2.485	0.07	0.056	-
26	Redfish <22	3.97	0.730	-	0.270	7.161	1.55	0.038	-
27	Redfish 22+	3.94	1.523	-	0.230	3.440	0.43	0.067	-
28	A plaice <26	3.4	0.043	-	0.440	4.695	1.24	0.094	-0.070
29	A plaice 26+	3.55	0.101	-	0.520	2.410	0.24	0.216	-0.070
30	Flounders <30	3.28	0.162	-	0.530	5.826	0.48	0.091	-
31	Flounders 30+	3.24	0.256	-	0.590	3.210	0.33	0.184	-
32	Haddock <3	3.42	0.289	-	0.660	4.092	1.47	0.161	0.070
33	Haddock 3+	3.57	0.807	-	0.420	2.080	0.91	0.202	0.070
34	L sculpin <25	3.78	0.060	-	0.330	6.646	3.39	0.050	-0.080
35	L sculpin 25+	3.83	0.074	-	0.710	3.930	0.11	0.181	-0.080
36	Herring <4	3.93	3.459	-	0.630	3.935	1.83	0.160	-
37	Herring 4+	3.93	2.250	-	0.810	2.360	1.04	0.343	-
38	Other pelagic	3.67	0.866	0.560	-	3.310	2.86	0.169	-
39	Mackerel	3.86	0.536	0.530	-	5.080	3.03	0.104	-
40	Mesopelagic	3.54	0.008	0.970	-	18.900	0.95	0.051	-
41	S-m benthivores	3.69	0.010	0.860	-	4.680	52.42	0.184	-
42	Squids	5.39	0.292	3.400	-	13.200	3.25	0.258	-
43	Lobster	3.23	0.301	0.910	-	6.067	1.29	0.150	0.130
44	Large crabs	3.3	0.121	0.654	-	4.360	7.99	0.150	-
45	Small crabs	2.65	0.840	1.310	-	8.733	1.23	0.150	-
46	Shrimps	2.67	10.745	0.910	-	6.067	0.95	0.150	-
47	Scallop	2.1	0.647	0.342	-	2.280	0.99	0.150	0.060
48	Bivalves	2.19	63.373	0.690	-	4.600	0.13	0.150	-
49	Other molluscs	2.88	2.479	0.750	-	5.000	0.59	0.150	-
50	Other arthropoda	2.05	0.621	2.300	-	15.333	6.68	0.150	-
51	Echinoderms	2.06	12.637	0.330	-	2.200	0.44	0.150	-

Table 46. Continued.

	Group name	TL	B (t.km²)	P/B (year^{-1})	Z (year^{-1})	Q/B (year^{-1})	EE	P/Q	BA (year^{-1})
52	Sessile benthic groups	2.31	26.025	0.320	-	2.133	0.13	0.150	-
53	Worms	2.22	7.345	1.250	-	8.333	0.83	0.150	-
54	Meiofauna	2.05	4.091	10.800	-	72.000	0.53	0.150	-
55	Gelatinous zoop	3.55	0.520	15.510	-	62.050	0.23	0.250	-
56	Macrozoop	3.06	41.310	3.040	-	19.500	0.68	0.156	-
57	Mesozoop	2.54	23.796	35.500	-	118.333	0.65	0.300	-
58	Microzoop	2.56	5.386	72.000	-	240.000	2.11	0.300	-
59	Microflora	2	2.606	91.250	-	380.208	4.33	0.240	-
60	Phytoplankton	1	33.664	70.639	-	-	0.95	-	-
61	Discards	1	0.064	-	-	-	7.21	-	-
62	Detritus	1	1.000	-	-	-	1.22	-	-

Table 47. Basic parameters for the balanced 1995-2000 4X model.

	Group name	TL	B (t.km²)	P/B (year^{-1})	Z (year^{-1})	Q/B (year^{-1})	EE	P/Q	BA (year^{-1})
1	Whales	4.1	0.407	0.071	-	4.940	0.11	0.014	0.008
2	Toothed cetaceans	4.88	0.050	0.180	-	14.500	0.33	0.012	-
3	Seals	4.83	0.044	0.147	-	7.339	0.70	0.020	0.084
4	Sea birds	4.46	0.006	0.250	-	87.600	0.95	0.003	-
5	Sharks	4.81	0.026	0.180	-	4.780	0.15	0.038	-0.075
6	Large pelagic	4.82	0.024	0.400	-	4.240	0.61	0.094	-
7	Cod <1	3.66	0.004	-	1.550	10.469	0.95	0.148	-0.050
8	Cod 1-3	4.08	0.223	-	0.390	2.915	0.78	0.134	-0.050
9	Cod 4-6	4.47	0.272	-	0.820	1.801	0.41	0.455	-0.050
10	Cod 7+	4.47	0.076	-	0.820	1.326	0.16	0.618	-0.050
11	S Hake <25	3.92	0.441	-	1.600	7.436	0.96	0.215	-
12	S Hake 25-31	4.01	0.264	-	1.300	4.097	0.39	0.317	-
13	S Hake 31+	4.75	0.047	-	1.300	3.280	0.44	0.396	-
14	Halibut <46	3.86	0.001	-	0.570	5.093	0.92	0.112	-
15	Halibut 46-81	4.65	0.005	-	0.270	2.585	0.29	0.104	-
16	Halibut 82+	4.65	0.017	-	0.270	1.610	0.64	0.168	-
17	Pollock <49	3.91	0.117	-	0.470	5.143	0.98	0.091	-0.070
18	Pollock 49+	4.25	0.155	-	0.850	2.940	0.70	0.289	-0.070
19	D piscvores <40	4.33	0.080	-	0.440	5.372	0.98	0.082	-0.050
20	D piscvores 40+	4.6	0.266	-	0.620	2.500	0.37	0.248	-0.050
21	L benthivores <40	3.78	0.103	-	0.500	3.462	0.97	0.144	-
22	L bentivores 40+	3.55	0.071	-	0.640	1.920	0.77	0.333	-
23	Skates <49	3.63	0.064	-	0.200	3.077	0.98	0.065	-
24	Skates 49+	3.91	0.074	-	0.260	1.900	0.52	0.137	-
25	Dogfish	4.45	2.102	0.139	-	1.740	0.11	0.080	-
26	Redfish <22	3.9	0.730	-	0.270	5.017	0.67	0.054	-
27	Redfish 22+	3.88	1.523	-	0.230	2.410	0.47	0.095	-
28	A plaice <26	3.35	0.043	-	0.440	4.695	0.83	0.094	-0.070
29	A plaice 26+	3.58	0.101	-	0.520	2.410	0.31	0.216	-0.070
30	Flounders <30	3.23	0.162	-	0.530	5.826	0.57	0.091	-
31	Flounders 30+	3.21	0.256	-	0.590	3.210	0.32	0.184	-
32	Haddock <3	3.38	0.289	-	0.660	4.092	0.95	0.161	0.070
33	Haddock 3+	3.43	0.807	-	0.420	2.080	0.87	0.202	0.070
34	L sculpin <25	3.74	0.061	-	0.600	7.919	0.74	0.076	-0.050
35	L sculpin 25+	3.77	0.074	-	0.500	3.930	0.13	0.127	-0.050

Table 47. Continued.

	Group name	TL	B (t.km²)	P/B (year^{-1})	Z (year^{-1})	Q/B (year^{-1})	EE	P/Q	BA (year^{-1})
36	Herring <4	3.87	3.508	-	0.640	3.946	0.98	0.162	-
37	Herring 4+	3.87	2.250	-	0.810	2.360	0.91	0.343	-
38	Other pelagic	3.59	0.866	0.740	-	3.310	0.93	0.224	-
39	Mackerel	3.77	0.536	0.583	-	5.080	0.98	0.115	-
40	Mesopelagic	3.37	0.013	0.970	-	18.900	0.95	0.051	-
41	S-m benthivores	3.58	0.038	1.410	-	4.700	0.95	0.300	-
42	Squids	3.98	0.174	4.000	-	11.333	0.98	0.353	-
43	Lobster	3.1	0.301	0.910	-	6.067	0.97	0.150	0.100
44	Large crabs	3.18	0.157	0.654	-	4.360	0.81	0.150	-
45	Small crabs	2.64	0.965	1.310	-	8.733	0.99	0.150	-
46	Shrimps	2.61	1.303	3.000	-	20.000	0.95	0.150	-
47	Scallop	2.05	0.647	0.342	-	2.280	0.98	0.150	0.050
48	Bivalves	2.1	63.373	0.690	-	4.600	0.13	0.150	-
49	Other molluscs	2.81	2.000	0.750	-	5.000	0.79	0.150	-
50	Other arthropoda	2.03	0.853	4.400	-	29.333	0.88	0.150	-
51	Echinoderms	2.06	12.637	0.330	-	2.200	0.46	0.150	-
52	Sessile benthic groups	2.23	26.025	0.320	-	2.133	0.15	0.150	-
53	Worms	2.18	7.345	1.250	-	8.333	0.84	0.150	-
54	Meiofauna	2.05	4.091	10.800	-	72.000	0.55	0.150	-
55	Gelatinous zoop	3.4	0.520	15.510	-	62.050	0.14	0.250	-
56	Macrozoop	2.93	41.310	3.040	-	19.500	0.73	0.156	-
57	Mesozoop	2.37	23.796	29.200	-	73.000	0.75	0.400	-
58	Microzoop	2.34	5.801	82.800	-	165.600	0.98	0.500	-
59	Microflora	2	3.679	104.938	-	209.876	0.96	0.500	-
60	Phytoplankton	1	33.664	70.639	-	-	0.77	-	-
61	Discards	1	0.063	-	-	-	0.88	-	-
62	Detritus	1	1.000	-	-	-	0.70	-	-

Table 48. Percent diet composition for the unbalanced 1995-2000 4X model.

	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12
1	Whales												
2	T. cetaceans												
3	Seals					0.535							
4	Sea birds				1.053								
5	Sharks												
6	Large pelagic						0.186						
7	Cod <1	0.008	0.959	0.425	0.001	0.055	0.440		0.222	0.422	0.422		
8	Cod 1-3		1.378	3.694		1.982	1.579			0.170	0.170		
9	Cod 4-6					6.906							
10	Cod 7+												
11	S Hake <25	1.233	13.015	0.392	0.148	0.569	0.400	0.586	19.893	26.940	26.940	7.353	31.520
12	S Hake 25-31		2.380	0.289		0.286	1.438			0.012	0.012		
13	S Hake 31+		2.122	1.015		0.055							
14	Halibut <46			0.727									
15	Halibut 46-81												
16	Halibut 82+												
17	Pollock <49	0.063	0.099	6.152	0.007		0.125		0.000	0.040	0.040		
18	Pollock 49+												
19	D piscivores <40		2.360	0.685	0.023	0.317	0.253		0.389	0.524	0.524		
20	D piscivores 40+		0.025	0.103		1.202							
21	L benth. <40		5.658	1.601		11.752	0.546		1.405	0.610	0.610		
22	L bent. 40+		0.312	0.250		8.710							
23	Skates <49			0.992		0.115	0.413			0.003	0.003		
24	Skates 49+												
25	Dogfish		0.025			4.228	0.925						
26	Redfish <22			12.250		0.413	2.468		0.381	0.024	0.024		
27	Redfish 22+			5.575		0.960	8.862			5.025	5.025		
28	A plaice <26		0.118	0.000		0.302	0.027		0.001				
29	A plaice 26+			0.002		0.450				0.973	0.973		
30	Flounders <30		0.002	2.518		4.473	0.360		1.811	0.426	0.426		
31	Flounders 30+			3.106		7.823							
32	Haddock <3	1.226	3.522	0.155	0.121	0.796	0.790		0.400	0.226	0.226		0.173
33	Haddock 3+		0.511	0.073		1.447							
34	L sculpin <25			0.210	0.105		0.025			0.037	0.037		
35	L sculpin 25+			0.977									
36	Herring <4	8.582	8.917	0.591	31.901	6.782	11.166		4.798	16.194	16.194		
37	Herring 4+	8.582	10.463	43.179		27.128	40.100		2.592	5.448	5.448		
38	Other pelagic	3.266	0.684	9.113	11.225	6.453	20.714		1.352	9.290	9.290	2.860	4.118
39	Mackerel	2.021	4.930	5.154	7.285	3.993	4.596		7.281				
40	Mesopelagic				0.190				0.006				
41	S-m benthivores			0.345	1.544		0.521		0.258	0.076	0.076		
42	Squids	2.205	39.551	0.354	5.709	2.178	2.552		0.528	0.742	0.742	5.152	
43	Lobster			0.006			0.020		0.007	0.073	0.073		
44	Large crabs					0.091	0.001		14.242	16.995	16.995		
45	Small crabs							0.419	11.804	9.624	9.624	0.077	
46	Shrimps			0.070			0.399	17.754	11.554	0.880	0.880	45.314	30.087
47	Scallop								0.017	0.000	0.000		
48	Bivalves								0.159	0.489	0.489		0.023
49	Other molluscs								0.364	0.125	0.125		
50	Other arthropoda							37.418	0.167	0.008	0.008	4.930	0.983
51	Echinoderms							0.993	1.203	0.562	0.562		
52	S. benthic groups						1.019		1.529	1.397	1.397		

Table 48. Continued.

	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12
53	Worms							0.248	0.336	0.100	0.100	0.163	0.000
54	Meiofauna												
55	Gelatinous zoop						0.005	0.497	0.211				
56	Macrozoop	67.964			24.472			40.834	17.028	2.547	2.547	32.268	29.885
57	Mesozoop	4.850						1.251	0.063	0.018	0.018	1.882	2.126
58	Microzoop												
59	Microflora												
60	Phytoplankton												
61	Discards		2.971		0.444								
62	Detritus												
63	Import				15.772		0.071						1.085
64	Sum	100	100	100	100	100	100	100	100	100	100	100	100

Table 48. Continued.

	Prey \ Predator	13	14	15	16	17	18	19	20	21	22	23	24
1	Whales												
2	T. cetaceans												
3	Seals												
4	Sea birds												
5	Sharks												
6	Large pelagic												
7	Cod <1	0.059		1.172	1.172	0.029		0.099	0.103				
8	Cod 1-3							0.496	0.031				
9	Cod 4-6												
10	Cod 7+												
11	S Hake <25	59.381	12.518	6.800	6.800	16.587	36.653	7.840	19.013	5.488	1.669	0.944	0.060
12	S Hake 25-31			3.515	3.515				0.858				
13	S Hake 31+												
14	Halibut <46												
15	Halibut 46-81												
16	Halibut 82+												
17	Pollock <49					0.056	0.024		2.092				0.207
18	Pollock 49+												
19	D piscivores <40			10.974	10.974		0.124	0.167	2.337				
20	D piscivores 40+												
21	L benth. <40			5.704	5.704	0.081	0.124	25.038	7.763	4.777	3.599	0.385	2.098
22	L bent. 40+												
23	Skates <49							0.359	0.693				
24	Skates 49+												
25	Dogfish												
26	Redfish <22					0.062	0.002		0.191				9.504
27	Redfish 22+								1.894				
28	A plaice <26			0.071	0.071			0.484	1.760				0.064
29	A plaice 26+												
30	Flounders <30		0.719	0.576	0.576			0.603	0.195	0.018			
31	Flounders 30+								0.441				
32	Haddock <3			2.427	2.427	0.358	1.482	5.824	2.135				
33	Haddock 3+								19.688				
34	L sculpin <25			0.972	0.972			8.262	1.386			1.226	0.027
35	L sculpin 25+												
36	Herring <4	24.804	3.475	42.543	42.543	0.155	7.562	11.184	17.957			1.929	2.916
37	Herring 4+	2.787				0.350	6.105		5.010				
38	Other pelagic	4.626	1.279	0.238	0.238	12.021	0.982	0.063	5.129	1.386	3.350	3.510	6.651
39	Mackerel			0.852	0.852		3.835		1.521				
40	Mesopelagic						0.011		0.029	1.937		0.139	
41	S-m benthivores		0.238					3.270	0.272	9.554	27.432	0.495	1.689
42	Squids	3.750	1.082	1.194	1.194	0.382	2.259	8.954	0.266	0.414	0.046	0.564	1.561
43	Lobster							0.181	0.035	2.786	1.858		0.459
44	Large crabs		0.678	7.844	7.844			1.948	2.931	2.146	0.174	2.121	12.077
45	Small crabs		21.208	6.535	6.535	0.300	0.008	0.384	0.951	13.739	17.546	9.059	14.664
46	Shrimps	1.977	45.462	0.522	0.522	17.017	17.150	3.216	1.020	19.959	4.925	14.648	23.174
47	Scallop							0.000	0.008	1.668	13.829		
48	Bivalves	0.000		0.008	0.008		0.017	0.040	0.038	2.615	4.245	0.122	0.006
49	Other molluscs			0.008	0.008	0.652	0.004	0.081	0.000	0.063	3.487	0.013	0.380
50	Other arthropoda					2.797		0.139	0.010	5.246	3.295	7.881	0.553
51	Echinoderms						0.008		0.000	3.191	6.063		0.135
52	S. benthic groups			0.307	0.307	0.017	0.001	0.087		0.266	0.037	0.072	0.019

Table 48. Continued.

	Prey \ Predator	13	14	15	16	17	18	19	20	21	22	23	24
53	Worms		1.512	0.012	0.012	0.091		0.062		1.620	2.314	19.139	13.445
54	Meiofauna												
55	Gelatinous zoop					0.197	0.038	0.009		0.013	0.675		0.327
56	Macrozoop	2.492	11.829	2.057	2.057	43.530	23.086	20.561	4.205	22.794	5.262	23.191	9.595
57	Mesozoop	0.125				5.319	0.474	0.233	0.030	0.318	0.195	14.562	0.391
58	Microzoop												
59	Microflora												
60	Phytoplankton												
61	Discards												
62	Detritus												
63	Import			5.670	5.670		0.050	0.418	0.011				
64	Sum	100	100	100	100	100	100	100	100	100	100	100	100

Table 48. Continued.

	Prey \ Predator	25	26	27	28	29	30	31	32	33	34	35	36
1	Whales												
2	T. cetaceans												
3	Seals												
4	Sea birds												
5	Sharks												
6	Large pelagic												
7	Cod <1												
8	Cod 1-3												
9	Cod 4-6												
10	Cod 7+												
11	S Hake <25	1.616		3.092		9.282				3.002			
12	S Hake 25-31												
13	S Hake 31+												
14	Halibut <46												
15	Halibut 46-81												
16	Halibut 82+												
17	Pollock <49									0.439			
18	Pollock 49+												
19	D piscivores <40	4.187											
20	D piscivores 40+												
21	L benth. <40	0.675								0.087	0.121	0.257	
22	L bent. 40+	0.264											
23	Skates <49												
24	Skates 49+												
25	Dogfish												
26	Redfish <22	1.036								0.052	0.188	0.398	
27	Redfish 22+												
28	A plaice <26												
29	A plaice 26+												
30	Flounders <30	0.007											
31	Flounders 30+												
32	Haddock <3									1.694	0.324	0.687	
33	Haddock 3+												
34	L sculpin <25										0.171	0.363	
35	L sculpin 25+												
36	Herring <4	25.587								1.319			
37	Herring 4+	4.070											
38	Other pelagic	0.838	1.282	4.938	0.774	1.269	1.586	0.187	2.030	0.557	2.604	5.515	
39	Mackerel	4.584											
40	Mesopelagic	0.001		0.003									
41	S-m benthivores	3.911								0.004	0.531	1.125	
42	Squids	7.459							0.080	2.581			
43	Lobster	0.683							0.669	0.768	0.792	0.756	
44	Large crabs	1.245						0.170	0.456	1.458	6.524	6.225	
45	Small crabs	0.915				2.250		1.528	5.411	8.883	32.233	30.755	
46	Shrimps	6.915	15.546	43.750	28.163	7.676	0.204	0.441	10.710	6.174	27.027	25.788	15.653
47	Scallop	0.231			3.074	6.285		0.070	0.091	0.096	0.033	0.031	
48	Bivalves	0.000			24.766	7.397	7.465	3.655	9.377	3.618	0.015	0.014	
49	Other molluscs	0.035			2.489	1.457	0.822	1.041	0.736	1.760	0.421	0.402	
50	Other arthropoda	0.004	4.076	0.642	6.649	1.378	23.118	16.711	10.564	3.075	3.489	3.329	4.519
51	Echinoderms	0.002			11.512	36.009	2.090	2.204	19.078	34.946	0.928	0.885	
52	S. benthic groups	0.044				0.025	6.388	13.633	0.103	3.543	0.328	0.313	0.341

Table 48. Continued.

