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Abstract

End-to-end models are important tools when moving towards an ecosystem based approach to fisheries management. Atlantis is one such end-to-end model. Atlantis has been developed for several areas, including Australia, U.S., and European waters, and models for other areas are under development, The models give unique opportunities to explore spatial impact of climate and fisheries, and includes all levels from physical forcing to top predators in the system, including bacteria, phytoplankton, zooplankton, fish, benthos and marine mammals. Atlantis for the Nordic and Barents Seas (NoBa) has been built with the aim of representing the key species and processes in the areas, where the main objective is to explore combined climate and fisheries scenarios. In setting up the model several thousand parameters need to be defined This report provides an overview and explanations of key parameters used to initialize the model.

1 Introduction

Atlantis is a marine ecosystem model that considers not only biophysical interactions but also economic and social aspects (Fulton et al., 2004; Fulton et al. 2007). Developed in Australia, it is now being used in several other ecosystems of the world, e.g. the California Current System, the Gulf of Maine/Middle Atlantic Bight, the Gulf of California, etc. (see Fulton et al., 2011 for a complete list). It was decided to develop an Atlantis model for the Nordic and Barents Seas and the model was set up and tuned through two projects funded by the Norwegian Research Council – MENUII and @ECO. The main objective of introducing such a complex model at the Institute of Marine Research was the increasing demand of applying ecosystem-based approaches to management and also being able to evaluate the combined effects of fisheries and climate. For both the Barents Sea and the Norwegian Sea, there are white papers on introducing ecosystem-based approaches to management (St.Meld. 20 (2014–2015), St.meld. nr. 37 (2008-2009)). Nevertheless, fisheries management is still mainly based on a single species approach, although ecosystem considerations are taken into account in a large part of the advisory processes. While it is clear that Atlantis cannot, and will never, be used for setting quotas (Link et al., 2010), it is rated as one of the best “what if” scenario models in the world (Plagányi, 2007).

Here, we present the parameters used in the Nordic and Barents Seas Atlantis (NoBa; Figure 1), citations to where they were initially found and (if needed) how they were tuned. Figures of biomass levels and horizontal distributions are presented in Appendix I and II, respectively. NoBa is the first Atlantis model to be set up for high-latitude ecosystems, with large seasonal variance in light and sea-ice. The ice-module is still under development at CSIRO, and is not implemented in the version of the model discussed within this document.

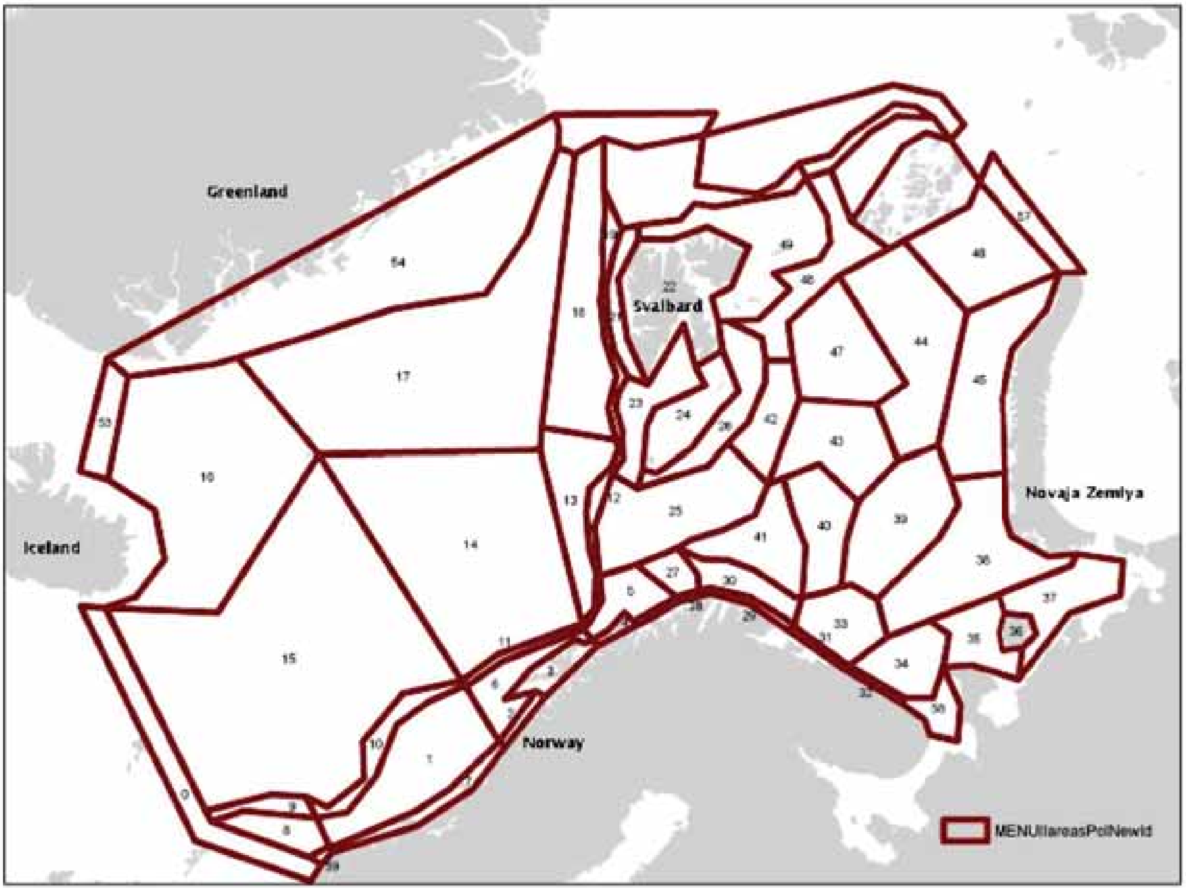

Figure. 1: Overview of the NoBa polygons covering the model domain.

As with all Atlantis models, NoBa is a spatial box model, covering the area shown in Fig. 1. The spatial domain of NoBa covers the Nordic Seas (Norwegian, Greenland and Iceland seas) and the Barents Sea. The total area is 4 million km^2 divided into 60 polygons (Fig. 1). The polygons were decided upon by a group of experts covering fields such as oceanography, demersal fish, pelagic fish, benthos and marine mammals. We tried to create polygons which were relatively homogenous with respect to hydrography and bathymetry, as these are important features determining the distribution of biota in the Barents Sea. The boundaries of the model are in large part defined by “natural” boundaries, such as land and topography. There is somewhat higher resolution in the Barents Sea, as this was intended as the main focus area for both Menu II and @ECO. Each polygon has up to seven depth levels, depending on their total depth. The depths of the vertical layers are 0-50 m, 50-150 m, 150-250 m, 250-375 m, 375-500 m, 500-1000 m and 1000-1200 m. If the mean depth of the polygon is more than 1200 m, the lowest depth level will stretch to the bottom. The model tracks nitrate and silicate, and is a deterministic end-to-end model (Fulton et al., 2007). The concept of an end-to-end model is that it includes modules for biology, harvesting, economy, management and assessment.

The vertebrate components in the model can have up to 10 age classes, with minimum 1 year represented in each class. Currently, the code can only use age-classes representing whole years (e.g., 1,2,5 etc). This implies that vertebrates that has a longevity of 25 years, have to be represented by age classes of 3 years. The invertebrates are not divided into age classes, but two of the invertebrate groups in NoBa (shrimp and squid) are divided into juveniles and adults. Atlantis does not include larval stages; the ‘recruits’ discussed in the following sections represent the youngest part of age class 1. All components in NoBa are connected through a diet matrix, where the fraction of prey available for the predator is defined. If there is lack of spatial and or temporal overlap between a component and its favorite prey, they switch to another available prey. The predators can only eat the specified prey if the prey size is within the gape size limit defined in the model. Gape size is a fraction of how large the prey can be compared to the body size of the predator. The time of day the predators feed is also defined for vertebrates and some invertebrate components. This indicates whether the predator feeds at night, day or does not have a preference for when it feeds. However, there is a loop that ensures that they eat each day, also during wintertime and summertime with either 24 hours darkness or 24 hours of sunlight.

All vertebrates, and also the invertebrates that are divided into juvenile and adult group have a length-weight relationship of the form:

$$W = a \times L^b$$

where W is the weight, L is the length and a and b are species or group dependent parameters (Hile, 1936; Martin, 1949).

The mortality in Atlantis is divided in two or three sources, depending on whether the harvesting module is used. If the harvest module is active, there is fisheries mortality in addition to natural and predation mortality. The natural mortality (as also seen in the sections below) is very low, and accounts for mortality due to age and illness. Predation, which is usually the largest contribution to natural mortality, is treated separately within Atlantis models. Due to the very low levels of natural mortality, the mortality levels found in literature are not feasible for the model. Therefore, the parameter values used in NoBa are based upon tuning to avoid extinctions and obtain reasonable estimates of abundances in comparisons to observed values. There are also additional terms of mortality connected to starvation, oxygen limitation and ocean acidification. In NoBa, we use a mortality of 0.0001 d^{-1} for starvation mortality. In the NoBa area, mortality due to oxygen limitation is rather unlikely, hence the parameter values are not used. In the ocean acidification simulations that have been performed with NoBa, we have chosen to perturb the natural mortality rates, and not used the option for additional mortality.

There are several options for recruitment in the model. In NoBa we define a Beverton-Holt relationship for most fish-species, except capelin and polar cod, which have a Beverton-Holt relationship with log-normal variation added. The Norwegian Spring Spawning herring uses a standard Beverton-Holt, but with the possibility of very strong year classes. For the recruitment of mammals, each adult is assumed to have a fixed number of pups/calves. Recruitment and recruitment success of most stocks are uncertain and difficult to estimate, therefore these are estimated in the model in order to achieve realistic abundance levels for the different stocks, and to a lesser degree are based on literature values.

The model is initiated at early 1980s levels, as the physical forcing is available from 1980. Atlantis needs time series of temperature, salinity and volume fluxes across the polygon borders (at all levels), and NoBa gets these from a Regional ocean modeling system (ROMS; Shchepetkin and McWilliams, 2005) covering the Northeast Atlantic (Skogen et al, 2007). However, for species or groups (hereafter components) where little or no information on abundance and weights could be found for this period, we use average values over the period 1993-2002. This particular period is chosen as information on weights and abundances are present for all the commercial fish species which lack information from the early 1980s. This way, the information given to the model is as consistent as possible. Below, we present information on each of the 53 components included in the model, and their sources.

2 Model – groups and parameters

2.1 Creating netcdf files for Atlantis

Atlantis simulates the flow of nitrogen through trophic levels across time and space. When initialized, the model needs nitrogen concentrations (mgN m^{-3}) for each component. The concentrations are rough estimates, calculated from approximate horizontal distributions and total biomasses. For the vertebrates, the model relies upon estimates of abundance and weights. The invertebrate biomasses stabilize within a few years of the simulations. The weights are defined in terms of N concentrations, whereas numbers are defined only for the components which are added as vertebrates. Weights are divided into structural and reserve weights, this enables tracking the length and condition separately, as structural weight represents bone weight and reserve weight represents soft-tissue weight. The fraction of each component in the respective polygons is defined using the best current knowledge on species distributions and migration patterns.

The C:N ratio (5.7) and the dry-weight to wet weight (20) are based on analyses by Beth Fulton (pers.comm). These values deviate from those observed in northern areas, where the C:N ratio has been measured being closer to 9 (Körtzinger et al. 2001). However, as these values are, in addition to being set in the parameter files, hard-coded into the model (dry-weigth to wet-weight), it was recommended not to change them. We have run the model with different values for the C:N ratio, and it does not significantly influence the results that we get. The dry weight-to-wet weight parameter will change a lot between the different species.

2.2 Biological components in NoBa, references, use and abbreviations

Due to the amount of parameterization required for each component, it is recommended to keep the number of components as low as possible (Beth Fulton, pers. comm.). To represent the ecosystems in the Nordic and Barents seas, 53 components are chosen. The components included in the model and their abbreviations are presented in Table 1.

Table 1: Abbreviations and names of the groups included in the NoBa model. The third column presents either the species included in the group, or which species the group is parameterized as, the fourth column specifies if the species is migratory, and the fifth column specifies if they care for their young. The Latin names of the species are provided in the sub-sections below.

Full name	**Abbreviation**	**Species included**	**Migratory**	**Care for young**
Polar Bear	POB		No	Yes
Killer whale	KWH		No	Yes
Sperm whale	SWH		Yes	Yes
Humpback whale	HWH		Yes	Yes
Minke whale	MWH		Yes	Yes
Fin whale	FWH		Yes	Yes
Bearded seal	BES		No	No
Harp seal	HAS		No	No
Hooded seal	HOS		Yes	No
Ringed seal	RIS		No	No
Arctic sea birds	SBA		No	No
Boreal sea birds	SBB		No	No
Sharks, other	SHO	Picked dogfish, Porbeagle, Tope shark	No	No
Demersals, other	DEO	Ling, Tusk	No	No
Pelagic large	PEL	Atlantic salmon	Yes	No
Pelagic small	PES	Lumpfish, Norway pout	No	No
Redfish, other	REO	Golden redfish	No	No
Demersal, large	DEL	Monkfish, Atlantic halibut, Atlantic wolffish, northern wolffish, spotted wolffish	No	No
Flatfish, other	FLA	European plaice, common dab, winter flounder	No	No
Long rough dab	LRD		No	No
Skates and rays	SSK	Arctic skate, starry ray, sailray, longnosed skate, thornback ray, round skate, spinytail skate	No	No
Mesopelagic fish	MES	Silvery lightfish, glacier lantern fish	No	No
Greenland halibut	GRH		No	No
Mackerel	MAC		Yes	No
Haddock	HAD		No	No
Saithe	SAI		No	No
Redfish	RED		No	No
Blue whiting	BWH		Yes	No
Norwegian Spring Spawning herring	SSH		No	No
Northeast arctic cod	NCO		No	No
Polar cod	PCO		No	No

Table 1 cont.

Full name	Abbreviation	Species included	Migratory	Care for young
Capelin	CAP		No	No
Prawn	PWN	Pandalus borealis	No	No
Cephalopods	CEP	Gonatus fabricii	No	No
Red king crab	KCR		No	No
Snow crab	SCR		No	No
Gelatineous zooplankton	ZG	Aurelia aurita, cyanea capillata	No	No
Large zooplankton	ZL	Thysanoessa inermis	No	No
Medium zooplankton	ZM	Parameterized as Calanus finmarchicus	Yes, due to overwintering	No
Small zooplankton	ZS	Small copepods, oncaea, pseudocalanus, (Oithona similis)	No	No
Dinoflagellates	DF		No	No
Small phytoplankton	PS	Flagellates	No	No
Large phytoplankton	PL	Diatoms	No	No
Predatory benthos	BC	Echinoderms, sea urchins, annelids and anemones	No	No
Detrivore benthos	BD	Selected annelids, echinoderms	No	No
Benthic filter feeders	BFF	Selected molluscs, barnacles, moss animals, anemones (Tridonta borealis)	No	No
Sponges	SPO	Geodia baretti	No	No
Corals	COR	Lophelia pertusa	No	No
Pelagic bacteria	PB		No	No
Benthic bacteria	BB		No	No
Refractory detritus	DR		No	No
Carrion	DC		No	No
Labile detritus	DL		No	No

2.2.2 Bacteria

Bacteria tend to reach equilibrium in a couple of time-steps in Atlantis models (Beth Fulton, pers. comm.), and hence we only need a reasonable estimate for their biomass as an initial value. As a rough estimate for the biomass, we use the value from Wassmann et al. (2006) of 7.5 mgC m^{-3}, which we then integrate over the mean depth of the Barents Sea (230 m) and multiply by the entire model grid area (about 4 million km^2). Pelagic and benthic bacteria have equal initialization estimates. The growht rate can be found in Table 3.

2.2.3 Detritus

NoBa is initiated with a value of 60 million tons for each of the three detritus groups (Table 1). The parameters are defined as in the SE-Australian Atlantis model (Fulton et al., 2004).

2.2.4 Dinoflagellates

The most important dinoflagellate species in the Norwegian Sea is the *Ceratium spp.* (Rey et al., 2004), represented by three species, *C. arcticum, C. longipes and C. tripos*. A rough estimate of the biomass of this group is based on Wassmann et al. (2006). Although they occur in highest concentrations in the photic zone, they can occur in the water column and their maximum depth is taken to be 5000 m. These are all autotrophs (photosynthesizers). A growth rate of dinoflagellates in the central Barents Sea during spring bloom has been measured to be 0.39 d^{-1} (Hansen and Østerhus, 2000), which is used as the initial value for NoBa. However, to avoid collapse of the dinoflagellates, the growth rate has to be increased to 1.0 d^{-1} (Table 3). No information on irradiance levels for dinoflagellates in the Norwegian Sea or Barents Sea is available hence we use those from the SE-Australia Atlantis. In a study by Killberg-Thoreson et al. (2014), the authors found that the half saturation levels varied between 4.2-24.9 mgN m^{-3}. In NoBa, we chose to use a rate in the lower part of this range, 7.5 mgN m^{-3}. Clearance rate ranges from 0.05 to 0.3 mgN d^{-1} (Pahlow and Prowe, 2010) and is set to 0.15 mgN d^{-1} in NoBa (Table 4). The lowest food concentration is defined to be 0.75 mgN m^{-3}. There is no information on assimilation efficiency for dinoflagellates in our area, therefore we again use parameters from the SE-Australia Atlantis model. The range for lysis varies from 0.01-0.4 d^{-1} (Garcés and Masó, 2001); in NoBa this is initialized at 0.2 d^{-1}.

2.2.5 Flagellates

In NoBa, the flagellates include *Phaeocystis pouchetii* and *Emiliania huxleyii.* The total flagellate biomass is estimated based on information in Wassmann et al. (2006). Initially, we used the growth rate applied in the NORWECOM model (0.88 d^{-1} ; Skogen and Søiland, 1998). Due to resulting low growth, it was increased to 1.47 d^{-1} (Table 3). The light saturation levels for flagellates is taken from the Australian values, as no local information could be found. The half saturation for nitrogen is initialized at 1.5 mgN m^3. No information on lysis is available, hence this is again taken from the SE-Australia Atlantis model. The mortality rate is $3.5e^{-5}d^{-1}$.

2.2.6 Diatoms

The total biomass of diatoms is calculated based on information in Wassmann et al. (2006) Growth rate (Table 3), mortality rate and half saturation are available from the NORWECOM model (Skogen and Søiland, 1998). Their mortality rate is $7e^{-4}d^{-1}$. The light saturation is taken from the SE-Australia Atlantis model, as is lysis (Fulton et al., 2004).

2.2.7 Filter feeders

According to Wassmann et al. (2006), *Tridonta borealis* is among the dominant benthic taxa in terms of biomass in the Barents Sea, hence the parameterization for the filter feeders in NoBa is based on this species. The total biomass of the filter feeders is from Dommasnes et al. (2001). It is assumed that the filter feeders follow a Holling type 2 functional response and have no diel variation in filtration rate. Their maximum depth is set to 3300 m (Aldea et al., 2008). As filter feeders, it is assumed that they eat labile detritus, small and large phytoplankton and dinoflagellates. No information is available on their clearance rate, so it is chosen to match that in the SE-Australia Atlantis model (Table 4; Fulton et al., 2004). The same is the case for the growth rate (Table 3), lower threshold for feeding and half saturation.

2.2.8 Predatory benthos

The predatory benthos includes echinoderms, sea urchins, annelids and anemones. The biomass is calculated based on estimates by Dommasnes et al. (2001). These groups are underreported in the literature for our study area, and hence parameters related to bioturbation, bioirrigation, maximum biomass, growth rates and clearance rates are taken from the SE-Australia model (Fulton et al., 2004; for information on growth rate and consumption rate see Tables 3 and 4).

2.2.9 Deposit feeders

Deposit feeders include selected annelids and echinoderms. The biomass is calculated based on the estimates by Dommasnes et al. (2001). This component has the same challenge as the predatory benthos and hence many of the parameters related to the deposit feeders are taken from the SE-Australia Atlantis model. See Tables 3 and 4 for information on growth rate and consumption rate.

2.2.10 Corals

The coral component parameterization in the model is based upon *Lophelia pertusa* (Linnaeus, 1758), as most information could be found for this species. The biomass is calculated based on the estimates by Dommasnes et al. (2001). L. pertusa is a cold-water coral that can be found at deep waters around the North Atlantic between 140 and 190 m (Lindberg et al., 2007). They are slow growing, hence vulnerable to some fisheries, especially bottom trawling (Fosså et al., 2002). It is assumed that they eat both night and day, and feed on copepods, krill, and other particles that they can capture (Mortensen, 2001). Hence, in NoBa they are also allowed to feed on phytoplankton, small zooplankton and labile detritus. Growth rate and consumption rate are the same as in the SE-Australia model (Fulton et al., 2004).

2.2.11 Sponges

Sponges are parameterized based upon *Geodia baretti* (Bowerbank, 1858), as this species is one of the most common in our areas and are in some places found in large concentrations (Cárdenas et al., 2013). It is assumed that they have a mean concentration of 1.6 kg m^{-2}, and that they can reach a maximum size of 24 kg (http://www.seawater.no/fauna/porifera/barretti.html). They are able to grow densely, with reports from our areas of biomasses up to 5 kg m^{-2} (Kutti et al., 2013). Based on this, we apply a maximum filter feeder biomass of 45000 mgN m^{-2}. Sponges grow at great depths (8800 m) and their maximum depth is therefore set to 5000 m, the maximum depth found within the NoBa model domain. Their diet consists of small and meso-zooplankton, phytoplankton, bacteria and labile detritus (Tina Kutti, pers.comm.). Growth rate and consumption rate are as in the SE-Australia model (Fulton et al., 2004), information on these can be found in Tables 3 and 4.

2.2.12 Red king crab (*Paralithodes camtschaticus*, Tilenau 1815)

The estimate of total biomass of the red king crab in the Barents Sea is from Jan H. Sundet (2014). He estimates the total biomass in the Norwegian sector in 2010 to be about 3400 tons and assumes the Russian part of the king crab population to be about ten times that in Norwegian waters, giving a total of 37 400 tons. Presently, the king crab is modeled as a biomass pool, as for all invertebrates. Britayev et al. (2010) estimates that there are over 40 million individuals in the Barents Sea, with a horizontal distribution according to Sundet and Hjelset (2010). They prefer depths between 5 and 400 m (Anisimova et al. 2010; Sundet, 2014).

Red king crabs prey on scallops, starfish, sea urchins, blue mussels (Jørgensen and Primicerio, 2007), echinoderms, capelin, bivalves, sipunculids (worms), detritus, algae, polychaetes, foraminifers, gastropoda (slugs), bryozoa, crustacean and tunicata (Britayev et al., 2010). We assume that they only eat during the night time during the seasons with daylight. The upper and lower gape size for crustaceans are taken from the Australian Atlantis model, as is the lower threshold for feeding and half saturation. Their daily net consumption is between 8-19.6% of their weight (Britayev et al., 2010). This gives a clearance rate of 4.2 mg mgN^{-1}d^{-1} (Table 4) They have an assimiliation efficiency of roughly 0.05 (Zouh et al., 1998; Stevens and Lovrich 2014).

They mature at age 5 (Falk-Petersen et al., 2011). In NoBa, they have a growth rate of 0.01 mgN d^{-1}. This does not correspond well to the calculated growth rate (Table 3) based on information in Falk-Petersen et al (2011), of roughly 10 mgN d^{-1}. This is possibly caused by the red king crabs being implemented as a biomass pool. In the next version, the red king crabs will be implemented as a vertebrate, this way their recruitment, distributions and other key life parameters will be used differently. Their mortality rate in NoBa is 5.0e^{-9} d^{-1}.
Red king crab prefer temperatures between 2.3 and 6.8°C (http://eol.org/pages/342038/details).

2.2.13 Snow crab (*Chionoecetes opilio*, Fabricius, 1788)

The estimated total biomass and horizontal distribution of the snow crab in the Barents Sea is based on information from Carsten Hvingel (pers. comm.). The snow crab was first found in the Barents Sea at the Goose Bank in 1996 (Sundet, 2014). Although being an invertebrate, it is implemented as a vertebrate in the model. This provides more opportunities for e.g. its horizontal distribution, walking speed and recruitment. They are found between 50 and 1450 m depth (Dawe et al., 2002) and their vertical distribution in NoBa can be found in Table 2.

Their diet consists of crustaceans, polychaetes, echinoderms, gastropods., poriferans, ophiuroids and certain bivalve species (Kolts et al., 2013 and references therein). We also assume that they feed on detritus.

The longevity of snow crab is defined to be roughly 6 years in NoBa. Growth rates (Table 3) are calculated based upon their weight-at-age (Jan H. Sundet, pers. comm.) but had to be multiplied by a factor of 100 to reach reasonable weights within each age class (Tab. 3). We assume that this is explained by their implementation as vertebrates rather than invertebrates.

Clearance rates (Table 4) are calculated assuming that their stomach weighs roughly 10% of their body weight and that they have 80% fullness in their stomachs (Table 4).

No information about natural mortality of snow crabs can be found, hence this is tuned in the model to ensure the population level is close to that observed. NoBa is run with mortality levels of $5e^{-9}d^{-1}$ for both juveniles and adults.

The snow crab spawns in spring and after roughly 50 days we assume that the recruits enter NoBa over a time window of 30 days. The fraction of mature per age class is based on an educated guess, and can be found in Table 5.

Their geographic range in the Barents Sea is limited by their narrow temperature preference, -1 to 4˚C, with a maximum of 7˚C (Foyle et al., 1989). Although they can walk relatively long distances, their speed is relatively slow, which is defined to be 10 m h^{-1} in NoBa.

2.2.14 Zooplankton - General

Estimates of large, meso and small zooplankton biomass in the Norwegian Sea are collected from Skjoldal et al. (2004). These are based on several cruises performed during 1994. The size categories for these three groups of zooplankton come from those observations: < 1 mm, 1-2 mm and > 2 mm.

The biomass estimates for the different zooplankton components in the Barents Sea are computed from the values of dry weight biomass per meter squared integrated over the whole water column in 1994 as given in SJØMIL (http://poseidon.imr.no:8080/sjomil/). The values are then multiplied by the area of the Barents Sea, and a conversion rate between dry weight and nitrogen weight applied.

2.2.15 Small zooplankton

The small zooplankton group includes small copepods, cyclopoids, oncaea and *Pseudocalanus*. In general, the parameterization for the group is based upon *Oithona similis*, one of the more abundant species in northern waters. In the region, it is second to *C. finmarchicus* in numbers, but due to its small size it only makes up 0.2-5% of the total zooplankton biomass (Rey, 2004). The small zooplankton are most common in upper 50 m but *Microcalanus pusillus* are found at greater depths (Rey, 2004), hence the maximum depth is taken to be 3000 m. The vertical distribution can be found in Table 2.

Their diet consists of detritus, plants and animals (Rey, 2004) with a clearance rate of 0.22 mgN $animal^{-1}d^{-1}$ (Nakamura and Turner, 1997). However, 0.4 mgN $animal^{-1}d^{-1}$ (Table 4) is used to avoid starvation and extinction in the model. According to Bunker and Hirst (2004), a half saturation of 0.22 mgN m^{-3} is representative for this group. The small zooplankton group has no diel preference for feeding. A growth rate of 0.55 mg N d^{-1}(Nakamura and Turner, 1997) is too small so in NoBa it is 3.55 mgN d^{-1} (Table 3) to ensure that the biomass is within a reasonable range. The mortality rate is 0.0001 d^{-1}.

2.2.16 Mesozooplankton

Calanus finmarchicus is the dominant species in the mesozooplankton group based on biomass. Hence, the mesozooplankton group is parameterized according to this species. During summertime, mesozooplankton are usually present in the upper 200 m, with higher concentration in 0-100 m (Espen Bagøien, pers. comm.). The vertical distribution can be found in Table 2. They eat during the night having swum toward the surface where there are higher concentrations of phytoplankton, but at the same time there is a higher risk of being eaten.