	Prey \ Predator	25	26	27	28	29	30	31	32	33	34	35	36
53	Worms	0.313			10.753	7.757	38.558	46.114	16.932	10.247	3.270	3.120	
54	Meiofauna												
55	Gelatinous zoop	21.288	2.469	0.159		0.419		0.162	0.708	0.347			
56	Macrozoop	13.737	75.177	46.124	4.669	18.306	3.800	1.089	9.283	10.355	20.118	19.195	76.739
57	Mesozoop	0.002	0.832	1.292	7.151	0.492	10.164	2.885	13.773	4.997	0.883	0.842	2.749
58	Microzoop												
59	Microflora												
60	Phytoplankton												
61	Discards												
62	Detritus												
63	Import	0.353	0.617				5.806	10.112					
64	Sum	100	100	100	100	100	100	100	100	100	100	100	100

Table 48. Continued.

	Prey \ Predator	37	38	39	40	41	42	43	44	45	46	47	48
1	Whales												
2	T. cetaceans												
3	Seals												
4	Sea birds												
5	Sharks												
6	Large pelagic												
7	Cod <1						0.014						
8	Cod 1-3												
9	Cod 4-6												
10	Cod 7+												
11	S Hake <25						2.419						
12	S Hake 25-31												
13	S Hake 31+												
14	Halibut <46												
15	Halibut 46-81												
16	Halibut 82+												
17	Pollock <49						0.114						
18	Pollock 49+												
19	D piscivores <40						0.358						
20	D piscivores 40+												
21	L benth. <40						0.470						
22	L bent. 40+												
23	Skates <49						0.150						
24	Skates 49+												
25	Dogfish												
26	Redfish <22						3.674						
27	Redfish 22+												
28	A plaice <26					0.304							
29	A plaice 26+												
30	Flounders <30					0.304							
31	Flounders 30+												
32	Haddock <3						2.126						
33	Haddock 3+												
34	L sculpin <25												
35	L sculpin 25+												
36	Herring <4						11.014						
37	Herring 4+												
38	Other pelagic						3.696						
39	Mackerel						2.566						
40	Mesopelagic												
41	S-m benthivores					0.262		1.518	3.275				
42	Squids						48.690		1.457				
43	Lobster							1.000					
44	Large crabs					18.942		6.556	1.157				
45	Small crabs					0.239	1.128	10.059	1.878				
46	Shrimps	15.653	7.596	6.862		19.779	1.973	0.016	0.420				
47	Scallop								1.662				
48	Bivalves					2.288		23.574	43.986	5.000			
49	Other molluscs					1.372		3.410	4.639	5.000			
50	Other arthropoda	4.519	12.656	6.148		17.652		1.072	3.503	5.000	1.500		
51	Echinoderms					1.687		23.864	7.610				
52	S. benthic groups	0.341		0.238		0.371		6.640	0.026	5.000			

Table 48. Continued.

	Prey \ Predator	37	38	39	40	41	42	43	44	45	46	47	48
53	Worms		0.080	0.792		13.989	0.995	6.780	27.112	10.000	1.500		
54	Meiofauna							1.181		20.000			
55	Gelatinous zoop		0.119	0.131			0.118						
56	Macrozoop	76.739	35.757	65.643		22.114	20.496				12.000		
57	Mesozoop	2.749	42.897	20.187	100.000	0.698					24.000		
58	Microzoop												
59	Microflora									5.000	1.700	10.000	19.000
60	Phytoplankton		0.238								6.800	40.000	79.000
61	Discards							1.944	3.275	5.000			
62	Detritus							7.777		40.000	52.500	50.000	2.000
63	Import		0.659					4.610					
64	Sum	100	100	100	100	100	100	100	100	100	100	100	100

Table 48. Continued.

	Prey \ Predator	49	50	51	52	53	54	55	56	57	58	59
45	Small crabs	2.500										
46	Shrimps	2.500										
47	Scallop											
48	Bivalves	30.000		1.601								
49	Other molluscs	2.500		0.834								
50	Other arthropoda	10.000	2.500	0.834		6.667						
51	Echinoderms	2.500										
52	S. benthic groups			0.834								
53	Worms			0.834		6.667						
54	Meiofauna	25.000	2.500			6.667	5.000					
55	Gelatinous zoop											
56	Macrozoop				3.303			15.000	5.000			
57	Mesozoop				3.303			67.000	45.000	5.000		
58	Microzoop				3.303			13.000	15.000	20.000	10.000	
59	Microflora				14.014			1.000	3.000	15.000	40.000	
60	Phytoplankton				56.056			4.000	12.000	60.000	15.000	
61	Discards											
62	Detritus	25.000	95.000	95.063	20.020	80.000	95.000		20.000		35.000	100.000
63	Import											
64	Sum	100	100	100	100	100	100	100	100	100	100	100

Table 49. Percent diet composition for the balanced 1995-2000 4X model.

	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12
1	Whales												
2	T. cetaceans												
3	Seals					0.651							
4	Sea birds				0.266								
5	Sharks												
6	Large pelagic						0.222						
7	Cod <1	0.002	0.359	0.096	0.000	0.013	0.105		0.072	0.156	0.156		
8	Cod 1-3		2.592	4.165		2.414	1.885			0.314	0.314		
9	Cod 4-6					8.409							
10	Cod 7+												
11	S Hake <25	0.420	7.251	0.145	0.061	0.227	0.157	0.310	8.763	12.355	12.355	2.581	10.402
12	S Hake 25-31		11.377	0.653		0.699	3.497			0.045	0.045		
13	S Hake 31+		2.038	1.144		0.067							
14	Halibut <46			0.163									
15	Halibut 46-81												
16	Halibut 82+												
17	Pollock <49	0.059	0.167	6.198	0.008		0.134		0.000	0.066	0.066		
18	Pollock 49+												
19	D piscivores <40		0.498	0.088	0.003	0.044	0.035		0.071	0.110	0.110		
20	D piscivores 40+		0.047	0.116		1.463							
21	L benth. <40		1.617	0.285		2.059	0.104		0.156	0.179	0.179		
22	L bent. 40+		0.586	0.281		10.607							
23	Skates <49			0.643		0.081	0.284			0.003	0.003		
24	Skates 49+												
25	Dogfish		0.047			5.149	1.105						
26	Redfish <22			13.816		0.503	2.947		0.614	0.044	0.044		
27	Redfish 22+			6.288		1.169	10.584			9.264	9.264		
28	A plaice <26		0.142	0.000		0.233	0.020		0.001				
29	A plaice 26+			0.002		0.548				1.794	1.794		
30	Flounders <30		0.003	2.839		5.447	0.430		2.922	0.785	0.785		
31	Flounders 30+			3.502		9.527							
32	Haddock <3	1.255	6.485	0.171	0.149	0.949	0.925		0.632	0.407	0.407		0.223
33	Haddock 3+		0.961	0.082		1.761							
34	L sculpin <25			0.130	0.073		0.016			0.038	0.038		
35	L sculpin 25+			1.101									
36	Herring <4	7.393	13.658	0.558	30.928	6.828	10.933		6.408	23.640	23.640		
37	Herring 4+	8.959	19.688	48.701		33.038	47.893		4.180	10.044	10.044		
38	Other pelagic	1.940	0.740	5.680	7.664	4.388	12.766		1.248	9.192	9.192	1.832	3.050
39	Mackerel	1.040	4.417	2.816	4.363	2.365	2.667		5.530				
40	Mesopelagic				0.238				0.010				
41	S-m benthivores			0.058	0.286		0.093		0.062	0.021	0.021		
42	Squids	1.177	26.796	0.206	3.595	1.355	1.555		0.438	0.703	0.703	2.913	
43	Lobster			0.002			0.007		0.003	0.040	0.040		
44	Large crabs					0.009	0.000		1.710	2.263	2.263		
45	Small crabs							0.664	18.577	17.313	17.313	0.085	
46	Shrimps			0.071			0.331	10.232	6.882	0.550	0.550	12.267	7.439
47	Scallop								0.026	0.001	0.001		
48	Bivalves								0.255	0.902	0.902		0.030
49	Other molluscs								0.586	0.230	0.230		
50	Other arthropoda							23.248	0.135	0.007	0.007	2.694	0.641
51	Echinoderms							1.606	1.940	1.035	1.035		
52	S. benthic groups						1.217		2.467	2.574	2.574		

Table 49. Continued.

	Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12
53	Worms							0.401	0.542	0.184	0.184	0.183	0.000
54	Meiofauna												
55	Gelatinous zoop						0.006	0.803	0.340				
56	Macrozoop	72.693			31.537			60.714	35.330	5.709	5.709	75.329	74.000
57	Mesozoop	5.064						2.022	0.102	0.034	0.034	2.115	2.791
58	Microzoop												
59	Microflora												
60	Phytoplankton												
61	Discards		0.532		0.055								
62	Detritus												
63	Import				20.773		0.084						1.425
64	Sum	100	100	100	100	100	100	100	100	100	100	100	100

Table 49. Continued.

	Prey \ Predator	13	14	15	16	17	18	19	20	21	22	23	24
1	Whales												
2	T. cetaceans												
3	Seals												
4	Sea birds												
5	Sharks												
6	Large pelagic												
7	Cod <1	0.030		0.377	0.377	0.002		0.041	0.030				
8	Cod 1-3							1.021	0.045				
9	Cod 4-6												
10	Cod 7+												
11	S Hake <25	24.755	4.175	3.401	3.401	1.750	12.698	4.922	7.902	2.355	0.842	0.347	0.024
12	S Hake 25-31			12.163	12.163				2.597				
13	S Hake 31+												
14	Halibut <46												
15	Halibut 46-81												
16	Halibut 82+												
17	Pollock <49					0.018	0.031		2.803				0.229
18	Pollock 49+												
19	D piscivores <40			1.830	1.830		0.021	0.039	0.391				
20	D piscivores 40+												
21	L benth. <40			1.396	1.396	0.005	0.029	1.976	1.728	0.997	0.867	0.069	0.407
22	L bent. 40+												
23	Skates <49							0.427	0.596				
24	Skates 49+												
25	Dogfish												
26	Redfish <22					0.023	0.003		0.284				11.732
27	Redfish 22+								2.829				
28	A plaice <26			0.072	0.072			0.633	1.659				0.051
29	A plaice 26+												
30	Flounders <30		0.799	0.932	0.932			1.242	0.290	0.025			
31	Flounders 30+								0.658				
32	Haddock <3			3.844	3.844	0.128	2.126	5.672	3.123				
33	Haddock 3+								29.415				
34	L sculpin <25			0.863	0.863			3.403	1.134			0.302	0.018
35	L sculpin 25+												
36	Herring <4	44.749	3.218	46.732	46.732	0.047	9.100	18.559	21.354			1.812	2.999
37	Herring 4+	7.026				0.127	8.937		7.483				
38	Other pelagic	6.424	0.816	0.222	0.222	2.366	0.825	0.075	4.286	1.080	2.957	2.243	4.578
39	Mackerel			0.682	0.682		2.718		1.119				
40	Mesopelagic						0.016		0.044	2.631		0.156	
41	S-m benthivores		0.039					0.956	0.060	1.757	4.677	0.083	0.307
42	Squids	4.706	0.618	0.991	0.991	0.072	1.684	8.818	0.204	0.290	0.037	0.327	0.987
43	Lobster							0.111	0.015	1.110	0.853		0.169
44	Large crabs		0.064	0.999	0.999			0.336	0.365	0.245	0.023	0.201	1.137
45	Small crabs		22.966	10.335	10.335	0.107	0.011	0.775	1.392	18.213	26.491	9.961	17.660
46	Shrimps	0.644	22.953	0.224	0.224	7.770	8.528	1.903	0.520	9.076	2.218	5.436	9.963
47	Scallop							0.000	0.010	2.107	19.625		
48	Bivalves	0.001		0.013	0.013		0.024	0.082	0.057	3.553	6.587	0.137	0.008
49	Other molluscs			0.012	0.012	0.237	0.006	0.166	0.000	0.086	5.410	0.015	0.469
50	Other arthropoda					0.500		0.143	0.007	3.454	2.510	4.238	0.340
51	Echinoderms						0.012		0.000	4.335	9.409		0.167
52	S. benthic groups			0.495	0.495	0.006	0.002	0.178		0.362	0.057	0.081	0.023

Table 49. Continued.

	Prey \ Predator	13	14	15	16	17	18	19	20	21	22	23	24
53	Worms		1.681	0.020	0.020	0.033		0.128		2.201	3.590	21.521	16.597
54	Meiofauna												
55	Gelatinous zoop					0.072	0.056	0.017		0.018	1.048		0.403
56	Macrozoop	11.351	42.670	5.226	5.226	14.805	52.408	47.040	7.536	45.673	12.497	36.697	31.251
57	Mesozoop	0.314				1.934	0.694	0.480	0.044	0.432	0.302	16.375	0.482
58	Microzoop												
59	Microflora												
60	Phytoplankton												
61	Discards												
62	Detritus												
63	Import			9.174	9.174	70.000	0.074	0.860	0.017				
64	Sum	100	100	100	100	100	100	100	100	100	100	100	100

Table 49. Continued.

	Prey \ Predator	25	26	27	28	29	30	31	32	33	34	35	36
1	Whales												
2	T. cetaceans												
3	Seals												
4	Sea birds												
5	Sharks												
6	Large pelagic												
7	Cod <1												
8	Cod 1-3												
9	Cod 4-6												
10	Cod 7+												
11	S Hake <25	0.675		1.051		2.114				1.034			
12	S Hake 25-31												
13	S Hake 31+												
14	Halibut <46												
15	Halibut 46-81												
16	Halibut 82+												
17	Pollock <49									0.422			
18	Pollock 49+												
19	D piscivores <40	0.593											
20	D piscivores 40+												
21	L benth. <40	0.138								0.015	0.022	0.047	
22	L bent. 40+	0.338											
23	Skates <49												
24	Skates 49+												
25	Dogfish												
26	Redfish <22	1.332								0.056	0.209	0.453	
27	Redfish 22+												
28	A plaice <26												
29	A plaice 26+												
30	Flounders <30	0.009											
31	Flounders 30+												
32	Haddock <3									1.774	0.353	0.764	
33	Haddock 3+												
34	L sculpin <25										0.105	0.227	
35	L sculpin 25+												
36	Herring <4	25.851								1.179			
37	Herring 4+	5.230											
38	Other pelagic	0.619	0.774	2.942	0.493	0.539	1.061	0.119	1.263	0.343	1.653	3.527	
39	Mackerel	2.854											
40	Mesopelagic	0.001		0.003									
41	S-m benthivores	0.723								0.001	0.088	0.190	
42	Squids	4.755							0.045	1.407			
43	Lobster	0.262							0.217	0.245	0.263	0.256	
44	Large crabs	0.136						0.016	0.042	0.132	0.587	0.574	
45	Small crabs	1.151				1.630		1.654	5.756	9.284	34.769	33.896	
46	Shrimps	3.423	5.868	20.746	13.638	0.781	0.067	0.138	3.517	2.223	13.428	12.798	6.750
47	Scallop	0.277			3.163	4.308		0.072	0.092	0.095	0.034	0.033	
48	Bivalves	0.000			27.435	5.474	8.711	4.039	10.192	3.866	0.016	0.016	
49	Other molluscs	0.045			2.758	1.078	0.959	1.150	0.800	1.882	0.469	0.457	
50	Other arthropoda	0.003	2.098	0.338	3.556	0.506	11.712	8.392	5.415	1.616	1.904	1.856	2.311
51	Echinoderms	0.002			12.753	26.645	2.439	2.436	20.735	37.349	1.032	1.006	
52	S. benthic groups	0.056				0.018	7.455	15.069	0.111	3.786	0.365	0.356	0.357

Table 49. Continued.

	Prey \ Predator	25	26	27	28	29	30	31	32	33	34	35	36
53	Worms	0.403			11.912	5.740	44.994	50.972	18.404	10.951	3.639	3.546	
54	Meiofauna												
55	Gelatinous zoop	27.360	2.596	0.168		0.310		0.179	0.769	0.371			
56	Macrozoop	23.311	87.139	73.391	16.372	50.493	3.966	1.397	17.672	16.631	40.082	39.043	87.703
57	Mesozoop	0.002	0.875	1.363	7.921	0.364	11.861	3.189	14.970	5.340	0.982	0.957	2.878
58	Microzoop												
59	Microflora												
60	Phytoplankton												
61	Discards												
62	Detritus												
63	Import	0.454	0.649				6.775	11.177					
64	Sum	100	100	100	100	100	100	100	100	100	100	100	100

Table 49. Continued.

	Prey \ Predator	37	38	39	40	41	42	43	44	45	46	47	48
1	Whales												
2	T. cetaceans												
3	Seals												
4	Sea birds												
5	Sharks												
6	Large pelagic												
7	Cod <1						0.001						
8	Cod 1-3												
9	Cod 4-6												
10	Cod 7+												
11	S Hake <25						0.296						
12	S Hake 25-31												
13	S Hake 31+												
14	Halibut <46												
15	Halibut 46-81												
16	Halibut 82+												
17	Pollock <49						0.014						
18	Pollock 49+												
19	D piscivores <40						0.054						
20	D piscivores 40+												
21	L benth. <40						0.022						
22	L bent. 40+												
23	Skates <49						0.019						
24	Skates 49+												
25	Dogfish												
26	Redfish <22						0.470						
27	Redfish 22+												
28	A plaice <26					0.288							
29	A plaice 26+												
30	Flounders <30					0.453							
31	Flounders 30+												
32	Haddock <3						0.277						
33	Haddock 3+												
34	L sculpin <25												
35	L sculpin 25+												
36	Herring <4						1.226						
37	Herring 4+												
38	Other pelagic						0.473						
39	Mackerel						0.307						
40	Mesopelagic												
41	S-m benthivores					0.059		0.084	0.177				
42	Squids						3.793		0.836				
43	Lobster							0.334					
44	Large crabs					2.004		0.594	0.110				
45	Small crabs					0.350	1.474	11.036	2.056				
46	Shrimps	6.750	3.362	2.502		10.773	1.001	0.016	0.421				
47	Scallop								1.727				
48	Bivalves					3.416		26.460	49.158	5.596			
49	Other molluscs					2.048		3.827	5.184	5.596			
50	Other arthropoda	2.311	6.521	3.149		11.603		0.358	1.145	1.619	0.453		
51	Echinoderms					2.519		26.785	8.505				
52	S. benthic groups	0.357		0.251		0.554		7.453	0.029	5.596			

Table 49. Continued.

	Prey \ Predator	37	38	39	40	41	42	43	44	45	46	47	48
53	Worms		0.088	0.837		20.889	1.327	7.610	30.299	11.192	1.527		
54	Meiofauna							1.325		22.383			
55	Gelatinous zoop		0.131	0.138			0.157						
56	Macrozoop	87.703	41.500	71.767		44.002	89.089				12.361		
57	Mesozoop	2.878	47.407	21.356	100.000	1.042					24.433		
58	Microzoop												
59	Microflora									2.720	0.858	5.000	9.500
60	Phytoplankton		0.263								6.923	42.222	88.266
61	Discards							0.214	0.355	0.533			
62	Detritus							8.729		44.766	53.446	52.778	2.234
63	Import		0.728					5.174					
64	Sum	100	100	100	100	100	100	100	100	100	100	100	100

Table 49. Continued.

	Prey \ Predator	49	50	51	52	53	54	55	56	57	58	59
45	Small crabs	0.686										
46	Shrimps	2.085										
47	Scallop											
48	Bivalves	33.228		1.610								
49	Other molluscs	2.769		0.839								
50	Other arthropoda	3.083	0.750	0.250		2.000						
51	Echinoderms	2.769										
52	S. benthic groups			0.839								
53	Worms			0.839		7.000						
54	Meiofauna	27.690	2.545			7.000	5.000					
55	Gelatinous zoop											
56	Macrozoop				3.931			16.145	5.594			
57	Mesozoop				3.597			69.604	47.728	5.857		
58	Microzoop				2.631			9.593	11.221	16.191	9.973	
59	Microflora				7.007			0.503	1.517	7.665	20.249	
60	Phytoplankton				61.037			4.155	12.727	70.287	20.934	
61	Discards											
62	Detritus	27.690	96.705	95.623	21.799	84.000	95.000		21.212		48.844	100.000
63	Import											
64	Sum	100	100	100	100	100	100	100	100	100	100	100

Table 50. Basic parameters for the balanced 1995-2000 WSS model.

	Group name	TL	B (t.km^2)	P/B (year^{-1})	Z (year^{-1})	Q/B (year^{-1})	EE	P/Q	BA (year^{-1})
1	Whales	4.06	0.361	0.071	-	4.720	0.15	0.015	0.011
2	Toothed cetaceans	4.93	0.058	0.120	-	12.330	0.07	0.010	-
3	Seals	4.86	0.060	0.138	-	6.880	0.90	0.020	0.088
4	Sea birds	4.42	0.006	0.250	-	87.600	1.00	0.003	-
5	Sharks	4.79	0.035	0.180	-	4.780	0.15	0.038	-0.075
6	Large pelagic	4.84	0.036	0.400	-	4.230	0.63	0.095	-
7	Cod <1	3.71	0.002	-	1.650	9.957	0.89	0.166	-0.050
8	Cod 1-3	4.06	0.137	-	0.390	2.662	0.98	0.146	-0.050
9	Cod 4-6	4.44	0.181	-	0.820	1.605	0.62	0.511	-0.050
10	Cod 7+	4.44	0.057	-	0.820	1.139	0.25	0.720	-0.050
11	S Hake <25	3.97	0.382	-	1.300	7.249	0.98	0.179	-
12	S Hake 25-31	4.01	0.332	-	1.290	4.153	0.41	0.311	-
13	S Hake 31+	4.73	0.058	-	1.250	3.280	0.53	0.381	-
14	Halibut <46	3.86	0.002	-	0.570	5.093	0.97	0.112	-
15	Halibut 46-81	4.62	0.007	-	0.270	2.585	0.28	0.104	-
16	Halibut 82+	4.62	0.023	-	0.270	1.610	0.64	0.168	-
17	Pollock <49	3.93	0.073	-	0.490	5.066	0.98	0.097	-0.070
18	Pollock 49+	4.21	0.088	-	0.850	2.940	0.76	0.289	-0.070
19	D piscvores <40	4.33	0.045	-	0.440	5.137	0.78	0.086	-0.020
20	D piscvores 40+	4.55	0.117	-	0.620	2.500	0.87	0.248	-0.020
21	L benthivores <40	3.79	0.073	-	0.515	3.516	0.77	0.146	-
22	L bentivores 40+	3.5	0.062	-	0.640	1.920	0.91	0.333	-
23	Skates <49	3.67	0.038	-	0.210	3.283	0.98	0.064	-
24	Skates 49+	4	0.072	-	0.200	1.900	0.84	0.105	-
25	Dogfish	4.42	1.176	0.139	-	1.740	0.12	0.080	-
26	Redfish <22	3.93	0.931	-	0.270	5.017	0.77	0.054	-
27	Redfish 22+	3.91	1.941	-	0.230	2.410	0.44	0.095	-
28	A plaice <26	3.42	0.047	-	0.440	4.695	0.52	0.094	-0.070
29	A plaice 26+	3.54	0.112	-	0.520	2.410	0.22	0.216	-0.070
30	Flounders <30	3.26	0.113	-	0.530	5.826	0.61	0.091	-
31	Flounders 30+	3.2	0.179	-	0.590	3.210	0.42	0.184	-
32	Haddock <3	3.38	0.300	-	0.660	4.199	0.83	0.157	0.070
33	Haddock 3+	3.39	0.859	-	0.450	2.080	0.56	0.216	0.070
34	L sculpin <25	3.74	0.041	-	0.600	7.935	0.43	0.076	-
35	L sculpin 25+	3.77	0.038	-	0.500	3.930	0.17	0.127	-
36	Herring <4	3.9	1.774	-	0.640	3.946	0.72	0.162	-
37	Herring 4+	3.9	1.138	-	0.810	2.360	0.67	0.343	-
38	Other pelagic	3.59	0.870	0.680	-	3.310	0.90	0.205	-0.100
39	Mackerel	3.78	0.729	0.583	-	5.080	0.86	0.115	-
40	Mesopelagic	3.37	0.010	0.970	-	18.900	0.76	0.051	-
41	S-m benthivores	3.65	0.047	1.410	-	4.680	0.67	0.301	-
42	Squids	4.03	0.287	4.000	-	11.333	0.91	0.353	-
43	Lobster	3.04	0.143	0.910	-	6.067	0.94	0.150	0.100
44	Large crabs	3.24	0.075	0.654	-	4.360	0.80	0.150	-
45	Small crabs	2.56	0.856	1.310	-	8.733	0.83	0.150	-
46	Shrimps	2.63	1.167	3.000	-	20.000	0.86	0.150	-
47	Scallop	2.05	1.130	0.342	-	2.280	0.97	0.150	0.050
48	Bivalves	2.1	3.813	0.690	-	4.600	0.16	0.150	-
49	Other molluscs	2.68	2.061	0.750	-	5.000	0.94	0.150	-
50	Other arthropoda	2.03	0.690	4.400	-	29.333	0.74	0.150	-
51	Echinoderms	2.03	17.578	0.330	-	2.200	0.46	0.150	-

Table 50. Continued.

	Group name	TL	B (t.km²)	P/B (year^{-1})	Z (year^{-1})	Q/B (year^{-1})	EE	P/Q	BA (year^{-1})
52	Sessile benthic groups	2.24	14.295	0.320	-	2.133	0.15	0.150	-
53	Worms	2.14	4.091	1.250	-	8.333	0.66	0.150	-
54	Meiofauna	2.05	4.097	10.800	-	72.000	0.54	0.150	-
55	Gelatinous zoop	3.41	0.520	15.510	-	62.050	0.10	0.250	-
56	Macrozoop	2.95	41.310	3.040	-	19.500	0.66	0.156	-
57	Mesozoop	2.37	26.631	29.200	-	73.000	0.77	0.400	-
58	Microzoop	2.32	5.257	82.800	-	165.600	0.98	0.500	-
59	Microflora	2	3.665	104.996	-	209.992	0.94	0.500	-
60	Phytoplankton	1	30.508	77.646	-	-	0.70	-	-
61	Discards	1	0.055	-	-	-	0.87	-	-
62	Detritus	1	1.000	-	-	-	0.65	-	-

Table 51. Basic parameters for the balanced 1995-2000 BoF model.

	Group name	TL	B ($t.km^{2}$)	P/B (year^{-1})	Z (year^{-1})	Q/B (year^{-1})	EE	P/Q	BA (year^{-1})
1	Whales	4.04	0.474	0.072	-	5.110	0.08	0.014	0.006
2	Toothed cetaceans	4.76	0.038	0.270	-	17.770	0.64	0.015	-
3	Seals	4.74	0.021	0.186	-	9.270	0.41	0.020	0.070
4	Sea birds	4.36	0.007	0.250	-	87.600	0.97	0.003	-
5	Sharks	4.77	0.012	0.180	-	4.780	0.15	0.038	-0.075
6	Large pelagic	4.73	0.009	0.300	-	4.230	0.56	0.071	-
7	Cod <1	3.59	0.008	-	1.600	8.246	0.98	0.194	-0.026
8	Cod 1-3	4.03	0.424	-	0.400	2.377	0.62	0.168	-0.026
9	Cod 4-6	4.41	0.447	-	0.820	1.497	0.26	0.548	-0.026
10	Cod 7+	4.41	0.105	-	0.820	1.139	0.10	0.720	-0.026
11	S Hake <25	3.79	0.501	-	1.600	7.405	1.00	0.216	-
12	S Hake 25-31	3.91	0.263	-	1.500	4.116	0.35	0.364	-
13	S Hake 31+	4.64	0.033	-	1.450	3.280	0.29	0.442	-
14	Halibut <46	3.81	0.001	-	0.570	5.093	0.68	0.112	-
15	Halibut 46-81	4.58	0.003	-	0.270	2.585	0.33	0.104	-
16	Halibut 82+	4.58	0.008	-	0.270	1.610	0.64	0.168	-
17	Pollock <49	3.84	0.202	-	0.480	5.053	0.99	0.095	-0.070
18	Pollock 49+	4.17	0.247	-	0.850	2.940	0.69	0.289	-0.070
19	D piscvores <40	4.22	0.129	-	0.430	5.533	0.99	0.078	-0.050
20	D piscvores 40+	4.58	0.475	-	0.620	2.500	0.20	0.248	-0.050
21	L benthivores <40	3.68	0.123	-	0.500	3.440	0.99	0.145	-
22	L bentivores 40+	3.43	0.069	-	0.640	1.920	0.72	0.333	-
23	Skates <49	3.58	0.057	-	0.260	3.275	0.87	0.079	-
24	Skates 49+	3.77	0.077	-	0.200	1.900	0.46	0.105	-
25	Dogfish	4.36	3.392	0.139		1.740	0.09	0.080	-
26	Redfish <22	3.8	0.298	-	0.200	4.960	0.94	0.040	-
27	Redfish 22+	3.79	0.941	-	0.200	2.410	0.73	0.083	-
28	A plaice <26	3.27	0.037	-	0.440	4.695	0.99	0.094	-0.070
29	A plaice 26+	3.53	0.087	-	0.520	2.410	0.47	0.216	-0.070
30	Flounders <30	3.22	0.229	-	0.530	5.826	0.66	0.091	-
31	Flounders 30+	3.21	0.363	-	0.590	3.210	0.32	0.184	-
32	Haddock <3	3.35	0.390	-	0.690	3.731	0.99	0.185	0.070
33	Haddock 3+	3.45	0.731	-	0.450	2.080	0.99	0.216	0.070
34	L sculpin <25	3.71	0.103	-	0.600	7.919	0.96	0.076	-0.050
35	L sculpin 25+	3.73	0.123	-	0.500	3.930	0.10	0.127	-0.050
36	Herring <4	3.77	6.036	-	0.640	3.946	0.99	0.162	-
37	Herring 4+	3.77	3.872	-	0.810	2.360	0.99	0.343	-
38	Other pelagic	3.56	0.853	0.885	-	3.310	0.95	0.267	-
39	Mackerel	3.7	0.254	0.583	-	5.080	0.99	0.115	-
40	Mesopelagic	3.35	0.016	0.970	-	18.900	0.98	0.051	-
41	S-m benthivores	3.5	0.025	1.410	-	4.680	0.98	0.301	-
42	Squids	3.84	0.009	4.000	-	11.333	0.97	0.353	-
43	Lobster	3.12	0.532	0.910	-	6.067	1.00	0.150	0.100
44	Large crabs	3.15	0.278	0.654	-	4.360	0.97	0.150	-
45	Small crabs	2.71	1.093	1.310	-	8.733	1.00	0.150	-
46	Shrimps	2.52	1.476	3.000	-	20.000	0.98	0.150	-
47	Scallop	2.05	1.760	0.342	-	2.280	0.97	0.150	0.050
48	Bivalves	2.09	133.113	0.690	-	4.600	0.10	0.150	-
49	Other molluscs	2.88	1.929	0.750	-	5.000	0.69	0.150	-
50	Other arthropoda	2.04	1.044	4.400	-	29.333	0.98	0.150	-
51	Echinoderms	2.08	6.753	0.330	-	2.200	0.54	0.150	-

Table 51. Continued.

	Group name	TL	B (t.km²)	P/B (year^{-1})	Z (year^{-1})	Q/B (year^{-1})	EE	P/Q	BA (year^{-1})
52	Sessile benthic groups	2.2	39.760	0.320	-	2.133	0.15	0.150	-
53	Worms	2.21	11.149	1.250	-	8.333	0.98	0.150	-
54	Meiofauna	2.05	4.091	10.800	-	72.000	0.58	0.150	-
55	Gelatinous zoop	3.36	0.520	15.510	-	62.050	0.21	0.250	-
56	Macrozoop	2.82	41.310	3.040	-	19.500	0.88	0.156	-
57	Mesozoop	2.35	15.746	35.122	-	87.805	0.68	0.400	-
58	Microzoop	2.34	6.344	82.800	-	165.600	0.88	0.500	-
59	Microflora	2	3.693	104.938	-	209.876	0.99	0.500	-
60	Phytoplankton	1	36.820	64.834	-	-	0.83	-	-
61	Discards	1	0.075	-	-	-	0.91	-	-
62	Detritus	1	1.000	-	-	-	0.77	-	-

Table 52. Comparison of prey selection indices for a selection of prey-predator interactions in the Bay of Fundy (BoF), Western Scotian Shelf (WSS) and 4X models.

Model	Prey \ Predator	Whales	T. cetaceans	Seals	Sea birds	Sharks	L. pelagic	Cod <1	Cod 1-3	Cod 4-6	S Hake <25	S Hake 25-31	S Hake 31+	Halibut 82+	Pollock <49	Pollock 49+
BoF	Cod <1	0.091	0.897	0.650	-0.971	-0.239	0.885		0.858	0.915			0.686	0.955	0.424	
WSS	Cod <1	0.054	0.890	0.690	-0.959	-0.217	0.882		0.849	0.913			0.670	0.951	0.396	
4X	Cod <1	0.043	0.889	0.647	-0.972	-0.238	0.881		0.845	0.910			0.646	0.950	0.400	
BoF	S Hake <25	0.399	0.364	-0.909	-0.873	-0.858	-0.755	0.043	0.838	0.836	0.826	0.980	0.966	0.261	0.898	0.956
WSS	S Hake <25	0.356	0.332	-0.897	-0.883	-0.853	-0.760	-0.017	0.825	0.828	0.807	0.980	0.960	0.228	0.895	0.949
4X	S Hake <25	0.410	0.390	-0.898	-0.868	-0.842	-0.734	0.047	0.845	0.850	0.829	0.983	0.966	0.289	0.907	0.956
BoF	S Hake 25-31		0.773	-0.367		-0.332	0.763			-0.864				0.882		
WSS	S Hake 25-31		0.730	-0.361		-0.364	0.729			-0.880				0.855		
4X	S Hake 25-31		0.728	-0.421		-0.385	0.726			-0.883				0.854		
BoF	Pollock <49	0.131	-0.673	0.812	-0.933		-0.340		-0.999	-0.657					-0.235	-0.591
WSS	Pollock <49	0.081	-0.692	0.836	-0.940		-0.353		-0.999	-0.666					-0.249	-0.615
4X	Pollock <49	0.104	-0.680	0.820	-0.936		-0.335		-0.999	-0.658					-0.240	-0.616
BoF	D piscvores <40		-0.219	-0.771	-0.965	-0.878	-0.758		-0.483	-0.452				0.618		-0.684
WSS	D piscvores <40		-0.080	-0.655	-0.958	-0.825	-0.681		-0.366	-0.314				0.705		-0.606
4X	D piscvores <40		-0.083	-0.694	-0.957	-0.832	-0.684		-0.375	-0.325				0.703		-0.624
BoF	L benthivores <41		0.284	-0.471		0.462	-0.480		-0.214	-0.313				0.457	-0.754	-0.637
WSS	L benthivores <41		0.372	-0.310		0.576	-0.387		-0.120	-0.207				0.533	-0.695	-0.581
4X	L benthivores <41		0.369	-0.373		0.558	-0.391		-0.131	-0.218				0.530	-0.700	-0.599
BoF	Redfish <22			0.546		-0.788	0.313		-0.357	-0.955					-0.771	-0.991
WSS	Redfish <22			0.583		-0.785	0.289		-0.394	-0.956					-0.781	-0.992
4X	Redfish <22			0.531		-0.794	0.283		-0.403	-0.957					-0.787	-0.992

Table 52. Continued.

Model	Prey \ Predator	Whales	T. cetaceans	Seals	Sea birds	Sharks	L. pelagic	Cod <1	Cod 1-3	Cod 4-6	S Hake <25	S Hake 25-31	S Hake 31+	Halibut 82+	Pollock <49	Pollock 49+
BoF	Haddock <3	0.852	0.500	-0.838	-0.589	-0.336	0.132		0.041	-0.344		0.127		0.505	0.245	0.764
WSS	Haddock <3	0.855	0.521	-0.798	-0.583	-0.265	0.177		0.068	-0.305		0.185		0.526	0.290	0.774
4X	Haddock <3	0.854	0.519	-0.823	-0.583	-0.288	0.171		0.057	-0.316		0.141		0.524	0.274	0.760
BoF	Herring <4	0.649	-0.408	-0.959	0.561	-0.591	0.045		-0.119	0.317			0.674	0.354	-0.916	0.354
WSS	Herring <4	0.696	-0.309	-0.942	0.658	-0.490	0.163		-0.024	0.449			0.785	0.526	-0.898	0.437
4X	Herring <4	0.695	-0.312	-0.949	0.658	-0.508	0.157		-0.035	0.439			0.767	0.524	-0.901	0.412
BoF	Herring 4+	0.829	0.019	0.455		0.343	0.769		-0.055	0.203			0.254		-0.662	0.571
WSS	Herring 4+	0.840	0.091	0.628		0.457	0.833		-0.016	0.264			0.297		-0.631	0.600
4X	Herring 4+	0.839	0.087	0.580		0.437	0.830		-0.027	0.252			0.258		-0.641	0.579
BoF	Other pelagic	0.779	-0.746	0.142	0.737	0.016	0.804		-0.026	0.684	0.650	0.796	0.711	-0.862	0.889	0.078
WSS	Other pelagic	0.713	-0.794	0.117	0.659	-0.053	0.756		-0.143	0.619	0.559	0.757	0.641	-0.889	0.860	-0.046
4X	Other pelagic	0.712	-0.795	0.045	0.659	-0.077	0.753		-0.154	0.611	0.552	0.736	0.615	-0.889	0.855	-0.075
BoF	Macrozoop	0.679			-0.387			0.462	-0.349	-0.896	0.549	0.562	-0.707	-0.938	0.212	0.149
WSS	Macrozoop	0.643			-0.438			0.402	-0.387	-0.902	0.503	0.554	-0.727	-0.943	0.188	0.100
4X	Macrozoop	0.641			-0.438			0.401	-0.396	-0.904	0.496	0.520	-0.746	-0.944	0.172	0.070

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Appendix 1.

Appendix 1A. Conversion factors based on estimates reported by Fanning (1985) that were applied to the time series of biomass to account for changes in research vessels fishing power .

Ecopath group	Conversion fator	Period applied	Observation
Cod	1.25	1970 - 81	
Haddock	1.2	1970 - 81	
Demersal piscivores	1.2	1970 - 81	a
Silver hake	2.3	1970 - 81	
Redfish	1.55	1970 - 81	
A plaice	1.4_1.2	1970 - 81	b
Flounders	1.4_1.2	1970 - 81	c
Pollock	2	1970 - 81	d
Halibut	1.2	1970 - 81	e
Other pelagic	2.3	1970 - 81	e
Dogfish	1.2	1970 - 81	e
Skates	1.2	1970 - 81	e
L sculpin	1.2	1970 - 81	e
L benthivores	1.2	1970 - 81	e
Small-medium benthivores	1.2	1970 - 81	e
Squids	1.2	1970 - 81	e

a. White hake was the only species in this group that was included in Fanning's analyis. The results suggested that no converstion was necessary for this species. However, Don Clark (DFO, pers. comm.) advised that a correction factor of 1.2 could be used and was used since it corresponds to the change in wing spread between the two gears employed;
b. 1.4 for fish <=28 cm and 1.2 for larger fish;
c. The estimate for witch and yellowtail flounder was 1.2. For winter flounder a value of 1.4 was estimated but not significant. The approach adopted was to use 1.4 for the small flounders (<30 cm, as for a plaice) and 1.2 for large the large ones;
d. Fanning's estimate for Pollock (1.3) was not significant. Howeveron Don Clark (DFO, pers. comm.) advised that a correction factor similar to the silver hake's could be used for this species, since both are benthopelagic;
e. None of these species were included in Fanning's analysis. The approach adopted was to use a factor of 1.2 for the all species except the other pelagic functional group, for which the estimate for silver hake was used.

Appendix 1B. Biomass adjustments for inshore/offshore effects.

Average ITQ standardized catch rates (weight/tow) for the inshore (= model area - DFO RV summer survey area) and offshore (= DFO summer survey area) areas were estimated for the period 1996-2009 for each species regularly sampled. Then a total area average was estimated, using the size of the inshore and offshore areas as weighing factors, and a correction factor for the biomass estimates was defined as:
Correction factor = Survey biomass/DFO survey area * Model area *R; where R is the ratio between the total and the offshore average catch rates derived from the ITQ survey data.
Considering the 4X model, if the total and the offshore ITQ catch rates are equal, the ratio (R) is 1 and the correction factor is about 1.15, which is the ratio between the 4X model area and the the DFO 4X survey area. If the catch rate in inshore areas is zero, the correction factor is about 0.87 (1/1.5).

Appendix 2.

Growth and natural mortality parameters of fish species.