Mesozooplankton feed on both flagellates and diatoms (Debes et al., 2008). Clearance rate (Table 4) is computed as a mean based on values in Debes et al. (2008), which gives a value of 0.41 mgN d^{-1}. The growth rate of 0.43 d^{-1} found by Samuelsen et al. (2009) is too high so is reduced to 0.10 d^{-1} (Table 3) to obtain biomass values in NoBa within the observed range. The mortality rate is 0.015 d^{-1}. q10 was selected to be 2.1 (Samuelsen et al., 2009). The half saturation for feeding is taken to be 3 mgC m^{-3} (Torgersen and Fiksen, 2004) and is converted to nitrogen (17 mgN m^{-3}) by using the Redfield ratio, and the lower threshold for feeding is 8 mgC m^{-3} (Heath et al., 2000), which in the model corresponds to a parameter value of 45.6 mgN m^{-3}. The assimilation efficiency is 0.24 (Corner et al., 1967).

During winter, they go into diapause, and overwinter at depths up to 3000 m, hence we use this as the maximum depth (Espen Bagøien, pers. comm.). The start day for spring migration to the surface is day 35 (Samuelsen et al., 2009). Around day 150 the first individuals start descending toward their overwintering depth (Samuelsen et al., 2009), the main migration occurs around July-August (Rey, 2004). Based on this information, the migration day is defined to be day 210 (late July/beginning of August). It is assumed that they leave/enter over a period of 20 days. According to Samuelsen et al. (2009), there is a mortality rate of 0.001 d^{-1} during diapause, hence it is assumed that 90% of the individuals enter the model again, and that there is no increase in biomass during diapause. Mesozooplankton overwinter in polygons outside of the shelf and the Barents Sea, as these are the only ones where the depth is sufficiently large for diapause.

2.2.17 Large zooplankton

The large zooplankton group parameterization is based on *Thysanoessa inermis* (Espen Strand, pers. comm.*)*, with a diet consisting only of phytoplankton (Dalpadado et al., 2008). During daytime, they spend most of the time at depths around 200-300 m., but swim towards the surface at night for feeding (Espen Bagøien, pers. comm.). Their vertical distribution can be found in Table 2. Their diet consists mainly of diatoms. The clearance rate (Table 4) given in Pinchuk and Hopcroft (2007) of 0.15 mgN m^{-3} is too low and is adjusted to 0.2 mgN m^{-3} to avoid over-predation. The growth rate (Table 3) is computed based on information from Pinchuk and Hopcroft (2007) to be 0.07 mm d^{-1} and on the assumption that they have a weight of roughly 1.08 mg mm^{-1} (Monica Martinussen, unpublished data). This gives a growth rate of 0.076 d^{-1}. The natural mortality rate is set very low, $8e^{-10}$, due to heavy predation by several predators. As explained in section 1, this mortality rate does not include predation, only loss by old age or other sources.

2.2.18 Gelatineous zooplankton

The biomass estimate for gelatinous zooplankton (jellyfish) is from Dalpadado et al. (1998) who provide estimates for the Nordic Seas based on several scientific surveys in 1994. In total, the biomass estimate is 11 million tons but with high uncertainty.

Jellyfish is parameterized based upon several different groups, with *Aurelia spp., Cyanea spp.* and *Mertensia* the most common (Aino Hosia, pers. comm.). In high- and mid-latitude areas, they have a seasonal bloom that reflects the seasonality in the phytoplankton in the area (Gibbons et al., 2009).

In NoBa, Holling type 1 functional response is used for jellyfish feeding (Hansson and Kjøboe, 2006). Clearance rates (Table 4) of 1.6 and 19.8 mgC d^{-1} have been reported for *A. aurita* and *Cyanea capillata*, respectively (Martinussen and Båmstedt, 1995). However, 19.8 mgC d^{-1} gives a converted ratio of 2.99 mgN d^{-1}, which has to be adjusted to 0.5 mgN d^{-1} to avoid over-predation by this group on e.g. fish larvae/recruits and to keep the biomass of the jellyfish within reasonable limits. The diet of the group is mesozooplankton, some krill, and fish eggs and larvae. Some species and younger ages eat micro-zooplankton (Aino Hosia, pers. comm.). Light conditions have no impact on their predation; hence we define no diel pattern in their foraging activity (Eiane et al., 1997). They are therefore equally vertically distributed both night and day, in the upper 120 m (www.sealifebase.ca), with a larger part toward the upper layers (Aino Hosia, pers.comm.). Their vertical distribution can be found in Table 2. In NoBa, this group has a growth rate (Table 3) of 0.0001 mgN d^{-1}. This a tuned value used with the main aim of stabilizing the group within reasonable limits.

Natural mortality is 0.001 d^{-1}.

2.2.19 Shrimp (*Pandalus borealis*, Krøyer 1838)

The shrimps are parameterized based upon *Pandalus borealis*, a representative group for the Barents Sea. The model is initialized with 1.6 million tons (wet weight), based on estimates from trawl catches in Dalpadado et al. (1998). *P. borealis* lives at 20-1000 m, but are common at 80-650 m (Gjøsæter, 2009). Their vertical distribution can be found in Table 2.

The prawn’s diet consists of copepods, worms and detritus among other things (Bergstrøm, 2000).

Their longevity is 8 years, and they start out as males. At age 4-7 years, they change sex from male to female (Pedersen et al., 2003). They grow approximately 4 mm per year (Aschan, 2000; Nilssen and Aschan, 2009) and gain around 1 g per mm growth (Skuladottir et al., 2007), which gives a daily growth rate of $2.14e^{-5}$ d^{-1}.

Unfortunately no information has been found on their clearance rates, but the assimilation efficiency is roughly 42% (Rouleau et al., 1992).

A natural mortality rate 1.64e^{-6} d^{-1} is applied in NoBa. As explained in the introduction, natural mortality in NoBa does not include predation, hence needs to be set very low.

P. borealis spawn in June-October (around Svalbard in May-June), and the eggs hatch in the spring the following year. Females often spend a year resting after spawning. Newly hatched larvae have a length of roughly 5 mm (Gjøsæter, 2009) and recruits weigh about 0.06 g. The larvae live in the pelagic realm for 11 months (Gjøsæter, 2009).

Shrimp prefer temperatures between -0.6 to 12.4°C (www.eol.org/pages/138602/details).

2.2.20 Squid (*Gonatus fabricii,* Lichtenstein, 1818)

The squid group is parameterized based upon data for *Gonatus fabricii* (Lichtenstein, 1881), as it is representative for the NoBa area. Dommasnes (2001) estimates a *Gonatus fabricii* biomass of 8.2 million tons, calculated from Figure 3 in Bjørke and Gjøsæter (1998). Dalpadado (1998) estimates a squid biomass of 4.1 million tons, but the estimates of Bjørke and Gjøsæter (2004) support the numbers given by Dommasnes and we therefore choose to initialize the model with 8.2 million tons. Based on information from www.sealifebase.ca, the *G. fabricii* are distributed vertically between 0 and 2700 m, however, the highest biomass is found in surface waters (0-30 m) (Dalpadado, 1998). The vertical distribution of squid can be found in Table 2.

Young squid eat amphipods, copepods, arrow worms, krill and shrimps, while older individuals prey on redfish, pearlside fry and other *Gonatus fabricii* (Bjørke and Gjøsæter, 2004). They do not feed while spawning (Bjørke and Gjøsæter, 2004).

The length-weight relationship (Eq. 1) is also given in Bjørke and Gjøsæter (2004) where a =0.912e^{-5} and b =2.99.

No information about clearance rate or growth rates can be found, therefore, in NoBa we use a growth rate of 0.24 mg N d-1 (Table 3), tuned such that the biomass stays within reasonable limits. The clearance rate used in NoBa is 0.0019 mgN d^{-1} (Table 4).

The natural mortality is 0.0047 e^{-10} for both juveniles and adults.

G. fabricii have a life span of 2 years (Bjørke and Gjøsæter, 2004) and we assume that they mature as 1-year olds. They spawn in early summer, and the total spawning may last for 5-7 months (Bjørke and Gjøsæter, 2004). A recruit is assumed to weigh 0.06 mgN.

2.2.21 Mesopelagic fish

In the mesopelagic fish group, species such as pearlside (*Maurolicus muelleri,* Cocco 1838) and glacier lanternfish (*Benthosema glaciale,* J. C. H. Reinhardt, 1837) are included. An initial biomass of 3.9 million tons (Dalpadado et al., 1998; Skjoldal et al., 2004) is used in NoBa, and their horizontal distribution is also defined based on findings in these papers. Mesopelagic fish live at 200-500 m depth along the continental shelf (but can be found in the depth range of 0-1524 m (www.fishbase.org), and make extensive vertical migration at night to feed on plankton and each other, before returning to greater depths during daytime (Salvanes., 2004). Their vertical distribution in the NoBa model is given in Table 2.

Their diet consists of diatoms, copepods, krill and other planktonic organisms (Salvanes, 2004).

A length-weight relationship (Eq. 1) for pearlside was found at www.fishbase.org with a=0.0016 and b=3.961. This relationship is used, together with estimates of length-at-age, to calculate the mean weight for each age-class. Lengths are based on those reported at www.fishbase.org. The abundance is calculated based on the total biomass value (3.9 million tons) and an estimated mean weight of each individual of 0.0012 kg.

Growth rates are initially calculated as the difference between each age-class in mgN d^{-1} (Table 3). However, this leads to too low biomasses and has to be adjusted to values 10 times higher. The same was the case of clearance rates (Table 4), which are calculated based on the assumption of 80% fullness in the stomach and that the stomach is about 10% of the total weight (Trond Kristiansen, pers. comm.).

The mortality rate it is set to $6.25e^{-20}d^{-1}$ and $1e^{-17}d^{-1}$ for juveniles and adults, respectively.

The mesopelagic fish mature at age 1 in NoBa, and are defined to be batch spawners from March to September (Salvanes, 2004). They release 200-500 eggs per batch. No information about feeding while spawning could be found for the relevant species but we assume in NoBa that they do feed. As a group, they start spawning around day 90 and that spawning continues for a maximum of 120 days. Within this period, portions of the population will spawn, but the whole population will finish spawning within 120 days. The time window before they become recruits is the same length as for capelin (120 days) and they enter the model over a period of 30 days. The number of recruits entering the area is set to $2.9e^{11}$, based on the abundance of adult fish and a rough estimation of the abundance and survival rate. The fraction of mature per age class is based on an educated guess and can be found in Table 5.

Their swimming speed is low, with a maximum of 540 m h^{-1} (Torgersen and Kaartvedt, 2001). Their temperature tolerance is between 5 and 15°C (Salvanes, 2004).

2.2.22 Small pelagics

The group includes lumpfish (*Cyclopterus lumpus,* Linnaeus 1758) and Norway pout (*Trisopterus esmarkii,* Nilsson 1855) and is based on the small pelagics group used in Dommasnes et al. (2001). Their biomass estimate of 140 000 tons is used. The horizontal distribution is based on information in Bakketeig et al. *(*2014) and includes the whole NoBa domain.

Lumpfish are benthopelagic with a depth range between 0-400 m, although they are usually found between 50 and 60 m (Blacker, 1983; Eriksen et al., 2014; Kennedy et al. (submitted)).

Their maximum length is taken to be 62 cm with a maximum weight of 9.5 kg. Lumpfish eat mainly jellyfish (Davenport, 1985; Bjelland, 2004), and can eat more than their bodyweight each day (Bjelland et al., 2004). It feeds while spawning (Mitamura et al., 2007).

Norway pout are also benthopelagic with a depth range between 30-300 m, but usually found between 100 and 200 m. Their longevity is about five years during which it can reach a maximum of 35 cm but 19 cm is more common. They feed on planktonic invertebrates, small fishes and eggs/larvae (www.fishbase.org).

As there are some differences in the vertical distribution of the lump sucker and the Norway pout, we assume a 0-500 m distribution for the group as a whole. A larger proportion of the group is placed in the upper two layers. The fraction of the species in each layer is given in Table 2.

The length-weight distribution for small pelagics is from Hedeholm et al. (2014), who found that a=2.019 and b=2.4755 in equation 1 for females and a=1.452 and b=2.4755 for males. This, in addition to the length-age distribution given in Albert et al. (2002) and the information about the amount of food that lumpfish can consume (Bjelland et al., 2004), are used to compute the clearance rate for the small pelagics (Table 4). A growth rate is calculated based on the amount of weight each individual needs to gain to reach the weight of the next age class within a given time window (Table 3). The assimilation efficiency is the same as for cod (0.8).

The mortality rate is $1.23e^{-10}$ and $5.21e^{-10}$ for juveniles and adults.

In the NoBa model, the small pelagics mature at 3-5 years. They spawn along the coast in spring, and it is assumed that the group as a whole spawns for two months (60 days). They enter the model domain as one-year olds, as the lumpfish do when they emigrate from the coastal macroalgae habitat and immigrate to the open ocean (Moring, 2001). No information about the total number of new recruits is available, therefore it is roughly estimated by assuming that 50% of the population is female, each with a mean weight of 2.5 kg, and 50% of these spawn successfully. Hence, $1.36e^{7}$ new recruits enter the model domain over a time window of 30 days. The fraction of mature is based on an educated guess and can be found in Table 5.

From information about their horizontal distribution (Bakketeig et al., 2014) in combination with their vertical distribution, we assume that they are fairly tolerant to temperature, between -1.9 to 17°C. However, their horizontal distribution when spawning indicates a spawning temperature tolerance of 4-10°C. Kennedy et al. (2014) found that female lumpfish could move with a speed up to 2042 m h^{-1}.

2.2.23 Large pelagics

The large pelagics group includes only Atlantic salmon (*Salmo salar,* Linnaeus 1758). An initial biomass of 4205 tons is used, calculated from the number of returning fish and a mean weight of 5 kg (ICES WGNAS, 2014). The Atlantic salmon has a depth range of 0-600 m (Audun Rikardsen, pers comm). Vertical distributions can be found in Table 2. Its horizontal distribution is based on Thorstad et al. (2011).

Juveniles feed on aquatic insects, molluscs, crustaceans and fish larvae, while adults feed on mesopelagic fish, blue whiting, mackerel, sand eels, herring, squid and crustaceans (Rikardsen and Dempson, 2011). Atlantic salmon do not feed while spawning.

Their maximum reported age is 13 years, with a maximum length of 150 cm for males and 120 cm for females, however, the average length is approximately 70-75 cm for second winter salmon (http://www.fisheries.noaa.gov/pr/species/fish/atlantic-salmon.html). Growth rates are calculated as the necessary weight gain (mgN d^{-1}) before moving onto the next age class. This had to be multiplied by a factor of four to reproduce weights in the range of those observed. From www.fishbase.org we have a length-weight relationship (Eq. 1) with a=0.0092 and b=3. Most die before they reach 13 years, hence we assume a longevity of 10 years.

With no available information on clearance rates, we assume 80% fullness in the stomach and the stomach being roughly 10% of the body weight to calculate a clearance rate.

The natural mortality is $8.22e^{-10}d^{-1}$ in NoBa for both juveniles and adults. There is a high mortality rate among the spawners,

At day 90, they leave the model domain for a period of 20 days to spawn. The second age class is the first to include mature fish. They spawn for a period of 30 days and the juveniles enter the model after one year over a time window of 30 days. The fraction of mature fish per age class listed in Table 5 is based on personal communication with V. Wennevik.

They have a swimming speed of 1681 m h^{-1} (Wienerroither et al., 2011). It is a temperate fish that prefers temperatures between 2-22°C (Todd et al., 2011; Rikardsen et al., 2008).

2.2.24 Sharks

This group is parameterized as Spurdog (*Squalus acanthias*, Linnaeus 1758). An initial biomass of 200 000 tons is used, 50% of what the whole ICES domain contains. Numbers of individuals per age class are estimated based on information of weight-at-age and total biomass.

Spurdogs are benthopelagic (www.fishbase.org) with a depth range of 0-1460 m. However, it is usually found between 10 and 200 m. The vertical distributions are given in Table 3. Horizontal distributions are based on information in Havforskningsrapporten (Bakketeig et al., 2013).

Spurdogs eat jellies, crabs, shrimps, polychaetes, squid and fish (herring, gadidae, small pelagics, flatfish, mackerel) and have no preference of time of day for feeding (Stehlik, 2007). The weight-at-age is a mean of the weight of females/males given in the WGEF report (2010).

A length-weight relationship following equation 1 was found at www.fishbase.org, with *a* = 0.00108 and *b*=3.301. The spurdog can reach up to 75 years old, but the expected longevity is around 25 years (Kjell Nedreaas, pers. comm.). Growth rates are calculated based on the amount of weight the individuals need to gain before moving up to the next age class (Table 3).

As no information can be found on their clearance rate, the assumption of 80% fullness in the stomach and that the stomach is roughly 10% of the total biomass is used to compute the rate (Table 4). Mortality rates for the spurdogs are $3.52e^{-09}$ to $5.74e^{-10}$ d^{-1}.

They mature at 12-15 years old (Bjelland, 2006), and have 2-16 pups (average 6-7) each. The fraction of mature per age class is based on ICES WGEF (2010), and can be seen in Table 5. This amounts to $2e^{5}$ recruits (WGEF, 2010). The gestation period is 18-22 months (Stehilk et al., 2007) and therefore it is expected that they feed during this period. The Irish Sea is considered an important region in which the spurdogs give birth during late autumn and early winter. Here it is assumed that mating and birth is in November-December over a time window of 30 days and the recruits enter the model domain over a time window of 30 days.

The horizontal distribution, in combination with information from www.fishbase.org, indicates a preferred temperature of 7-15°C. However, it has been reported that they can be found between 1 and 20°C. A preferred spawning temperature of 4-15°C is assumed. They have a relatively high swimming speed at 7.2 km h^{-1} (Domenici et al., 2004).

2.2.25 Other demersals

The species in this group include ling (*Molva molva*, Linnaeus 1758) and tusk (*Brosme brosme*, Linnaeus 1758). Blue ling is not included on advice from Kjell Nedreaas, Kristin Helle and Asbjørn Borge. The initial biomass for the group is estimated as in Dommasnes (2001) with 0.7 tons per km^2.

The vertical depth range of ling is between 60 and 1500 m (Bakketeig et al., 2011) and for tusk it is between 18-2000 m but they are usually found between 18-549 m (www.fisbase.org). Their vertical distributions can be found in Table 2. The horizontal distribution is based on information in Bakketeig et al. (2011).

The group feeds on amphipods, munida, right-eyed flounders (*pleuronectidae*), prawns, *sebastes spp*, and gadidae (haddock, cod and saithe) (Beck et al., 2011) and it is assumed they are actively feeding during daytime.

Weight-at-age is based on information in Bergstad et al. (1996) and a length-weight relationship following equation 1 was found at www.fishbase.org with *a*=0.0039 and *b*=3.074.

However, as this length-weight relationship does not fit with the information in Bergstad et al. (1996), it is adjusted to a=0.2 and b=3.1. Ling has a longevity of 25 years with an average length of 106 cm. A maximum length of 200 cm and 45 kg have been reported. Its depth range is between 60 and 1500 m (Bakketeig et al., 2011). Tusk has a longevity of 20 years with an average length of 50 cm, a maximum length of 120 cm and maximum weight of 30 kg (www.fishbase.org). Growth rates are the amount of weight they need to gain each day to reach the mean weight of the next ageclass within a time window (Table 3).

The clearance rate (Table 4) is calculated based on information in Bergstad et al. (1996). The model mortality rates are $4.37e^{-9}d^{-1}$ and $5.75e^{-10}d^{-1}$ for juveniles and adults, respectively.

The group matures at 3.5 years with spawning from April to July (Bakketeig et al., 2011), when they may can release up to 2 million eggs. It is assumed that the group spawns for 90 days and that the larval time is equal to that of other large demersals and cod, which is in NoBa 150 days. The recruits arrive in the model domain over a time window of 30 days. The number of recruits that enter the model is based on the assumption that 50% of the females spawn, which means that $1.4e^{7}$ recruits enter the model. The fraction of mature per age class is based on an educated guess and can be found in Table 5.

The group tolerates temperatures between 0 and 10°C (http://www.fao.org/fishery/species/2217/en). The preferred spawning temperature is between 1 and 10°C in the model. With no available information on their swimming speed, we assume it to be the same as for the North Atlantic cod (1.08 km h^{-1}).

2.2.26 Capelin (*Mallotus villosus*, Müller 1776)

Capelin is a pelagic, semelparous, planktivorous fish. The initial biomass is defined to represent that of the early 1980s (ICES AFWG, 2015), i.e. 5.7 million tons, and the horizontal distribution is based on Gjøsæter (1998) and Bakketeig et al. (2012). Capelin are found at depths between 0 and 725 m (www.fishbase.org) and their vertical distribution, as parametrized in the NoBa model, is given in Table 2.

Capelin feed on small, medium and large zooplankton in the model (Orlova et al., 2010) and although they may feed while spawning, the food is not digested (Harald Gjøsæter, pers. comm.). Therefore, capelin is parameterized as not feeding during spawning. The capelin eats mostly during daytime (Harald Gjøsæter, pers. comm.).

Length-weight numbers in NoBa represent those in 1984 (Sigurd Tjelmeland, pers. comm.) with a=0.00033 and b=3.98 in Eq. (1). As the capelin dies after spawning, their longevity is 5 years in the model. Growth rates (Table 3) are calculated as the weight gain necessary each day to reach the mean weight of the next ageclass within a given time window.

The clearance rate (Table 4) is computed based on the assumption that it eats roughly 0.06 of its bodyweight each day (Trond Kristiansen, pers. comm.). Half saturation for feeding is 0.2

of the zooplankton concentration (Huse et al., 2004), and it is assumed that it has the same assimilation efficiency as polar cod (Hop, 1994), 80% in NoBa.

The natural mortality is defined to be very low, 1.48e^{-18} d^{-1} and 1.10e^{-22} d^{-1} for juveniles and adults, respectively.

Capelin mature between two to five years of age and spawn in March-April (Sigurd Tjelmeland, pers. comm.). In NoBa, the spawning lasts for one month for the whole stock. The age of recruits is defined to be 350 days in NoBa and the recruits enter the model domain over a period of 30 days. The fraction of mature per age class is based on an educated guess and can be found in Table 5.

Capelin is a relatively slow swimmer with a maximum swimming speed of 702 m h^{-1}, calculated based on estimates of speeds in body lengths s^{-1} from Behrens et al. (2006) and estimates of body lengths from Gjøsæter (1998). It has a wide temperature tolerance, from -1.8 to 6.0°C.

2.2.27 Polar cod (*Boreogadus saida*, Lepechin 1774)

Polar cod is a small, pelagic planktivore. NoBa is initialized with 308 000 tons of polar cod (Bogstad et al. 2000), where the abundance is based on an assumption of mean weight per fish and the total biomass. Polar cod is usually found at depths down to 400 m (www.fishbase.org) and is not dependent on the demersal habitat. The vertical distribution, as parameterized in NoBa, can be found in Table 2. The horizontal distribution is from Bakketeig et al. (2012).

Polar cod do not feed while spawning (Hop et al., 1995); otherwise they usually feed during daytime predominantly on medium and large zooplankton.

Their longevity is defined to be 10 years. It is assumed that the length-weight relationship is similar to that of capelin with a=0.00033 and b=3.98 in Eq. 1. Weight per age class is based on information from Sigurd Tjelmeland (pers. comm.) and the growth rate (Table 3) was initially calculated as the daily increase in weight needed to achieve the weight of the next age class within one year. However, for the youngest age class this is not sufficient and it is increased from 0.3 to 1.0 mg N d^{-1}.

Clearance rate (Table 4) is based on the assumption that the stomach is roughly 10% of the total body weight, and that the stomach can have 80% fullness (Trond Kristiansen, pers. comm.). This is on the high side and is decreased by a factor of 10 to have individual weights within the range of those observed. Polar cod have an assimilation efficiency of 0.8 (Hop et al., 1997).

Their natural mortality is set low, 1.48e^{-13}d^{-1} and 5.48e^{-13}d^{-1} for the juveniles and adults, respectively.

Polar cod mature at 2-4 years old and spawn in winter, from December to March. The fraction of mature per age class is based on an educated guess and can be found in Table 5. It takes one year from spawning until the recruits enter the model, the latter being over a time window of 30 days because Atlantis does not include larvae.

Polar cod are slow swimmers. Their swimming speed is calculated based on information from Ware (1978) of swimming speeds of 1-2 body lengths s^{-1} and Wienerroither et al. (2011), where the mean length of Polar cod is calculated to be 11.5 cm. This gives a swimming speed of 621 m hr^{-1} in NoBa. Polar cod prefer cold waters, usually with temperatures <2 °C (Sigurd Tjelmeland, pers. comm.).

2.2.28 Northeast Arctic cod (*Gadus morhua,* Linnaeus 1758)

The Northeast Arctic cod in the Barents Sea is the largest cod stock in the world (Kjesbu et al., 2014). Their horizontal distribution is based on IMR (2011) and the initial biomass is from 1981, with roughly 1 020 000 tons in the Barents Sea. The abundance per age class is according to ICES AFWG (2010). Their depth range is 0-600 m, but they are usually found between 50-400 m (ICES AFWG, 2015) and the juveniles (<6 months) usually spend their time in the upper 50 m of the water column (Bjarte Bogstad, pers. comm.). Their vertical distribution can be found in Table 2.

Cod feed while spawning (Michalsen et al., 2008) and the maximum size of their prey is roughly 50% of predator length (Bjarte Bogstad, pers. comm.). They prey on *Euphausiidae, Hyperiidae,* prawns, cod (cannibalism), herring, capelin, haddock, polar cod, blue whiting, Greenland halibut, redfish, long rough dab (ICES, AFWG 2010) and squid (Bjørke, 2001). They also eat jellyfish and some detritus (Bjarte Bogstad, pers. comm.). Their assimilation efficiency is considered to be roughly 15% (Bogstad and Mehl, 1997), and the clearance rate is assumed to be 0.08% of their bodyweight.

Their longevity is assumed to be roughly 20 years, hence 2 years in each age class. Growth rates (Table 3) for all age classes are calculated based on the assumed growth moving from one age class to the next. The mean weight per age class is calculated based on information on mean weight per age for 1993-2002 (ICES AFWG, 2015). However, this did not induce sufficient growth of the cod compared to the average weights observed and therefore we increased the growth rate by a factor of 10 for the older age classes and by a factor of 20-40 for the younger age classes. The length-weight relationship with a=0.009, b=3 in Eq. 1 is from www.fishbase.org.

Clearance rates (Table 4) are calculated based on the assumption that the stomach is 10% of the bodyweight and has a fullness of 80%. This is, however, too high and has to be decreased by a factor of roughly 7. Their assimilation efficiency is considered to be roughly 15% (Bjarte Bogstad, pers. comm.).

Natural mortality is $1.48e^{-10}d^{-1}$ and $5.48e^{-9}d^{-1}$ for juveniles and adults, respectively.

In NoBa, the minimum size of spawning individuals is 60 cm, they start maturing at age 6, at age 7 50% of the age class is mature, and at age 9 100% is mature (Bjarte Bogstad, pers. comm.). An overview of the fraction of mature per age class can be found in Table 5. They spawn in March and April (Bakketeig et al., 2014) over a period of 60 days. The first recruits enter the model 150 days after they are hatched, over a time window of 30 days, since Atlantis does not include the larvae stage.

Cod in the Barents Sea have a fairly large temperature tolerance, -0.5 to 10°C (Bjarte Bogstad, pers. comm.) and are relatively fast swimmers with a swimming speed of roughly 2500 m h^{-1}, calculated from the assumption of a swimming speed of 1 body length per section.

2.2.29 Haddock (*Melongrammus aeglefinus*, Linnaeus 1758)

Haddock is a demersal piscivore, the initial biomass estimate of 185 000 tons is from the 1980s (Bogstad et al., 2000). The abundance is based on the ICES AFWG (2010). Haddock can be found between 10 and 450 m but usually stay within 10-200 m (www.fishbase.org). Their vertical distribution is given in Table 2. Horizontal distribution is based on Bakketeig et al. (2010).

Haddock prey on Euphausiidae, Hyperiidae, prawns, Echinodermata, Mollusca, polychaeta, cod, herring, capelin, haddock, long rough dab, (other fish and food) and fishery waste (ICES AFWG 2010) and they eat predominantly during the day (Dolgov, 1989).

Their longevity is set to 20 years, which is on the high side but is due to computational restraints in the model, which restricts us to include only whole years (hence, 1.5 could not be used) . The growth (Table 3) is calculated as that needed to increase from one age class to the next in mgN d^{-1}. However, the growth rate had to be increased by a factor of 10 to obtain appropriate individual weights within each age class. Their length-weight relationship is represented by a=0.012 and b=2.95 in Eq. 1 (Gjert Endre Dingsør, pers. comm.)