Species	Ecopath group	Model	L_∞	K	Φ	M	Sources/ Method
Cod	Cod	4X	138.5	0.142	3.44	0.17	a
		WSS	156.7	0.108	3.42	0.14	a
		BOF	137.0	0.167	3.50	0.20	a
Silver Hake	Silver Hake	WSS	36.7	0.460	2.79	0.59	a
Halibut	Halibut	4X	159.9	0.140	3.55	0.15	b
Pollock		4X	96.3	0.156	3.16	0.21	a
		WSS	87.6	0.180	3.14	0.24	a
		BOF	96.6	0.185	3.24	0.24	a
White Hake	D piscivores	4X	156.3	0.075	3.26	0.11	c
		WSS	131.2	0.090	3.19	0.13	c
		BOF	190.1	0.060	3.34	0.09	c
Red Hake	L benthivores	4X	60.2	0.190	2.84	0.27	d
Ocean Pout	L benthivores	4X	83.6	0.090	2.80	0.14	d
Wolffish	L benthivores	4X	108.9	0.089	3.02	0.13	d
Lumpfish	L benthivores	4X	57.5	0.110	2.56	0.18	d
	L benthivores	4X		0.140			d
Winter	Skates	4X	88.4	0.180	3.15	0.24	e
Thorny	Skates	4X	89.6	0.070	2.75	0.12	e
Little	Skates	4X	60.0	0.190	2.84	0.27	e
Smooth	Skates	4X	60.7	0.120	2.65	0.19	e
All	Skates	4X	79.0	0.135	2.93	0.20	e
Dogfish	Dogfish	4X	105.7	0.065	2.86	0.13	f
Redfish	Redfish	4X	51.0	0.063	2.21	0.12	d
A Plaice	A Plaice	4X	61.2	0.116	2.64	0.19	a
Winter	Flounders	BOF	47.9	0.250	2.76	0.35	a
Witch	Flounders	BOF	65.3	0.123	2.72	0.19	a
Yellowtail	Flounders	BOF	43.8	0.222	2.63	0.32	a
Winter	Flounders	WSS	55.1	0.209	2.80	0.30	a
Witch	Flounders	WSS	60.2	0.106	2.58	0.17	a
Yellowtail	Flounders	WSS	49.9	0.201	2.70	0.29	a
All	Flounders	4X		0.214			a
Haddock	Haddock	4X	59.3	0.272	2.98	0.35	a
		WSS	60.9	0.223	2.92	0.30	a
		BOF	60.9	0.365	3.13	0.43	a
L Sculpin	L Sculpin	4X	37.6	0.120	2.23	0.21	d
Herring	Herring	4X	32.9	0.270	2.46	0.41	g
Argentine	Other pelagic	4X	45.9	0.180	2.58	0.28	d
Shad American	Other pelagic	4X	59.2	0.310	3.04	0.39	d
Alewife	Other pelagic	4X	38.7	0.130	2.29	0.23	d
Mackerel	Mackerel	4X	44.5	0.269	2.73	0.38	d
Longfin Hake	S-m benthivores	4X	38.7	0.458	2.84	0.58	d

The life-history routine in FishBase (Froese and Pauly 2009 http://www.fishbase.org) was used to estimate M and its confidence limits from L_∞ and K and ambient temperature. Ambient temperature was assumed to be equal to the average summer bottom temperature as recorded during the RV surveys (7.1 °C). L_∞ and K were derived from:

a. Local size-at-age data; b. Male and female size-at-age data in Armsworthy and Campana (2010); c. Bundy and Simon 2005; d. L_∞ estimated from L_{max} recorded in RV surveys for the period modelled here and equation 17 ($\log(L_\infty) = 0.044 + 0.9841 \cdot \log(L_{\max})$). K was determined from L_∞ and equation 19 ($\Phi = \log(K) + 2 \cdot \log(L_\infty)$), where Φ was estimated from published studies or local data sets;
e. McPhie and Campana (2009); f. Campana et al. (2007); g. Derived from data reported by Power et al. 2006 (Table 18). Average parameters for functional groups composed of several species (e.g., flounders) are weighted by biomass.

Appendix 3.

Allen (1971) has demonstrated that for the populations under equilibrium conditions and for specific individual growth and population survivorship models the biomass-weighted average population production to biomass ratio (*P/B*) equals the biomass-weighted average total mortality. Where growth and survivorship are described by the von Bertalanffy and exponential models respectively, if it is assumed that the total mortality (*Z*) is constant through the life span, the average *P/B* for a given population is estimated from:

$$P = 3KN_0W_\infty\left(\frac{1}{Z+K} - \frac{2}{Z+2K} + \frac{1}{Z+3K}\right) \qquad \text{Eq. A3.1.}$$

and

$$B = N_0W_\infty\left(\frac{1}{Z} - \frac{3}{Z+K} + \frac{3}{Z+2K} - \frac{1}{Z+3K}\right) \qquad \text{Eq. A3.2.}$$

where *P* is the total production of the cohort or population, *B* is the average biomass, N_0 the population numbers at age 0, W_∞ and *K* the asymptotic weight and the curvature of the von Bertalanffy model respectively.

If *Z* varies with age, the average *P/B* for a given population is estimated from:

$$P = 3W_\infty K\sum^N\left(\frac{S_{n-1}e^{-KT_{n-1}} - S_ne^{-KT_n}}{Z_n+K} - \frac{2\left(S_{n-1}e^{-2KT_{n-1}} - S_ne^{-2KT_n}\right)}{Z_n+2K} + \frac{S_{n-1}e^{-3KT_{n-1}} - S_ne^{-3KT_n}}{Z_n+3K}\right) \qquad \text{Eq. A3.3.}$$

and

$$B = W_\infty\sum^N\left(\frac{S_{n-1}-S_n}{Z_n} - \frac{3\left(S_{n-1}e^{-KT_{n-1}} - S_ne^{-KT_n}\right)}{Z_n+K} + \frac{3\left(S_{n-1}e^{-2KT_{n-1}} - S_ne^{-2KT_n}\right)}{Z_n+2K} - \frac{S_{n-1}e^{-3KT_{n-1}} - S_ne^{-3KT_n}}{Z_n+3K}\right) \qquad \text{Eq. A3.4.}$$

where S_n *and* S_{n-1} are the numbers of survivors at time n and n-1 and T_n and T_{n-1} the corresponding ages. In this case the average *P/B* for the population, from age 0 to ∞, is equal to the biomass-weighted average population *Z*. As the relatively large (recruits and mature) individuals account for most of the population biomass, the adult average *Z* is generally a close approximation for the population *P/B* under equilibrium conditions. If the population is growing or decreasing, *P/B* can be then estimated as the sum of *Z* and the relative average biomass population growth rate (*BA/B*).

Appendix 4.

Table A4.1. Percent diet composition for 4X baleen whales (Mysticeti) and toothed cetaceans (Odontocetes).

	Prey/Predator	1	2	3	4	5	6	7	8	9	10
7	Cod <1	-	0.02	0.02	-	0.01	0.45	-	2.71	-	0.96
8	Cod 1-3	-	-	-	-	-	-	-	4.45	-	1.38
9	Cod 4-6	-	-	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-	-	-
11	S Hake <25	-	2.92	2.44	-	1.23	31.03	-	15.86	0.10	13.02
12	S Hake 25-30	-	-	-	-	-	6.56	-	2.09	0.10	2.38
13	S Hake 31+	-	-	-	-	-	6.12	-	1.63	0.10	2.12
14	Halibut <46	-	-	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-	-	-
17	Pollock <49	-	0.15	0.12	-	0.06	-	-	0.32	-	0.10
18	Pollock 49+	-	-	-	-	-	-	-	-	-	-
19	D piscivores <40	-	-	-	-	-	1.11	-	6.69	-	2.36
20	D piscivores 40+	-	-	-	-	-	0.10	-	-	-	0.03
21	L benth. <40	-	-	-	-	-	13.77	-	6.69	-	5.66
22	L bent. 40+	-	-	-	-	-	1.20	-	-	-	0.31
23	Skates <49	-	-	-	-	-	-	-	-	-	-
24	Skates 49+	-	-	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-	0.10	0.02
26	Dogfish 73+	-	-	-	-	-	-	-	-	-	-
27	Redfish <22	-	-	-	-	-	-	-	-	-	-
28	Redfish 22+	-	-	-	-	-	-	-	-	-	-
29	A plaice <26	-	-	-	-	-	0.45	-	-	-	0.12
30	A plaice 26+	-	-	-	-	-	-	-	-	-	-
31	Flounders <30	-	-	-	-	-	-	-	0.00	-	0.00
32	Flounders 30+	-	-	-	-	-	-	-	-	-	-
33	Haddock <3	-	2.91	2.42	-	1.23	10.92	-	2.19	-	3.52
34	Haddock 3+	-	-	-	-	-	1.35	-	0.51	-	0.51
35	L sculpin <25	-	-	-	-	-	-	-	-	-	-
36	L sculpin 25+	-	-	-	-	-	-	-	-	-	-
37	Herring <4	11.47	29.82	22.94	-	8.58	5.94	-	23.73	0.10	8.92
38	Herring 4+	-	-	-	-	8.58	6.97	-	27.86	0.10	10.46
39	Other pelagic	2.18	5.67	4.36	-	3.27	0.35	-	1.92	-	0.68
40	Mackerel	1.35	3.51	2.70	-	2.02	0.75	-	1.43	17.08	4.93
41	Mesopelagic	-	-	-	-	-	-	-	-	-	-
42	S-m benthivores	-	-	-	-	-	-	-	-	-	-
43	Squids	5.00	-	-	-	2.20	1.51	100.00	1.91	82.32	39.55
44	Lobster	-	-	-	-	-	-	-	-	-	-
45	Large crabs	-	-	-	-	-	-	-	-	-	-
46	Small crabs	-	-	-	-	-	-	-	-	-	-
47	Shrimps	-	-	-	-	-	-	-	-	-	-
48	Scallop	-	-	-	-	-	-	-	-	-	-
49	Bivalves	-	-	-	-	-	-	-	-	-	-
50	Other molluscs	-	-	-	-	-	-	-	-	-	-
51	Other arthropoda	-	-	-	-	-	-	-	-	-	-
52	Echinoderms	-	-	-	-	-	-	-	-	-	-
53	S. benthic groups	-	-	-	-	-	-	-	-	-	-
54	Worms	-	-	-	-	-	-	-	-	-	-
55	Meiofauna	-	-	-	-	-	-	-	-	-	-
56	Gelatinous zoop	-	-	-	-	-	-	-	-	-	-
57	Macrozoop	80.00	55.00	65.00	50.00	67.96	-	-	-	-	-
58	Mesozoop	-	-	-	50.00	4.85	-	-	-	-	-
59	Microzoop	-	-	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	11.41	-	-	-	2.97
63	Detritus	-	-	-	-	-	-	-	-	-	-
64	Import	-	-	-	-	-	-	-	-	-	-
	Sum	100	100	100	100	100	100	100	100	100	100
	Biomass	0.228	0.113	0.125	0.050	0.516	0.019	0.013	0.022	0.018	0.072

Diet data for (1) sei and fin whales, (2) humpback, (3) minke and (4) right whales. Diet 5. Biomass-weighted average of diets 1 to 4. Percent estimates of small and large herring were assumed to be half of total herring (17.16%).

Diet data for (6) common and white-sided dolphins, (7) grampus dolphin, (8) harbour porpoise and (9) pilot whale. Diet 10. Biomass-weighted average of diets 6 to 10.

Observation: 0.00 means that percent was lower than 0.01.

Table A4.2. Percent diet composition for BoF baleen whales (Mysticeti) and toothed cetaceans (Odontocetes).

	Prey/Predator	1	2	3	4	5	6	7	8
7	Cod <1	-	0.00	0.00	-	0.00	0.45	2.71	2.34
8	Cod 1-3	-	-	-	-	-	-	4.45	3.72
9	Cod 4-6	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-
11	S Hake <25	-	2.42	2.85	-	1.10	31.03	15.86	18.36
12	S Hake 25-30	-	-	-	-	-	6.56	2.09	2.83
13	S Hake 31+	-	-	-	-	-	6.12	1.63	2.37
14	Halibut <46	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-
17	Pollock <49	-	0.11	0.13	-	0.05	-	0.32	0.27
18	Pollock 49+	-	-	-	-	-	-	-	-
19	D piscivores	-	-	-	-	-	1.11	6.69	5.77
20	D piscivores	-	-	-	-	-	0.10	-	0.02
21	L benth. <40	-	-	-	-	-	13.77	6.69	7.86
22	L bent. 40+	-	-	-	-	-	1.20	-	0.20
23	Skates <49	-	-	-	-	-	-	-	-
24	Skates 49+	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-
26	Dogfish 73+	-	-	-	-	-	-	-	-
27	Redfish <22	-	-	-	-	-	-	-	-
28	Redfish 22+	-	-	-	-	-	-	-	-
29	A plaice <26	-	-	-	-	-	0.45	-	0.07
30	A plaice 26+	-	-	-	-	-	-	-	-
31	Flounders <30	-	-	-	-	-	-	0.00	0.00
32	Flounders 30+	-	-	-	-	-	-	-	-
33	Haddock <3	-	1.71	2.02	-	0.78	10.92	2.19	3.63
34	Haddock 3+	-	-	-	-	-	1.35	0.51	0.65
35	L sculpin <25	-	-	-	-	-	-	-	-
36	L sculpin 25+	-	-	-	-	-	-	-	-
37	Herring <4	13.14	35.70	26.28	-	8.35	5.94	23.73	20.80
38	Herring 4+	-	-	-	-	8.35	6.97	27.86	24.42
39	Other pelagic	1.43	3.89	2.86	-	1.82	0.35	1.92	1.66
40	Mackerel	0.43	1.16	0.85	-	0.54	0.75	1.43	1.32
41	Mesopelagic	-	-	-	-	-	-	-	-
42	S-m	-	-	-	-	-	-	-	-
43	Squids	5.00	-	-	-	2.07	1.51	1.91	1.84
44	Lobster	-	-	-	-	-	-	-	-
45	Large crabs	-	-	-	-	-	-	-	-
46	Small crabs	-	-	-	-	-	-	-	-
47	Shrimps	-	-	-	-	-	-	-	-
48	Scallop	-	-	-	-	-	-	-	-
49	Bivalves	-	-	-	-	-	-	-	-
50	Other	-	-	-	-	-	-	-	-
51	Other	-	-	-	-	-	-	-	-
52	Echinoderms	-	-	-	-	-	-	-	-
53	S. benthic	-	-	-	-	-	-	-	-
54	Worms	-	-	-	-	-	-	-	-
55	Meiofauna	-	-	-	-	-	-	-	-
56	Gelatinous	-	-	-	-	-	-	-	-
57	Macrozoop	80.00	55.00	65.00	50.00	67.56	-	-	-
58	Mesozoop	-	-	-	50.00	9.37	-	-	-
59	Microzoop	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	11.41	0.00	1.88
63	Detritus	-	-	-	-	-	-	-	-
64	Import	-	-	-	-	-	-	-	-
	Sum	100	100	100	100	100	100	100	100
	Biomass	0.272	0.055	0.207	0.123	0.657	0.009	0.048	0.057

Diet data for (1) sei and fin whales, (2) humpback, (3) minke and (4) right whales.

Diet 5. Biomass-weighted average of diets 1 to 4. Percent estimates of small and large herring were assumed to be half of total herring (16.70%).

Diet data for (6) white-sided dolphins and (7) harbour porpoise.

Diet 8. Biomass-weighted average of diets 6 and 7.

Observation: 0.00 means that percent was lower than 0.01.

Table A4.3. Percent diet composition for WSS baleen whales (Mysticeti) and toothed cetaceans (Odontocetes).

Prey/Predator	1	2	3	4	5	6	7	8	9
7Cod <1	-	0.04	0.02	0.02	0.45	-	2.71	-	0.30
8Cod 1-3	-	-	-	-	-	-	4.45	-	0.26
9Cod 4-6	-	-	-	-	-	-	-	-	-
10Cod 7+	-	-	-	-	-	-	-	-	-
11S Hake <25	-	3.61	2.14	1.67	31.03	-	15.86	0.10	10.46
12S Hake 25-30	-	-	-	-	6.56	-	2.09	0.10	2.17
13S Hake 31+	-	-	-	-	6.12	-	1.63	0.10	2.01
14Halibut <46	-	-	-	-	-	-	-	-	-
15Halibut 46-81	-	-	-	-	-	-	-	-	-
16Halibut 82+	-	-	-	-	-	-	-	-	-
17Pollock <49	-	0.21	0.12	0.10	-	-	0.32	-	0.02
18Pollock 49+	-	-	-	-	-	-	-	-	-
19D piscivores <40	-	-	-	-	1.11	-	6.69	-	0.73
20D piscivores 40+	-	-	-	-	0.10	-	-	-	0.03
21L benth. <40	-	-	-	-	13.77	-	6.69	-	4.60
22L bent. 40+	-	-	-	-	1.20	-	-	-	0.37
23Skates <49	-	-	-	-	-	-	-	-	-
24Skates 49+	-	-	-	-	-	-	-	-	-
25Dogfish <73	-	-	-	-	-	-	-	0.10	0.04
26Dogfish 73+	-	-	-	-	-	-	-	-	-
27Redfish <22	-	-	-	-	-	-	-	-	-
28Redfish 22+	-	-	-	-	-	-	-	-	-
29A plaice <26	-	-	-	-	0.45	-	-	-	0.14
30A plaice 26+	-	-	-	-	-	-	-	-	-
31Flounders <30	-	-	-	-	-	-	0.00	-	0.00
32Flounders 30+	-	-	-	-	-	-	-	-	-
33Haddock <3	-	4.60	2.72	2.13	10.92	-	2.19	-	3.47
34Haddock 3+	-	-	-	-	1.35	-	0.51	-	0.44
35L sculpin <25	-	-	-	-	-	-	-	-	-
36L sculpin 25+	-	-	-	-	-	-	-	-	-
37Herring <4	8.85	21.56	17.70	7.48	5.94	-	23.73	0.10	3.22
38Herring 4+	-	-	-	7.48	6.97	-	27.86	0.10	3.78
39Other pelagic	3.35	8.15	6.69	5.65	0.35	-	1.92	-	0.22
40Mackerel	2.80	6.83	5.61	4.74	0.75	-	1.43	17.08	6.66
41Mesopelagic	-	-	-	-	-	-	-	-	-
42S-m benthivores	-	-	-	-	-	-	-	-	-
43Squids	5.00	-	-	2.35	1.51	100.00	1.91	82.32	57.61
44Lobster	-	-	-	-	-	-	-	-	-
45Large crabs	-	-	-	-	-	-	-	-	-
46Small crabs	-	-	-	-	-	-	-	-	-
47Shrimps	-	-	-	-	-	-	-	-	-
48Scallop	-	-	-	-	-	-	-	-	-
49Bivalves	-	-	-	-	-	-	-	-	-
50Other molluscs	-	-	-	-	-	-	-	-	-
51Other arthropoda	-	-	-	-	-	-	-	-	-
52Echinoderms	-	-	-	-	-	-	-	-	-
53S. benthic groups	-	-	-	-	-	-	-	-	-
54Worms	-	-	-	-	-	-	-	-	-
55Meiofauna	-	-	-	-	-	-	-	-	-
56Gelatinous zoop	-	-	-	-	-	-	-	-	-
57Macrozoop	80.00	55.00	65.00	68.39	-	-	-	-	-
58Mesozoop	-	-	-	-	-	-	-	-	-
59Microzoop	-	-	-	-	-	-	-	-	-
60Microflora	-	-	-	-	-	-	-	-	-
61Phytoplankton	-	-	-	-	-	-	-	-	-
62Discards	-	-	-	-	11.41	-	-	-	3.50
63Detritus	-	-	-	-	-	-	-	-	-
64Import	-	-	-	-	-	-	-	-	-
Sum	100	100	100	100	100	100	100	100	100
Biomass	0.197	0.153	0.069	0.420	0.025	0.022	0.005	0.030	0.082

Diet data for (1) sei and fin whales, (2) humpback and (3) minke whales.

Diet 4. Biomass-weighted average of diets 1 to 3. Percent estimates of small and large herring were assumed to be half of total herring (14.95%).

Diet data for (5) common and white-sided dolphins, (6) grampus dolphin, (7) harbour porpoise and (8) pilot whale.

Diet 9. Biomass-weighted average of diets 5 to 6.

Observation: 0.00 means that percent was lower than 0.01.

Table A4.4. Percent diet composition for 4X seals.

	Prey/Predator	4X
7	Cod <1	0.42
8	Cod 1-3	3.69
9	Cod 4-6	-
10	Cod 7+	-
11	S Hake <25	0.39
12	S Hake 25-30	0.29
13	S Hake 31+	1.02
14	Halibut <46	0.73
15	Halibut 46-81	-
16	Halibut 82+	-
17	Pollock <49	6.15
18	Pollock 49+	-
19	D piscivores <40	0.68
20	D piscivores 40+	0.10
21	L benth. <40	1.60
22	L bent. 40+	0.25
23	Skates <49	0.99
24	Skates 49+	-
25	Dogfish <73	-
26	Dogfish 73+	-
27	Redfish <22	12.25
28	Redfish 22+	5.58
29	A plaice <26	0.00
30	A plaice 26+	0.00
31	Flounders <30	2.52
32	Flounders 30+	3.11
33	Haddock <3	0.16
34	Haddock 3+	0.07
35	L sculpin <25	0.21
36	L sculpin 25+	0.98
37	Herring <4	0.59
38	Herring 4+	43.18
39	Other pelagic	9.11
40	Mackerel	5.15
41	Mesopelagic	-
42	S-m benthivores	0.34
43	Squids	0.35
44	Lobster	0.01
45	Large crabs	-
46	Small crabs	-
47	Shrimps	0.07
48	Scallop	-
49	Bivalves	-
50	Other molluscs	-
51	Other arthropoda	-
52	Echinoderms	-
53	S. benthic groups	-
54	Worms	-
55	Meiofauna	-
56	Gelatinous zoop	-
57	Macrozoop	-
58	Mesozoop	-
59	Microzoop	-
60	Microflora	-
61	Phytoplankton	-
62	Discards	-
63	Detritus	-
64	Import	-
	Sum	100

4X seals percent died composition derived from grey seal diet for the eastern Scotian Shelf, based on quantitative fatty acid signature analysis data (see also Iverson et al. 2004) for the years between 1991 and 2004 and scat data for the years between 1991 and 2010. A simple average of the two data sets was estimated. The predation on small-medium pelagic species was adjusted to account for differences in the relative abundance of the several types of small pelagic species between the eastern Scotian Shelf and the 4X area. This greatly increased the proportion of herring compared to the original data set. For functional groups represented by 2 or more stanzas, the proportions of each stanza in the seals diet were tentatively estimated based on the prey length frequency distribution presented in Bowen et al. (1993) and Bowen and Harrison (1994).