Haddock consume roughly 7% of their bodyweight each day (Dolgov, 1989) that together with information on weight per age class is used to calculate their clearance rate (Table 4). However, the clearance rate had to be decreased by a factor of 2-3 to limit the growth of the individual age classes.

The mortality rate for adults is $7.64e^{-11}d^{-1}$ and $3.48e^{-11}d^{-1}$ for adults and juveniles, respectively.

Haddock mature at 4-7 years age (Russkikh and Dingsør, 2011 and references therein). The fraction of mature per age class is based on ICES AFWG (2015) and can be found in Table 5. They spawn in February-June and can spawn up to 25 batches over a five week period (Russkikh and Dingsør, 2011). The recruits enter the model 90 days after spawning, over a time window of 30 days, and mainly in the uppermost 50 m. The initial number of recruits entering the model is $1.5e^9$ (Gjert Endre Dingsør, pers. comm.) based on estimates of the number 1-year olds.

Haddock has a fairly large temperature tolerance, although they prefer warmer waters than Northeast Arctic cod (2-10°C) and temperature at spawning is between 4 and 6 °C (Russkikh and Dingsør, 2011). It is assumed that they have a swimming speed of about 3600 m h^{-1}, based on the assumption that normal swimming speed is 1-2 body lengths s^{-1} (Gjert Endre Dingsør, pers. comm.) and an approximate mean length of 50 cm.

2.2.30 Skates and rays

The functional group skates and rays includes Arctic skate (*Amblyraja hyberborea*, (Collett, 1879)), starry ray (*Amblyraja radiata*, (Donovan, 1808)), sailray (*Rajella lintea*, (Fries, 1838)), thornback ray (*Raja clavata* (Linnaeus, 1758)), round skate (Rajella fyllae (Lütken, 1887)) and spinytail skate (*Bathyraja spinicauda* (Jensen, 1914)). The biomass estimate in NoBa is retrieved from ICES WGEF (2010) with a total of 106 000 tons. According to ICES WGEF (2010), there is a low abundance of young skates and rays hence we assume an abundance that takes this into consideration. The group is demersal with a depth range of 20 to 1000 m, however they are usually found at depths between 50-100 m (www.fishbase.org). Their vertical distributions can be found in Table 2. Within this group, *Amblyraja radiata* (Starry ray) is the dominant species, 96 % by number and 92 % by biomass (ICES WGEF 2010). The vertical distribution (Table 2) in NoBa is set according to ICES WGEF (2010).

Skates and rays feed on amphipods, decapods (with a large component of prawns), polychaetes, capelin, other fish, and euphausiids (Jaworski and Ragnarsson, 2006; Dolgov, 2005), and they feed actively during both day and night. They have a wide temperature tolerance, from at least -1.2°C (He., 2003) up to 8 °C (Wienerroither et al., 2011). No information about their swimming speed can be found, so we used that from the South-East Australian Atlantis model, i.e. 12500 m h^{-1}.

From www.fishbase.org, a length-weight relationship is found: a=0.157 and b=2.19. Compared to reported weights (Wienerroither et al., 2011), the weight gain from this relationship is too low, and therefore b is adjusted to 2.4. The growth rate (Table 3) is calculated as the difference in size (mg N d^{-1}) between the age-classes, however, this is increased by a factor of 2 to achieve close to observed individual weights for each age class. Longevity of roughly 15 years is assumed.

The clearance rate (Table 4) is calculated based on the length-age relationship in Gallagher et al. (2004), combined with the length-weight relationship (as given above) to compute the weight at different age classes. Thereafter, it is assumed that the fish has 80% fullness in the stomach and that the stomach is roughly 10% of its body mass weight (Trond Kristiansen, pers. comm.).

The natural mortality (www.fishbase.org) is $4.93e^{-10}$ d^{-1} for both adults and juveniles.

The group is egg-laying with generally low fecundity. They mature around 87.5 cm, which corresponds approximately to 5-6 years old (www.fishbase.org). In spring, females migrate to the coast to spawn, followed by males. The starry rays dispose 15-20 egg cases at a time, with a peak in March-August (Wienerroither et al., 2011). The eggs hatch after 16-20 weeks, and we assume that at day 140 after spawning the recruits begin to arrive and continue over a time window of 40 days. The initial number of recruits ($10.6e^{6}$) is based on the assumption that 50% are female where each recruit four juveniles every year. The fraction of mature per age class is based on an educated guess and can be found in Table 5.

2.2.31 Long rough dab (*Hippoglossoides platessoides,* Fabricius 1780)

The long rough dab is a demersal piscivore, and the initial biomass of 200 000 tons is based on Walsh (1996) and Wienerroither et al. (2011). Long rough dab are widely distributed but mainly boreal (Wienerroither et al., 2011) and are usually found at depths between 90-250 m (www.fishbase.org). The vertical distribution is given in Table 2.

Long rough dab prey on benthos (mollusca, echinodermata and polychaeta) but also on euphausiidae, hyperiidae, prawns, cod, herring, capelin, haddock and polar cod (ICES AFWG 2010). They eat while spawning and mainly feed during the day.

Longevity is assumed to be 20 years (Wienerroither et al., 2011). Growth rates (Table 3) are based on the combination of a length-weight relationship from www.fishbase.org (a=0.0044, b=3.204 in Eq. 1), and the length-at-age relationship given by Fossen et al. (1999). However, these are increased by a factor of approximately 10 to achieve reasonable weights-at-age. The preference for rebuilding reserves (4.5) is from Fossen et al. (1999).

Clearance rates (Table 4) calculated based on the assumption of 80% fullness of the stomach and a stomach that weighs 10% of the total body weight provide a value that is too high. The rates are decreased by a factor of 10 to avoid the biomass of age classes becoming too high.

Mortality rates are $9.10e^{-11}d^{-1}$ and $7.56e^{-11}d^{-1}$ for juveniles and adults, respectively.

The long rough dab matures at around 5 years (Wienerroither et al., 2011), and the fraction of mature per age class can be found in Table 5. Spawning starts in March, peaks in April-May and ends in July. The first larvae appear in May. The recruits enter the uppermost layer of the model over a time window of 60 days when they are 60 days old. The number of recruits is based on information on 0-group indices taken from the SJØMIL database (www.imr.no).

Long rough dab are rather slow swimmers with a swimming speed of 1080 m h^{-1} (Winger et al., 1999). They have a wide temperature tolerance, -1.8 °C to 7.2°C (Walsh, 1996), and prefer soft and sandy bottom (Wienerroither et al., 2011).

2.2.32 Other flatfish

The functional group 'Other flatfish' includes righteye flounders (*Pleuronectidae spp.*), turbots (*Scophthalmidae spp*) and true soles (*Soleidae spp*). We use the a biomass of roughly 75 000 tons (Skaret, pers comm). This estimate is at the same order as the biomass estimates in Wienerroither et al. (2011), which are mainly based on Russian data. The group is parameterized principally as European plaice (*Pleuronectes platessa, Linnaeus (1758)*), as this is the commercially most important species (Tore Jakobsen, pers. comm.). In addition to this, common dab (*Limanda limanda*, Gottsche (1835)) is another main species. Horizontal distribution of the group is based on Wienerroither et al. (2011). The flatfish are usually found between 0-250 m depth; however, the juveniles prefer shallower waters, around 0-10 m (Wienerroither et al., 2011). The vertical distributions of juveniles and adults can be found in Table 2.

Plaice do not feed while spawning (Kennedy et al., 2008), and are active at night as they spend the day buried in the sand (www.fishbase.org). Their main diet consists of annelids, bivalves, echinodermatas and crustaceans (sole) (Wienerroither et al., 2011).

European plaice grow fastest during their first 6 years and are usually <0.5 m, weigh 2-3 kg and have a longevity of approximately 15 years (Wienerroither et al., 2011). The weight-at-age from 5-14 years is calculated from Kuznetsova et al. (2004). A length-weight relationship (Eq. 1) is found at www.fishbase.org with a=0.0089 and b=3.053. The growth rate (Table 3) is initially calculated as the growth in mg N d^{-1} that they had to gain to move from one age class to the next, but is on the low side for the three youngest age classes, and so is increased roughly 10 times for these ages.

The clearance rate (Table 4) is calculated based on the assumption that the stomach has 80% fullness and that it is 10% of the total body weight.

The mortality is $1.60e^{-9}d^{-1}$ and $6.03e^{-10}d^{-1}$ for juveniles and adults, respectively.

The European plaice mature at ages 6-9 (males) and 9-11 (females) and spawn between January and July with a peak in March-May (Wienerroither et al., 2011). In NoBa, it is assumed that the population as a whole spawns for 60 days in NoBa. The larvae hatch after 20 days, and the mean larval duration is 33 days (Allen et al., 2008) before they enter the model over a time window of 30 days. As this is a functional group consisting of a large number of species, where little information could be found on the fraction of mature per age class, we defined a fraction based on information from other demersal components in the model (Table 5).

The flatfish are mainly boreal and prefer soft bottoms. The European plaice prefers temperatures between 1-3 °C (Wienerroither et al., 2011) but is found in temperatures between 1 and 15°C (www.fishbase.org).

2.2.33 Greenland halibut (*Reinhardtius hippoglossoides*, Walbaum 1792)

Greenland halibut is a benthopelagic fish found along the continental shelf break, along the Norwegian coast and in the Barents Sea. The initial total biomass of roughly 93 000 tons (1984) is based on ICES AFWG (2010) estimates, and the horizontal distribution is from Bakketeig et al. (2015). The abundance is based on information in ICES AFWG (2010). However, for the older age classes, there are no available estimates. Based on the assumption that the population usually decreases with age, we applied a 15 % decrease from the abundance in the previous age class (hence, age class nine has 15% lower abundance than age class eight). They are usually found at depths between 500 and 800 m (IMR, 2015). The vertical distribution can be found in Table 2 and is calculated based on information in Vollen and Alber (2008).

The adults eat while spawning (Michalsen and Nedreaas, 1998) and have a diet consisting of polychaeta, cephalopoda, crustaceans, asteroida, cod, herring, blue whiting, redfish (both *mentella* and *marinus*), Greenland halibut and squid (Bjørke, 2001; Michalsen and Nedreaas, 1998), with no preference (day/night) for feeding (Michalsen and Nedreaas, 1998).

Weight-at-age is based on ICES AFWG (2010) and is calculated as a mean over the period 1993-2002 (see introduction for explanation). Maximum age determination is uncertain (Wienerroither et. al., 2011, IMR 2014), but here a longevity of 20 years is assumed. There exists little information about the weight-at-age for the first four years hence we assume these values to be 0.1, 0.25, 0.35 and 0.55 kg, respectively. The length-weight relationship (Eq. 1) for Greenland halibut in the Bering Sea has a=0.0019 and b=3.367 (www.fishbase.org). Growth rates (Table 3) are calculated based on the weight (mg N d^{-1}) that needs to be gained to be the right size when moving one age class up. However, this does not fit for the older age classes, where the initial growth rates need to be increased by a factor of 20 to obtain weights similar to those reported.

The clearance rate (Table 4) is based on the assumption that the stomach is 80% full and that it weighs roughly 10% of the total body mass.

The mortality for juvenile and adult Greenland halibut is $1.09e^{-10}d^{-1}$ and $4.20e^{-9}d^{-1}$, respectively.

Greenland halibut mature at around 6 years (7 for females, 5 for males) (Wienerroither et al., 2011), and spawn in December-February. The fraction of mature per age class (Table 5) is based on ICES AFWG (2010). The population as a whole spawns for 90 days (IMR, 2006) in NoBa. The recruits enter the model after 270 days and over a time window of 30 days. The juveniles are usually found between 100-300 m (IMR, 2009).

There exists little information about swimming speed, other than that it is relatively fast for being a flatfish (Wienerroither et al., 2011). Hence, we assume a swimming speed of approximately 1-2 body lengths per second, which gives 3600 m h^{-1}. Greenland halibut is an Arctic fish, and is rarely found in waters warmer than 4°C (Wienerrother et al., 2011).

2.2.34 Other redfish (Golden redfish: *Sebastes norvegicus*, Ascanius, 1772)

Golden redfish is a long-lived species that does not go into the open ocean (Drevetnyak et al., 2011). The initial biomass estimate is based on Bogstad et al. (2000) of roughly 470 000 tons. Horizontal distribution is based on Bakketeig et al. (2010), whereas the abundance and weight at age is from ICES AFWG 2010. Their depth range (Table 2) is 100-1000 m, but they are usually found between 100-500 m (www.fishbase.org).

Golden redfish are believed to be planktivores (Bjelland et al., 2004) but adult fish are also known to consume fish (IMR, 2014; Wienerroither et al., 2011) in addition to larger plankton. In NoBa, we assume that they do not feed while spawning.

They have a longevity of about 40 years in the model. The growth rate (Table 3) is calculated based on the weight (mg N d^{-1}) that needs to be gained each day to gain the correct weight before moving to the next age group. Yet, this proves to be too low in the model and is increased by a factor of roughly 20 to avoid the youngest and oldest age classes being too small compared to observed values. The length-weight relationship (Eq. 1) with a=0.0196 and b=3.0 is from www.fishbase.org. However, as no information on weights is available for age 0-7, an increase of 20% from year to year for the two first age classes is assumed. For the other age classes, an average weight is calculated based on the period 1993-2002 (see introduction for explanation).

Clearance rates (Table 4) are calculated from an assumption of 80% fullness in the stomach and that the stomach is roughly 10% of the individual's biomass (Trond Kristiansen, pers. comm.).

The mortality rates used for juveniles and adults in the model are $2.05e^{-10}d^{-1}$ and $1.05e^{-10}d^{-1}$, respectively.

Golden redfish give birth to live fish (Drevetnyak et al., 2011). The spawning takes place in April-May, and they can release up to 360 000 larvae (Wienerroither et al., 2011) over a period from days to weeks (Planque and Nedreaas, 2011). The fraction of mature fish in each age class in NoBa is given in Table 5 and based on ICES AFWG (2015). The recruits enter the model 90 days after hatching, over a time window of 30 days.

The swimming speed is unknown, but they perform long range migration; northern Barents Sea to southern Barents Sea, roughly 1000 miles in two months. This gives a swimming speed of 13 000 m h^{-1} They are usually found in temperatures between -0.6 and 7.6°C (Drevetnyak et al., 2011, and references therein).

2.2.35 Redfish (Beaked redfish *Sebastes mentella*, Travin 1951)

The beaked redfish is a pelagic deepwater species which only exists in Atlantic waters (Benjamin Planque, pers. comm.). The initial biomass is based on estimates from ICES AFWG (2010), at roughly 320 000 tons. The horizontal distribution is taken from IMR (2011). Beaked redfish are usually found at depths between 300 and 500 m (Barents Sea) and along the slope at depths between 450 and 650 m (south of 70˚N) (Benjamin Planque, pers. comm.). Their vertical distribution in the model is listed in Table 2.

Beaked redfish prey on shrimp, small fish, plankton and squids (Wienerroither et al., 2011; IMR 2014). Their gape size is small, hence size of prey is about 1/10 of the length of the fish (Benjamin Planque, pers. comm.).

In NoBa, we have chosen a longevity of 40 years. Because it is a long-lived species, the growth rates (Table 3) are small and estimated based on the weight needed to be gained each day (mg N d-1) to gain the appropriate amount of weight before moving into the next age class. However, these did not fit all age classes, and were increased by a factor of 6 for age classes 1 and 2 and decreased by a factor of 4 for the older age classes. A length-weight relationship (Eq. 1) of a=0.061 and b=2.57 is used (Benjamin Planque, pers. comm.). Weight-at-age is based on Planque and Nedreaas (2011) and ICES AFWG (2010).

Consumption rate (Table 4) is calculated based on the assumption that the stomach has 80% fullness and that the stomach is 10% of the body mass. This fits fairly well but has to be decreased by roughly 20% for the oldest age classes.

The mortality for juveniles and adult beaked redfish in NoBa is $7.85e^{-11}d^{-1}$ and $8.15e^{-12}d^{-1}$, respectively.

Beaked redfish give birth to live fish, and there are large variations in the interannual number of recruits (Benjamin Planque, pers. comm.). They spawn in March-April and can release up to 150 000 larvae (Wienerroither et al., 2011) over a period of days to weeks (Planque and Nedreaas, 2011). The recruits enter the model 90 days after hatching, over a time window of 30 days. Beaked redfish mature at the age of eight years, and the fraction of mature fish for the early age classes is low (ICES AFWG, 2014). The fraction of mature fish per age class can be found in Table 5.

Beaked redfish prefer waters warmer than 2-4 C, and are tolerant in the upper part of the scale. Therefore, we apply a maximum temperature range of 30 C (Benjamin Planque, pers. comm.). The swimming speed is not known but as they have long range migrations, we set it at 12.5 km h^{-1}.

2.2.36 Norwegian Spring Spawning Herring (*Clupea harengus*, Linnaeus 1758)

Norwegian spring spawning (NSS) herring comprise one of the three largest pelagic fish stocks in the Norwegian Sea. The initial biomass estimate of 500 000 tons is based on Bogstad et al. (2000) for the Barents Sea and Holst et al. (2004) for the Norwegian Sea, and is representative of the early 1980s. The abundance estimates are based on ICES WGWIDE (2010). The horizontal distribution is as in IMR (2011). Herring have a depth range of 0-360 m (www.fishbase.org) and the vertical distribution is found in Table 2.

Herring do not eat while spawning (Nøttestad et al., 1996), but otherwise eat about 3% of their bodyweight each day (Kjell Rong Utne, pers. comm.). They can, however, feed during the night (Batty et al., 1986) but at much lower levels than during day time. Herring do not feed in wintertime (Kjell Rong Utne, pers. comm.). Their main prey are *Calanus spp*, krill and amphipods, but they also prey on larvae and fish eggs (Dalpadado et al., 2000 and references therein).

The longevity of the herring is taken to be 20 years in NoBa, while the maximum reported longevity is 25 years (IMR, 2014). A length-weight relationship (Eq. 1) is found at www.fishbase.org with a=0.0232 and b=2.81. The growth rate (Table 3) is defined as the weight a fish needs to gain per day to increase to the weight of the next age class. However, to achieve reasonable weight levels compared to observed weight-at-age, the calculated growth rate has to be multiplied by a factor of approximately 2. Weight-at-age is calculated based on ICES WGWIDE (2011).

The clearance rate (Table 4) is calculated using a consumption rate of 3% by weight per day and their weight-at-age.

The mortality rates in the model are $2.47e^{-13}d^{-1}$ and $2.11e^{-13}d^{-1}$ for juveniles and adults, respectively.

NSS herring spawn in February-March (IMR 2014) and NoBa assumes that the population as a whole spawns for 30 days. Depending on strong/weak year classes, the age of maturity varies between 3 and 9 (ICES WGWIDE, 2014). In NoBa, the maturity fraction for a normal age class is used (ICES WGWIDE, 2014), hence, the first mature age class is at 4 years and at 6 years all are mature. The fraction of mature per age class can be found in Table 5. The larval period lasts for about 120 days (Erling Kåre Stenevik, pers. comm.) before they enter the model over a time window of 30 days.

NSS herring can tolerate temperatures between 1-18°C (www.fishbase.org). In Røttingen and Røttingen (1991) and references therein, swimming speeds of between 2700 and 3100 m h^{-1} are reported. In NoBa we apply a swimming speed of 3000 m h^{-1}.

2.2.37 Blue whiting (*Micromesistius poutassou,* A. Risso 1827)

Blue whiting is another of the three large pelagic stocks in the Norwegian Sea. The total biomass estimate of 1.2 million tons (Monstad, 2004) is adjusted to only include those in the Nordic Seas. We use the same approach as in Dommasnes (2001), where the author considers that roughly 50% of the biomass in the North Atlantic is within our model domain. The abundance estimate is based on information from ICES WGWIDE (2010). The horizontal distribution is from IMR (2011). Blue whiting is observed down to 900 m, however, it is usually found between 100-600 m (IMR 2014). The vertical distribution of blue whiting in NoBa is found in Table 2.

Blue whiting is a planktivore as larvae and juveniles but later switches to a diet of krill, mesopelagic fish, cephalopods, polar cod (young), capelin and redfish (Monstad, 2004; Wienerroither et al., 2011), and, in addition, young herring (Dolgov et al., 2010). They eat approximately 3% of their bodyweight each day (Kjell Rong Utne, pers. comm.) and do not feed while spawning (Hátún et al., 2007).

Individuals can reach up to 20 years old but rarely exceed 10 years (Bakketeig et al., 2014), hence we use 10 years as the maximum age in NoBa. The following length-weight relationship (Eq. 1) is applied: a= 0.0082 and b=2.9 (www.fishbase.org). Weight-at-age is based on estimates from ICES WGWIDE (2010) as a mean over the period 1993-2002 (see introduction for explanation). The growth rates (Table 3) represent the weight (in mg N) a fish needs to gain each day to reach the level of the next age class. However, these need to be adjusted in NoBa to rates approximately 10 times higher to reach observed sizes.

Clearance rates (Table 4) are calculated assuming that the blue whiting consumes about the same amount as the herring each day, i.e. 3% of its total body weight (Kjell Rong Utne, pers. comm.).

In NoBa, we apply mortality rates of $1.38e^{-12}d^{-1}$ and $5.48e^{-14}d^{-1}$ for juveniles and adults, respectively.

Blue whiting spawn west of the British Isles in February-April at a depth of 300-400 m (Monstad, 2004). In NoBa, it is assumed that the population as a whole spawns for 45 days. The blue whiting matures at ages 2-7 (Wienerroither et al., 2011), and the fraction of mature at age is according to ICES WGWIDE (2011). This fraction can be found in Table 5. The larvae enter the model as juveniles after a larval period of 60 days and over a time window of 30 days. The vertical distribution of the recruits is based on the results in Hillgruber et al. (2000) and the number is based on information in ICES WGWIDE (2010) using the estimate of 1984.

This species can tolerate temperatures down to 1°C (Monstad, 2004). Here, we use a swimming speed of 2880 m h^{-1}, calculated from a body length of 0.4 m and a speed of 2 body lengths s^{-1}.

2.2.38 Mackerel (*Scomber scombrus,* Linnaeus 1758)

Mackerel is a planktivorous fish, which has the Norwegian Sea as its northern limit, and is presently found at the entrance to the Barents Sea (Wienerroither et al., 2011). The biomass estimate of 3.2 million tons and the abundance for 1984 is from ICES WGWIDE (2010) and covers the whole Northeast Atlantic. Here, we follow the approach of Dommasnes (2001) and assume that 12.5% of the stock is within the model domain (although about 25% feeds in the Norwegian Sea during summer). The horizontal distribution is based on Iversen (2004). Mackerel are usually found at depths between 0 and 200 m but are observed down to 1000 m (www.fishbase.org). Their vertical distribution is found in Table 2.

Mackerel prey on zooplankton, fish larvae and juvenile fish (IMR 2015; Iversen, 2004).

Longevity is defined to be 20 years in NoBa, as maximum age usually lies between 15 and 16 years old (and rarely above 25) (Bakketeig et al., 2015). Weight-at-age is based on information in ICES WGWIDE 2010 and is an average over the period 1993-2002 (see introduction for explanation), whereas the length-weight relationship (Eq. 1) is represented by a=0.0038 and b=3.21 (www.fishbase.org). Growth rates (Table 3) in the model are calculated as the necessary weight (mgN) the fish need to gain per day to reach the weight of the next age class. However, these growth rates are increased by a factor of 100 in the model to reach realistic weights within each age class.

Lacking a swim bladder, mackerel have to move all the time, and hence require a significant amount of food, except during wintertime when their metabolism drops (Bakketeig et al., 2014; Svein Iversen, pers. comm.). A rough estimate is that mackerel eat about 3% of their body weight each day (Utne et al., 2012), and the clearance rates (Table 4) for each age class is calculated based on this and the mean weight per age class. A lower threshold for feeding was found in Macy et al. (1998) of 0.4 copepods l^{-1}.

The mortality rates in NoBa for juveniles and adults are $4.11e^{-12}$ and $4.11e^{-10}$, respectively.

Mackerel spawn in March to July, northwest of Scotland/UK, after which they swim into the Norwegian Sea to feed (Iversen, 2004). They normally mature as 3-year olds, although some mature at age 1 and at age 2. The fraction of mature per age class is taken from WGWIDE (2014) and can be found in Table 5. In NoBa, the population spawns for one month after which the larvae period is about three weeks. After three weeks the recruits enter the model domain over a time window of 30 days. They leave the Norwegian Sea in August/September when they migrate southward toward the Shetland Islands and Ireland.

The maximum swimming speed can be 25-30 body lengths per second, with the normal speed being 2-3 body lengths per second (Svein Iversen, pers. comm.). In NoBa, we apply a speed of 7000 m h^{-1}. Mackerel prefer temperatures above 6°C.

2.2.39 Saithe (*Pollachius virens*, Linnaeus 1758)

The Northeast Arctic saithe population is mainly distributed along the Norwegian coast and shelf (Bakketeig et al., 2014) and in the Barents Sea (Wienerroither et al., 2011). The biomass estimate of roughly 350 000 tons from 1984 is from ICES AFWG 2010, as is the abundance per age class. Abundance for the first two age classes is adapted to the development of the curve of age class 3-10. Saithe is usually found between 100 and 300 m (Bakketeig et al., 2014). Its vertical distribution in NoBa can be found in Table 2.

The young saithe prey on Calanus, krill and other pelagic copepods, and adults eat herring, blue whiting, Norway pout and young haddock, cod, capelin and polar cod (ICES AFWG, 2010; Bakketeig et al., 2011). In addition, Bjørke (2001) reported predation on squid as well. Saithe eat while spawning (Sigbjørn Mehl, pers. comm.).

The longevity of saithe is set to 20 years in NoBa, growth rates (Table 3) are calculated as the necessary weight (mgN) needed to be gained each day to reach the weight of the next age class. However, these have to be multiplied by a factor of 5-10 to gain observed weights. Information on weight-at-age is from Sigbjørn Mehl (pers. comm.). We apply a length-weight relationship (Eq. 1) with a=0.0103 and b=2.963.

Clearance rates (Table 4) are calculated using the assumption of 80% fullness of the stomachs, and that the stomach weighs 10% of the total body mass. These had to be increased by a factor of 5 for the older age classes to support the appropriate growth of the fish.

The mortality rates applied in NoBa are $5.48e^{-16}d^{-1}$ and $5.67e^{-13}d^{-1}$ for juveniles and adults, respectively.

Saithe mature when they are 5-6 years old and the fraction of mature per age class (Table 5) is based on information from Sigbjørn Mehl (pers. comm.). They spawn in January to March, with a main peak in February (Mehl et al., 2011). In NoBa, we assume that they are about 45 days old when they enter the model domain over a time window of 30 days. The recruits are mainly pelagic.

Saithe is a good swimmer, with speeds of 3.6-10.8 km h^{-1} (He and Wardle, 1988). In NoBa, we use a swimming speed of 7200 m h^{-1}.

2.2.40 Other large demersals

Other large demersals is a functional group consisting of Monkfish (*Lophius piscatorius*, Linnaeus 1758), Atlantic halibut (*Hippoglossus hippoglossus*, Linnaeus 1758), Atlantic wolffish (Anarhichas *lupus*, Linnaeus 1758), Northern wolffish (*Anarhichas denticulatus*, Krøyer 1845) and spotted wolffish (*Anarhichas minor*, Olafsen 1772). The group is initialized with a biomass of 120 000 tons, which represents the total biomass of wolffish in the early 1980s, in addition to a small biomass representing the other species included in the group (Bakketeig et al. 2015). There are few estimates on abundance per age class, hence we apply a high abundance for the young, with decreasing abundance for the older age classes. Northern wolffish have been found at depths down to 1325 m, whereas spotted wolfish are usually found at depths between 50-250 m (Shevelev and Johannesen, 2011). The vertical distribution used in NoBa is found in Table 2.

Wolffish typically feed on fish, echinoderms, molluscs, crustaceans, ctenophores and jellyfish (Shevelev and Johannessen, 2011). They feed while spawning (Shevelev and Johannesen, 2011). As they are demersal, we assume some habitat dependency exists. Likewise, we assume that they feed during the day. Minimum depth is defined as 20 m and the maximum depth is taken to be 2000 m.

Their longevity is defined to be 20 years in NoBa (Bakketeig et al., 2015). They grow fast during the first years, increasing to 15-20 cm during the first year, thereafter to 45-60 cm after 5 years. Growth rates (Table 3) in NoBa are calculated as the necessary weight gain per day (mgN d-1) to reach the weight level for the next age class. However, this has to be increased by a factor of 2-3 to reach a realistic level. Weight-at-age is calculated using a length-weight relationship (Eq. 1) of a =0.078 and b=2.615 (www.fishbase.org) together with length-at-age information (Wienerroither et al., 2011).

Clearance rates (Table 4) are calculated based on the assumption that they have 80% fullness in the stomachs, and that the stomachs weigh roughly 10% of the total body weight (Trond Kristiansen, pers. comm.).

The mortality rates applied in NoBa are $9.93e^{-9}d^{-1}$ and $4.43e^{-8}d^{-1}$ for juveniles and adults, respectively.

Wolffish mature at 70-90 cm length and at 7-10 years (Wienerroither et al., 2011). The Atlantic wolffish spawn in July-October, with a peak in August (Shevelev and Johannesen, 2011). In NoBa, it is assumed that the recruits enter over a time window of 30 days, 150 days after spawning. There was little information on the fraction of mature per age class and the numbers applied in NoBa is an educated guess of what we assume could be representative for the stock (Table 5).

They can be present in temperatures from -1.4 to 10°C (Wienerroither et al., 2011) and we assume that they can swim at 2 body lengths per second, which gives a swimming speed of 10000 m h^{-1}.

2.2.41 Minke whale (*Balaenoptera acutorostrata*, Lacepede 1804)

Minke whales are by far the most abundant whale species in the Barents and Nordic Seas with roughly 110 000 animals (29600 in the Norwegian Sea, 79700 in the Barents Sea (Skaug et al. 2004, Øien et al. 2009). The horizontal distribution is based on information in Nøttestad and Olsen (2004), Skaug et al. (2004) and Øien et al. (2009). Vertically, we assume that they cannot dive deeper than 500 m. In the model, they are mainly present in the uppermost layer but do dive when feeding (Table 2). There is a lack of information on population age distributions, therefore we have taken an educated guess to create an age distribution of the stock.

Minke whales can eat both day and night (Vikingsson, 1997 and references therein) and prefer fish to zooplankton in northern areas (Lindstrøm et al., 2002; Skern-Mauritzen et al., 2011). Krill, herring and capelin are known to be very important prey for the minke whales (Haug et al., 2002 and references therein). A Holling type 3 functional response best reflects the functional response (Ulf Lindstrøm, pers. com).

Their longevity is around 50 years (Nøttestad and Olsen, 2004). A length-weight relationship (Eq. 1) is represented by a=0.01 and b=3.0 (www.sealifebase.org). The growth rates (Table 3) are calculated as the weight gain per day to reach the mean individual weight of the next age class in a given time window. However, this had to be multiplied by a factor of 20 to stay within reasonable limits on the individual weights.

Clearance rates (Table 4) are calculated based on the assumption that they consume roughly 3% of their bodyweight each day (for more information on this see section 2.2.44).

The mortality rates are $2.49e^{-7}d^{-1}$ and $7.48e^{-9}d^{-1}$ for juveniles and adults, respectively.

Minke whales are known to migrate out of the area during wintertime, although some stay at high latitudes also during the winter (Nils Øien, pers.com). In the model, they leave the model domain in the beginning of December, and return in March. They mate in this period, and roughly 90% of the females have one pup each year. The length of gestation is 300 days and we assume that the recruits enter the model over a time window of 20 days. The calves have a maximum weight of roughly 5700 kg. Fraction of mature per age class can be found in Table 5, and are based on numbers used in the SE-Australia model (Fulton et al., 2004).

They travel over large distances and have a swimming speed of 10 km h^{-1}. Due to their long migrations, they can also tolerate large temperature ranges, which in NoBa is -1 to 30°C.

2.2.42 Humpback whale (*Megaptera novaeangliae*, Borowski 1781)

Humpback whales have the lowest abundance of the three baleen whales included in NoBa. There are roughly 4700 animals in the Nordic and Barents Seas (Øien et al. 2009) and their horizontal distribution is based on Nøttestad and Olsen (2004) and Øien et al. (2009). They have a maximum diving depth of around 200 m, hence they are defined to be mostly in the uppermost layer with the exception of diving during feeding (Table 2).

Humpback whales eat both day and night and prefer fish to zooplankton in northern areas (Skern-Mauritzen et al., 2011 and references therein). Their diet consists of krill, capelin, Norwegian spring spawning herring, polar cod, blue whiting, mackerel, haddock and saithe.

Their longevity is around 50 years (Zerbini et al., 2010). Growth rates (Table 3) in NoBa are calculated as the weight (mg N) gain per day necessary to reach the mean individual weight of the next age class within a given time window. From www.sealifebase.org we obtain a length-weight relationship (Eq. 1) of a=0.0620 and b=2.950.

Each whale eats up to 0.5-1 tons per day (www.acsonline.org) or roughly 3% of their bodyweight. This information is used to calculate the clearance rates (Table 4).

The mortality rates are set to $4.90e^{-14}d^{-1}$ and $1.37e^{-13}d^{-1}$ for juveniles and adults, respectively.

Humpback whales mature around age 5-10 and mate in January-February. The fraction of mature per age class is based on the SE-Australia model, and can be found in Table 5. They have a gestation period of 350 days after which recruits enter the model over a time window of 20 days in the upper 50 m. Females give birth to a calf every 2nd or 3rd year that typically weighs roughly 1 ton at birth. The humpback whales migrate out of the model domain in early December and return in early March, but it is believed that some stay within the model domain during winter (Nils Øien pers com).

They are good swimmers, with a swimming speed of 10 km h^{-1}. Due to extensive migration pattern, they tolerate a large range of temperatures, probably from -1 to 30°C.

2.2.43 Fin whale (*Balaenoptera physalus*, Linnaeus 1758)

Fin whales are by far the largest baleen whales of the three species included in the model. There are roughly 10 000 animals in the Nordic and Barents Sea area (Øien et al., 2009), and their horizontal distribution is based on Øien et al. (2009 and Nils Øien pers. comm.). Likewise the humpback and minke whales, the fin whales migrate out of the model domain in early December and return in early March. Their maximum diving depth is 470 m (Panigada et al., 1999), however, the most of the fin whales are defined to be present in the uppermost layer. Their vertical distribution in NoBa is given in Table 2.

Fin whales can eat both day and night, and prefer zooplankton to fish in northern areas (Vikingsson, 1997). They prey on krill, mackerel, herring, blue whiting, haddock and saithe.

Fin whales grow most during their early years, e.g. 95% of maximum body size is reached by the time they are 9-13 years old. The oldest individuals observed have been between 80-90 years old (http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/finwhale.htm). In NoBa, their longevity is taken to be 60 years. Perrin et al. (2009) report a length-weight relationship (Eq. 1) of a=0.0015 and b=3.46. The growth rate (Table 3) is calculated as the weight (mgN) necessary to gain each day before moving to the next age class. Yet, these led to an underestimation of the weight of each age class and they had to be multiplied by a factor of approximately 10.

Clearance rates (Table 4) are calculated based on the assumption that they need approximately the same fraction of food as killer whales (see section 2.2.44), 3% of the bodyweight per day (Vikingsson et al. 1997 and references therein).

The mortality rates are set to $3.04e^{-06}d^{-1}$ and $5.10e^{-08}d^{-1}$ for juveniles and adults, respectively.

Fin whales mature at age 6-8 years and mate in December to March. The fraction of mature per age class can be found in Table 5, and is based on information in the SE-Australian model (Fulton et al., 2004). The gestation period lasts for 11 months and they usually have one calf every 2 years. The calves enter the model over a period of 20 days.

They migrate over large distances and have a swimming speed of 10.0 km h^{-1}. Due to their extensive migrations, it is believed that they can tolerate large temperature differences, which in NoBa is taken to be between -1 and 30°C.

2.2.44 Killer whale (*Orcinus orca*, Fitzinger 1860)

The killer whale is the largest sized species among the dolphins (Bjørge, 2010). Roughly 10 000 animals reside in the Nordic and Barents seas. They are excellent swimmers and hunters, and are known to steal from fisheries (Similä, 2005). Their maximal reported diving depth is 254 m (Miller et al., 2010) but they usually stay within the upper 50 m. Their vertical distribution in NoBa is found in Table 2. Horizontally, killer whales usually stay within 800 km of the coast, and in Norwegian coastal waters where they are known to follow the Norwegian spring-spawning herring population. We have therefore chosen the herring distribution (IMR, 2010) as an indication of where they are found along the Norwegian coast (http://www.cms.int/reports/small_cetaceans/data/o_orca/o_orca.htm).

Killer whales prey on spring-spawning herring, cod, squid, seals, bottle nosed whales, eider ducks, northern fulmars and little auks (Similä and Ugarte, 1993 and references therein). In addition, they are known to prey on mackerel, salmon and young of humpback, minke and fin whales. Killer whales can eat both day and night, and a Holling type 3 is set to reflect the intake rate.

Female killer whales can live 80-90 years, however, the mean longevity is 50 years for both females and males (Bjørge, 2010). This is the longevity used in NoBa. Their weight at age is based on Clark et al (2000) and a linear growth is assumed after age 10. They are known to grow approximately 36.6 cm yr^{-1} (Noren, 2011). In NoBa, we calculate the growth rates (Table 3) as the weight (mgN) necessary to gain before moving to the next age group. However, these growth rates are not sufficient and have to be multiplied with a factor of 10 for the young and a factor of 100 for the older individuals. A length-weight relationship (Eq. 1) with a=0.006 and b=3.2 was found at www.sealifebase.org. At birth, killer whale calves weigh around 200 kg (Bjørge, 2010).

The clearance rate (Table 4) is based on a typical female killer whale that needs 193 211 kcal d^{-1} and a male that needs 287 331 kcal d^{-1} (Williams et al, 2004). These correspond to a diet of approximately (based on the energy content of stellar sea lions) 80-120 kg per day for adults, or roughly 3% of their body weight. To obtain a sufficient growth rate within the model, the clearance rate has to be doubled for all age classes. In captivity, killer whales have shown assimilation efficiencies of 82% on a fish diet (Kreite, 1995).

Mortality rates are set to $5.05e^{-06}d^{-1}$ and $1.20e^{-10}d^{-1}$ for juveniles and adults, respectively.

Female killer whales mature at 10-12 years old, the males a few years later, around the age of 15. They mate in May and the gestation period is 16 months. They have a calf every 5 years. The recruits are assumed to enter the model as one-year olds, over a time window of 10 days. Usually, killer whales reproduce until they are age 30, where after they have a non-reproductive period of 10-20 years (Bjørge, 2010). The fraction of mature per age class can be found in Table 5, and are based on the SE-Atlantis model (Fulton et al., 2004).

Killer whales are excellent swimmers and their swimming speed is assumed to be 20 000 m h^{-1} in NoBa. We have defined their temperature range to be of the same as for baleen whales, -1 to 30°C.

2.2.45 Sperm whale (*Physeter macrocephalus*, Linnaeus 1758)

The sperm whale population in the Nordic and Barents Seas consists only of males, whereas the mothers and calves reside in warmer waters. It is the only toothed whale in NoBa and has an abundance of 5200 animals (Nøttestad and Olsen, 2004). Sperm whales can dive to at least 985 m (Watwood et al., 2006) and there is also evidence of dives down to 2000 m (Santos et al., 1999). They are mainly present in the upper 500 m (Table 2) but in waters with bottom depths larger than 500 m. Sperm whales are migratory, and leave the model domain in December with return in March.

Sperm whales prey on squid, Greenland halibut and redfish.

In NoBa, the longevity of sperm whale is set to be 50 years, although they can live to be older. A length-weight relationship (Eq. 1) with a=0.0649 and b=2.740 was found at www.sealifebase.org. No information on weight distributions and numbers per age group is available, therefore we assume that they grow fastest during their first years and that thereafter the growth curve flattens out. The same is assumed for the abundance per age class. Growth rates (Table 3) are calculated as the weight (mgN) necessary to gain each day to reach a representative weight for the next age class within reasonable time. This fits well for all but the first age class, where it has to be doubled.

Sperm whales are assumed to have the same clearance rate (Table 4) as killer whale, in NoBa this is 3% of their body mass per day.

The mortality rates are $7.25e^{-06}d^{-1}$ and $9.20e^{-06}d^{-1}$ for the juveniles and adults, respectively.

Sperm whales mature as 10 year olds and mate in November-December. The fraction of mature per age class can be found in Table 5, and are based on numbers used in the SE-Australia model (Fulton et al., 2004). The gestation period is 14-16 months hence they can give birth to a calf that weighs about 1000 kg (www.wikipedia.org). The recruits enter the model as 10 year olds (as only adult males are known to reside in the model domain) over a time window of 10 days.

Their swimming speed is about 5000 m h^{-1} and in NoBa they tolerate a large temperature span, of 2-30°C.

2.2.46 Harp seal (*Pagophilus groenlandicus*, Erxleben 1777)

The harp seal is one of the most conspicuous sea mammal predators in the Norwegian and Barents Seas. There are three distinct stocks in the North Atlantic; one in the Barents and White Seas (the East Ice), one in the Greenland Sea (the West Ice), and one in the Northwest Atlantic off Newfoundland/Labrador and in the Gulf of St. Lawrence. Among the stocks inhabiting Norwegian waters (the West and East Ice stocks), the East Ice stock is by far the largest, estimated to 2 220 000 animals (Nilssen et al., 2000) in the late 1990's, whereas the West Ice stock constitute ca. 500 000 animals (ICES WGHARP, 2014). Although harp seals only depend on ice during the breeding and moulting season (March-May) they spend most of their time in vicinity to ice (Nordøy et al. 2008). Visual observations and telemetry studies suggests that Barents Sea harp seals migrate from breeding and moulting areas in the White Sea in May to feeding areas along the ice-edge in the north (Nordøy et al. 2008). They follow the ice southwards during the autumn. In addition, a major part of the West Ice stock migrates into the Barents Sea to feed in August-November (Folkow et al., 2004). Harp seals can potentially dive down to 600-700 m but the majority of dives are shallower than 150 m (Nordøy et al. 2008); the vertical distribution of harp seals in NoBa is given in Table 2.

The harp seals feed along the ice edge and over large parts of the North Atlantic (Haug and Bjørge, 2010), and prey on crustaceans, capelin, polar cod, herring, cod, other fish (including saithe and haddock) and squid (Nilssen et al., 2000).

Their longevity is roughly 25 years (Kjellqvist et al. 1995) and is set to 30 years in NoBa. Growth rates (Table 3) are calculated as the necessary weight gain (mgN d^{-1}) needed before moving into the next age class. These have to be multiplied by a factor of 0.5 to reduce the growth in the different age classes. The length-weight relationship (Eq. 1) is represented in NoBa as the average between the female and the male length-weight relationship. Females are represented by a=0.0006 and b=2.3242, males by a=0.0001 and b=2.6412 (Anne Kirstine Frie, pers comm). The relationship used in NoBa is a=0.003 and b=2.4827.

Clearance rates (Table 4) are calculated assuming that the harp seals consume the same proportion of food each day as ring seals; roughly 4.9% of their bodyweight (Ryg and Øritsland, 1991). However, this leads to too high individual weigths and the rates were multiplied by a factor of 0.2-0.5 for the different age classes. The assimilation efficiencies in NoBa are set to 0.81 for fish and 0.72 for crustaceans (Nordøy et al. 1993).

The mortality rates are set to $7.20e^{-08}d^{-1}$ and $1.29e^{-09}d^{-1}$ for juveniles and adults, respectively.

In NoBa, the harp seals mature at age 7. They breed in the White Sea and off the east coast of Greenland in February and March (Haug et al., 2006). The assumed fraction of mature per age class can be found in Table 5. The gestation period is 11.5 months (Sergeant 1991) and they enter the model as one year olds over a time window of 10 days. The pregnancy rate is 0.81 (ICES WGHARP 2013), but is uncertain and could possibly be below 0.7 (Anne Kirstine Frie, pers. comm). In late April/early May they moult in the funnel of the White Sea (Nordøy et al, 2008) before they leave the White Sea to feed in the Barents Sea. The number of pups per adult per year is taken to be 0.45, based on WGHARP (2013).

Harp seals have a swimming speed of 5400 m h^{-1} and prefer cold to temperate water temperatures between -1.9 to 10°C (Ulf Lindstrøm, pers. comm.).

2.2.47 Hooded seal (*Cystophora cristata*, Erxleben 1777)

Hooded seals are initialized with a population of 130 000 animals (Øigard et al., 2014). Their horizontal distribution is mainly along the Greenland coast, in the pack-ice off Jan Mayen, where they give birth and breed in late March (Folkow et al., 2010). However, they are known to perform extensive feeding migrations in the deeper parts of the Nordic Seas, which can last up to several weeks. Hence, they are also present in large parts of the Nordic Seas (Folkow et al., 1996). They are excellent divers, reaching to 1000 m (Kovacs et al., 2009) and their vertical distribution in NoBa is given in Table 2.

Hooded seals have a longevity of around 30 years (Kovacs and Lavigne, 1986). They don't feed during nursing period (Lydersen and Kovacs, 1999) but otherwise consume squid, polar cod, capelin, cod, Greenland halibut, redfish, prawns, other gadoid fish and amphipods (Haug et al. 2007). They do not have diurnal patterns in foraging (Ulf Lindstrøm, pers. comm.).

Growth rates (Table 3) are calculated as the necessary weight (mgN d^{-1}) that needs to be gained before moving into the next age class. Since these growth rates lead to reduced weights, especially for the older age classes, values had to be increased by a factor of up to 200. The length-weight relationship (Eq. 1) used in NoBa is an average between the length-weight relationships for females and males. Males are represented by a=0.0003 and b=2.4986, females by a=0.0005 and b=2.8188 (Anne Kirstine Frie, pers comm). The values used in NoBa are a=0.00038 and b=2.62668.

Clearance rates (Table 4) are calculated assuming that hooded seals eat the proportionally same amounts as ringed seals, i.e. about 4.9% of its bodyweight each day (Ryg and Øritsland, 1991). Nevertheless, these values had to be multiplied by a factor of 2 in the model to avoid decreasing weights.

The mortality rates are set to $4.50e^{-07}d^{-1}$ and $4.83e^{-08}d^{-1}$ for juveniles and adults, respectively.

Hooded seals mature at the age of 5-5.5 years (Anne Kirstine Frie, pers. comm.). The assumed fraction of mature per age class can be found in Table 5. Their gestation period is 11.5 months and the recruits enter the model as one year olds over a time window of 10 days. The fraction of mature per age class is provided in Table 2 (Ulf Lindstrøm, pers. comm.). The pregnancy rate is 0.68, which is 20% lower than earlier pregnancy rates (ICES WGHARP, 2013).

Hooded seals are good swimmers, 6480 m h^{-1} and prefer cold to temperate waters, between -1.9 and 10°C (Ulf Lindstrøm, pers. comm.).

2.2.48 Bearded seal (*Erignathus barbatus*, Erxleben 1777)

The bearded seal is found all across the Arctic (Kovacs et al., 2009). Their abundance has not been assessed, hence estimates of their numbers range from 4000-100 000 (Cameron et al., 2010). However, Lydersen and Wiig (1995) operated with a relationship between ringed and bearded seal of 13:1, which gives about 15 000 bearded seals within the model domain. They are excellent divers and can reach deeper than 448 m (Gjertz et al., 2000). Their vertical distribution is found in Table 2. Their horizontal distribution is based on information in Kovacs et al. (2009).

The diet of bearded seals mainly consists of fish (Hjelset et al., 1999) including polar cod, stout eelblenny, cod, cottidae and long rough dab. In addition, they also feed on crustaceans (mainly decapods, crabs and shrimps), gastropods and bivalves. Mothers forage during their lactation period (Lydersen et al., 1996).

Bearded seals have a longevity of approximately 25 years (Andersen et al., 1999). Growth rates (Table 3) are calculated as the necessary weight gain (mgN d^{-1}) before moving up to the next age class. Weight-at-age is partly determined using information from Andersen et al. (1999) and educated guesses of the development of weight-at-age.

Clearance rates (Table 4) are calculated assuming that the bearded seals consume as much as the ringed seals; 4.9% of their body weight each day (Ryg and Øritsland,1991).

Mortality rates are set to $7.50e^{-06}d^{-1}$ and $5.20e^{-07}d^{-1}$ for juveniles and adults, respectively.

Bearded seals mature at around age 5 and mate in June after the lactation period of roughly 24 days (Gjertz et al., 2000) is over. The assumed fraction of mature per age class can be found in Table 5. The gestation period lasts for roughly 11 months (http://www.eoearth.org/view/article/150454/), and the recruits enter the model domain as one year olds over a period of 30 days. At birth, the pup weighs about 35-40 kg.

They can have a swimming speed of 1960 m h^{-1} (Gjertz et al., 2000). We assume that they prefer cold to temperate water and define their temperature range in NoBa to be between -1.9 and 9°C.

2.2.49 Ringed seal (*Phoca hispida,* Schreber 1775)

Ringed seals are extremely dependent on sea ice and as they can maintain breathing holes in thick ice, are found much farther north than the other seals in the Barents Sea (Kovacs et al., 2009). The model abundance of 100 000 individuals is based on Kovacs et al. (2009). Ring seals are excellent divers and the maximum diving depth exceeds 500 m (Born et al., 2004) with diurnal variations (Lydersen., 1991). The vertical distribution is given in Table 2. The information on seasonal horizontal distribution is based on Freitas et al. (2008) with offshore migration of ringed seals usually starting around July 31st (day 212) and lasting for a maximum 90 days, meaning a return at the end of October (day 304).

Labansen et al. (2007) report that around Svalbard, about 98% of the diet of ringed seal is fish, 1.88% is crustaceans and 0.06% is other invertebrates. Included in the fish are polar cod, *Stichaeidae spp.*, larvae of *cottidae* and *Gadidae spp*. Of the crustaceans, decapoda is the most important prey.

The longevity of ringed seals in NoBa is set to 30 years, following Krafft et al. (2006b). The growth rates (Table 3) are calculated as the necessary weight gain (mgN d^{-1}) before moving to the next age group. We assume a lower growth rate for the older age classes than for the young.

Clearance rates (Table 4) are calculated assuming that they eat roughly 4.9% of their body mass each day (Ryg and Øritsland, 1991). An assimilation efficiency of 80% is based on information in Ryg and Øritsland.(1991).

The mortality rates are set to $1.46e^{-7}d^{-1}$ and $6.46e^{-7}d^{-1}$ for juveniles and adults, respectively.

The age at maturity is 3.5±0.4 years for females and 4.3±0.3 years for males and has been decreasing since three decades earlier (Krafft et al., 2006). The assumed fraction of mature per age class can be found in Table 5. Harp seals usually produce one pup each year, that at birth weighs around 4.5 kg (Bjørn Krafft, pers. comm.). They give birth to pups in caves, which they build over breathing holes or creases in snow formations on the shelter side of glaciers. We assume in the model that they give birth at the beginning of April (Bjørn Krafft, pers. comm.) and that mating is around day 130, lasting for about one month. The length of gestation in NoBa is 325 days. The pups enter the model as one year old over a time window of 10 days.

Ringed seals adjust well to low temperatures but can also be found along the Norwegian coast in summer with temperatures above 10°C (Bjørn Krafft, pers. comm.). Their swimming speed is taken to be that in Freitas et al. (2008), 2512.5 m h^{-1}.

2.2.50 Seabirds

In Barrett et al. (2006), the number of seabirds is estimated to be 26 million individuals in the Barents and Norwegian Sea. In the latter there are 6.1 million individuals (total biomass of 3800 tons) and 20 million individuals (total biomass of 12800 tons) in the former. This corresponds well to the number given in Dommasnes et al. (2001) who estimate 27 698 045 individuals. In NoBa, we split the birds into two groups: boreal and arctic seabirds. The boreal seabirds migrate into the Barents Sea for summer feeding but do not spend the winter there. The arctic seabirds spend all their time in the Barents Sea.

Seabirds - boreal

Atlantic Puffins (*Fratercula arctica,* Linnaeus 1758) are the most numerous seabird species on mainland Norway (Barrett et al., 2006) and are therefore chosen as representative for this group. Information about their horizontal resolution along the coast of Norway is based on Anker-Nilssen and Aarvak (2009). Vertical distribution (used in the model for calculating overlap with prey) can be found in Table 2. They spend most of their time in the uppermost layer, this also includes their time on land, but do have a maximum diving depth of 100 m (Axelsen et al., 2001).

The diet of boreal sea birds includes small pelagics (NoBa component), haddock, saithe, herring, cod and polar cod, in addition to shrimp, squid, jellyfish, and large and small zooplankton (Barrett et al., 2002; Bjørke, 2001). They also have the possibility of consuming detritus. We assume that they are active feeding only during daytime.

Atlantic puffins have a maximum longevity of 34 years (http://genomics.senescence.info/species/entry.php?species=Fratercula_arctica).
As adults, they have a body weight of 460 g (Barrett et al., 2002). Their growth rates (Table 3) are calculated as the necessary weight gain (mgN d^{-1}) before moving onto the next age class. However, the birds do not grow much as adults, hence the rates are very low for adult age classes. As we are not able to find any information about the length-weight relationship (Eq. 1) for the local population, it is taken from the SE-Australian Atlantis model (Fulton et al., 2004); a=0.02 and b=3.0.

The amount of food consumed daily (34% of total body weight) is calculated from Barrett et al. (2002). However, in NoBa this has to be increased by 50% to avoid the birds losing weight (Table 4).

The mortality rates are $5.37e^{-9}$ and $2.74e^{-11}$ for juveniles and adults, respectively.

Atlantic puffins mature at ages 4-5 (http://www.npolar.no/en/species/atlantic-puffin.html). The fraction of mature per age class is based on numbers in the SE-Australia model (Fulton et al., 2004) and can be found in Table 5. They arrive at the breeding site in late March and early April, and lay eggs in May-June (.http://www.npolar.no/en/species/atlantic-puffin.html). The egg is incubated by both sexes for 42 days (http://www.npolar.no/en/species/atlantic-puffin.html), and the chick typically weighs 45 g at hatching (Thyco Anker-Nilssen, pers. comm.). We assume that they get the same number of chicks as the arctic sea birds, with 0.7 chicks per year (Birkhead et al., 1977).

In NoBa, we assume a temperature tolerance between 1 and 20°C and hatching between 4 and 20°C. When they hunt, they have been observed to have speeds up to 5.4 km h^{-1} (Axelsen et al., 2001).

Arctic seabirds

Arctic seabirds in NoBa are parameterized as Brünnich's Guillemot (*Uria lomvia,* Linnaeus 1758). Their horizontal distribution is based on information at http://www.npolar.no/no/arter/polarlomvi.html. Arctic seabirds are fairly large, with an adult weight of 900-1100 g (http://www.npolar.no/en/species/common-guillemot.html). They spend most of their time at sea in the uppermost layer but can dive down to 150 m (Mehlum et al., 2001). The vertical distribution, used in the model to calculate overlap with prey, is listed in Table 2. The population does not migrate out of the model domain but moves around the Barents Sea depending on the season.

They prey on fatty fish and invertebrates (Barrett et al., 2006). In NoBa, this includes herring, polar cod, capelin, prawns, some crustaceans, squid, large and medium zooplankton and some benthic filter feeders. We assume that they are only actively feeding during daytime.

A maximum longevity of 29 years has been reported (http://genomics.senescence.info/species/entry.php?species=Uria_lomvia). We have chosen to reduce this a bit, as it is the mean longevity we apply in the model. In NoBa we therefore use a longevity of 20 years. Their growth rates (Table 3) represent the necessary weight gain (mgN d^{-1}) needed before moving into the next age class. However, they grow very little as adults (Barrett et al., 2002). In NoBa, growth rates have to be multiplied by a factor of 2 for the youngest age classes and by 6 for the oldest age classes to maintain their weight according to observed weights. We cannot find a length-weight relationship (Eq. 1) for these birds, hence the numbers are kept as in the SE-Australian version, a=0.02 and b=3.0.

The clearance rates (Table 4) are calculated based on Barrett et al. (2002). These indicate that the arctic seabirds consume roughly 30% of their bodyweight each day. Albeit, this has to be increased to 50% in the model to avoid the weights dropping below observed values.

NoBa uses mortality rates of $2.10e^{-08}d^{-1}$ and $2.74e^{-13}d^{-1}$ for juveniles and adults, respectively.