Table A4.5. Percent diet composition for 4X seabirds.

	Prey/Predator	WSS	BoF	4X
4	Sea birds	1.16	0.97	1.05
5	Sharks	-	-	-
6	Large pelagic	-	-	-
7	Cod <1	0.00	0.00	0.00
8	Cod 1-3	-	-	-
9	Cod 4-6	-	-	-
10	Cod 7+	-	-	-
11	S Hake <25	0.13	0.16	0.15
12	S Hake 25-30	-	-	-
13	S Hake 31+	-	-	-
14	Halibut <46	-	-	-
15	Halibut 46-81	-	-	-
16	Halibut 82+	-	-	-
17	Pollock <49	0.01	0.01	0.01
18	Pollock 49+	-	-	-
19	D piscivores <40	0.01	0.03	0.02
20	D piscivores 40+	-	-	-
21	L benth. <40	-	-	-
22	L bent. 40+	-	-	-
23	Skates <49	-	-	-
24	Skates 49+	-	-	-
25	Dogfish <73	-	-	-
26	Dogfish 73+	-	-	-
27	Redfish <22	-	-	-
28	Redfish 22+	-	-	-
29	A plaice <26	-	-	-
30	A plaice 26+	-	-	-
31	Flounders <30	-	-	-
32	Flounders 30+	-	-	-
33	Haddock <3	0.15	0.10	0.12
34	Haddock 3+	-	-	-
35	L sculpin <25	0.12	0.10	0.11
36	L sculpin 25+	-	-	-
37	Herring <4	21.38	40.07	31.93
38	Herring 4+	-	-	-
39	Other pelagic	15.58	7.88	11.23
40	Mackerel	13.40	2.57	7.29
41	Mesopelagic	0.18	0.20	0.19
42	S-m benthivores	1.87	1.30	1.55
43	Squids	6.52	5.09	5.71
44	Lobster	-	-	-
45	Large crabs	-	-	-
46	Small crabs	-	-	-
47	Shrimps	-	-	-
48	Scallop	-	-	-
49	Bivalves	-	-	-
50	Other molluscs	-	-	-
51	Other arthropoda	-	-	-
52	Echinoderms	-	-	-
53	S. benthic groups	-	-	-
54	Worms	-	-	-
55	Meiofauna	-	-	-
56	Gelatinous zoop	-	-	-
57	Macrozoop	23.12	25.55	24.49
58	Mesozoop	-	-	-
59	Microzoop	-	-	-
60	Microflora	-	-	-
61	Phytoplankton	-	-	-
62	Discards	0.69	0.26	0.44
63	Detritus	-	-	-
64	Import	15.78	15.79	15.78
	Sum	100	100	100
	Biomass	0.0079	0.0102	

Western Scotian Shelf (WSS), Bay of Fundy (BoF) and 4X (WSS+BoF) seabirds percent dient compostion. These diets were derived from the generic diet compostion presente in Table 9 (main text), taking into account both the relative abudance of the seabirds species and prey items in each system. The 4X diet is a biomass-weighted average of WSS and Bof diets.

Observation: 0.00 means that percent was lower than 0.01.

Table A4.6. Percent diet composition for 4X sharks.

	Prey/Predator	1	2	3
3	Seals	2.14	-	0.53
4	Sea birds	-	-	-
5	Sharks	-	-	-
6	Large pelagic	-	-	-
7	Cod <1	0.03	0.06	0.05
8	Cod 1-3	0.91	2.33	1.98
9	Cod 4-6	3.18	8.13	6.90
10	Cod 7+	-	-	-
11	S Hake <25	-	0.76	0.57
12	S Hake 25-30	-	0.38	0.29
13	S Hake 31+	-	0.07	0.05
14	Halibut <46	-	-	-
15	Halibut 46-81	-	-	-
16	Halibut 82+	-	-	-
17	Pollock <49	-	-	-
18	Pollock 49+	-	-	-
19	D piscivores <40	0.57	0.23	0.32
20	D piscivores 40+	2.17	0.87	1.20
21	L benth. <40	13.16	11.26	11.73
22	L bent. 40+	9.75	8.35	8.70
23	Skates <49	0.46	-	0.11
24	Skates 49+	-	-	-
25	Dogfish <73	2.75	4.71	4.22
26	Dogfish 73+	-	-	-
27	Redfish <22	0.41	0.41	0.41
28	Redfish 22+	0.96	0.96	0.96
29	A plaice <26	-	0.40	0.30
30	A plaice 26+	-	0.60	0.45
31	Flounders <30	0.17	5.90	4.47
32	Flounders 30+	0.29	10.32	7.81
33	Haddock <3	0.49	0.90	0.79
34	Haddock 3+	0.89	1.63	1.44
35	L sculpin <25	-	-	-
36	L sculpin 25+	-	-	-
37	Herring <4	8.99	6.03	6.77
38	Herring 4+	35.95	24.13	27.09
39	Other pelagic	8.55	5.74	6.44
40	Mackerel	5.29	3.55	3.99
41	Mesopelagic	-	-	-
42	S-m benthivores	-	-	-
43	Squids	2.89	1.94	2.17
44	Lobster	-	-	-
45	Large crabs	-	0.12	0.09
	Sum	100	100	100

Diet 1. Blue shark diet derived from information reported by Maccord and Campana (2003).

Diet 2. Porbeagle diet derived from information reported by Joyce et al. (2002).

Diet 3. A weighted average of the two studies was calculated, with a larger weighting factor given to the porbeagle data (3:1) since the information reported by Maccord and Campana (2003) referred to percentage in numbers. Since the diet data was collected over a broad area, predation on prey items, which are not common in the model area, such as mesopelagic species, was allocated to other pelagic prey items (herring, mackerel, etc.). The predation on small pelagic species, including squids, was adjusted to account for differences in the relative abundance of the several types of small pelagic species in the models. Percentages of small and large herring were assumed to be 20% and 80% respectively of total herring consumed.

Observation: 0.00 means that percent was lower than 0.01.

Table A4.7. Percent diet composition for 4X large pelagics.

	Prey/Predator	1	2	3
6	Large pelagic	-	0.37	0.19
7	Cod <1	0.88	0.00	0.44
8	Cod 1-3	3.15	0.01	1.58
9	Cod 4-6	-	-	-
10	Cod 7+	-	-	-
11	S Hake <25	0.06	0.74	0.40
12	S Hake 25-30	0.21	2.67	1.44
13	S Hake 31+	-	-	-
14	Halibut <46	-	-	-
15	Halibut 46-81	-	-	-
16	Halibut 82+	-	-	-
17	Pollock <49	0.17	0.08	0.13
18	Pollock 49+	-	-	-
19	D piscivores <40	-	0.51	0.25
20	D piscivores 40+	-	-	-
21	L benth. <40	-	1.09	0.55
22	L bent. 40+	-	-	-
23	Skates <49	0.83	-	0.41
24	Skates 49+	-	-	-
25	Dogfish <73	1.85	-	0.92
26	Dogfish 73+	-	-	-
27	Redfish <22	-	4.94	2.47
28	Redfish 22+	-	17.72	8.86
29	A plaice <26	0.05	-	0.03
30	A plaice 26+	-	-	-
31	Flounders <30	0.72	-	0.36
32	Flounders 30+	-	-	-
33	Haddock <3	-	1.58	0.79
34	Haddock 3+	-	-	-
35	L sculpin <25	0.05	-	0.02
36	L sculpin 25+	-	-	-
37	Herring <4	11.50	10.83	11.17
38	Herring 4+	41.31	38.89	40.10
39	Other pelagic	31.08	10.35	20.71
40	Mackerel	3.34	5.85	4.60
41	Mesopelagic	-	-	-
42	S-m benthivores	0.67	0.37	0.52
43	Squids	1.91	3.19	2.55
44	Lobster	0.04	-	0.02
45	Large crabs	0.00	-	0.00
46	Small crabs	-	-	-
47	Shrimps	0.00	0.79	0.40
48	Scallop	-	-	-
49	Bivalves	-	-	-
50	Other molluscs	-	-	-
51	Other arthropoda	-	-	-
52	Echinoderms	-	-	-
53	S. benthic groups	2.04	-	1.02
54	Worms	-	-	-
55	Meiofauna	-	-	-
56	Gelatinous zoop	0.01	-	0.01
57	Macrozoop	-	-	-
58	Mesozoop	-	-	-
59	Microzoop	-	-	-
60	Microflora	-	-	-
61	Phytoplankton	-	-	-
62	Discards	-	-	-
63	Detritus	-	-	-
64	Import	0.14	-	0.07
	Sum	100	100	100

Diet 1. Bluefin tuna diet derived from information reported by Chase (2002).
Diet 2. Swordfish diet derived from data provided by Sean Smith (DFO, pers. comm.).
Diet 3. Simple average of diet 1 and 2.
Observation: 0.00 means that percent was lower than 0.01.

Table A4. 8. Percent diet composition for 4X Atlantic cod. Average data for cod 4+ were used for the stanzas 4-6 and 7+.

		1			2			3			4		
	Prey/Predator	<1	1-3	4+	<1	1_3	4+	<1	1-3	4+	<1	1-3	4+
7	Cod <1	-	0.67	1.27	-	-	-	-	-	-	-	0.22	0.42
8	Cod 1-3	-	-	0.51	-	-	-	-	-	-	-	-	0.17
9	Cod 4-6	-	-	-	-	-	-	-	-	-	-	-	-
1	Cod 7+	-	-	-	-	-	-	-	-	-	-	-	-
1	S Hake <25	1.76	15.5	9.28	-	28.9	34.4	-	15.1	37.0	0.59	19.8	26.9
1	S Hake 25-30	-	-	0.04	-	-	-	-	-	-	-	-	0.01
1	S Hake 31+	-	-	-	-	-	-	-	-	-	-	-	-
1	Halibut <46	-	-	-	-	-	-	-	-	-	-	-	-
1	Halibut 46-81	-	-	-	-	-	-	-	-	-	-	-	-
1	Halibut 82+	-	-	-	-	-	-	-	-	-	-	-	-
1	Pollock <49	-	0.00	0.12	-	-	-	-	-	-	-	0.00	0.04
1	Pollock 49+	-	-	-	-	-	-	-	-	-	-	-	-
1	D piscivores	-	1.17	1.57	-	-	-	-	-	-	-	0.39	0.52
2	D piscivores	-	-	-	-	-	-	-	-	-	-	-	-
2	L benth. <40	-	4.21	0.46	-	-	1.37	-	-	-	-	1.40	0.61
2	L bent. 40+	-	-	-	-	-	-	-	-	-	-	-	-
2	Skates <49	-	-	0.01	-	-	-	-	-	-	-	-	0.00
2	Skates 49+	-	-	-	-	-	-	-	-	-	-	-	-
2	Dogfish <73	-	-	-	-	-	-	-	-	-	-	-	-
2	Dogfish 73+	-	-	-	-	-	-	-	-	-	-	-	-
2	Redfish <22	-	1.14	0.04	-	-	7.19	-	-	-	-	0.38	0.02
2	Redfish 22+	-	-	7.92	-	-	-	-	-	-	-	-	5.03
2	A plaice <26	-	0.00	-	-	-	-	-	-	-	-	0.00	-
3	A plaice 26+	-	-	2.92	-	-	-	-	-	-	-	-	0.97
3	Flounders <30	-	1.07	1.28	-	-	-	-	4.37	-	-	1.81	0.43
3	Flounders 30+	-	-	-	-	-	-	-	-	-	-	-	-
3	Haddock <3	-	1.20	0.68	-	-	-	-	-	-	-	0.40	0.23
3	Haddock 3+	-	-	-	-	-	-	-	-	-	-	-	-
3	L sculpin <25	-	-	0.11	-	-	-	-	-	-	-	-	0.04
3	L sculpin 25+	-	-	-	-	-	-	-	-	-	-	-	-
3	Herring <4	-	11.5	34.7	-	-	9.30	-	4.32	9.15	-	4.80	16.1
3	Herring 4+	-	6.26	11.7	-	-	-	-	-	-	-	2.59	5.45
3	Other pelagic	-	4.05	0.11	-	-	-	-	-	27.7	-	1.35	9.29
4	Mackerel	-	-	-	-	-	-	-	21.8	-	-	7.28	-
4	Mesopelagic	-	0.02	-	-	-	-	-	-	-	-	0.01	-
4	S-m	-	0.05	0.23	-	-	-	-	0.73	-	-	0.26	0.08
4	Squids	-	0.72	0.14	-	0.25	2.08	-	0.61	-	-	0.53	0.74
4	Lobster	-	0.02	-	-	-	0.22	-	-	-	-	0.01	0.07
4	Large crabs	-	0.13	0.77	-	25.1	32.0	-	17.5	18.2	-	14.2	16.9
4	Small crabs	1.26	12.9	17.2	-	14.6	6.82	-	7.86	4.79	0.42	11.8	9.62
4	Shrimps	1.61	2.87	1.28	-	16.4	0.19	51.6	15.3	1.17	17.7	11.5	0.88
4	Scallop	-	0.05	0.00	-	-	-	-	-	-	-	0.02	0.00
4	Bivalves	-	0.10	0.03	-	0.35	1.22	-	0.03	0.21	-	0.16	0.49
5	Other	-	1.04	0.31	-	0.04	0.07	-	0.01	-	-	0.36	0.13
5	Other	-	-	-	78.2	0.13	0.01	33.9	0.37	0.01	37.4	0.17	0.01
5	Echinoderms	-	0.37	0.28	-	1.28	1.31	2.98	1.97	0.10	0.99	1.20	0.56
5	S. benthic	-	1.49	1.03	-	0.02	3.16	-	3.08	-	-	1.53	1.40
5	Worms	-	0.25	0.22	-	0.27	-	0.74	0.49	0.08	0.25	0.34	0.10
5	Meiofauna	-	-	-	-	-	-	-	-	-	-	-	-
5	Gelatinous	-	0.00	-	-	0.63	-	1.49	-	-	0.50	0.21	-
5	Macrozoop	91.6	32.8	5.66	21.7	11.9	0.52	9.14	6.28	1.46	40.8	17.0	2.55
5	Mesozoop	3.75	0.19	0.00	-	-	0.05	-	-	-	1.25	0.06	0.02
5	Microzoop	-	-	-	-	-	-	-	-	-	-	-	-
6	Microflora	-	-	-	-	-	-	-	-	-	-	-	-
6	Phytoplankton	-	-	-	-	-	-	-	-	-	-	-	-
6	Discards	-	-	-	-	-	-	-	-	-	-	-	-
6	Detritus	-	-	-	-	-	-	-	-	-	-	-	-
6	Import	-	-	-	-	-	-	-	-	-	-	-	-
	Sum	100	100	100	100	100	100	100	100	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).
Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).
Diet 4. Simple average of diets 1 to 3. Percent estimates of small and large fish in multi-stanza prey groups were estimated based on the Canadian data.
Observation: 0.00 means that percent was lower than 0.01.

Table A4.9. Percent diet composition for 4X silver hake.

		1			2			3			4		
	Prey/Predator	<25	25-	31+	<25	25-	31+	<25	25-	31+	<25	25-	31+
7	Cod <1	-	-	0.18	-	-	-	-	-	-	-	-	0.06
8	Cod 1-3	-	-	-	-	-	-	-	-	-	-	-	-
9	Cod 4-6	-	-	-	-	-	-	-	-	-	-	-	-
1	Cod 7+	-	-	-	-	-	-	-	-	-	-	-	-
1	S Hake <25	-	-	25.7	0.64	46.8	54.2	21.4	47.7	98.0	7.35	31.5	59.3
1	S Hake 25-30	-	-	-	-	-	-	-	-	-	-	-	-
1	S Hake 31+	-	-	-	-	-	-	-	-	-	-	-	-
1	Halibut <46	-	-	-	-	-	-	-	-	-	-	-	-
1	Halibut 46-	-	-	-	-	-	-	-	-	-	-	-	-
1	Halibut 82+	-	-	-	-	-	-	-	-	-	-	-	-
1	Pollock <49	-	-	-	-	-	-	-	-	-	-	-	-
1	Pollock 49+	-	-	-	-	-	-	-	-	-	-	-	-
1	D piscivores	-	-	-	-	-	-	-	-	-	-	-	-
2	D piscivores	-	-	-	-	-	-	-	-	-	-	-	-
2	L benth. <40	-	-	-	-	-	-	-	-	-	-	-	-
2	L bent. 40+	-	-	-	-	-	-	-	-	-	-	-	-
2	Skates <49	-	-	-	-	-	-	-	-	-	-	-	-
2	Skates 49+	-	-	-	-	-	-	-	-	-	-	-	-
2	Dogfish <73	-	-	-	-	-	-	-	-	-	-	-	-
2	Dogfish 73+	-	-	-	-	-	-	-	-	-	-	-	-
2	Redfish <22	-	-	-	-	-	-	-	-	-	-	-	-
2	Redfish 22+	-	-	-	-	-	-	-	-	-	-	-	-
2	A plaice <26	-	-	-	-	-	-	-	-	-	-	-	-
3	A plaice 26+	-	-	-	-	-	-	-	-	-	-	-	-
3	Flounders	-	-	-	-	-	-	-	-	-	-	-	-
3	Flounders	-	-	-	-	-	-	-	-	-	-	-	-
3	Haddock <3	-	0.52	-	-	-	-	-	-	-	-	0.17	-
3	Haddock 3+	-	-	-	-	-	-	-	-	-	-	-	-
3	L sculpin	-	-	-	-	-	-	-	-	-	-	-	-
3	L sculpin	-	-	-	-	-	-	-	-	-	-	-	-
3	Herring <4	-	-	36.7	-	-	41.9	-	-	-	-	-	24.8
3	Herring 4+	-	-	4.13	-	-	-	-	-	-	-	-	2.79
3	Other pelagic	3.54	12.3	13.8	5.04	-	-	-	-	-	2.86	4.12	4.63
4	Mackerel	-	-	-	-	-	-	-	-	-	-	-	-
4	Mesopelagic	-	-	-	-	-	-	-	-	-	-	-	-
4	S-m	-	-	-	-	-	-	-	-	-	-	-	-
4	Squids	-	-	11.2	15.4	-	-	-	-	-	5.15	-	3.75
4	Lobster	-	-	-	-	-	-	-	-	-	-	-	-
4	Large crabs	-	-	-	-	-	-	-	-	-	-	-	-
4	Small crabs	0.11	-	-	-	-	-	0.12	-	-	0.08	-	-
4	Shrimps	72.0	52.5	3.27	42.6	13.5	1.34	21.2	24.1	1.32	45.3	30.0	1.98
4	Scallop	-	-	-	-	-	-	-	-	-	-	-	-
4	Bivalves	-	0.07	0.00	-	-	-	-	-	-	-	0.02	0.00
5	Other	-	-	-	-	-	-	-	-	-	-	-	-
5	Other	-	-	-	4.08	-	-	10.7	2.95	-	4.93	0.98	-
5	Echinoderms	-	-	-	-	-	-	-	-	-	-	-	-
5	S. benthic	-	-	-	-	-	-	-	-	-	-	-	-
5	Worms	0.06	0.00	-	0.09	-	-	0.34	-	-	0.16	0.00	-
5	Meiofauna	-	-	-	-	-	-	-	-	-	-	-	-
5	Gelatinous	-	-	-	-	-	-	-	-	-	-	-	-
5	Macrozoop	19.1	24.8	4.41	31.5	39.5	2.45	46.1	25.2	0.62	32.2	29.8	2.49
5	Mesozoop	5.09	6.38	0.37	0.56	-	-	-	-	-	1.88	2.13	0.12
5	Microzoop	-	-	-	-	-	-	-	-	-	-	-	-
6	Microflora	-	-	-	-	-	-	-	-	-	-	-	-
6	Phytoplankto	-	-	-	-	-	-	-	-	-	-	-	-
6	Discards	-	-	-	-	-	-	-	-	-	-	-	-
6	Detritus	-	-	-	-	-	-	-	-	-	-	-	-
6	Import	-	3.25	-	-	-	-	-	-	-	-	1.08	-
	Sum	100	100	100	100	100	100	100	100	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).
Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).
Diet 4. Simple average of diets 1 to 3. Percent estimates of small and large fish in multi-stanza prey groups were estimated based on the Canadian data.
Observation: 0.00 means that percent was lower than 0.01.