The common guillemot matures at an age of around five years (http://www.npolar.no/en/species/common-guillemot.html). The fraction of mature per age class is based on numbers used in the SE-Australia model (Fulton et al., 2004) and can be found in Table 5. Egg-laying starts at the end of May/early June. Thereafter the egg is incubated by both parents for about 32 days (http://www.npolar.no/en/species/common-guillemot.html). The average number of chicks per pair is 0.7 per year (Birkhead et al., 1977). The young bird leaves the nest at about 21 days of age. The arrival of recruits is highly synchronized, in NoBa they all arrive within a time window of 7 days. Common guillemots are the largest of the extant auk species: 41 cm and 900-1100 g.

When hunting, swimming speeds of up to 4995 m h^{-1} have been reported (Mehlum et al., 2001). As they are flexible regarding the temperature range that they can function in (Thyco Anker-Nilssen, pers. comm.). We assume a temperature range of -0.5°C to 20°C. For hatching, we increase the lower range to 4°C.

2.2.51 Polar Bear (*Ursus maritimus*, Phipps 1774)

The Barents Sea polar bear subpopulation contains somewhere between 1900 and 3600 bears (Aars et al., 2009). We initiate the model with a biomass of roughly 600 tons, where the total biomass is calculated assuming a weight of male bears of 400 kg and female bears of 150 kg, hence a mean weight for adult bears of 275 kg. As the cubs are much smaller, we choose a mean weight for the population of 200 kg (Jon Aars, pers. comm.). Their horizontal distribution is based on Haug et al. (2011). They are distributed in the uppermost layer and can dive down to 13 m (Jon Aars, pers. comm.). Their vertical distribution can be found in Table 2.

Polar bears eat mainly ringed seals, bearded seals, but also walrus, white whales and narwhale, harp seals, seabirds and carrion (Derocher et al., 2002). A large fraction of the seal kills are pups (Derocher et al., 2002). We assume that they have no preference for hunting time (day or night), due to the polar night.

The longevity of polar bears is up to 39 years, but this is rather unlikely in the wild (Jon Aars, pers. comm.). In NoBa their longevity is 20 years. A weight-age relationship is found in Rode et al. (2010) but as it is only valid for males, we reduce it slightly to fit a population containing both males and females. The growth rates (Table 3) are calculated as the necessary weight gain (mgN d^{-1}) necessary before moving into the next age class. No information is available on a length-weight relationship (Eq. 1). However, based on information of weight-at-age and that females usually are between 200-220 cm and males are from 230-260 cm, a relationship with a=0.09 and b=2.8 represents this fairly well.

Polar bears can gorge themselves, but from studies of other bear species, it seems likely that satiation occurs (Rockwell and Gormezano, 2009). We assume that they can have a stomach fullness of 20%. Nevertheless, the clearance rates (Table 4) that are initiated based on this value have to be increased by a factor of 2-3 and the polar bears are still underweight. The weights of the polar bears are currently still under tuning.

The mortality rates are $1.80e^{-05}d^{-1}$ and $5.01e^{-07}d^{-1}$ for juveniles and adults, respectively.

The polar bears mature around age 5 (Rosing-Asvid et al., 2002), and a assumed fraction of mature per age class can be found in Table 5. The mating period of polar bears lasts from March to May (Zeyl et al., 2009 and references therein). Gestation lasts for about 8 months (roughly 240 days; http://marinebio.org/species.asp?id=171). In NoBa, we assume that the cubs arrive over a period of about 30 days and that there are 0.35 cubs per adult per year (Wiig, 1998).

They have a fairly wide temperature range, from -40 to 20°C. For the cubs this is 0-10°C while they are in their snow caves. They can walk with a speed of 3000-4000 m h^{-1} (Jon Aars, pers. comm.).

2.3 Future prospects

NoBa Atlantis will always be ‘work in progress’, as the model base itself is developing continuously. Knowledge about key life history parameters and distributions will evolve, and the model will be updated accordingly. New species may be added when new questions arise, as was the case with the snowcrab. While the NoBa Atlantis model was developed for exploring combined climate and fisheries impacts on the ecosystem structure and functioning, the NoBa Atlantis will also provide a powerful tool for investigating a range of questions relating to e.g. cross sector management strategies, and the effects of pollution, climate change, ocean acidification, change in species distributions, overlap and interactions, marine protected areas, immigration of new and/or invasive species. However, the NoBa Atlantis, as other comprehensive ecosystem models, will not be used for tactical management decisions (e.g., setting quotas for fisheries). Thus, the building of such a large and complex model for a system is an investment that will serve a wide specter of issues relevant for ecosystem science and management.

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Figures and tables

Appendix A: Overview of parameters used in NoBa

Explanations of species and abbreviations can be found in **Table 1** in the main document.

Table 2a: Vertical distributions (fractions of population) of juveniles at daytime. L1 is the layer closest to the sediment, while L7 is the surface layer.

Species	L1	L2	L3	L4	L5	L6	L7
POB	0	0	0	0	0	0	1
KWH	0	0	0	0	0	0.2	0.8
SWH	0.1	0.2	0.2	0	0	0	0.5
HWH	0	0	0	0.1	0.1	0.1	0.7
MWH	0	0	0	0.1	0.1	0.1	0.7
FWH	0	0	0	0.1	0.1	0.1	0.7
BES	0	0	0	0	0	0.2	0.8
HAS	0	0	0	0.4	0.4	0.1	0.1
HOS	0	0	0	0.05	0.05	0.15	0.75
RIS	0	0	0	0	0	0.2	0.8
SBA	0	0	0	0	0	0.3	0.7
SBB	0	0	0	0	0	0	1
SHO	0	0	0	0	0.1	0.5	0.4
DEO	0	0	0	0	0.2	0.6	0.2
PEL	0	0	0	0	0.2	0.6	0.2
PES	0	0	0	0.1	0.2	0.3	0.4
REO	0	0.1	0.4	0.4	0.1	0	0
DEL	0	0	0.4	0.2	0.2	0.1	0.1
FLA	0	0	0	0	0	0	0.1
LRD	0	0	0	0	0.3	0.4	0.3
SSK	0	0.22	0.15	0.19	0.16	0.21	0.07
MES	0	0.05	0.3	0.15	0.4	0.1	0
GRH	0	0.2	0.4	0.2	0.2	0	0
MAC	0	0	0	0	0.2	0.3	0.5
HAD	0	0.05	0.05	0.15	0.6	0.1	0.05
SAI	0	0	0	0.2	0.3	0.3	0.2
RED	0	0	0.1	0.4	0.4	0.1	0
BWH	0	0	0	0.3	0.4	0.2	0.1
SSH	0	0	0	0	0.1	0.2	0.7
NCO	0	0.05	0.05	0.15	0.6	0.1	0.05
PCO	0	0	0	0	0.1	0.4	0.5
CAP	0	0	0	0	0.1	0.4	0.5
PWN	0	0.1	0.1	0.2	0.3	0.2	0.1
CEP	0	0	0	0.1	0.2	0.3	0.4
SCR	0	0	0	0	0.8	0.1	0.1
ZG	0	0	0.1	0.1	0.2	0.2	0.4
ZL	0	0	0.05	0.4	0.4	0.1	0.05
ZM	0	0	0	0	0.3	0.4	0.3
ZS	0	0.05	0.05	0.2	0.4	0.2	0.1

Table 2b: Vertical distributions (fractions of population) of juveniles at night-time. L1 is the layer closest to the sediment, while L7 is the surface layer.

Species	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**
POB	0	0	0	0	0	0	1
KWH	0	0	0	0	0	0.2	0.8
SWH	0.1	0.2	0.2	0	0	0	0.5
HWH	0	0	0	0.1	0.1	0.1	0.7
MWH	0	0	0	0.1	0.1	0.1	0.7
FWH	0	0	0	0.1	0.1	0.1	0.7
BES	0	0	0.05	0.05	0.1	0.1	0.7
HAS	0	0	0	0.4	0.4	0.1	0.1
HOS	0	0	0	0.05	0.05	0.15	0.75
RIS	0	0	0.05	0.14	0.3	0.3	0.2
SBA	0	0	0	0	0	0	1
SBB	0	0	0	0	0	0.2	0.8
SHO	0	0	0	0	0.1	0.5	0.4
DEO	0	0	0	0	0.2	0.7	0.1
PEL	0	0	0	0	0.2	0.6	0.2
PES	0	0	0	0.0	0.2	0.4	0.4
REO	0	0.1	0.4	0.4	0.1	0	0
DEL	0	0	0.4	0.2	0.2	0.1	0.1
FLA	0	0	0	0	0	0	1
LRD	0	0	0	0	0.4	0.5	0.1
SSK	0	0.22	0.15	0.19	0.16	0.21	0.07
MES	0	0	0	0	0	0.3	0.7
GRH	0	0.2	0.2	0.2	0.4	0	0
MAC	0	0	0	0	0.2	0.3	0.5
HAD	0	0.05	0.05	0.15	0.6	0.1	0.05
SAI	0	0	0	0.2	0.3	0.3	0.2
RED	0	0	0.1	0.4	0.4	0.1	0
BWH	0	0.3	0.3	0.4	0	0	0
SSH	0	0	0	0	0	0.3	0.7
NCO	0	0.05	0.05	0.15	0.6	0.1	0.05
PCO	0	0	0	0	0.1	0.4	0.5
CAP	0	0	0	0	0.1	0.4	0.5
PWN	0	0.1	0.1	0.2	0.3	0.2	0.1
CEP	0	0	0	0.1	0.1	0.4	0.4
SCR	0	0	0	0	0.8	0.1	0.1
ZG	0	0	0.1	0.1	0.2	0.2	0.4
ZL	0	0	0.0	0.05	0.05	0.2	0.7
ZM	0	0	0	0	0	0.3	0.7
ZS	0	0	0.05	0.05	0.1	0.4	0.4

Table 2c: Vertical distributions (fractions of population) of adults at daytime. L1 is the layer closest to the sediment, while L7 is the surface layer. The vertical movement for invertebrate components are not dependent on age, hence they are only included in the tables for the juveniles.

Species	L1	L2	L3	L4	L5	L6	L7
POB	0	0	0	0	0	0	1
KWH	0	0	0	0	0	0.2	0.8
SWH	0.1	0.2	0.2	0	0	0	0.5
HWH	0	0	0	0.1	0.1	0.1	0.7
MWH	0	0	0	0.1	0.1	0.1	0.7
FWH	0	0	0	0.1	0.1	0.1	0.7
BES	0	0	0	0	0	0.2	0.8
HAS	0	0	0	0.4	0.4	0.1	0.1
HOS	0	0.05	0.05	0.3	0.5	0.1	0.1
RIS	0	0	0	0	0	0.2	0.8
SBA	0	0	0	0	0	0.3	0.7
SBB	0	0	0	0	0	0	1
SHO	0	0	0	0.1	0.2	0.4	0.3
DEO	0	0.05	0.2	0.3	0.3	0.1	0.05
PEL	0	0	0	0	0.2	0.6	0.2
PES	0	0	0.1	0.2	0.2	0.4	0.1
REO	0	0.1	0.4	0.4	0.1	0	0
DEL	0	0	0.4	0.2	0.2	0.1	0.1
FLA	0	0	0	0	0.3	0.4	0.3
LRD	0	0.1	0.2	0.2	0.2	0.2	0.1
SSK	0	0.22	0.15	0.19	0.16	0.21	0.07
MES	0	0.05	0.3	0.15	0.4	0.1	0
GRH	0	0.2	0.4	0.4	0	0	0
MAC	0	0	0	0	0.2	0.3	0.5
HAD	0	0.05	0.05	0.15	0.6	0.1	0.05
SAI	0	0	0	0.2	0.3	0.3	0.2
RED	0	0	0.1	0.4	0.4	0.1	0
BWH	0	0.5	0.2	0.3	0.3	0.15	0
SSH	0	0	0	0.1	0.15	0.25	0.5
NCO	0	0.05	0.05	0.15	0.6	0.1	0.05
PCO	0	0	0.2	0.2	0.25	0.25	0.1
CAP	0	0.1	0.2	0.2	0.2	0.2	0.1

Table 2d: Vertical distributions (fractions of population) of adults at night-time. L1 is the layer closest to the sediment, while L7 is the surface layer. The vertical movement for invertebrate components are not dependent on age, hence they are only included in the tables for the juveniles.

Species	L1	L2	L3	L4	L5	L6	L7
POB	0	0	0	0	0	0	1
KWH	0	0	0	0	0	0.2	0.8
SWH	0.1	0.2	0.2	0	0	0	0.5
HWH	0	0	0	0.1	0.1	0.1	0.7
MWH	0	0	0	0.1	0.1	0.1	0.7
FWH	0	0	0	0.1	0.1	0.1	0.7
BES	0	0	0.05	0.05	0.1	0.1	0.7
HAS	0	0	0	0.4	0.4	0.1	0.1
HOS	0	0.05	0.05	0.3	0.5	0.1	0.1
RIS	0	0	0.05	0.15	0.3	0.3	0.2
SBA	0	0	0	0	0	0	1
SBB	0	0	0	0	0	0.2	0.8
SHO	0	0	0	0.1	0.2	0.4	0.3
DEO	0	0	0.05	0.4	0.4	0.1	0.05
PEL	0	0	0	0	0.2	0.6	0.2
PES	0	0	0	0.1	0..2	0.5	0.2
REO	0	0.1	0.4	0.4	0.1	0	0
DEL	0	0	0.4	0.2	0.2	0.1	0.1
FLA	0	0	0	0	0.3	0.4	0.3
LRD	0.4	0.5	0.1	0	0	0	0
SSK	0	0.22	0.15	0.19	0.16	0.21	0.07
MES	0	0	0	0	0	0.3	0.7
GRH	0	0.4	0.4	0.2	0	0	0
MAC	0	0	0	0	0.2	0.3	0.5
HAD	0	0.05	0.05	0.15	0.6	0.1	0.05
SAI	0	0	0	0.2	0.3	0.3	0.2
RED	0	0	0.1	0.4	0.4	0.1	0
BWH	0	0	0.2	0.3	0.3	0.2	0
SSH	0	0	0	0	0	0.4	0.6
NCO	0	0.05	0.05	0.15	0.6	0.1	0.05
PCO	0	0	0.2	0.2	0.25	0.25	0.1
CAP	0	0.1	0.2	0.2	0.2	0.2	0.1

Table 3: Growth rates (mgN d^{-1}) for all components included in NoBa. These are the adjusted growth rates, which NoBa runs with in the equilibrium run.

Species	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10
POB	8.3e8	6.7e8	7.57e8	3.36e8	0.84e8	2.5e8	1.68e8	0.84e8	0.84e8	0.84e8
KWH	4e4	9.4e4	10.5e4	10.5e4	10.5e4	10.5e4	10.5e4	10.5e4	10.5e4	10.5e4
SWH	3.8e4	2.9e4	2.9e4	1.9e4	1.4e4	0.96e4	0.96e4	0.96e4	-	-
HWH	3.3e4	3.8e4	5.8e4	1.9e4	0.48e4	0.48e4	0.48e4	0.48e4	0.48e4	0.48e4
MWH	1.4e5	0.2e5	0.2e5	0.2e5	0.2e5	0.2e5	0.08e5	0.08e5	0.08e5	0.08e5
FWH	9.0e5	9.0e5	1.9e5	2.4e5	0.5e5	0.5e5	0.5e5	0.5e5	0.7e5	0.4e5
BES	865	480	480	240	192	48	82	82	82	82
HAS	150	130	90	60	15	15	15	15	10	10
HOS	9.5e3	9.6e3	8.0e3	8.0e3	8.0e3	8.0e3	8.0e3	8.0e3	8.0e3	8.0e3
RIS	188	123	96	27	12	12	12	12	12	12
SBA	5	9	9	0.08	0.08	0.06	0.06	0.06	0.06	0.06
SBB	4	2.5	2	0.03	0.03	0.03	0.03	0.03	0.03	0.03
SHO	50	48	48	36	20	20	40	30	30	42
DEO	60	100	110	120	300	320	360	400	400	900
PEL	7	50	200	200	200	250	250	300	300	400
PES	3.2	3.5	14	13.1	8.2	20.2	18.8	14.4	7.8	16.8
REO	20	2	8	9	11	8	3	3	3	3
DEL	7	15	27	100	150	180	210	300	360	450
FLA	3.6	2.8	3.0	2.3	4.0	4.8	5.2	6.4	15.8	9.8
LRD	0.2	0.4	0.4	6.5	4.5	8	23	22	9	8
SSK	15.1	12.6	22.6	28.5	30.1	40.4	50.8	60.2	60.2	61
MES	0.005	0.005	0.005	0.005	0.015	0.02	0.03	0.03	0.04	0.05
GRH	10	15	24	38	50	60	70	80	100	120
MAC	25.4	13.3	32.5	32	38	38	35	39	39	39
HAD	20	25	29	34	39	44	47	47	47	47
SAI	15	14	28	45	120	180	200	240	300	350
RED	14.4	4.2	20	15	12	9	9	9	9	9
BWH	2.2	5.7	4.9	5.3	5.7	5.7	5.5	3.0	4.9	6.9
SSH	1.2	1.8	2.9	1.4	2.8	4.1	4.8	4.6	4.8	4.2
NCO	160	54	102	180	214	228	228	264	270	270
PCO	1.0	0.3	0.25	0.2	0.2	0.2	0.2	0.2	0.4	0.4
CAP	0.33	0.25	0.27	0.28	0.28	-	-	-	-	-
PWN	0.214	0.214	-	-	-	-	-	-	-	-
CEP	0.1	0.24	-	-	-	-	-	-	-	-
KCR	0.01	-	-	-	-	-	-	-	-	-
SCR	0.1	1	2	2	0.66	0.66	-	-	-	-
ZG	0.0001	-	-	-	-	-	-	-	-	-
ZL	0.076	-	-	-	-	-	-	-	-	-
ZM	0.1	-	-	-	-	-	-	-	-	-
ZS	3.55	-	-	-	-	-	-	-	-	-
DF	1.0	-	-	-	-	-	-	-	-	-
PS	1.47	-	-	-	-	-	-	-	-	-
PL	1.8	-	-	-	-	-	-	-	-	-
BC	0.0005	-	-	-	-	-	-	-	-	-
BD	0.0015	-	-	-	-	-	-	-	-	-
BFF	0.004	-	-	-	-	-	-	-	-	-
SPO	0.008	-	-	-	-	-	-	-	-	-
COR	0.002	-	-	-	-	-	-	-	-	-
PB	1.5	-	-	-	-	-	-	-	-	-
BB	0.75	-	-	-	-	-	-	-	-	-

Table 4: Clearance rate (mgN d-1) for all components in NoBa. See component section for explanation of how these were calcuated and tuned.

Species	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10
POB	2.4e5	4.9e5	8.6e5	9.0e5	10e5	10.4e5	12e5	12e5	12e5	13e5
KWH	4e5	8e5	10e5	14e5	18.4e5	19.7e5	21e5	24.4e5	26.2e5	26.9e5
SWH	4.7e6	6.3e6	7.9e6	8.9e6	9.7e6	10.2e6	10.8e6	11.3e6	-	-
HWH	2.1e6	4.2e6	7.4e6	8.4e6	8.7e6	8.9e6	9.2e6	9.5e6	9.7e6	10e6
MWH	7.9e5	8.9e5	10e5	11.1e5	12.1e5	13.2e5	13.7e5	14.2e5	14.7e5	15e5
FWH	1.1e7	1.7e7	1.8e7	1.9e7	1.9e7	2e7	2.0e7	2.0e7	2.1e7	2.1e7
BES	5.4e4	7.5e4	9.7e4	10.7e4	11.6e4	11.8e4	11.8e4	11.8e4	11.8e4	11.8e4
HAS	1.2e4	0.8e4	0.9e4	1.0e4	1.0e4	1.0e4	1.0e4	1.0e4	1.0e4	1.0e4
HOS	1.5e5	2.0e5	2.3e5	2.3e5	2.4e5	2.4e5	2.4e5	2.5e5	2.5e5	2.6e5
RIS	1.4e4	2.1e4	2.8e4	2.9e4	2.9e4	2.9e4	2.9e4	2.9e4	2.9e4	2.9e4
SBA	1.3e3	3.1e3	4.8e3	4.8e3	4.8e3	4.8e3	4.8e3	4.8e3	4.8e3	4.8e3
SBB	0.7e3	1.1e3	2.0e3	2.0e3	2.0e3	2.0e3	2.0e3	2.0e3	2.0e3	2.0e3
SHO	0.35e3	0.8e3	1.5e3	2.0e3	2.2e3	2.5e3	2.7e3	2.8e3	2.8e3	3.1e3
DEO	0.05e3	0.2e3	0.3e3	0.3e3	0.6e3	0.8e3	1.2e3	1.3e3	1.4e3	2.0e3
PEL	0.02e3	0.1e3	0.4e3	0.7e3	1e3	1.2e3	1.4e3	1.6e3	1.8e3	2.1e3
PES	0.05e3	0.1e3	0.4e3	0.6e3	0.7e3	1.1e3	1.4e3	1.7e3	1.8e3	2.1e3
REO	6	9.9	18.1	23	44.8	44.3	44.3	44.3	44.3	44.3
DEL	0.1e3	0.6e3	1.5e3	3.6e3	7.1e3	10.8e3	15.6e3	21.6e3	28.8e3	37.2e3
FLA	0.08e4	0.1e3	0.1e3	0.2e3	0.4e3	0.5e3	0.7e3	0.9e3	1.3e3	1.4e3
LRD	0.4	0.9	1.8	6.2	9.3	13.4	20.5	27.3	29.9	32.7
SSK	38.7	77.1	144.7	229.4	305.6	406.9	539.8	646.2	729	781.5
MES	0.5	0.8	1.7	4.3	0.8	1.3	18.1	25.9	35.9	47.7
GRH	12.3	26.9	52.7	92.8	151.0	226.1	330.8	437.8	476.7	511.8
MAC	52	80	100	120	160	180	200	202	226	260
HAD	20	84	120	220	240	300	330	360	400	420
SAI	0.06e3	0.1e3	0.2e3	0.4e3	1.0e3	1.9e3	2.2e3	2.6e3	2.8e3	3.0e3
RED	6.0	9.9	18.1	23.0	44.8	44.3	44.3	44.3	44.3	44.3
BWH	14.5	20.8	26.2	32	38.2	44.5	50.6	53.9	59.2	66.8
SSH	2.8	6.9	13.4	16.5	20.4	22.9	24.6	26	27.9	28.2
NCO	0.09e3	0.1e3	0.3e3	0.4e3	0.6e3	1.3e3	1.6e3	1.9e3	2e3	2.3e3
PCO	3	1.3	2.0	2.6	2.5	2.7	3.2	2.9	4.8	5.6
CAP	1.5	3	4	6	8	-	-	-	-	-
PWN	0.1	0.3	-	-	-	-	-	-	-	-
CEP	0.0015	0.0019	-	-	-	-	-	-	-	-
KCR	2.2	-	-	-	-	-	-	-	-	-
SCR	35.1	140.4	350.8	561.4	631.6	701.8	-	-	-	-
ZG	0.5	-	-	-	-	-	-	-	-	-
ZL	0.2	-	-	-	-	-	-	-	-	-
ZM	0.41	-	-	-	-	-	-	-	-	-
ZS	0.4	-	-	-	-	-	-	-	-	-
DF	0.14	-	-	-	-	-	-	-	-	-
PS	-	-	-	-	-	-	-	-	-	-
PL	-	-	-	-	-	-	-	-	-	-
BC	0.0006	-	-	-	-	-	-	-	-	-
BD	0.005	-	-	-	-	-	-	-	-	-
BFF	0.005	-	-	-	-	-	-	-	-	-
SPO	0.0006	-	-	-	-	-	-	-	-	-
COR	0.004	-	-	-	-	-	-	-	-	-
PB	0.0	-	-	-	-	-	-	-	-	-
BB	0.0	-	-	-	-	-	-	-	-	-

Table 5: Fraction of the ageclass which is mature. See individual sections for explanations and references.

Species	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10
POB	0	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
KWH	0	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.2	0.2
SWH	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.4	-	-
HWH	0	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
MWH	0	0.3	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
FWH	0	0.3	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
BES	0	0.6	0.9	1	1	1	1	1	1	1
HAS	0	0.2	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
HOS	0	0.2	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
RIS	0	0.2	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SBA	0	0	0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0
SBB	0	0	0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0
SHO	0	0.05	0.05	0.3925	0.45	0.5	0.5	0.5	0.5	0.5
DEO	0	0.6	1	1	1	1	1	1	1	1
PEL	0.2	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9	1
PES	0	0	0	0	0.4	0.6	0.9	1	1	1
REO	0	0.023	0.22	0.65	0.85	0.91	0.92	0.96	0.97	0.97
DEL	0	0.6	0.9	1	1	1	1	1	1	1
FLA	0	0	0.2	0.7	0.9	1	1	1	1	1
LRD	0	0	0.1	0.9	1	1	1	1	1	1
SSK	0	0	0.1	0.6	0.9	1	1	1	1	1
MES	0	0.5	1	1	1	1	1	1	1	1
GRH	0	0	0.07	0.1	0.5	0.9	1	1	1	1
MAC	0.1	0.5	0.9	1	1	1	1	1	1	1
HAD	0	0.1	0.8	1	1	1	1	1	1	1
SAI	0	0	0.02	0.5	0.84	0.96	1	1	1	1
RED	0	0.023	0.22	0.65	0.85	0.91	0.92	0.96	0.97	0.99
BWH	0.11	0.40	0.82	0.86	0.91	0.94	1	1	1	1
SSH	0	0.01	0.22	0.74	0.97	1	1	1	1	1
NCO	0	0	0.25	0.5	0.92	1	1	1	1	1
PCO	0	0	0.3	0.4	0.5	0.8	1	1	1	1
CAP	0	0.3	0.5	0.8	1	-	-	-	-	-
PWN	1	1	-	-	-	-	-	-	-	-
SCR	0	0.8	0.9	1	1	1	-	-	-	-
CEP	1	1	-	-	-	-	-	-	-	-

Appendix B: Figures

Figure 1-36: Horizontal distributions of those components which are horizontally distributed
Figure 37-90: Biomass development of all components included in NoBa

Atlantis counts January-March as winter (S1), April-June as spring (S2), July-September (S3) as summer and October-December as autumn (S4). This is hard-coded into the model, and not possible to change in the current versions. The reason for dividing the year like this, is that the fisheries usually divide the year into quarters accordingly to these months.

Note: Due to updates in the code and the frequenzy of output, figures 3-7, 11,13,15,16 and 20 are from indiseas runs, v 5830, figure 8 and 24 are from v 5830, parameter file Nordic_update_recr2_v1.2 while all other figures are from code v 5830, parameter file Nordic_update_recr2_v1.1.

B.1 Horizontal distributions

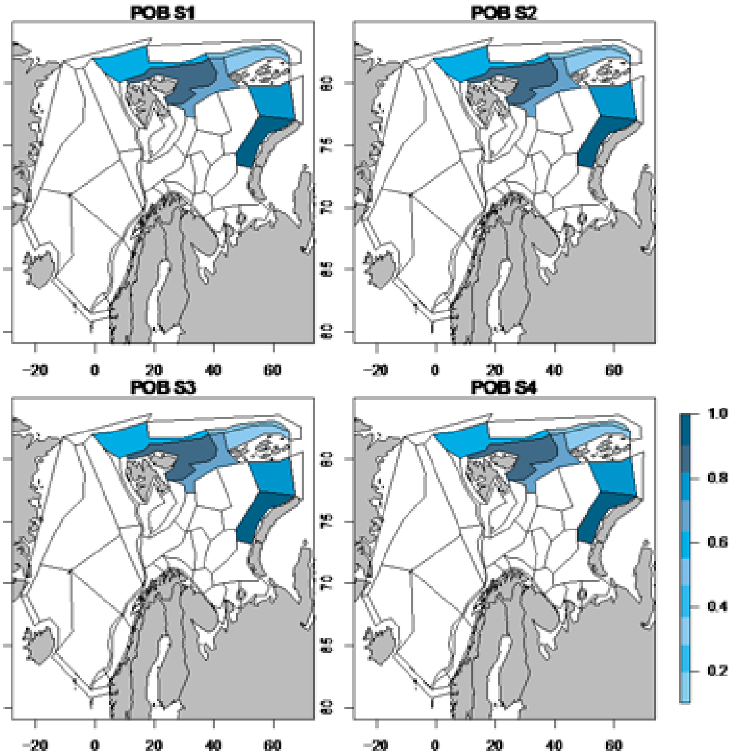

Figure 1: Fractions of polar bears (POB) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

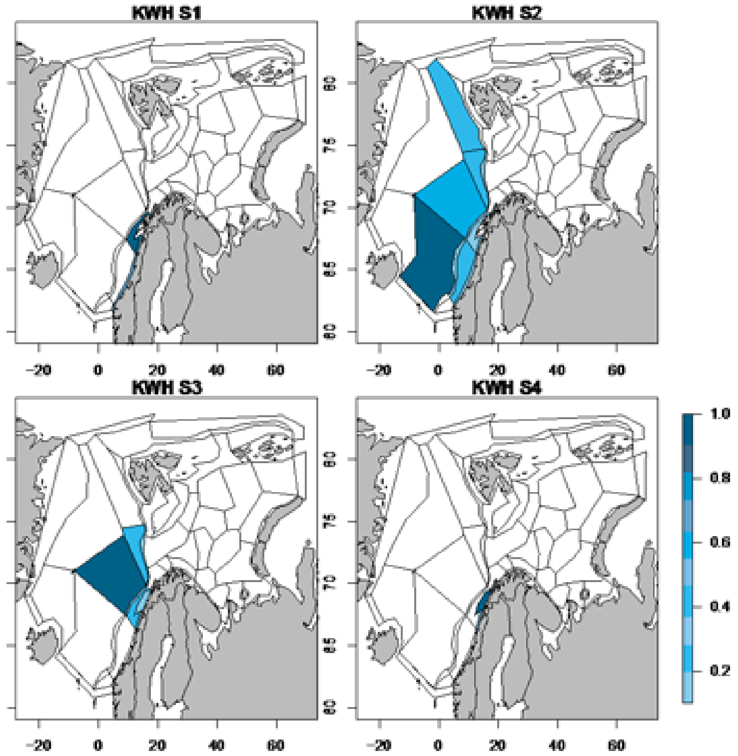

Figure 2: Fractions of killer whales (KWH) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

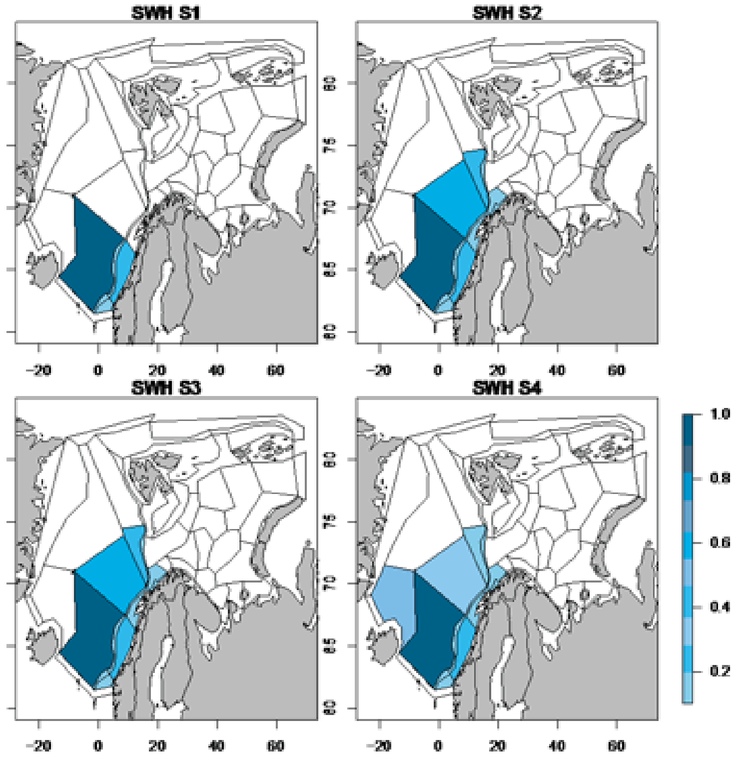

Figure 3: Fractions of sperm whales (SWH) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

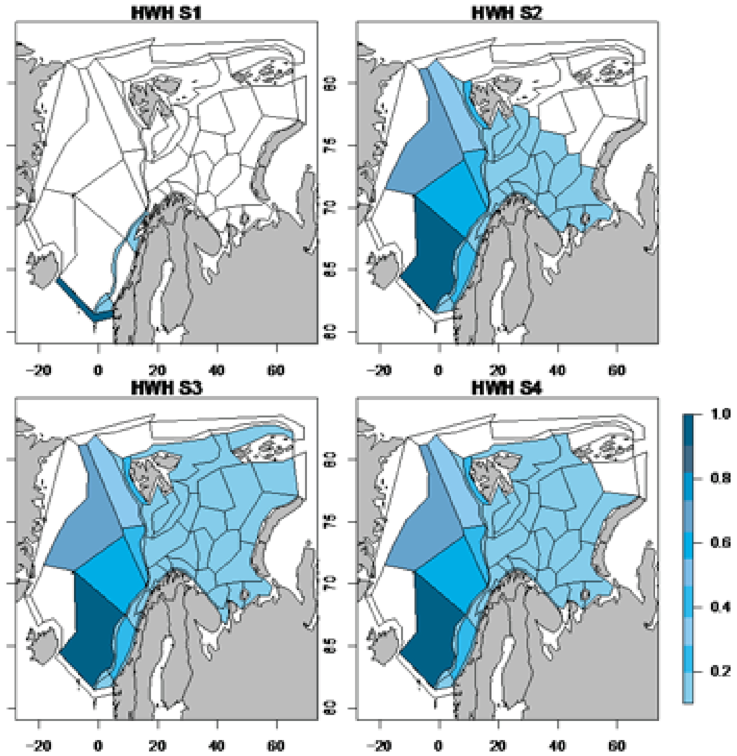

Figure 4: Fractions of humpback whales (HWH) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

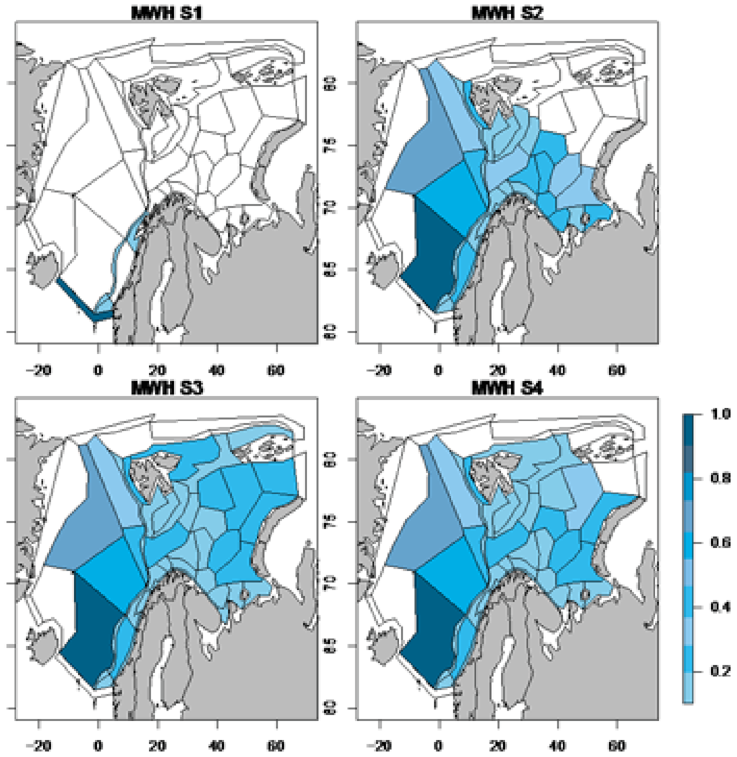

Figure 5: Fractions of minke whales (MWH) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

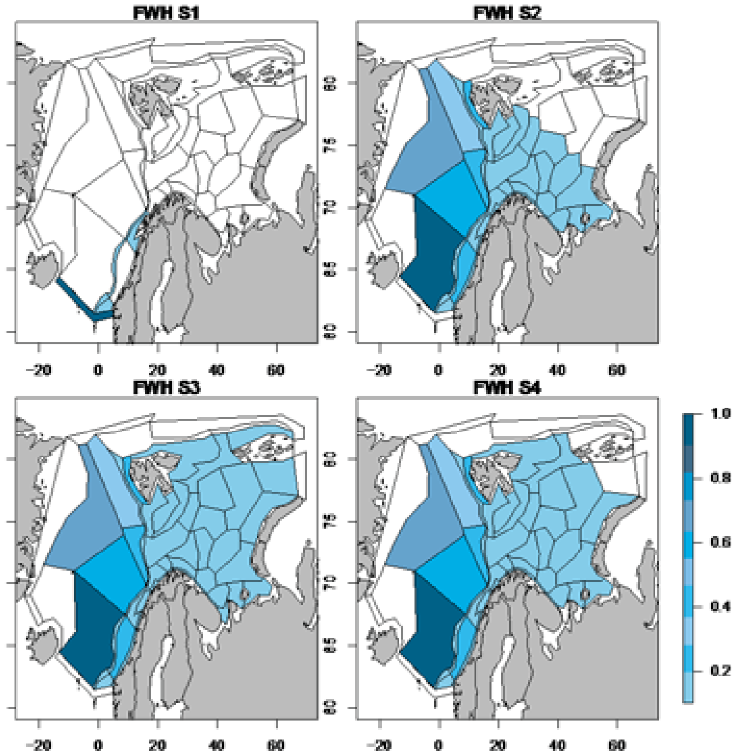

Figure 6: Fractions of fin whales (FWH) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

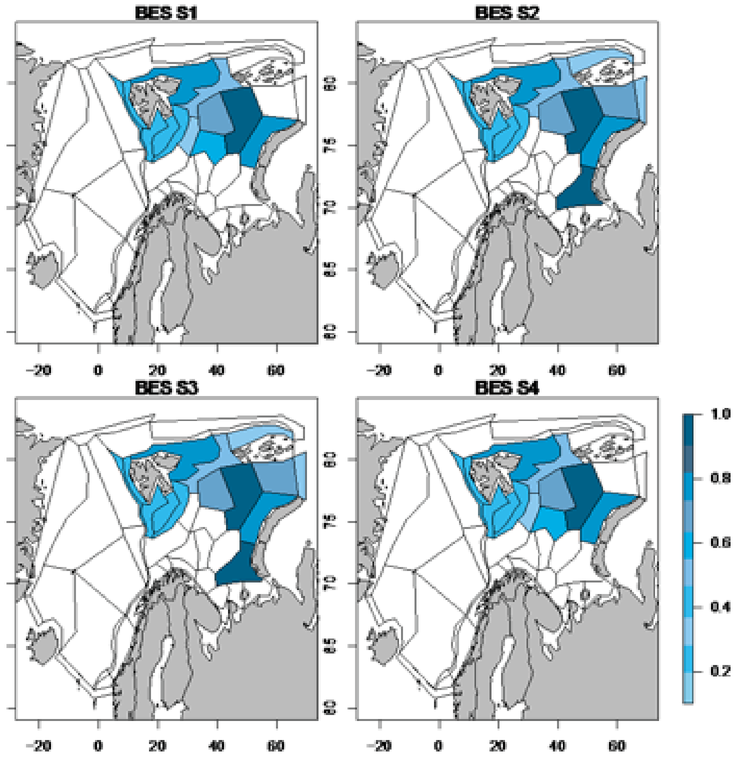

Figure 7: Fractions of bearded seals (BES) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

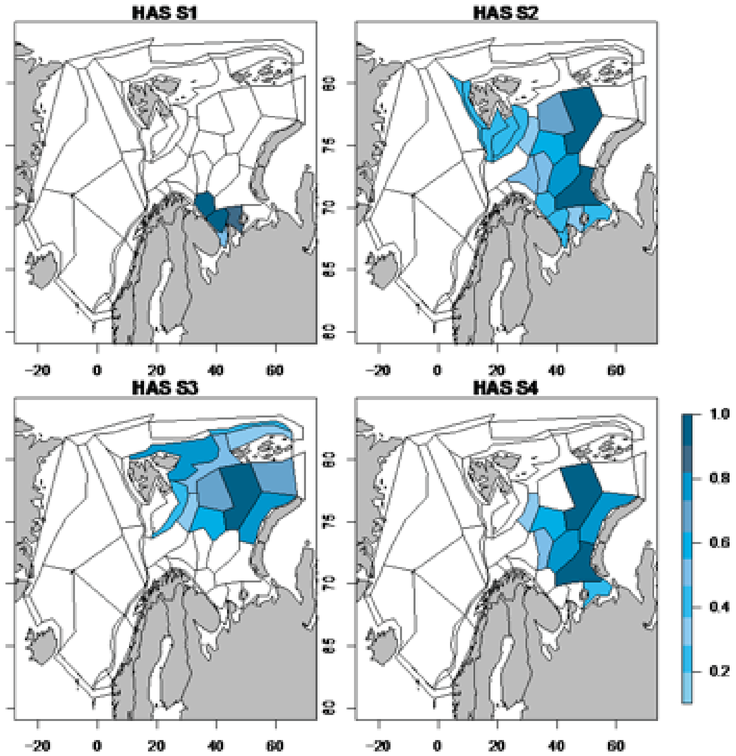

Figure 8: Fractions of harp seals (HAS) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

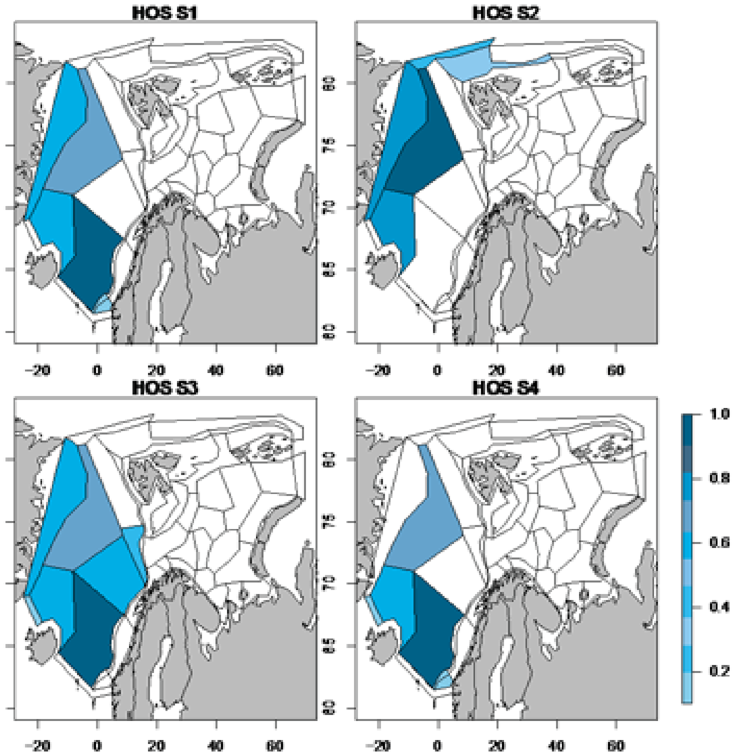

Figure 9: Fractions of hooded seals (HOS) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

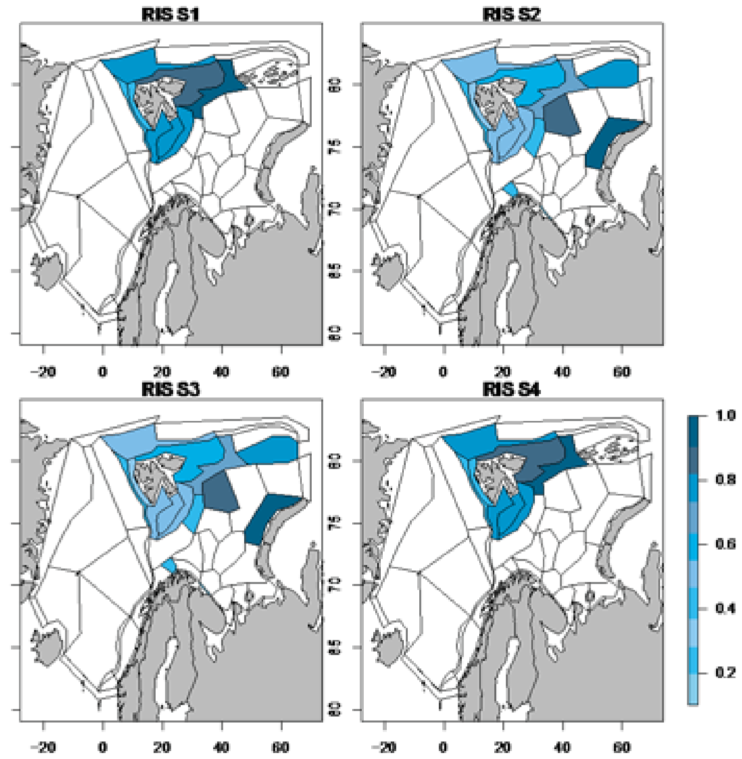

Figure 10: Fractions of ringed seals (RIS) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

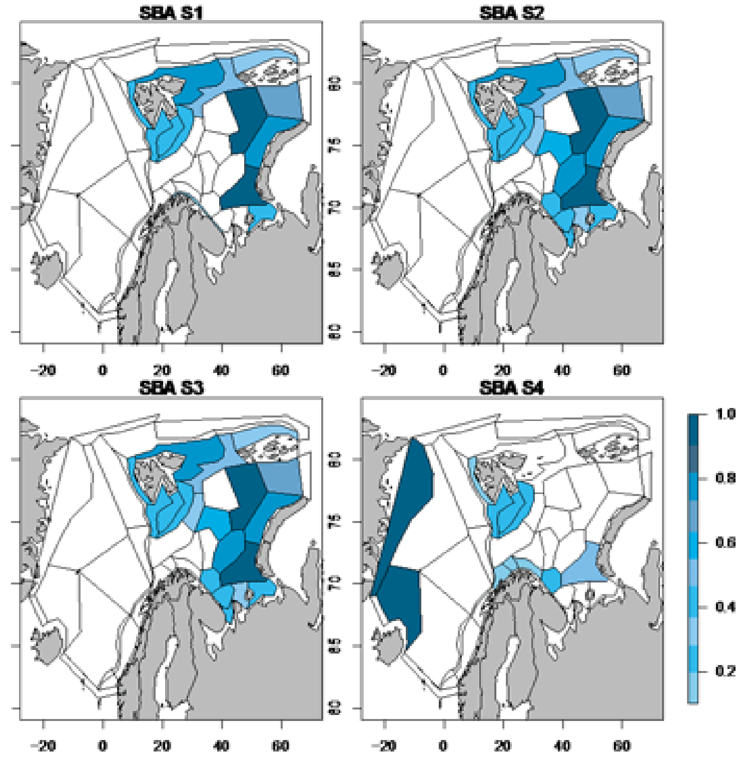

Figure 11: Fractions of arctic seabirds (SBA) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

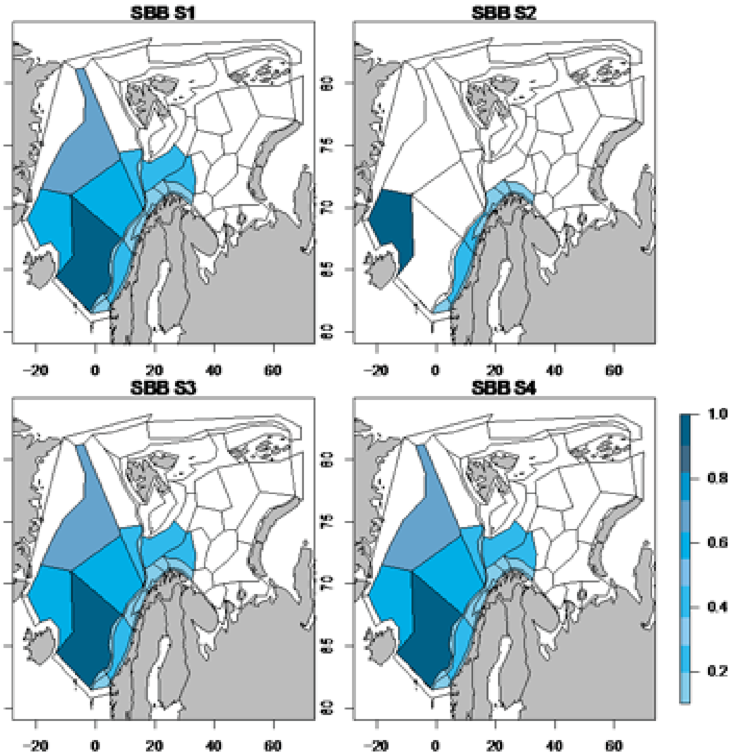

Figure 12: Fractions of boreal seabirds (SBB) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

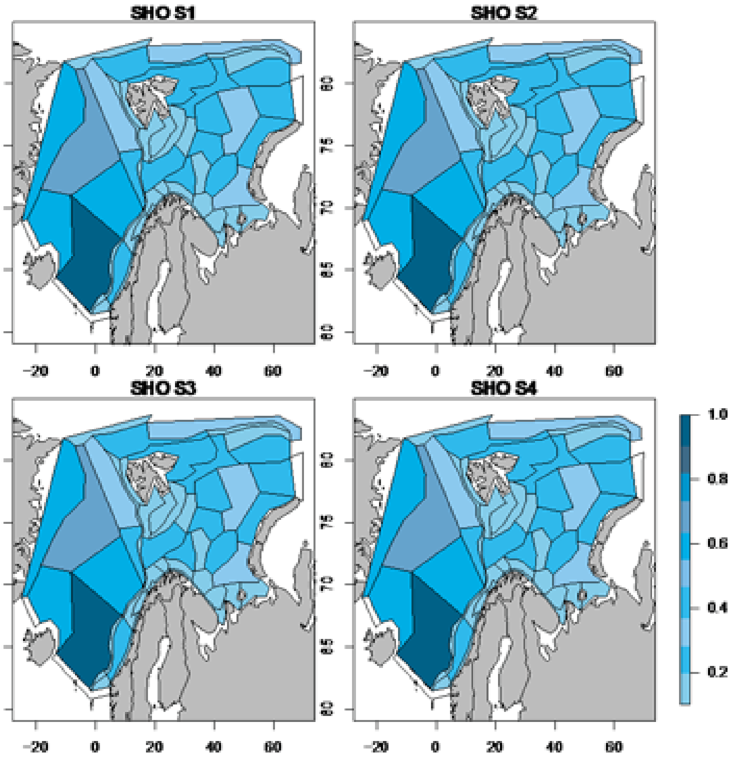

Figure 13: Fractions of other sharks (SHO) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

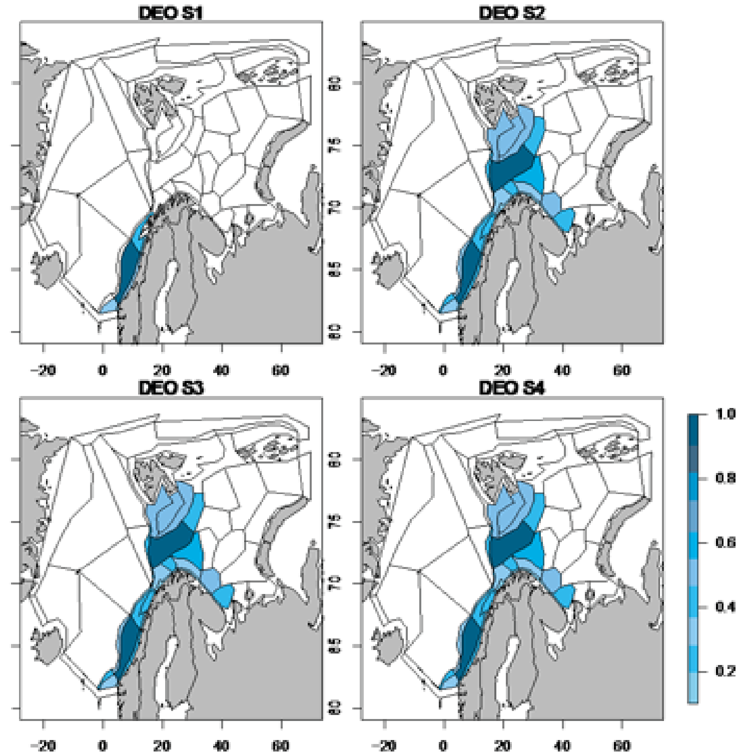

Figure 14: Fractions of other demersals (DEO) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

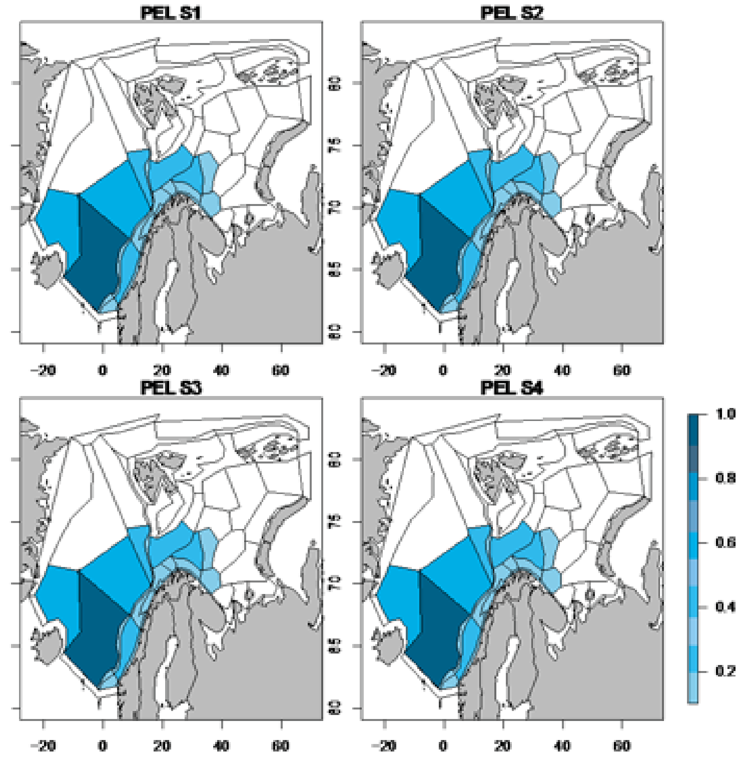

Figure 15: Fractions of large pelagics (PEL) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

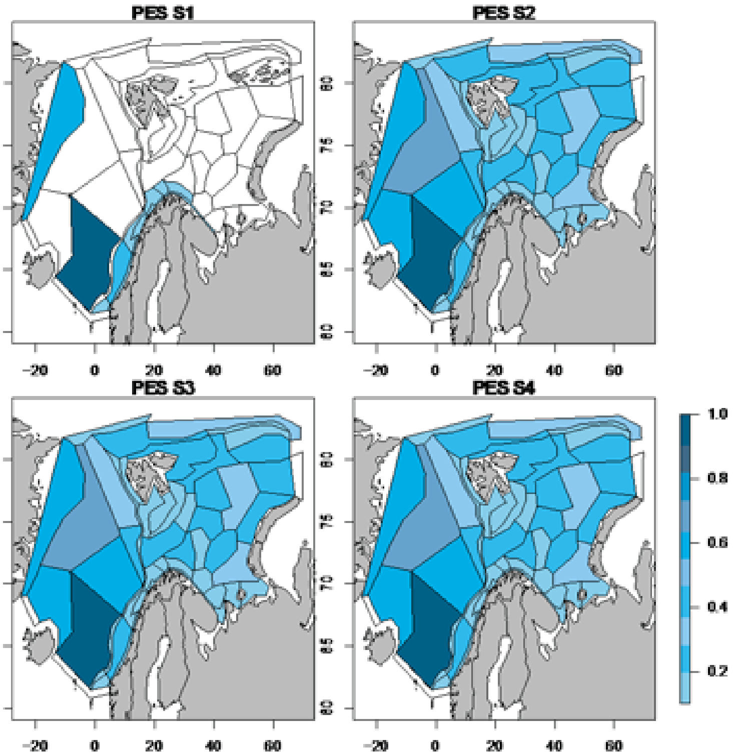

Figure 16: Fractions of small pelagics (PES) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