Table A4.10. Percent diet composition for 4X halibut. Average data for halibut 46+ cm were used for the stanzas 46-81 and 82+ cm.

		1		2		3		4	
	Prey/Predator	<46	46+	<46	46+	<46	46+	<46	46+
7	Cod <1	-	3.52	-	-	-	-	-	1.17
8	Cod 1-3	-	-	-	-	-	-	-	-
9	Cod 4-6	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-
11	S Hake <25	9.80	20.40	19.15	-	8.60	-	12.52	6.80
12	S Hake 25-30	-	10.55	-	-	-	-	-	3.52
13	S Hake 31+	-	-	-	-	-	-	-	-
14	Halibut <46	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-
17	Pollock <49	-	-	-	-	-	-	-	-
18	Pollock 49+	-	-	-	-	-	-	-	-
19	D piscivores <40	-	20.36	-	-	-	12.56	-	10.97
20	D piscivores 40+	-	-	-	-	-	-	-	-
21	L benth. <40	-	4.55	-	-	-	12.56	-	5.70
22	L bent. 40+	-	-	-	-	-	-	-	-
23	Skates <49	-	-	-	-	-	-	-	-
24	Skates 49+	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-
26	Dogfish 73+	-	-	-	-	-	-	-	-
27	Redfish <22	-	-	-	-	-	-	-	-
28	Redfish 22+	-	-	-	-	-	-	-	-
29	A plaice <26	-	0.21	-	-	-	-	-	0.07
30	A plaice 26+	-	-	-	-	-	-	-	-
31	Flounders <30	2.16	1.73	-	-	-	-	0.72	0.58
32	Flounders 30+	-	-	-	-	-	-	-	-
33	Haddock <3	-	7.28	-	-	-	-	-	2.43
34	Haddock 3+	-	-	-	-	-	-	-	-
35	L sculpin <25	-	2.91	-	-	-	-	-	0.97
36	L sculpin 25+	-	-	-	-	-	-	-	-
37	Herring <4	10.43	16.10	-	68.47	-	43.05	3.48	42.54
38	Herring 4+	-	-	-	-	-	-	-	-
39	Other pelagic	3.84	0.71	-	-	-	-	1.28	0.24
40	Mackerel	-	2.55	-	-	-	-	-	0.85
41	Mesopelagic	-	-	-	-	-	-	-	-
42	S-m benthivores	0.71	-	-	-	-	-	0.24	-
43	Squids	-	2.27	-	-	3.25	1.31	1.08	1.19
44	Lobster	-	-	-	-	-	-	-	-
45	Large crabs	0.33	0.06	1.20	18.87	0.50	4.60	0.68	7.84
46	Small crabs	13.50	5.25	29.14	6.90	20.99	7.45	21.21	6.54
47	Shrimps	59.16	1.42	31.72	-	45.51	0.15	45.46	0.52
48	Scallop	-	-	-	-	-	-	-	-
49	Bivalves	-	0.03	-	-	-	-	-	0.01
50	Other molluscs	-	0.02	-	-	-	-	-	0.01
51	Other arthropoda	-	-	-	-	-	-	-	-
52	Echinoderms	-	-	-	-	-	-	-	-
53	S. benthic groups	-	-	-	-	-	0.92	-	0.31
54	Worms	-	0.04	3.19	-	1.34	-	1.51	0.01
55	Meiofauna	-	-	-	-	-	-	-	-
56	Gelatinous zoop	-	-	-	-	-	-	-	-
57	Macrozoop	0.07	0.03	15.60	-	19.82	6.14	11.83	2.06
58	Mesozoop	-	-	-	-	-	-	-	-
59	Microzoop	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	-	-	-
63	Detritus	-	-	-	-	-	-	-	-
64	Import	-	-	-	5.75	-	11.26	-	5.67
	Sum	100	100	100	100	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).
Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).
Diet 4. Simple average of diets 1 to 3. Percent estimates of small and large fish in multi-stanza prey groups were estimated based on the Canadian data.
Observation: 0.00 means that percent was lower than 0.01.

Table A4.11. Percent diet composition for 4X pollock.

		1		2		3		4	
	Prey/Predator	<49	49+	<49	49+	<49	49+	<49	49+
7	Cod <1	0.09	-	-	-	-	-	0.03	-
8	Cod 1-3	-	-	-	-	-	-	-	-
9	Cod 4-6	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-
11	S Hake <25	0.34	32.29	49.43	52.94	-	24.73	16.59	36.65
12	S Hake 25-30	-	-	-	-	-	-	-	-
13	S Hake 31+	-	-	-	-	-	-	-	-
14	Halibut <46	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-
17	Pollock <49	0.17	0.07	-	-	-	-	0.06	0.02
18	Pollock 49+	-	-	-	-	-	-	-	-
19	D piscivores <40	-	-	-	0.37	-	-	-	0.12
20	D piscivores 40+	-	-	-	-	-	-	-	-
21	L benth. <40	-	-	-	0.37	0.24	-	0.08	0.12
22	L bent. 40+	-	-	-	-	-	-	-	-
23	Skates <49	-	-	-	-	-	-	-	-
24	Skates 49+	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-
26	Dogfish 73+	-	-	-	-	-	-	-	-
27	Redfish <22	-	0.01	0.19	-	-	-	0.06	0.00
28	Redfish 22+	-	-	-	-	-	-	-	-
29	A plaice <26	-	-	-	-	-	-	-	-
30	A plaice 26+	-	-	-	-	-	-	-	-
31	Flounders <30	-	-	-	-	-	-	-	-
32	Flounders 30+	-	-	-	-	-	-	-	-
33	Haddock <3	1.07	4.45	-	-	-	-	0.36	1.48
34	Haddock 3+	-	-	-	-	-	-	-	-
35	L sculpin <25	-	-	-	-	-	-	-	-
36	L sculpin 25+	-	-	-	-	-	-	-	-
37	Herring <4	0.47	15.50	-	12.98	-	-	0.16	7.56
38	Herring 4+	1.05	12.52	-	-	-	-	0.35	6.10
39	Other pelagic	36.06	1.26	-	1.69	-	-	12.02	0.98
40	Mackerel	-	-	-	9.28	-	2.22	-	3.83
41	Mesopelagic	-	0.03	-	-	-	-	-	0.01
42	S-m benthivores	-	-	-	-	-	-	-	-
43	Squids	1.15	5.69	-	1.09	-	-	0.38	2.26
44	Lobster	-	-	-	-	-	-	-	-
45	Large crabs	-	-	-	-	-	-	-	-
46	Small crabs	0.72	0.02	0.18	-	-	-	0.30	0.01
47	Shrimps	16.88	11.04	3.87	5.98	30.30	34.43	17.02	17.15
48	Scallop	-	-	-	-	-	-	-	-
49	Bivalves	-	0.05	-	-	-	-	-	0.02
50	Other molluscs	-	0.01	-	-	1.95	-	0.65	0.00
51	Other arthropoda	-	-	1.65	-	6.74	-	2.80	-
52	Echinoderms	-	0.02	-	0.01	-	-	-	0.01
53	S. benthic groups	-	0.00	0.05	-	-	-	0.02	0.00
54	Worms	-	-	0.27	-	-	-	0.09	-
55	Meiofauna	-	-	-	-	-	-	-	-
56	Gelatinous zoop	0.03	0.04	0.56	0.08	-	-	0.20	0.04
57	Macrozoop	28.13	15.58	43.26	15.06	59.19	38.62	43.53	23.09
58	Mesozoop	13.85	1.42	0.55	-	1.56	-	5.32	0.47
59	Microzoop	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	-	-	-
63	Detritus	-	-	-	-	-	-	-	-
64	Import	-	-	-	0.15	-	-	-	0.05
	Sum	100	100	100	100	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).
Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).
Diet 4. Simple average of diets 1 to 3. Percent estimates of small and large fish in multi-stanza prey groups were estimated based on the Canadian data.
Observation: 0.00 means that percent was lower than 0.01.

Table A4.12. Percent diet composition for 4X demersal piscivores.

		1		2		3		4	
	Prey/Predator	<40	40+	<40	40+	<40	40+	<40	40+
7	Cod <1	0.30	0.31	-	-	-	-	0.10	0.10
8	Cod 1-3	1.49	0.09	-	-	-	-	0.50	0.03
9	Cod 4-6	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-
11	S Hake <25	9.73	17.28	4.29	23.26	9.50	18.29	7.84	19.01
12	S Hake 25-30	-	0.78	-	-	-	-	-	0.86
13	S Hake 31+	-	-	-	-	-	-	-	-
14	Halibut <46	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-
17	Pollock <49	-	6.27	-	-	-	-	-	2.09
18	Pollock 49+	-	-	-	-	-	-	-	-
19	D piscivores <40	0.50	7.01	-	-	-	-	0.17	2.34
20	D piscivores 40+	-	-	-	-	-	-	-	-
21	L benth. <40	9.52	0.31	25.03	3.83	40.56	19.15	25.04	7.76
22	L bent. 40+	-	-	-	-	-	-	-	-
23	Skates <49	0.85	-	-	2.08	0.23	-	0.36	0.69
24	Skates 49+	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-
26	Dogfish 73+	-	-	-	-	-	-	-	-
27	Redfish <22	-	0.57	-	0.04	-	-	-	0.19
28	Redfish 22+	-	5.64	-	-	-	-	-	1.89
29	A plaice <26	1.45	-	-	1.25	-	4.03	0.48	1.76
30	A plaice 26+	-	-	-	-	-	-	-	-
31	Flounders <30	1.81	0.20	-	1.25	-	-	0.60	0.19
32	Flounders 30+	-	0.46	-	-	-	-	-	0.44
33	Haddock <3	0.14	0.07	-	26.01	17.33	38.70	5.82	2.13
34	Haddock 3+	-	0.69	-	-	-	-	-	19.69
35	L sculpin <25	1.41	0.07	7.12	-	16.25	4.08	8.26	1.39
36	L sculpin 25+	-	-	-	-	-	-	-	-
37	Herring <4	5.39	34.64	23.74	24.60	4.43	-	11.18	17.96
38	Herring 4+	-	9.66	-	-	-	-	-	5.01
39	Other pelagic	0.19	0.15	-	9.19	-	6.05	0.06	5.13
40	Mackerel	-	1.20	-	-	-	3.36	-	1.52
41	Mesopelagic	-	0.09	-	-	-	-	-	0.03
42	S-m benthivores	1.77	0.59	2.92	0.12	5.12	0.10	3.27	0.27
43	Squids	0.12	0.22	26.74	0.54	-	0.03	8.95	0.27
44	Lobster	0.54	0.10	-	-	-	-	0.18	0.03
45	Large crabs	0.10	0.02	5.41	6.09	0.33	2.68	1.95	2.93
46	Small crabs	0.38	0.24	0.52	0.54	0.25	2.07	0.38	0.95
47	Shrimps	5.56	1.72	1.09	0.53	2.99	0.81	3.22	1.02
48	Scallop	0.00	0.00	-	-	-	0.02	0.00	0.01
49	Bivalves	0.02	0.01	0.10	-	0.00	0.11	0.04	0.04
50	Other molluscs	-	0.00	0.24	-	-	-	0.08	0.00
51	Other arthropoda	-	-	0.07	0.01	0.34	0.02	0.14	0.01
52	Echinoderms	-	0.00	-	-	-	-	-	0.00
53	S. benthic groups	0.00	-	0.21	-	0.05	-	0.09	-
54	Worms	0.06	-	0.06	-	0.07	-	0.06	-
55	Meiofauna	-	-	-	-	-	-	-	-
56	Gelatinous zoop	-	-	0.03	-	-	-	0.01	-
57	Macrozoop	57.96	11.50	2.43	0.65	1.29	0.46	20.56	4.21
58	Mesozoop	0.70	0.09	-	-	-	-	0.23	0.03
59	Microzoop	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	-	-	-
63	Detritus	-	-	-	-	-	-	-	-
64	Import	-	-	-	-	1.25	0.03	0.42	0.01
	Sum	100	100	100	100	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).

Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).

Diet 4. Simple average of diets 1 to 3. Percent estimates of small and large fish in multi-stanza prey groups were estimated based on the Canadian data.

Observation: 0.00 means that percent was lower than 0.01.

Table A4.13. Percent diet composition for 4X large benthivores.

		1		2		3		4	
	Prey/Predator	<40	40+	<40	40+	<40	40+	<40	40+
7	Cod <1	-	-	-	-	-	-	-	-
8	Cod 1-3	-	-	-	-	-	-	-	-
9	Cod 4-6	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-
11	S Hake <25	-	-	-	5.01	16.47	-	5.49	1.67
12	S Hake 25-30	-	-	-	-	-	-	-	-
13	S Hake 31+	-	-	-	-	-	-	-	-
14	Halibut <46	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-
17	Pollock <49	-	-	-	-	-	-	-	-
18	Pollock 49+	-	-	-	-	-	-	-	-
19	D piscivores <40	-	-	-	-	-	-	-	-
20	D piscivores 40+	-	-	-	-	-	-	-	-
21	L benth. <40	-	-	14.33	10.80	-	-	4.78	3.60
22	L bent. 40+	-	-	-	-	-	-	-	-
23	Skates <49	-	-	-	-	-	-	-	-
24	Skates 49+	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-
26	Dogfish 73+	-	-	-	-	-	-	-	-
27	Redfish <22	-	-	-	-	-	-	-	-
28	Redfish 22+	-	-	-	-	-	-	-	-
29	A plaice <26	-	-	-	-	-	-	-	-
30	A plaice 26+	-	-	-	-	-	-	-	-
31	Flounders <30	0.06	-	-	-	-	-	0.02	-
32	Flounders 30+	-	-	-	-	-	-	-	-
33	Haddock <3	-	-	-	-	-	-	-	-
34	Haddock 3+	-	-	-	-	-	-	-	-
35	L sculpin <25	-	-	-	-	-	-	-	-
36	L sculpin 25+	-	-	-	-	-	-	-	-
37	Herring <4	-	-	-	-	-	-	-	-
38	Herring 4+	-	-	-	-	-	-	-	-
39	Other pelagic	4.16	10.05	-	-	-	-	1.39	3.35
40	Mackerel	-	-	-	-	-	-	-	-
41	Mesopelagic	5.81	-	-	-	-	-	1.94	-
42	S-m benthivores	-	3.20	28.66	35.86	-	43.23	9.55	27.43
43	Squids	1.24	0.14	-	-	-	-	0.41	0.05
44	Lobster	0.11	5.57	3.43	-	4.81	-	2.79	1.86
45	Large crabs	-	0.11	5.45	0.41	0.98	-	2.15	0.17
46	Small crabs	20.76	29.14	3.71	0.77	16.75	22.72	13.74	17.55
47	Shrimps	29.25	6.22	16.64	5.41	13.99	3.14	19.96	4.92
48	Scallop	0.08	6.67	4.23	30.58	0.69	4.24	1.67	13.83
49	Bivalves	0.51	8.60	0.84	1.03	6.49	3.10	2.61	4.24
50	Other molluscs	0.04	8.81	0.01	1.65	0.13	-	0.06	3.49
51	Other arthropoda	-	-	3.72	0.47	12.02	9.41	5.25	3.29
52	Echinoderms	0.31	15.65	2.06	0.73	7.20	1.81	3.19	6.06
53	S. benthic groups	-	0.11	0.37	-	0.43	-	0.27	0.04
54	Worms	0.37	2.23	0.42	4.17	4.07	0.54	1.62	2.31
55	Meiofauna	-	-	-	-	-	-	-	-
56	Gelatinous zoop	-	-	0.04	2.03	-	-	0.01	0.68
57	Macrozoop	36.48	2.92	16.08	1.07	15.82	11.79	22.79	5.26
58	Mesozoop	0.82	0.58	-	-	0.13	-	0.32	0.19
59	Microzoop	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	-	-	-
63	Detritus	-	-	-	-	-	-	-	-
64	Import	-	-	-	-	-	-	-	-
	Sum	100	100	100	100	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).
Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).
Diet 4. Simple average of diets 1 to 3. Percent estimates of small and large fish in multi-stanza prey groups were estimated based on the Canadian data.
Observation: 0.00 means that percent was lower than 0.01.

Table A4.14. Percent diet composition for 4X skates.

		1		2		3		4	
	Prey/Predator	<49	49+	<49	49+	<49	49+	<49	49+
7	Cod <1	-	-	-	-	-	-	-	-
8	Cod 1-3	-	-	-	-	-	-	-	-
9	Cod 4-6	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-
11	S Hake <25	-	-	2.83	0.18	-	-	0.94	0.06
12	S Hake 25-30	-	-	-	-	-	-	-	-
13	S Hake 31+	-	-	-	-	-	-	-	-
14	Halibut <46	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-
17	Pollock <49	-	0.62	-	-	-	-	-	0.21
18	Pollock 49+	-	-	-	-	-	-	-	-
19	D piscivores <40	-	-	-	-	-	-	-	-
20	D piscivores 40+	-	-	-	-	-	-	-	-
21	L benth. <40	0.50	2.22	-	-	0.65	4.08	0.38	2.10
22	L bent. 40+	-	-	-	-	-	-	-	-
23	Skates <49	-	-	-	-	-	-	-	-
24	Skates 49+	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-
26	Dogfish 73+	-	-	-	-	-	-	-	-
27	Redfish <22	-	0.10	-	28.41	-	-	-	9.50
28	Redfish 22+	-	-	-	-	-	-	-	-
29	A plaice <26	-	0.19	-	-	-	-	-	0.06
30	A plaice 26+	-	-	-	-	-	-	-	-
31	Flounders <30	-	-	-	-	-	-	-	-
32	Flounders 30+	-	-	-	-	-	-	-	-
33	Haddock <3	-	-	-	-	-	-	-	-
34	Haddock 3+	-	-	-	-	-	-	-	-
35	L sculpin <25	0.04	-	3.64	0.08	-	-	1.23	0.03
36	L sculpin 25+	-	-	-	-	-	-	-	-
37	Herring <4	-	-	-	8.75	5.79	-	1.93	2.92
38	Herring 4+	-	-	-	-	-	-	-	-
39	Other pelagic	8.10	14.38	2.43	0.80	-	4.76	3.51	6.65
40	Mackerel	-	-	-	-	-	-	-	-
41	Mesopelagic	0.42	-	-	-	-	-	0.14	-
42	S-m benthivores	0.07	3.28	-	1.79	1.42	-	0.49	1.69
43	Squids	1.69	4.66	-	0.02	-	-	0.56	1.56
44	Lobster	-	-	-	0.60	-	0.78	-	0.46
45	Large crabs	3.10	6.63	-	21.75	3.26	7.85	2.12	12.08
46	Small crabs	8.73	20.20	0.54	3.36	17.91	20.43	9.06	14.66
47	Shrimps	7.19	24.95	17.11	10.58	19.64	33.99	14.65	23.17
48	Scallop	-	-	-	-	-	-	-	-
49	Bivalves	-	-	-	-	0.37	0.02	0.12	0.01
50	Other molluscs	0.04	0.54	-	0.56	-	0.04	0.01	0.38
51	Other arthropoda	-	-	10.06	0.09	13.58	1.57	7.88	0.55
52	Echinoderms	-	0.41	-	-	-	-	-	0.14
53	S. benthic groups	0.00	-	-	0.06	0.21	-	0.07	0.02
54	Worms	21.67	18.31	16.58	7.44	19.17	14.59	19.14	13.45
55	Meiofauna	-	-	-	-	-	-	-	-
56	Gelatinous zoop	-	-	-	-	-	0.98	-	0.33
57	Macrozoop	4.77	2.38	46.81	15.49	18.00	10.92	23.19	9.60
58	Mesozoop	43.68	1.12	-	0.05	-	-	14.56	0.39
59	Microzoop	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	-	-	-
63	Detritus	-	-	-	-	-	-	-	-
64	Import	-	-	-	-	-	-	-	-
	Sum	100	100	100	100	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).

Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).

Diet 4. Simple average of diets 1 to 3. Percent estimates of small and large fish in multi-stanza prey groups were estimated based on the Canadian data.

Observation: 0.00 means that percent was lower than 0.01.

Table A4.15. Percent diet composition for 4X dogfish.