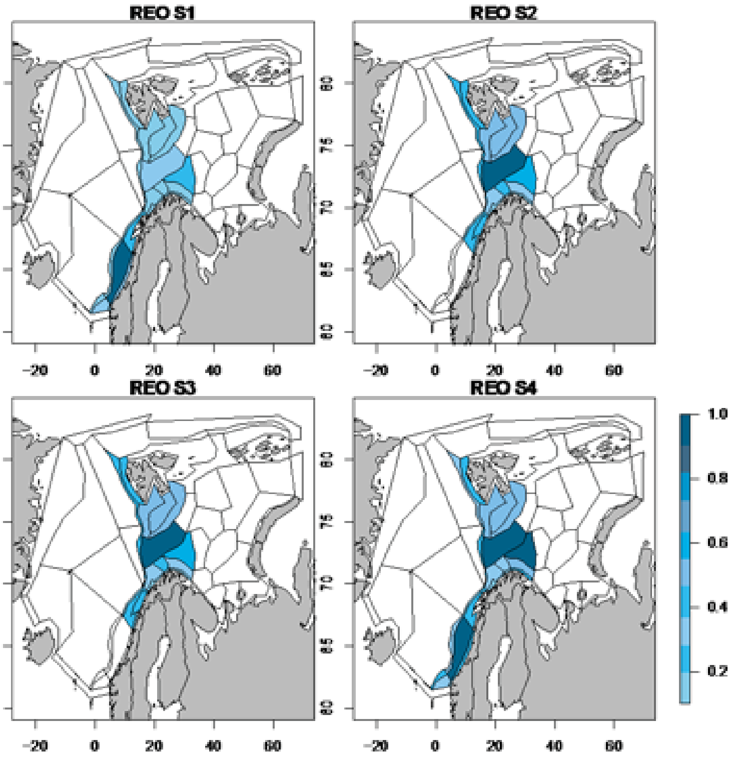

Figure 17: Fractions of other redfish (REO) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

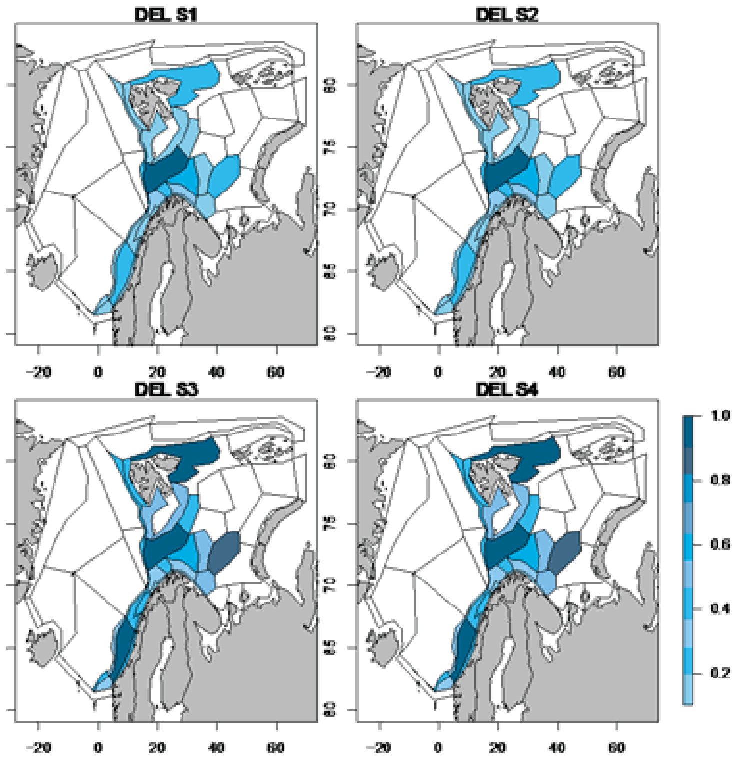

Figure 18: Fractions of large demersals (DEL) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

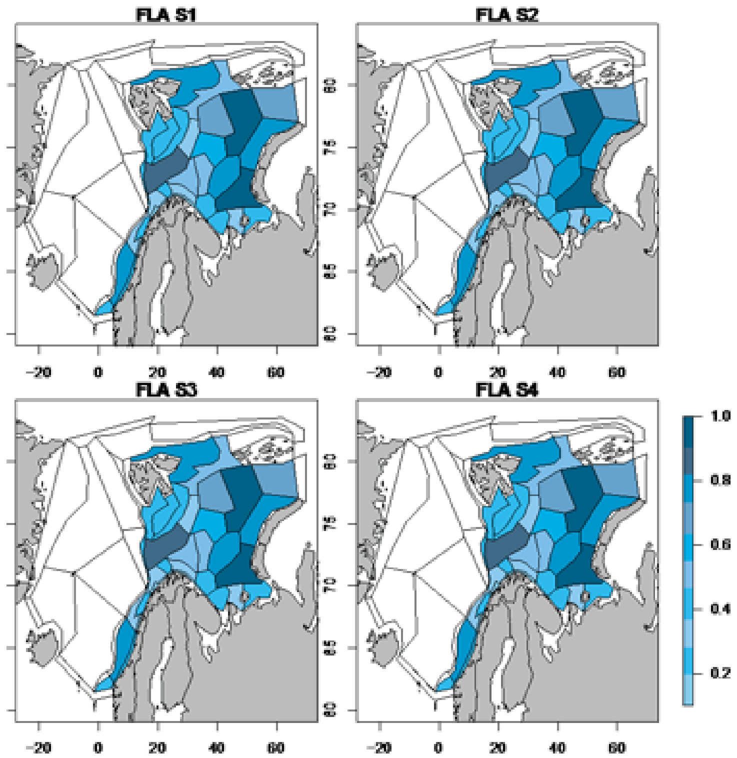

Figure 19: Fractions of other flatfish (FLA) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

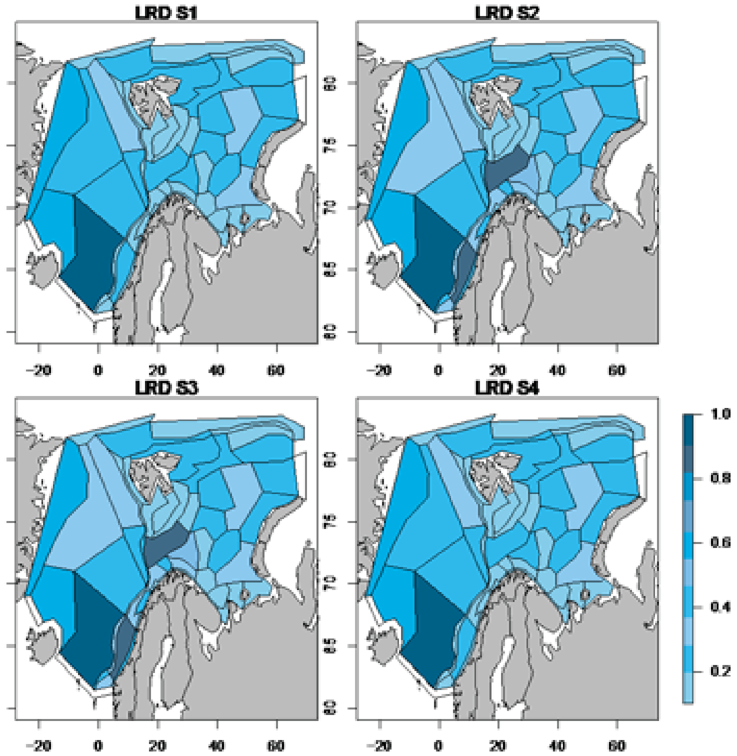

Figure 20: Fractions of long rough dab (LRD) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

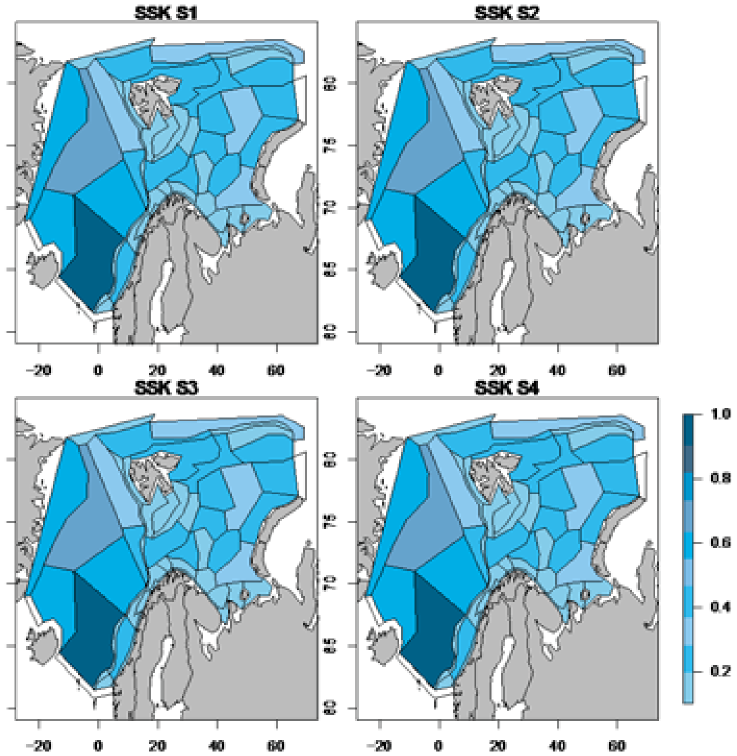

Figure 21: Fractions of skates and rays (SSK) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

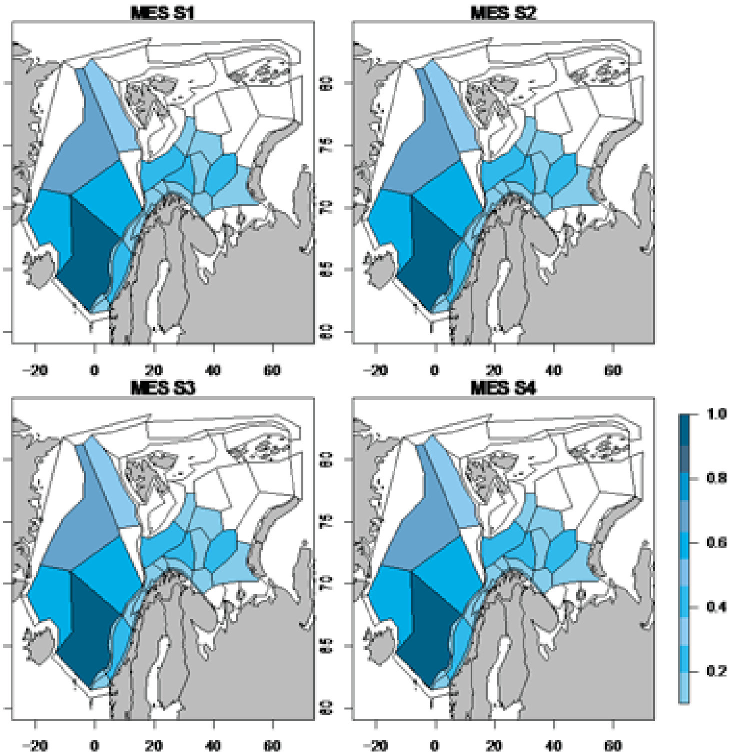

Figure 22: Fractions of mesopelagic fish (MES) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

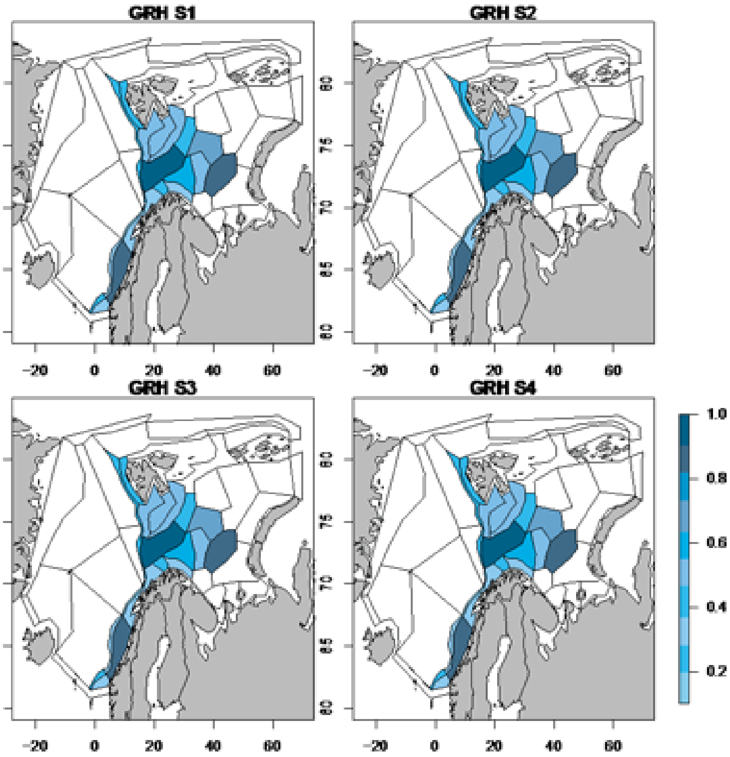

Figure 23: Fractions of Greenland halibut (GRH) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

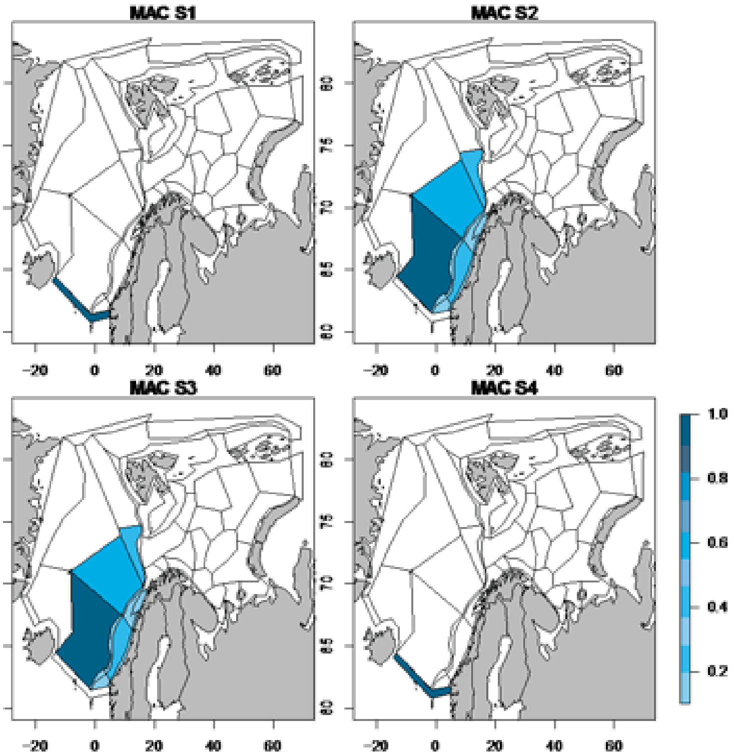

Figure 24: Fractions of mackerel (MAC) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

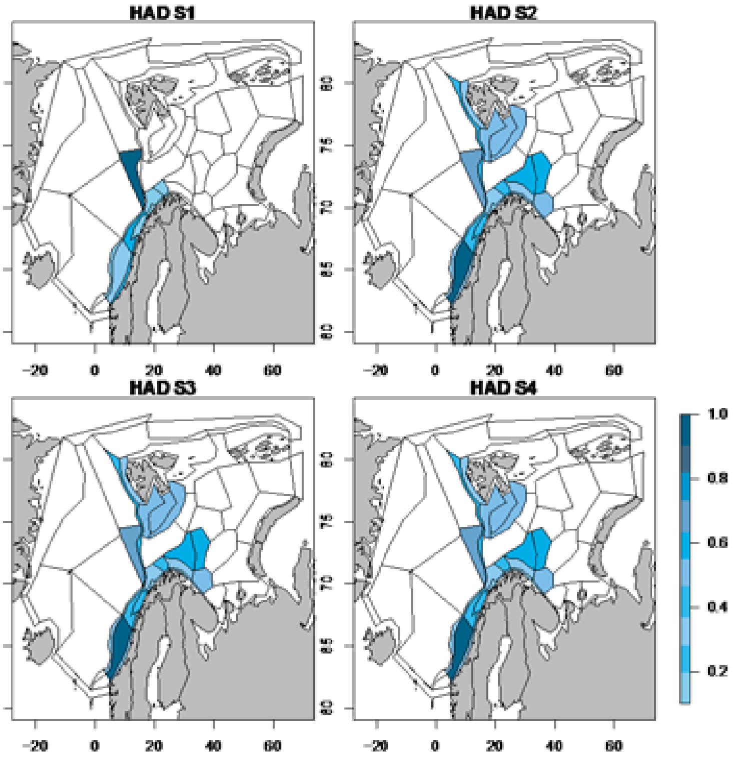

Figure 25: Fractions of haddock (HAD) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

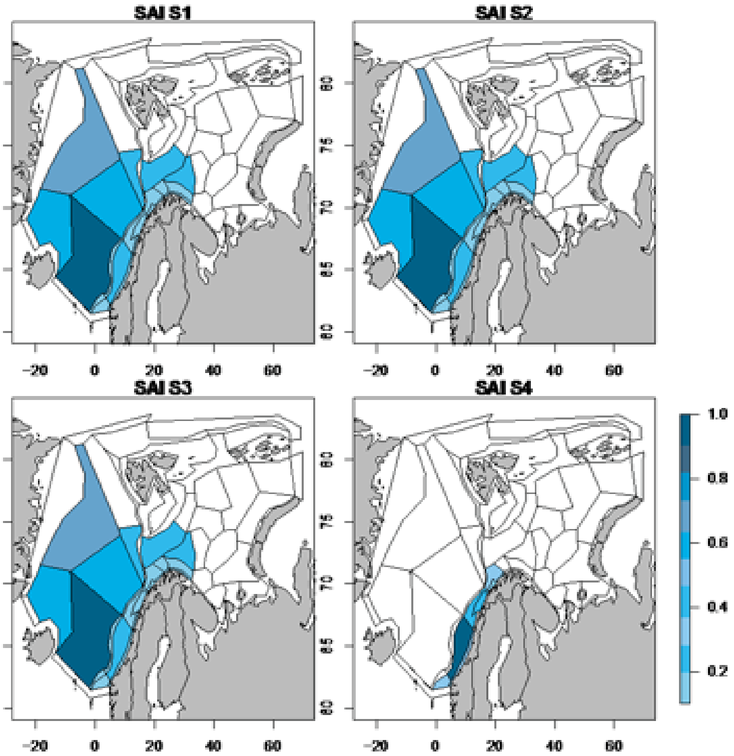

Figure 26: Fractions of saithe (SAI) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

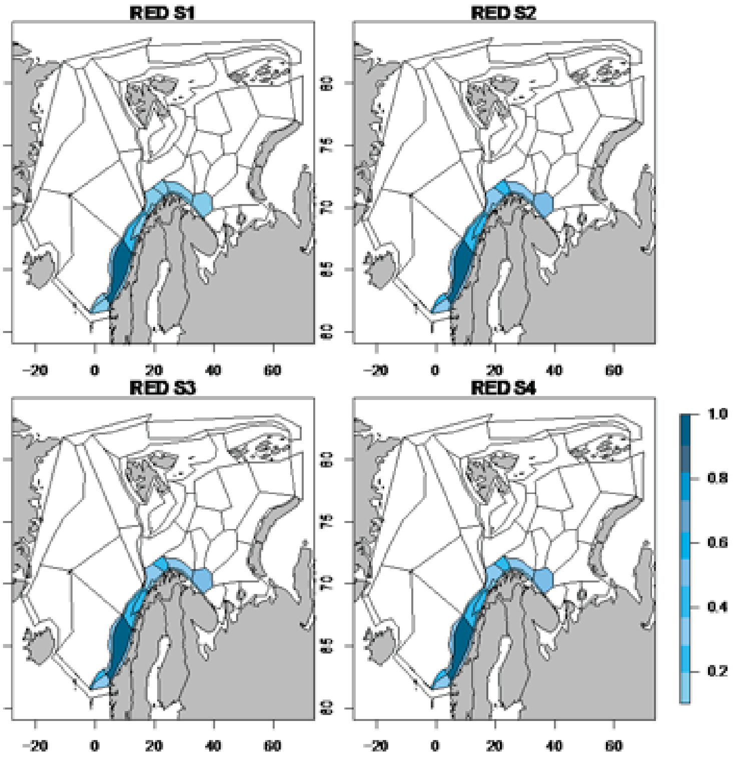

Figure 27: Fractions of redfish (RED) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

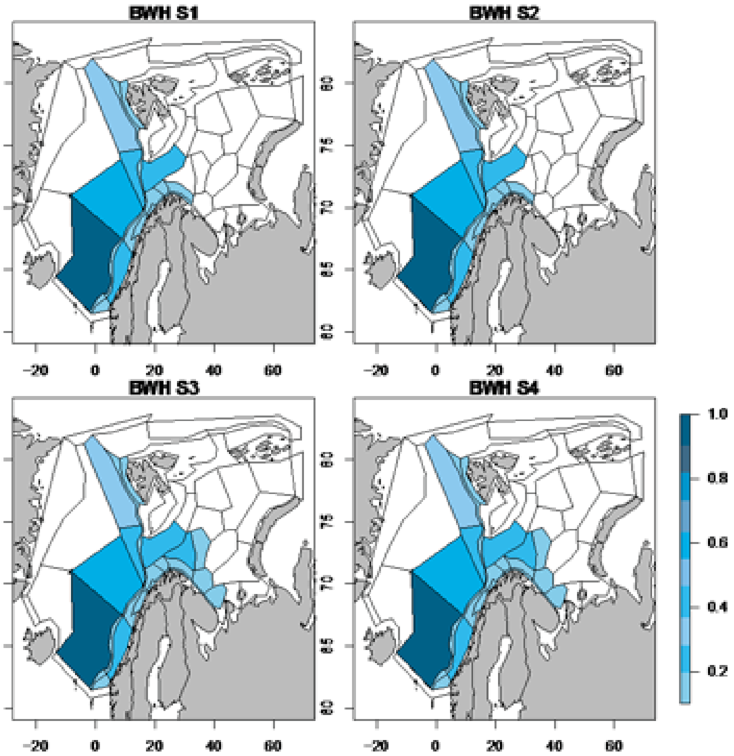

Figure 28: Fractions of blue whiting (BWH) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

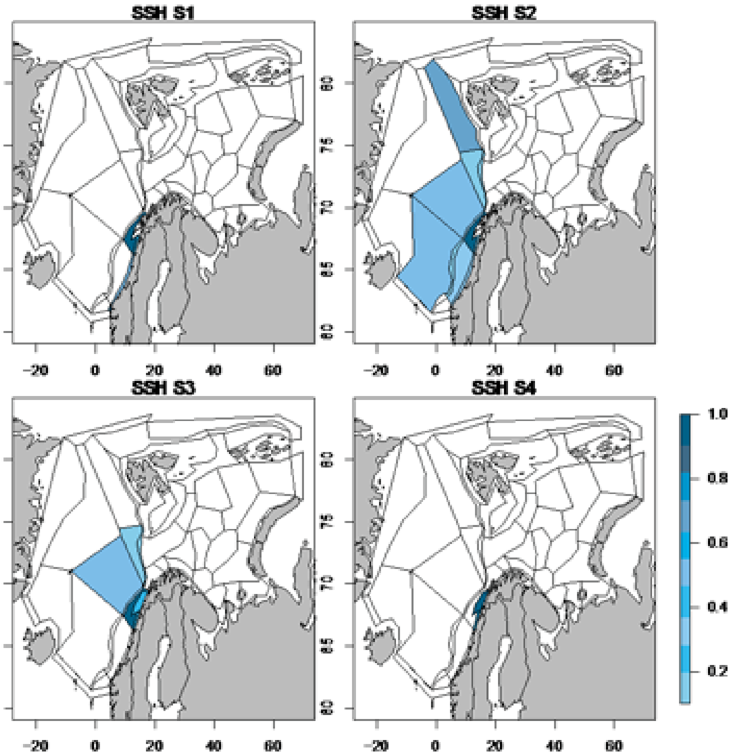

Figure 29: Fractions of Norwegian spring spawning herring (SSH) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

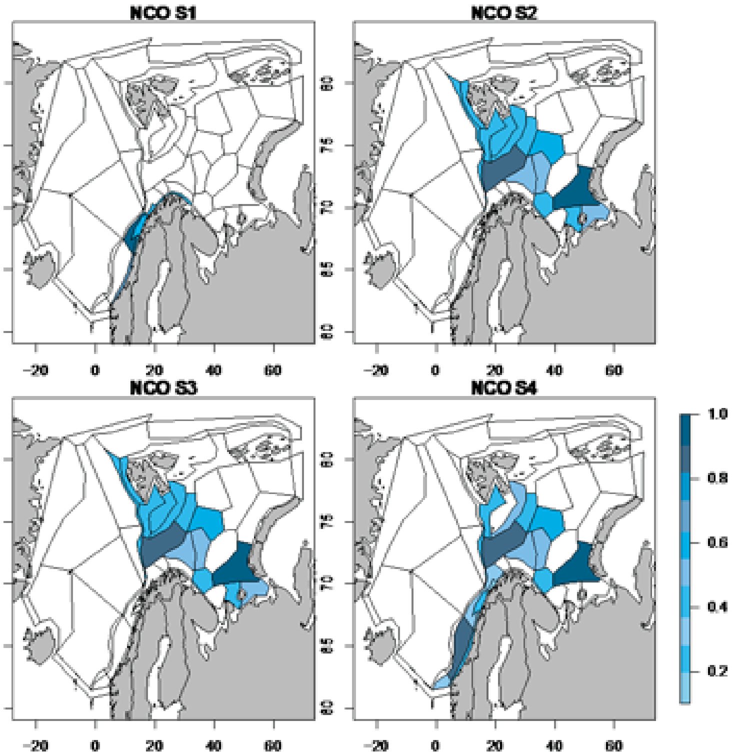

Figure 30: Fractions of Northeast arctic cod (NCO) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

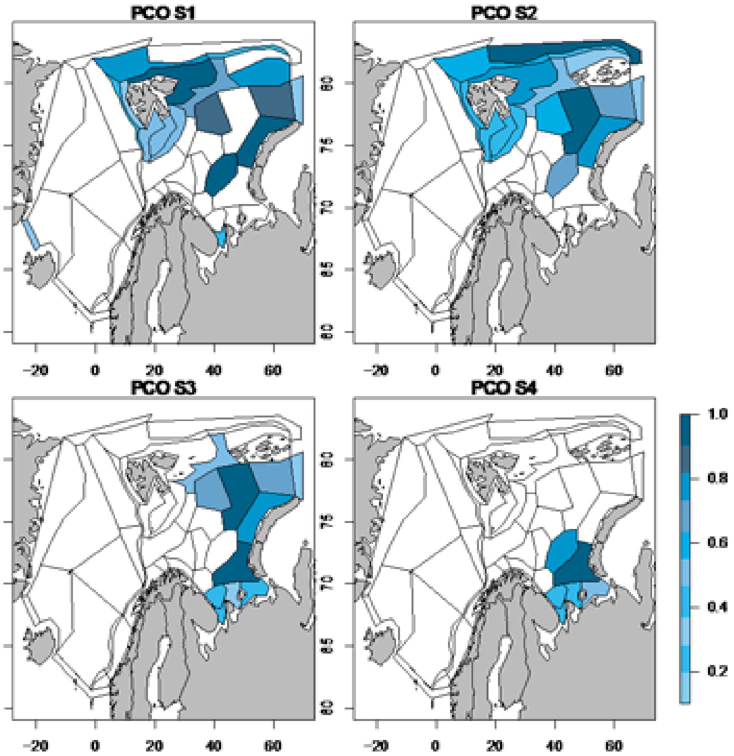

Figure 31: Fractions of polar cod (PCO) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

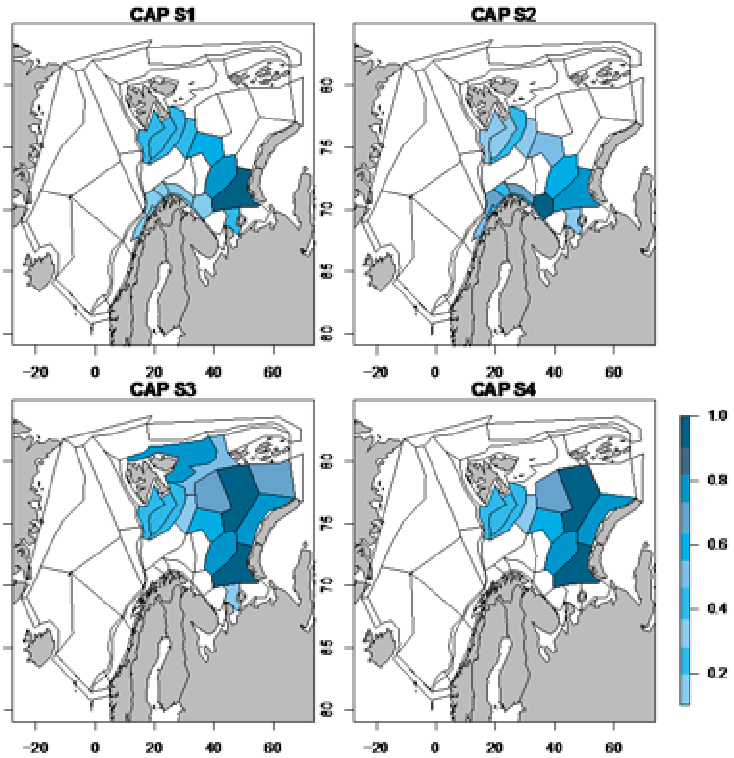

Figure 32: Fractions of bearded seals (CAP) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