		1		2		3		4	
	Prey/Predator	<73	73+	<73	73+	<73	73+	<73	73+
7	Cod <1	-	-	-	-	-	-	-	-
8	Cod 1-3	-	-	-	-	-	-	-	-
9	Cod 4-6	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-
11	S Hake <25	-	14.03	-	0.25	-	-	-	4.76
12	S Hake 25-30	-	-	-	-	-	-	-	-
13	S Hake 31+	-	-	-	-	-	-	-	-
14	Halibut <46	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-
17	Pollock <49	-	-	-	-	-	-	-	-
18	Pollock 49+	-	-	-	-	-	-	-	-
19	D piscivores <40	5.79	0.10	-	-	-	25.63	1.93	8.58
20	D piscivores 40+	-	-	-	-	-	-	-	-
21	L benth. <40	-	-	0.59	4.24	0.30	-	0.30	1.41
22	L bent. 40+	-	2.33	-	-	-	-	-	0.78
23	Skates <49	-	-	-	-	-	-	-	-
24	Skates 49+	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-
26	Dogfish 73+	-	-	-	-	-	-	-	-
27	Redfish <22	1.00	0.01	-	7.21	-	-	0.33	2.41
28	Redfish 22+	-	-	-	-	-	-	-	-
29	A plaice <26	-	-	-	-	-	-	-	-
30	A plaice 26+	-	-	-	-	-	-	-	-
31	Flounders <30	-	0.06	-	-	-	-	-	0.02
32	Flounders 30+	-	-	-	-	-	-	-	-
33	Haddock <3	-	-	-	-	-	-	-	-
34	Haddock 3+	-	-	-	-	-	-	-	-
35	L sculpin <25	-	-	-	-	-	-	-	-
36	L sculpin 25+	-	-	-	-	-	-	-	-
37	Herring <4	39.30	23.00	30.47	41.44	20.44	5.77	30.07	16.86
38	Herring 4+	-	16.36	-	-	-	-	-	11.99
39	Other pelagic	0.02	-	-	3.31	-	4.06	0.01	2.46
40	Mackerel	7.78	5.61	-	19.76	-	-	2.59	8.46
41	Mesopelagic	0.00	-	-	-	-	-	0.00	-
42	S-m benthivores	0.50	0.06	4.69	2.63	2.41	17.09	2.53	6.59
43	Squids	0.71	18.21	14.66	1.36	8.45	-	7.94	6.52
44	Lobster	-	0.26	-	5.78	-	-	-	2.01
45	Large crabs	-	-	-	-	-	11.00	-	3.67
46	Small crabs	1.20	0.32	-	-	1.33	2.84	0.84	1.05
47	Shrimps	16.19	1.01	0.11	1.90	8.46	10.00	8.26	4.30
48	Scallop	-	-	1.05	-	-	-	0.35	-
49	Bivalves	0.00	0.00	-	-	-	-	0.00	0.00
50	Other molluscs	0.03	0.26	-	-	-	-	0.01	0.09
51	Other arthropoda	-	-	-	0.02	0.01	-	0.00	0.01
52	Echinoderms	-	0.00	-	-	-	0.01	-	0.00
53	S. benthic groups	0.00	0.01	-	-	0.13	0.12	0.04	0.04
54	Worms	0.09	2.19	0.04	-	0.17	0.02	0.10	0.74
55	Meiofauna	-	-	-	-	-	-	-	-
56	Gelatinous zoop	0.37	0.03	40.84	8.10	42.28	17.53	27.83	8.55
57	Macrozoop	27.01	16.14	7.57	3.50	14.84	5.59	16.47	8.41
58	Mesozoop	0.01	0.00	-	-	-	-	0.00	0.00
59	Microzoop	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	-	-	-
63	Detritus	-	-	-	-	-	-	-	-
64	Import	-	-	-	0.50	1.17	0.35	0.39	0.28
	Sum	100	100	100	100	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).
Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).
Diet 4. Simple average of diets 1 to 3. Percent estimates of small and large fish in multi-stanza prey groups were estimated based on the Canadian data.
Observation: 0.00 means that percent was lower than 0.01.

Table A4.16. Percent diet composition for 4X redfish.

		1		2		3		4	
	Prey/Predator	<22	22+	<22	22+	<22	22+	<22	22+
7	Cod <1	-	-	-	-	-	-	-	-
8	Cod 1-3	-	-	-	-	-	-	-	-
9	Cod 4-6	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-
11	S Hake <25	-	-	-	7.92	-	1.36	-	3.09
12	S Hake 25-30	-	-	-	-	-	-	-	-
13	S Hake 31+	-	-	-	-	-	-	-	-
14	Halibut <46	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-
17	Pollock <49	-	-	-	-	-	-	-	-
18	Pollock 49+	-	-	-	-	-	-	-	-
19	D piscivores <40	-	-	-	-	-	-	-	-
20	D piscivores 40+	-	-	-	-	-	-	-	-
21	L benth. <40	-	-	-	-	-	-	-	-
22	L bent. 40+	-	-	-	-	-	-	-	-
23	Skates <49	-	-	-	-	-	-	-	-
24	Skates 49+	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-
26	Dogfish 73+	-	-	-	-	-	-	-	-
27	Redfish <22	-	-	-	-	-	-	-	-
28	Redfish 22+	-	-	-	-	-	-	-	-
29	A plaice <26	-	-	-	-	-	-	-	-
30	A plaice 26+	-	-	-	-	-	-	-	-
31	Flounders <30	-	-	-	-	-	-	-	-
32	Flounders 30+	-	-	-	-	-	-	-	-
33	Haddock <3	-	-	-	-	-	-	-	-
34	Haddock 3+	-	-	-	-	-	-	-	-
35	L sculpin <25	-	-	-	-	-	-	-	-
36	L sculpin 25+	-	-	-	-	-	-	-	-
37	Herring <4	-	-	-	-	-	-	-	-
38	Herring 4+	-	-	-	-	-	-	-	-
39	Other pelagic	3.85	5.54	-	7.92	-	1.36	1.28	4.94
40	Mackerel	-	-	-	-	-	-	-	-
41	Mesopelagic	-	0.01	-	-	-	-	-	0.00
42	S-m benthivores	-	-	-	-	-	-	-	-
43	Squids	-	-	-	-	-	-	-	-
44	Lobster	-	-	-	-	-	-	-	-
45	Large crabs	-	-	-	-	-	-	-	-
46	Small crabs	-	-	-	-	-	-	-	-
47	Shrimps	14.01	32.85	28.92	19.37	3.70	79.03	15.55	43.75
48	Scallop	-	-	-	-	-	-	-	-
49	Bivalves	-	-	-	-	-	-	-	-
50	Other molluscs	-	-	-	-	-	-	-	-
51	Other arthropoda	-	-	6.67	1.93	5.56	-	4.08	0.64
52	Echinoderms	-	-	-	-	-	-	-	-
53	S. benthic groups	-	-	-	-	-	-	-	-
54	Worms	-	-	-	-	-	-	-	-
55	Meiofauna	-	-	-	-	-	-	-	-
56	Gelatinous zoop	-	0.48	-	-	7.41	-	2.47	0.16
57	Macrozoop	80.07	57.31	63.98	62.81	81.48	18.25	75.18	46.12
58	Mesozoop	2.07	3.82	0.42	0.06	-	-	0.83	1.29
59	Microzoop	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	-	-	-
63	Detritus	-	-	-	-	-	-	-	-
64	Import	-	-	-	-	1.85	-	0.62	-
	Sum	100	100	100	100	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).

Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).

Diet 4. Simple average of diets 1 to 3. Percent estimates of small and large fish in multi-stanza prey groups were estimated based on the Canadian data.

Observation: 0.00 means that percent was lower than 0.01.

Table A4.17. Percent diet composition for 4X American plaice.

		1		2		3		4	
	Prey/Predator	<26	26+	<26	26+	<26	26+	<26	26+
7	Cod <1	-	-	-	-	-	-	-	-
8	Cod 1-3	-	-	-	-	-	-	-	-
9	Cod 4-6	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-
11	S Hake <25	-	27.84	-	-	-	-	-	9.28
12	S Hake 25-30	-	-	-	-	-	-	-	-
13	S Hake 31+	-	-	-	-	-	-	-	-
14	Halibut <46	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-
17	Pollock <49	-	-	-	-	-	-	-	-
18	Pollock 49+	-	-	-	-	-	-	-	-
19	D piscivores <40	-	-	-	-	-	-	-	-
20	D piscivores 40+	-	-	-	-	-	-	-	-
21	L benth. <40	-	-	-	-	-	-	-	-
22	L bent. 40+	-	-	-	-	-	-	-	-
23	Skates <49	-	-	-	-	-	-	-	-
24	Skates 49+	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-
26	Dogfish 73+	-	-	-	-	-	-	-	-
27	Redfish <22	-	-	-	-	-	-	-	-
28	Redfish 22+	-	-	-	-	-	-	-	-
29	A plaice <26	-	-	-	-	-	-	-	-
30	A plaice 26+	-	-	-	-	-	-	-	-
31	Flounders <30	-	-	-	-	-	-	-	-
32	Flounders 30+	-	-	-	-	-	-	-	-
33	Haddock <3	-	-	-	-	-	-	-	-
34	Haddock 3+	-	-	-	-	-	-	-	-
35	L sculpin <25	-	-	-	-	-	-	-	-
36	L sculpin 25+	-	-	-	-	-	-	-	-
37	Herring <4	-	-	-	-	-	-	-	-
38	Herring 4+	-	-	-	-	-	-	-	-
39	Other pelagic	2.32	3.81	-	-	-	-	0.77	1.27
40	Mackerel	-	-	-	-	-	-	-	-
41	Mesopelagic	-	-	-	-	-	-	-	-
42	S-m benthivores	-	-	-	-	-	-	-	-
43	Squids	-	-	-	-	-	-	-	-
44	Lobster	-	-	-	-	-	-	-	-
45	Large crabs	-	-	-	-	-	-	-	-
46	Small crabs	-	6.75	-	-	-	-	-	2.25
47	Shrimps	63.82	19.19	19.30	3.84	1.36	-	28.16	7.68
48	Scallop	3.62	1.95	5.57	1.00	0.03	15.90	3.07	6.28
49	Bivalves	0.15	2.36	9.87	2.61	64.27	17.22	24.77	7.40
50	Other molluscs	1.63	0.65	0.38	0.23	5.46	3.49	2.49	1.46
51	Other arthropoda	-	-	6.71	0.23	13.24	3.90	6.65	1.38
52	Echinoderms	2.27	20.94	20.25	73.68	12.01	13.41	11.51	36.01
53	S. benthic groups	-	0.07	-	-	-	-	-	0.02
54	Worms	4.68	13.74	25.32	1.53	2.27	8.00	10.75	7.76
55	Meiofauna	-	-	-	-	-	-	-	-
56	Gelatinous zoop	-	0.49	-	0.77	-	-	-	0.42
57	Macrozoop	1.41	0.73	12.59	16.12	-	38.07	4.67	18.31
58	Mesozoop	20.09	1.47	-	-	1.36	-	7.15	0.49
59	Microzoop	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	-	-	-
63	Detritus	-	-	-	-	-	-	-	-
64	Import	-	-	-	-	-	-	-	-
	Sum	100	100	100	100	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).
Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).
Diet 4. Simple average of diets 1 to 3. Percent estimates of small and large fish in multi-stanza prey groups were estimated based on the Canadian data.
Observation: 0.00 means that percent was lower than 0.01.

Table A4.18. Percent diet composition for 4X flounders.

		1		2		3		4	
	Prey/Predator	<30	30+	<30	30+	<30	30+	<30	30+
7	Cod <1	-	-	-	-	-	-	-	-
8	Cod 1-3	-	-	-	-	-	-	-	-
9	Cod 4-6	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-
11	S Hake <25	-	-	-	-	-	-	-	-
12	S Hake 25-30	-	-	-	-	-	-	-	-
13	S Hake 31+	-	-	-	-	-	-	-	-
14	Halibut <46	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-
17	Pollock <49	-	-	-	-	-	-	-	-
18	Pollock 49+	-	-	-	-	-	-	-	-
19	D piscivores <40	-	-	-	-	-	-	-	-
20	D piscivores 40+	-	-	-	-	-	-	-	-
21	L benth. <40	-	-	-	-	-	-	-	-
22	L bent. 40+	-	-	-	-	-	-	-	-
23	Skates <49	-	-	-	-	-	-	-	-
24	Skates 49+	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-
26	Dogfish 73+	-	-	-	-	-	-	-	-
27	Redfish <22	-	-	-	-	-	-	-	-
28	Redfish 22+	-	-	-	-	-	-	-	-
29	A plaice <26	-	-	-	-	-	-	-	-
30	A plaice 26+	-	-	-	-	-	-	-	-
31	Flounders <30	-	-	-	-	-	-	-	-
32	Flounders 30+	-	-	-	-	-	-	-	-
33	Haddock <3	-	-	-	-	-	-	-	-
34	Haddock 3+	-	-	-	-	-	-	-	-
35	L sculpin <25	-	-	-	-	-	-	-	-
36	L sculpin 25+	-	-	-	-	-	-	-	-
37	Herring <4	-	-	-	-	-	-	-	-
38	Herring 4+	-	-	-	-	-	-	-	-
39	Other pelagic	4.76	0.56	-	-	-	-	1.59	0.19
40	Mackerel	-	-	-	-	-	-	-	-
41	Mesopelagic	-	-	-	-	-	-	-	-
42	S-m benthivores	-	-	-	-	-	-	-	-
43	Squids	-	-	-	-	-	-	-	-
44	Lobster	-	-	-	-	-	-	-	-
45	Large crabs	-	-	-	0.51	-	-	-	0.17
46	Small crabs	-	1.99	-	1.74	-	0.85	-	1.53
47	Shrimps	0.48	0.21	0.13	0.61	-	0.50	0.20	0.44
48	Scallop	-	-	-	0.21	-	-	-	0.07
49	Bivalves	4.52	2.27	5.76	3.91	12.12	4.79	7.47	3.65
50	Other molluscs	1.15	0.93	0.53	1.46	0.78	0.73	0.82	1.04
51	Other arthropoda	-	-	42.36	29.51	27.00	20.62	23.12	16.71
52	Echinoderms	0.32	2.50	5.30	2.14	0.65	1.98	2.09	2.20
53	S. benthic groups	11.86	18.15	1.55	9.65	5.76	13.10	6.39	13.63
54	Worms	26.72	44.21	38.48	39.64	50.47	54.50	38.56	46.11
55	Meiofauna	-	-	-	-	-	-	-	-
56	Gelatinous zoop	-	-	-	0.40	-	0.09	-	0.16
57	Macrozoop	7.97	0.57	0.45	1.27	2.98	1.42	3.80	1.09
58	Mesozoop	30.49	8.65	-	-	-	-	10.16	2.88
59	Microzoop	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	-	-	-
63	Detritus	-	-	-	-	-	-	-	-
64	Import	11.74	19.97	5.43	8.95	0.24	1.42	5.81	10.11
	Sum	100	100	100	100	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).
Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).
Diet 4. Simple average of diets 1 to 3. Percent estimates of small and large fish in multi-stanza prey groups were estimated based on the Canadian data.
Observation: 0.00 means that percent was lower than 0.01.

Table A4.19. Percent diet composition for 4X haddock.

		1		2		3		4	
	Prey/Predator	<3	3+	<3	3+	<3	3+	<3	3+
7	Cod <1	-	-	-	-	-	-	-	-
8	Cod 1-3	-	-	-	-	-	-	-	-
9	Cod 4-6	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-
11	S Hake <25	-	-	-	5.37	-	3.63	-	3.00
12	S Hake 25-30	-	-	-	-	-	-	-	-
13	S Hake 31+	-	-	-	-	-	-	-	-
14	Halibut <46	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-
17	Pollock <49	-	1.32	-	-	-	-	-	0.44
18	Pollock 49+	-	-	-	-	-	-	-	-
19	D piscivores <40	-	-	-	-	-	-	-	-
20	D piscivores 40+	-	-	-	-	-	-	-	-
21	L benth. <40	-	0.00	-	0.15	-	0.10	-	0.09
22	L bent. 40+	-	-	-	-	-	-	-	-
23	Skates <49	-	-	-	-	-	-	-	-
24	Skates 49+	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-
26	Dogfish 73+	-	-	-	-	-	-	-	-
27	Redfish <22	-	0.16	-	-	-	-	-	0.05
28	Redfish 22+	-	-	-	-	-	-	-	-
29	A plaice <26	-	-	-	-	-	-	-	-
30	A plaice 26+	-	-	-	-	-	-	-	-
31	Flounders <30	-	-	-	-	-	-	-	-
32	Flounders 30+	-	-	-	-	-	-	-	-
33	Haddock <3	-	5.08	-	-	-	-	-	1.69
34	Haddock 3+	-	-	-	-	-	-	-	-
35	L sculpin <25	-	-	-	-	-	-	-	-
36	L sculpin 25+	-	-	-	-	-	-	-	-
37	Herring <4	-	-	-	-	-	3.96	-	1.32
38	Herring 4+	-	-	-	-	-	-	-	-
39	Other pelagic	6.09	1.67	-	-	-	-	2.03	0.56
40	Mackerel	-	-	-	-	-	-	-	-
41	Mesopelagic	-	-	-	-	-	-	-	-
42	S-m benthivores	-	0.01	-	-	-	-	-	0.00
43	Squids	-	7.09	0.24	0.38	-	0.27	0.08	2.58
44	Lobster	2.01	0.76	-	0.92	-	0.62	0.67	0.77
45	Large crabs	-	1.69	-	0.81	1.37	1.87	0.46	1.46
46	Small crabs	3.86	12.30	3.70	5.73	8.68	8.62	5.41	8.88
47	Shrimps	13.71	5.29	3.44	5.17	14.97	8.07	10.71	6.17
48	Scallop	0.08	0.13	0.18	0.10	0.01	0.06	0.09	0.10
49	Bivalves	3.29	1.90	12.73	2.55	12.12	6.40	9.38	3.62
50	Other molluscs	0.83	1.33	0.43	2.28	0.94	1.67	0.74	1.76
51	Other arthropoda	-	-	13.92	4.73	17.77	4.49	10.56	3.08
52	Echinoderms	10.09	30.84	26.10	40.03	21.04	33.97	19.08	34.95
53	S. benthic groups	0.03	0.35	0.09	6.06	0.19	4.21	0.10	3.54
54	Worms	14.97	8.27	27.77	11.60	8.06	10.87	16.93	10.25
55	Meiofauna	-	-	-	-	-	-	-	-
56	Gelatinous zoop	1.06	0.33	0.84	0.42	0.23	0.29	0.71	0.35
57	Macrozoop	3.92	6.51	10.50	13.69	13.43	10.87	9.28	10.36
58	Mesozoop	40.07	14.98	0.06	-	1.19	0.01	13.77	5.00
59	Microzoop	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	-	-	-
63	Detritus	-	-	-	-	-	-	-	-
64	Import	-	-	-	-	-	-	-	-
	Sum	100	100	100	100	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).
Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).
Diet 4. Simple average of diets 1 to 3. Percent estimates of small and large fish in multi-stanza prey groups were estimated based on the Canadian data.
Observation: 0.00 means that percent was lower than 0.01.

Table A4.20. Percent diet composition for 4X longhorn sculpin.

		1			2	3	4		
	Prey/Predator	<25	25+	All	All	All	<25	25+	All
7	Cod <1	-	-	-	-	-	-	-	-
8	Cod 1-3	-	-	-	-	-	-	-	-
9	Cod 4-6	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-
11	S Hake <25	-	-	-	-	-	-	-	-
12	S Hake 25-30	-	-	-	-	-	-	-	-
13	S Hake 31+	-	-	-	-	-	-	-	-
14	Halibut <46	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-
17	Pollock <49	-	-	-	-	-	-	-	-
18	Pollock 49+	-	-	-	-	-	-	-	-
19	D piscivores <40	-	-	-	-	-	-	-	-
20	D piscivores 40+	-	-	-	-	-	-	-	-
21	L benth. <40	0.01	-	0.00	-	0.64	0.12	0.26	0.21
22	L bent. 40+	-	-	-	-	-	-	-	-
23	Skates <49	-	-	-	-	-	-	-	-
24	Skates 49+	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-
26	Dogfish 73+	-	-	-	-	-	-	-	-
27	Redfish <22	2.18	0.43	0.99	-	-	0.19	0.40	0.33
28	Redfish 22+	-	-	-	-	-	-	-	-
29	A plaice <26	-	-	-	-	-	-	-	-
30	A plaice 26+	-	-	-	-	-	-	-	-
31	Flounders <30	-	-	-	-	-	-	-	-
32	Flounders 30+	-	-	-	-	-	-	-	-
33	Haddock <3	-	2.52	1.71	-	-	0.32	0.69	0.57
34	Haddock 3+	-	-	-	-	-	-	-	-
35	L sculpin <25	-	-	-	-	0.90	0.17	0.36	0.30
36	L sculpin 25+	-	-	-	-	-	-	-	-
37	Herring <4	-	-	-	-	-	-	-	-
38	Herring 4+	-	-	-	-	-	-	-	-
39	Other pelagic	4.65	18.04	13.74	-	-	2.60	5.52	4.58
40	Mackerel	-	-	-	-	-	-	-	-
41	Mesopelagic	-	-	-	-	-	-	-	-
42	S-m benthivores	3.27	0.41	1.33	-	1.47	0.53	1.12	0.93
43	Squids	-	-	-	-	-	-	-	-
44	Lobster	6.94	0.11	2.30	-	-	0.79	0.76	0.77
45	Large crabs	1.05	2.61	2.10	5.69	11.17	6.52	6.23	6.32
46	Small crabs	26.33	46.47	40.00	26.42	27.27	32.23	30.75	31.23
47	Shrimps	22.89	10.76	14.66	31.37	32.53	27.03	25.79	26.19
48	Scallop	-	0.00	0.00	0.09	-	0.03	0.03	0.03
49	Bivalves	0.01	0.06	0.04	-	-	0.01	0.01	0.01
50	Other molluscs	0.11	0.01	0.04	-	1.18	0.42	0.40	0.41
51	Other arthropoda	-	-	-	3.92	6.22	3.49	3.33	3.38
52	Echinoderms	0.12	-	0.04	0.14	2.52	0.93	0.89	0.90
53	S. benthic groups	0.06	0.02	0.03	0.92	-	0.33	0.31	0.32
54	Worms	1.68	1.65	1.66	6.30	1.54	3.27	3.12	3.17
55	Meiofauna	-	-	-	-	-	-	-	-
56	Gelatinous zoop	-	-	-	-	-	-	-	-
57	Macrozoop	24.43	16.11	18.78	25.14	14.56	20.12	19.20	19.49
58	Mesozoop	6.29	0.80	2.57	-	-	0.88	0.84	0.86
59	Microzoop	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	-	-	-
63	Detritus	-	-	-	-	-	-	-	-
64	Import	-	-	-	-	-	-	-	-
	Sum	100	100	100	100	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004). Average for all sizes is weighed by total stomach contents weight in each size category.

Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).

Diet 4. Simple average of diets 1 to 3. Percent estimates of small and large fish in multi-stanza prey and predator groups were estimated based on the Canadian data.

Observation: 0.00 means that percent was lower than 0.01.

Table A4.21. Percent diet composition for 4X herring. Average data for all sizes were used for the stanzas <4 and 4+

		1	2	3	4
	Prey/Predator	All	All	All	All
7	Cod <1	-	-	-	-
8	Cod 1-3	-	-	-	-
9	Cod 4-6	-	-	-	-
10	Cod 7+	-	-	-	-
11	S Hake <25	-	-	-	-
12	S Hake 25-30	-	-	-	-
13	S Hake 31+	-	-	-	-
14	Halibut <46	-	-	-	-
15	Halibut 46-81	-	-	-	-
16	Halibut 82+	-	-	-	-
17	Pollock <49	-	-	-	-
18	Pollock 49+	-	-	-	-
19	D piscivores <40	-	-	-	-
20	D piscivores 40+	-	-	-	-
21	L benth. <40	-	-	-	-
22	L bent. 40+	-	-	-	-
23	Skates <49	-	-	-	-
24	Skates 49+	-	-	-	-
25	Dogfish <73	-	-	-	-
26	Dogfish 73+	-	-	-	-
27	Redfish <22	-	-	-	-
28	Redfish 22+	-	-	-	-
29	A plaice <26	-	-	-	-
30	A plaice 26+	-	-	-	-
31	Flounders <30	-	-	-	-
32	Flounders 30+	-	-	-	-
33	Haddock <3	-	-	-	-
34	Haddock 3+	-	-	-	-
35	L sculpin <25	-	-	-	-
36	L sculpin 25+	-	-	-	-
37	Herring <4	-	-	-	-
38	Herring 4+	-	-	-	-
39	Other pelagic	-	-	-	-
40	Mackerel	-	-	-	-
41	Mesopelagic	-	-	-	-
42	S-m benthivores	-	-	-	-
43	Squids	-	-	-	-
44	Lobster	-	-	-	-
45	Large crabs	-	-	-	-
46	Small crabs	-	-	-	-
47	Shrimps	21.63	9.56	15.77	15.65
48	Scallop	-	-	-	-
49	Bivalves	-	-	-	-
50	Other molluscs	-	-	-	-
51	Other arthropoda	-	11.40	2.16	4.52
52	Echinoderms	-	-	-	-
53	S. benthic groups	-	1.02	-	0.34
54	Worms	-	-	-	-
55	Meiofauna	-	-	-	-
56	Gelatinous zoop	-	-	-	-
57	Macrozoop	75.97	74.75	79.50	76.74
58	Mesozoop	2.40	3.28	2.57	2.75
59	Microzoop	-	-	-	-
60	Microflora	-	-	-	-
61	Phytoplankton	-	-	-	-
62	Discards	-	-	-	-
63	Detritus	-	-	-	-
64	Import	-	-	-	-
	Sum	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).
Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).
Diet 4. Simple average of diets 1 to 3.
Observation: 0.00 means that percent was lower than 0.01.

Table A4.22. Percent diet composition for 4X "other pelagic" group.

		1	2	3	4
	Prey/Predator	All	All	All	All
7	Cod <1	-	-	-	-
8	Cod 1-3	-	-	-	-
9	Cod 4-6	-	-	-	-
10	Cod 7+	-	-	-	-
11	S Hake <25	-	-	-	-
12	S Hake 25-30	-	-	-	-
13	S Hake 31+	-	-	-	-
14	Halibut <46	-	-	-	-
15	Halibut 46-81	-	-	-	-
16	Halibut 82+	-	-	-	-
17	Pollock <49	-	-	-	-
18	Pollock 49+	-	-	-	-
19	D piscivores <40	-	-	-	-
20	D piscivores 40+	-	-	-	-
21	L benth. <40	-	-	-	-
22	L bent. 40+	-	-	-	-
23	Skates <49	-	-	-	-
24	Skates 49+	-	-	-	-
25	Dogfish <73	-	-	-	-
26	Dogfish 73+	-	-	-	-
27	Redfish <22	-	-	-	-
28	Redfish 22+	-	-	-	-
29	A plaice <26	-	-	-	-
30	A plaice 26+	-	-	-	-
31	Flounders <30	-	-	-	-
32	Flounders 30+	-	-	-	-
33	Haddock <3	-	-	-	-
34	Haddock 3+	-	-	-	-
35	L sculpin <25	-	-	-	-
36	L sculpin 25+	-	-	-	-
37	Herring <4	-	-	-	-
38	Herring 4+	-	-	-	-
39	Other pelagic	-	-	-	-
40	Mackerel	-	-	-	-
41	Mesopelagic	-	-	-	-
42	S-m benthivores	-	-	-	-
43	Squids	-	-	-	-
44	Lobster	-	-	-	-
45	Large crabs	-	-	-	-
46	Small crabs	-	-	-	-
47	Shrimps	15.08	0.71	7.00	7.60
48	Scallop	-	-	-	-
49	Bivalves	-	-	-	-
50	Other molluscs	-	-	-	-
51	Other arthropoda	-	37.97	-	12.66
52	Echinoderms	-	-	-	-
53	S. benthic groups	-	-	-	-
54	Worms	0.24	-	-	0.08
55	Meiofauna	-	-	-	-
56	Gelatinous zoop	-	0.36	-	0.12
57	Macrozoop	75.49	17.90	13.89	35.76
58	Mesozoop	7.22	42.35	79.12	42.90
59	Microzoop	-	-	-	-
60	Microflora	-	-	-	-
61	Phytoplankton	-	0.71	-	0.24
62	Discards	-	-	-	-
63	Detritus	-	-	-	-
64	Import	1.98	-	-	0.66
	Sum	100	100	100	100

Diet 1. Average summer diet derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).
Diet 2 and 3. Diet data for fish collected from USA fall (2) and spring (3) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).
Diet 4. Simple average of diets 1 to 3.
Observation: 0.00 means that percent was lower than 0.01.

Table A4.23. Percent diet composition for 4X mackerel.

		1	2	3
	Prey/Predator	All	All	All
7	Cod <1	-	-	-
8	Cod 1-3	-	-	-
9	Cod 4-6	-	-	-
10	Cod 7+	-	-	-
11	S Hake <25	-	-	-
12	S Hake 25-30	-	-	-
13	S Hake 31+	-	-	-
14	Halibut <46	-	-	-
15	Halibut 46-81	-	-	-
16	Halibut 82+	-	-	-
17	Pollock <49	-	-	-
18	Pollock 49+	-	-	-
19	D piscivores <40	-	-	-
20	D piscivores 40+	-	-	-
21	L benth. <40	-	-	-
22	L bent. 40+	-	-	-
23	Skates <49	-	-	-
24	Skates 49+	-	-	-
25	Dogfish <73	-	-	-
26	Dogfish 73+	-	-	-
27	Redfish <22	-	-	-
28	Redfish 22+	-	-	-
29	A plaice <26	-	-	-
30	A plaice 26+	-	-	-
31	Flounders <30	-	-	-
32	Flounders 30+	-	-	-
33	Haddock <3	-	-	-
34	Haddock 3+	-	-	-
35	L sculpin <25	-	-	-
36	L sculpin 25+	-	-	-
37	Herring <4	-	-	-
38	Herring 4+	-	-	-
39	Other pelagic	-	-	-
40	Mackerel	-	-	-
41	Mesopelagic	-	-	-
42	S-m benthivores	-	-	-
43	Squids	-	-	-
44	Lobster	-	-	-
45	Large crabs	-	-	-
46	Small crabs	-	-	-
47	Shrimps	10.99	-	6.86
48	Scallop	-	-	-
49	Bivalves	-	-	-
50	Other molluscs	-	-	-
51	Other arthropoda	9.85	-	6.15
52	Echinoderms	-	-	-
53	S. benthic groups	0.38	-	0.24
54	Worms	1.26	-	0.79
55	Meiofauna	-	-	-
56	Gelatinous zoop	0.21	-	0.13
57	Macrozoop	44.98	100.00	65.64
58	Mesozoop	32.33	-	20.19
59	Microzoop	-	-	-
60	Microflora	-	-	-
61	Phytoplankton	-	-	-
62	Discards	-	-	-
63	Detritus	-	-	-
64	Import	-	-	-
	Sum	100	100	100

Diet 1 and 2. Diet data for fish collected from USA fall (1) and spring (2) surveys in an overlapping portion of NAFO Division 4X for same time interval (Link and Almeida 2000, Smith and Link 2010).
Diet 4. Average of diets 1 and 2. Average diet is weighted by total stomach contents weight in samples.
Observation: 0.00 means that percent was lower than 0.01.

Table A4.24. Percent diet composition for 4X small-medium benthivores group.

	Prey/Predator	1	2	3	4	5	6	7	8	9
7	Cod <1	-	-	-	-	-	-	-	-	-
8	Cod 1-3	-	-	-	-	-	-	-	-	-
9	Cod 4-6	-	-	-	-	-	-	-	-	-
10	Cod 7+	-	-	-	-	-	-	-	-	-
11	S Hake <25	-	-	-	-	-	-	-	-	-
12	S Hake 25-30	-	-	-	-	-	-	-	-	-
13	S Hake 31+	-	-	-	-	-	-	-	-	-
14	Halibut <46	-	-	-	-	-	-	-	-	-
15	Halibut 46-81	-	-	-	-	-	-	-	-	-
16	Halibut 82+	-	-	-	-	-	-	-	-	-
17	Pollock <49	-	-	-	-	-	-	-	-	-
18	Pollock 49+	-	-	-	-	-	-	-	-	-
19	D piscivores <40	-	-	-	-	-	-	-	-	-
20	D piscivores 40+	-	-	-	-	-	-	-	-	-
21	L benth. <40	-	-	-	-	-	-	-	-	-
22	L bent. 40+	-	-	-	-	-	-	-	-	-
23	Skates <49	-	-	-	-	-	-	-	-	-
24	Skates 49+	-	-	-	-	-	-	-	-	-
25	Dogfish <73	-	-	-	-	-	-	-	-	-
26	Dogfish 73+	-	-	-	-	-	-	-	-	-
27	Redfish <22	-	-	-	-	-	-	-	-	-
28	Redfish 22+	-	-	-	-	-	-	-	-	-
29	A plaice <26	-	-	-	-	-	-	-	1.03	0.30
30	A plaice 26+	-	-	-	-	-	-	-	-	-
31	Flounders <30	-	-	-	-	-	-	-	1.03	0.30
32	Flounders 30+	-	-	-	-	-	-	-	-	-
33	Haddock <3	-	-	-	-	-	-	-	-	-
34	Haddock 3+	-	-	-	-	-	-	-	-	-
35	L sculpin <25	-	-	-	-	-	-	-	-	-
36	L sculpin 25+	-	-	-	-	-	-	-	-	-
37	Herring <4	-	-	-	-	-	-	-	-	-
38	Herring 4+	-	-	-	-	-	-	-	-	-
39	Other pelagic	-	-	-	-	-	-	-	-	-
40	Mackerel	-	-	-	-	-	-	-	-	-
41	Mesopelagic	-	-	-	-	-	-	-	-	-
42	S-m benthivores	1.87	0.50	-	-	-	-	-	-	0.26
43	Squids	-	-	-	-	-	-	-	-	-
44	Lobster	-	-	-	-	-	-	-	-	-
45	Large crabs	-	-	-	-	-	-	-	63.95	18.97
46	Small crabs	-	-	-	-	-	1.90	-	-	0.24
47	Shrimps	27.01	-	2.82	-	-	1.90	71.10	18.06	19.81
48	Scallop	-	-	-	-	-	-	-	-	-
49	Bivalves	-	-	-	1.04	12.94	-	-	2.32	2.29
50	Other molluscs	-	-	-	-	-	-	-	4.63	1.37
51	Other arthropoda	-	0.96	0.68	1.78	27.06	96.21	12.04	0.68	17.68
52	Echinoderms	-	-	-	-	-	-	-	5.69	1.69
53	S. benthic groups	-	-	-	-	-	-	-	1.25	0.37
54	Worms	-	-	0.39	97.19	60.00	-	16.86	1.37	14.01
55	Meiofauna	-	-	-	-	-	-	-	-	-
56	Gelatinous zoop	-	-	-	-	-	-	-	-	-
57	Macrozoop	69.88	92.59	96.12	-	-	-	-	-	22.15
58	Mesozoop	1.24	5.95	-	-	-	-	-	-	0.70
59	Microzoop	-	-	-	-	-	-	-	-	-
60	Microflora	-	-	-	-	-	-	-	-	-
61	Phytoplankton	-	-	-	-	-	-	-	-	-
62	Discards	-	-	-	-	-	-	-	-	-
63	Detritus	-	-	-	-	-	-	-	-	-
64	Import	-	-	-	-	-	-	-	-	-
	Sum	100	100	100	100	100	100	100	100	100
	Sample numbers	21	17	10	7	22	23	28	54	182

Diet 1. Average summer diet for longfin hake and and marlin-spike grenadier derived from NAFO Division 4X from 1999 and 2008 (no data for 2003-04) data (Cook and Bundy 2010, Laurinolli et al. 2004).

Diets 2 and 8. Based on data reported by Bowman et al. (2000) (Tables A-5, A-6, A-8, A-9, B-36 and B-46). This database includes samples collected in both Canadian and US waters. (2) longfin hake; (3) marling-spike grenadier; (4) fourbeard rockling; (5) hooker sculpin; (6) alligator-fish; (7) mailed sculpin; (8) cunner.

Diet 9. Average of diets 1 to 8, weighted by sample numbers.

Observation: 0.00 means that percent was lower than 0.01.

Appendix 5.

Commercial landings data by area and species were extracted from the Virtual Data Centre (Fisheries and Oceans Canada, Population Ecology Division database). Extraction of the data for NAFO Division 4X was straightforward since the landings data have been recorded at this scale since the 1950s. However, extracting the landings data for the western Scotian Shelf and the Bay of Fundy was more problematic since the data are not recorded at this spatial scale: instead the 4X landings data had to be separated into the BoF and WSS on the basis of positional information, which varies over time. There are 3 classes of landings information available: (1) between 1968 and 1985 landings at the NAFO sub-division levels are available only for the main commercial species; (2) since 1986 landings are available at the NAFO sub-division level for all species and (3) since 1991 latitude and longitude data are available for most, though not all, fisheries, but only the period after 1996 was considered here appropriate for the allocation of landings to the different areas modelled because of the low proportion of fishing trips with latitude and longitude information in the beginning of the series. Even in the most recent period there are still some years/species with a relatively high proportion of landings being allocated to the 4Xu (unidentified) subdivision (Table A.5.1).

Table A.5.1. Percentage of total 4X landings for selected species reported as 4Xu (unidentified) subdivision.

Year/Group	1	2	3	4t	5	6	7	8	9	10	11	12
1986	21.4	24.6	10.6	17.3	11.9	19.0	35.3	14.8	-	13.0	-	61.8
1987	26.4	31.1	22.8	22.9	24.1	30.5	30.1	36.3	0.4	15.0	10.6	73.7
1988	38.2	48.1	53.2	33.4	30.0	51.8	41.8	17.2	-	22.3	-	61.8
1989	26.3	23.6	68.3	34.4	15.3	22.1	28.1	2.1	1.8	13.4	-	51.5
1990	22.7	23.0	68.9	31.4	26.0	25.7	25.5	-	8.4	18.6	59.3	54.0
1991	8.1	10.0	47.9	20.1	1.0	2.1	19.8	87.3	0.8	7.2	99.8	66.9
1992	11.0	20.6	6.7	19.4	0.5	0.5	31.5	90.4	4.6	6.9	99.0	41.8
1993	4.7	4.0	0.6	7.4	97.9	1.2	10.2	3.8	18.1	5.2	99.3	70.8
1994	11.9	11.1	0.8	28.9	0.3	0.5	30.3	2.1	38.2	11.0	91.9	68.6
1995	17.7	5.6	0.5	8.2	4.5	0.7	9.2	0.9	70.2	11.5	95.8	9.8
1996	6.6	4.4	0.6	9.9	4.6	1.6	9.6	2.0	21.9	3.5	93.0	0.2
1997	11.4	6.6	1.0	17.4	1.3	2.8	13.1	6.2	20.9	5.6	94.3	1.2
1998	4.8	2.0	0.1	9.2	-	3.4	3.9	4.3	8.1	1.9	0.1	0.8
1999	2.2	0.8	0.0	4.5	0.3	1.2	1.8	0.6	5.6	1.1	0.9	0.4
2000	2.6	1.3	0.1	4.3	0.0	1.0	2.3	2.7	7.2	1.4	15.4	0.3
2001	2.2	0.8	0.1	3.9	0.0	0.7	2.4	0.9	3.8	1.7	-	0.3
2002	2.1	1.0	0.0	3.6	0.0	1.3	2.9	14.8	4.6	1.0	-	0.4
2003	5.0	1.5	0.1	11.5	0.1	0.1	7.0	11.2	8.9	2.6	-	0.3
2004	5.7	2.1	0.1	14.8	0.4	1.6	7.8	5.9	21.9	2.4	-	0.3
2005	4.0	1.2	0.0	10.1	0.1	0.9	4.3	5.3	26.2	1.0	0.0	1.1
2006	6.1	2.4	0.2	7.9	0.2	0.6	4.9	0.1	15.9	1.5	0.0	3.1
2007	4.5	1.5	0.5	6.5	0.1	0.5	4.9	6.9	14.2	1.3	-	2.3
2008	4.9	2.2	0.3	10.2	0.4	1.3	4.8	4.7	17.2	1.3	0.0	4.2

1. Cod; 2. Haddock; 3. Redfish; 4. Halibut; 5. American plaice; 6. Flounders; 7. Demersal piscivores; 8. Skates; 9. Dogfish; 10. Pollock; 11. Silver hake; 12. Herring.

Considering the 3 classes of landings described above, the allocation of the data to the BoF and WSS areas was peformed as follows:

1970-1985: Landings data at the NAFO sub-division level are available for the main commercial species (e.g. cod, haddock). In these cases the 4Xmnop and 4Xqrs5Yb landings for each year of the series were allocated to the WSS and BoF areas respectively. Species for which the landings data was not available at the NAFO sub-division level, the amount allocated to each system was based on the average WSS/4X and BoF/4X landings ratios as estimated in the period 1986-2008.

1986-1995: The amount of landings allocated to each system was based on the average ratios estimated in the period 1996-2008. For example the amount of the large pelagic fish caught in the portion of 4Xn subdivision that is inside the WSS shelf polygon was estimated as the total landings of 4Xn in a given year times the average 4Xn_WSS/$4Xn_p$ landings ratio for the period 1996-2008, where 4Xn_WSS represents the portion of 4Xn that is inside (on the continental shelf) the WSS polygon and $4Xn_p$ the amount of 4Xn landings with latitude and longitude information.

1996-2008: The amount of landings allocated to each system was based on the ratios estimated for a given year. For example the amount of 4Xn_WSS landings in 1996 was estimated as the total landings of 4Xn times the 4Xn_WSS/$4Xn_p$ ratio in the same year. In these years the proportion of fishing trips with latitude and longitude information in a given subdivision is generraly very high.

In all 3 cases described above, the allocation of the 4Xu (unidentified) between the WSS and BoF was based on the estimated ratios 4Xmnop/4X and 4Xqrs5Yb/4X. One exception for this was cod, a species for which the partition of 4Xu landings between the BoF and WSS systems has been reported in the stock assessment report (Clark and Emberley 2009; Table 3)