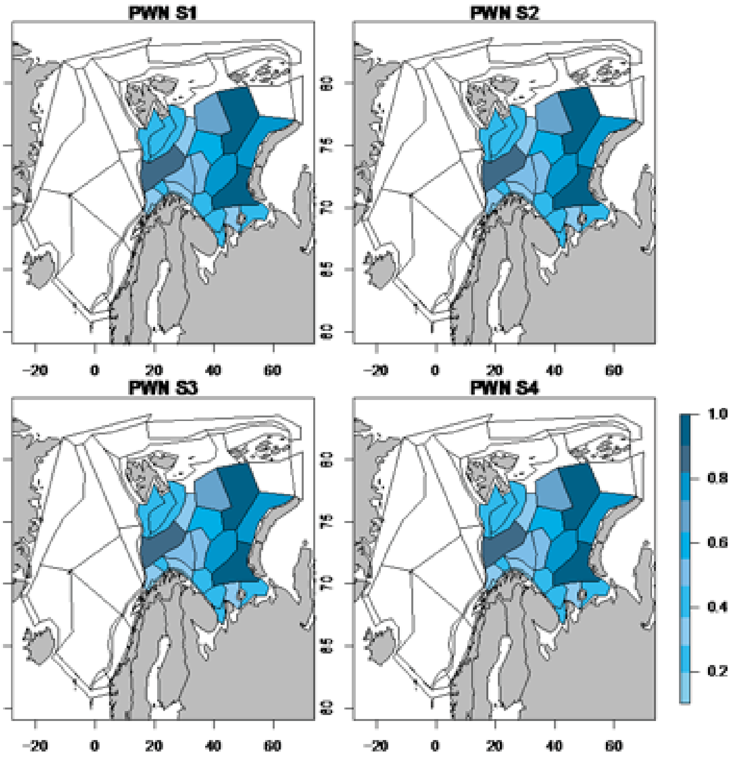

Figure 33: Fractions of shrimps (PWN) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

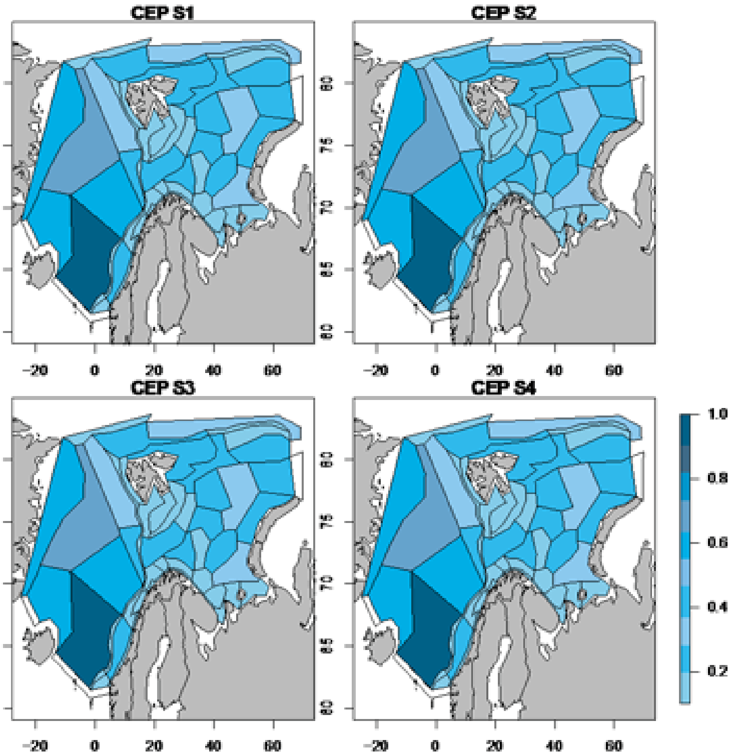

Figure 34: Fractions of squid (CEP) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

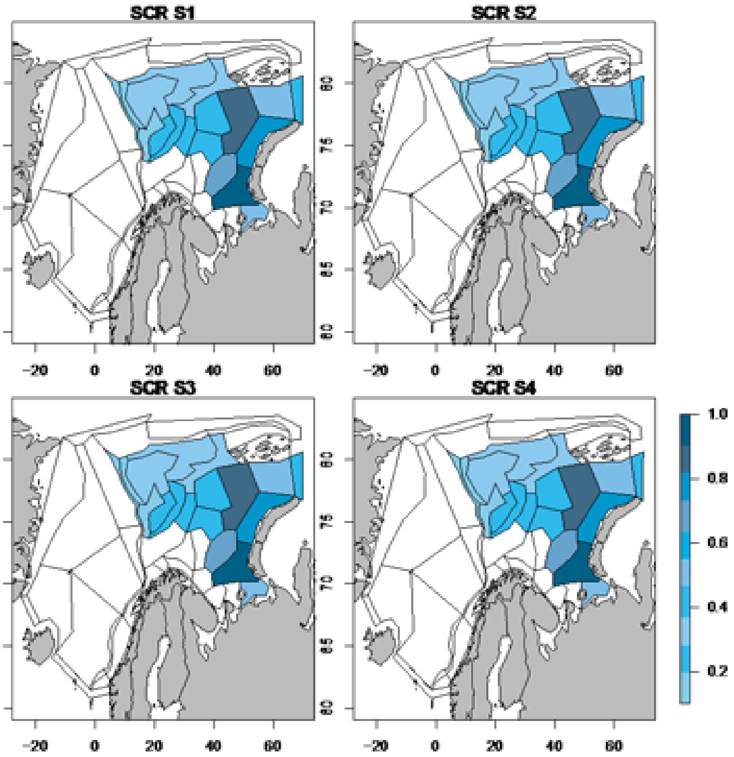

Figure 35: Fractions of snow crab (SCR) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

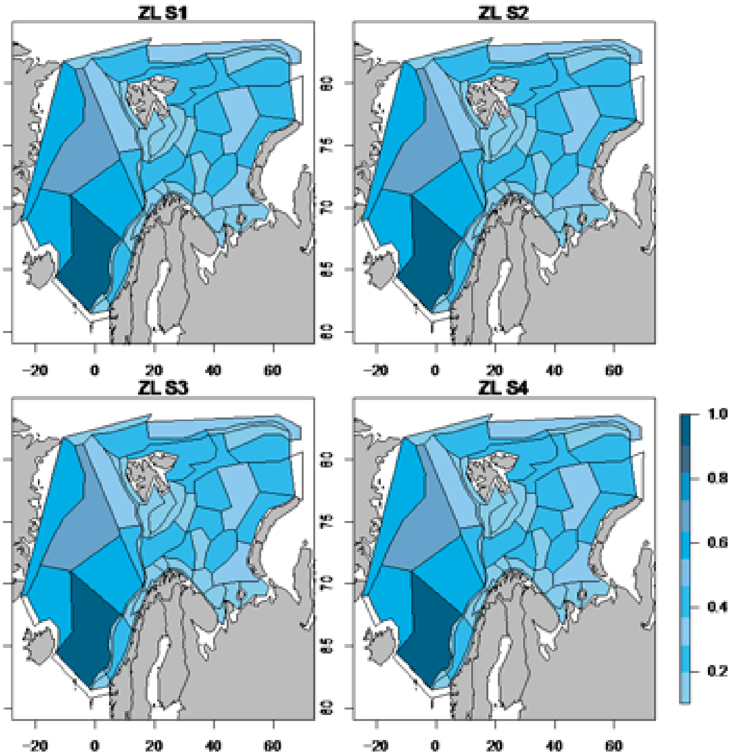

Figure 36: Fractions of large zooplankton (ZL) in the different polygons in the four seasons: winter (S1), spring (S2), summer (S3) and autumn (S4).

B.2 Biomasses

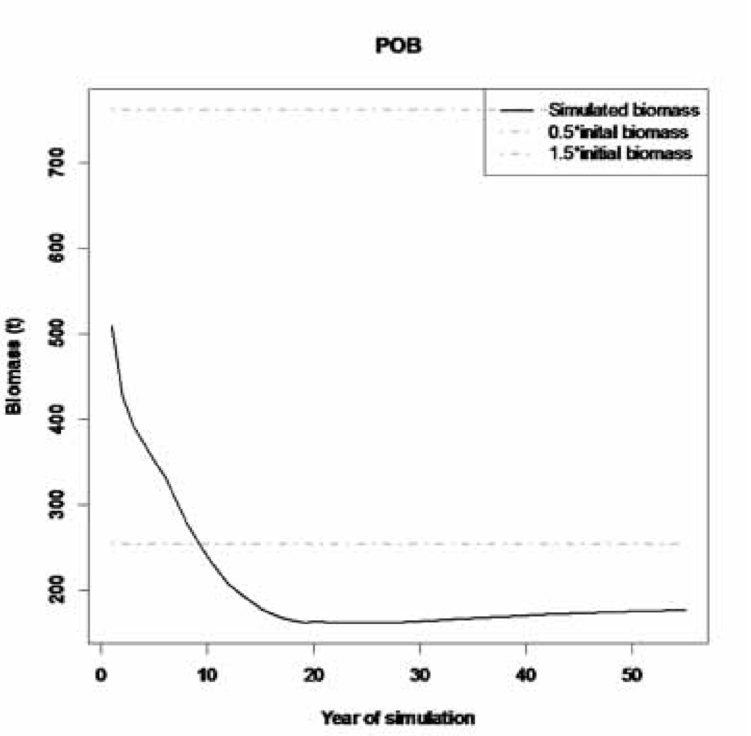

Figure 1: Biomass of polar bears (POB) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

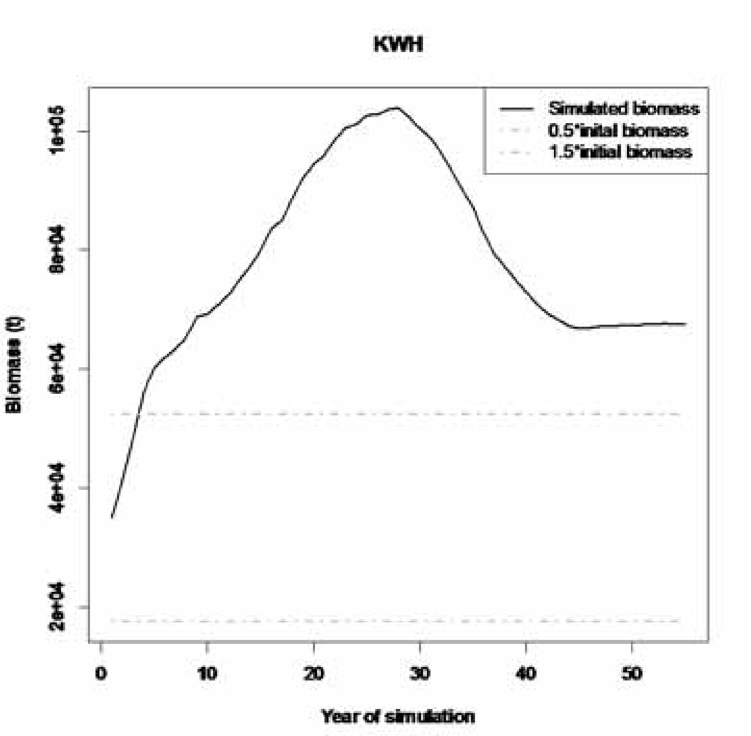

Figure 2: Biomass of killer whales (KWH) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

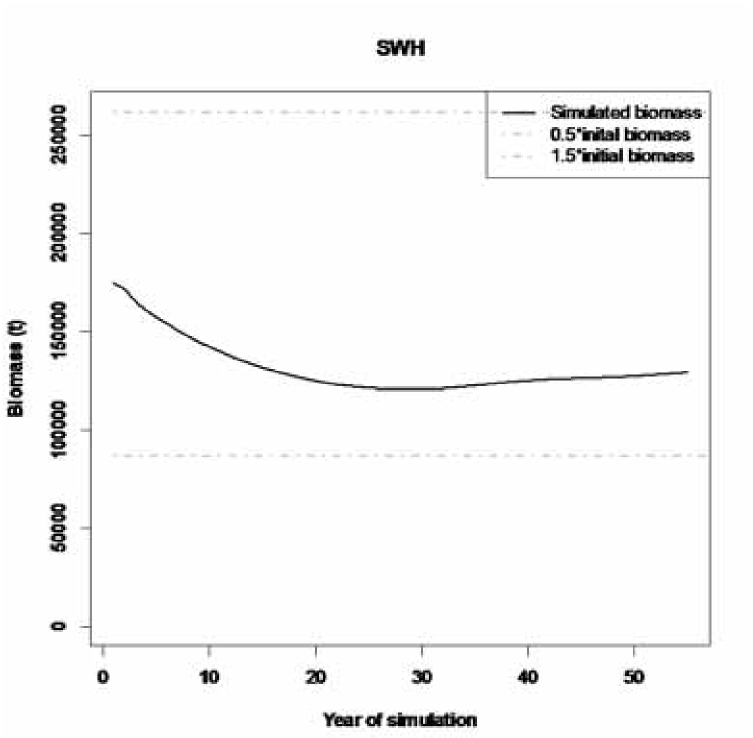

Figure 3: Biomass of sperm whales (SWH) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

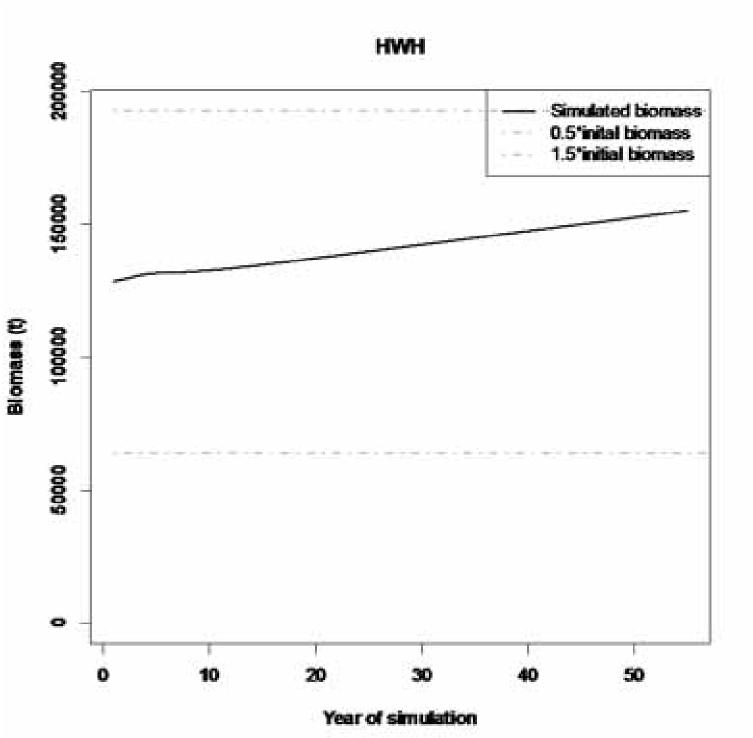

Figure 4: Biomass of humpback whales (HWH) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

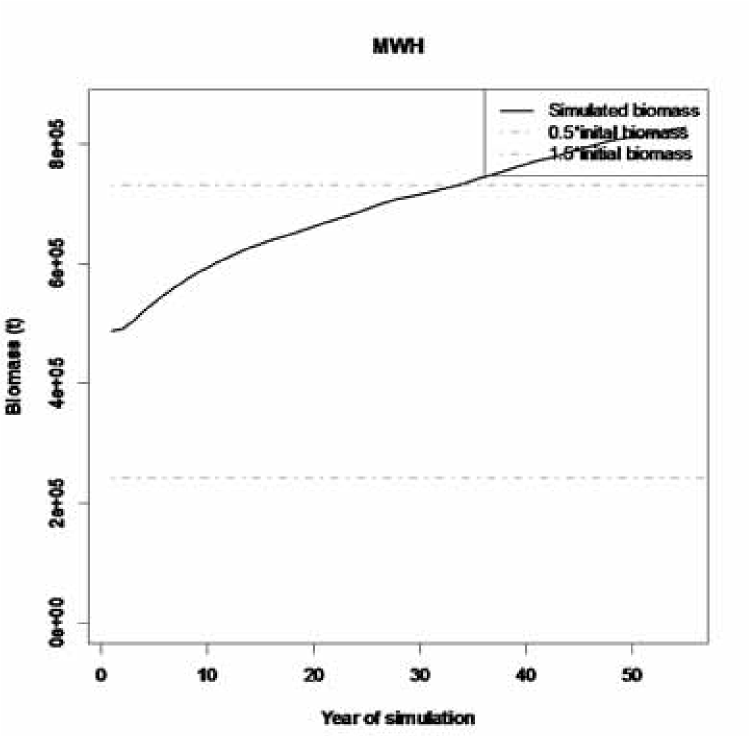

Figure 5: Biomass of minke whales (MWH) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

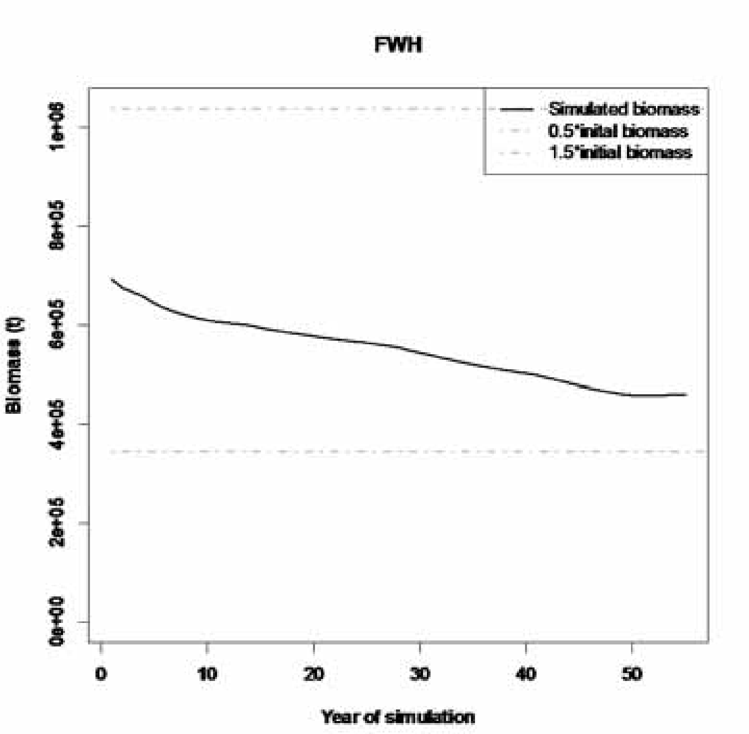

Figure 6: Biomass of fin whales (FWH) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

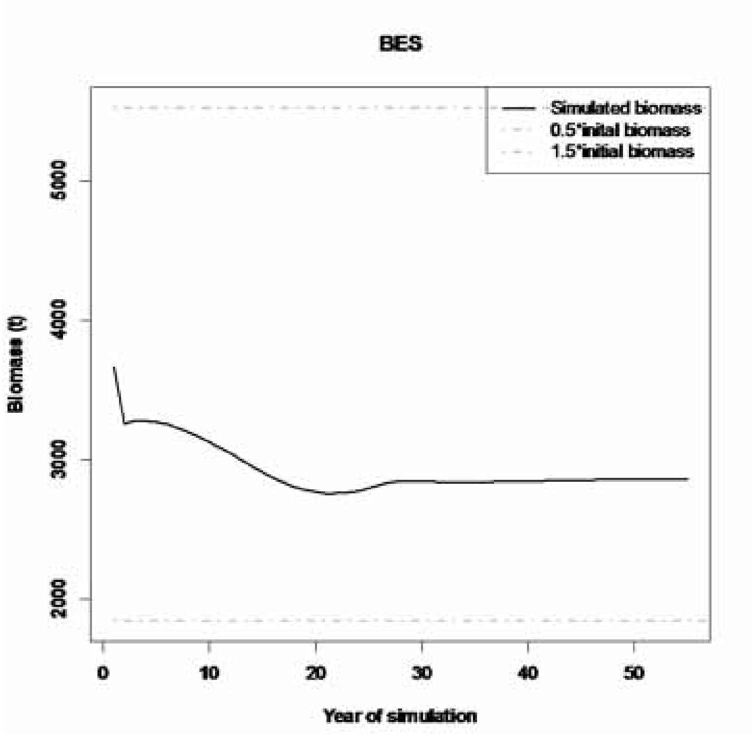

Figure 7: Biomass of bearded seals (BES) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

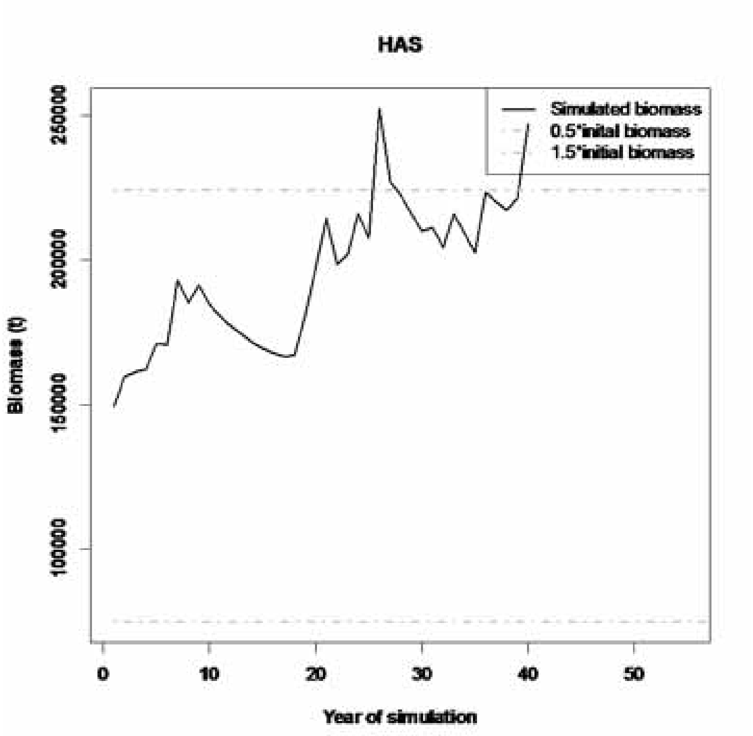

Figure 8: Biomass of harp seals (HAS) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

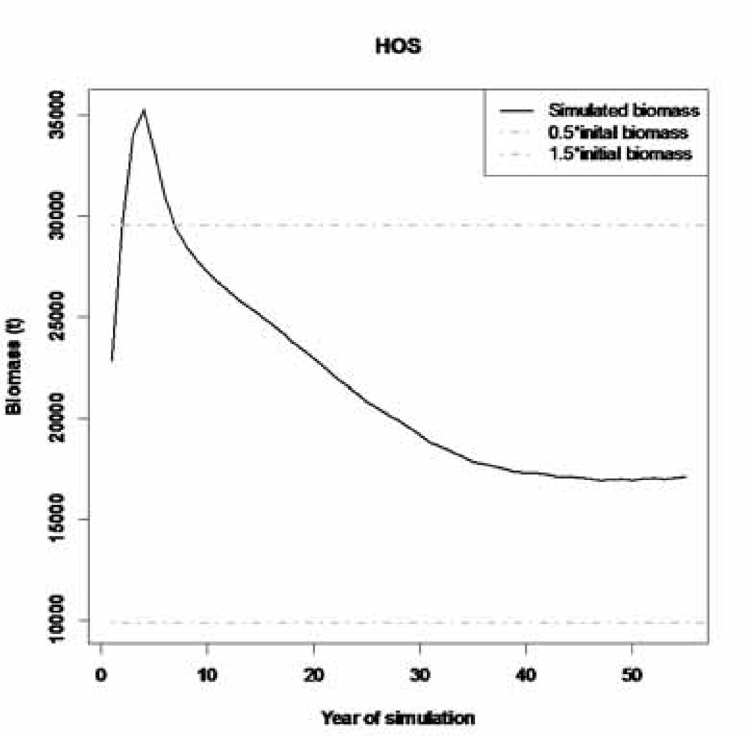

Figure 9: Biomass of hooded seals (HOS) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

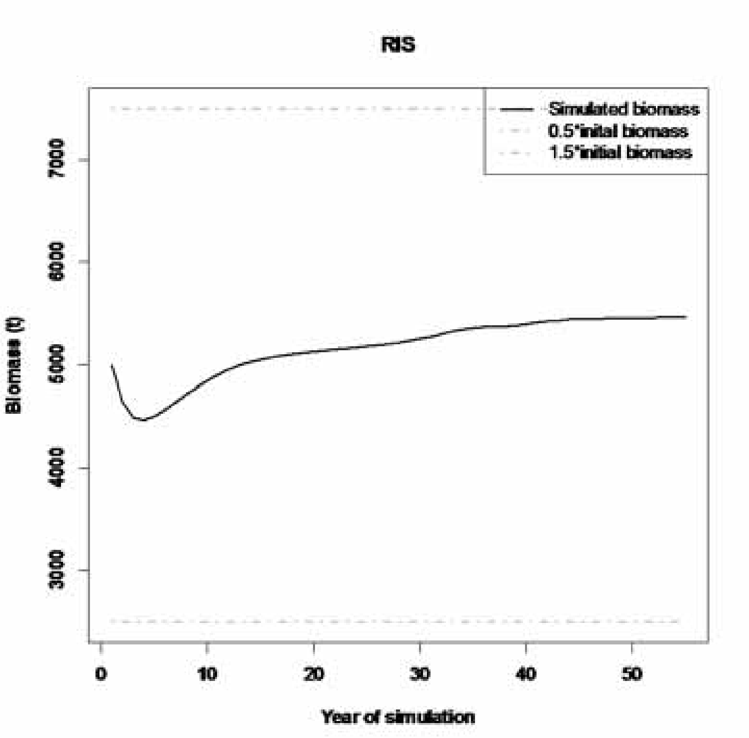

Figure 10: Biomass of ringed seals (RIS) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

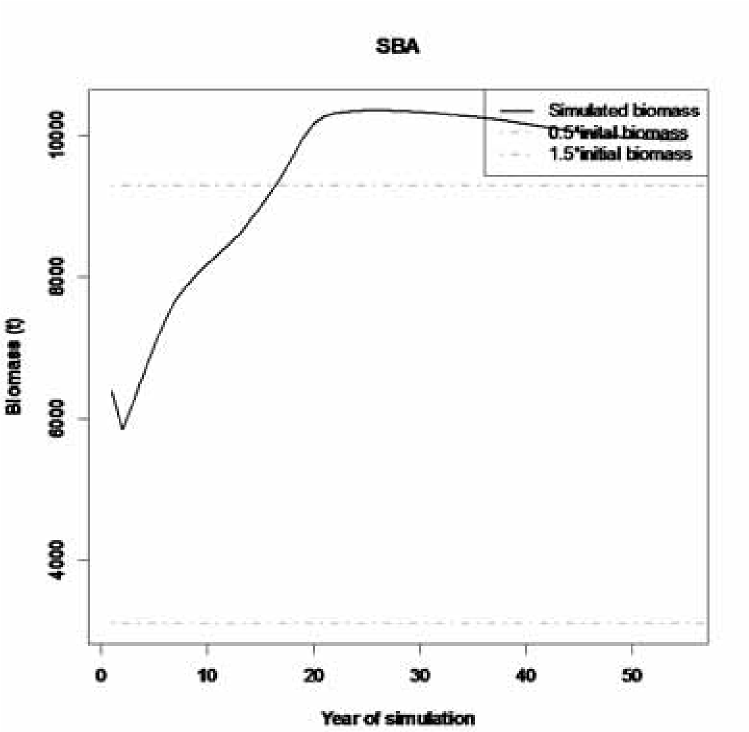

Figure 11: Biomass of arctic seabirds (SBA) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

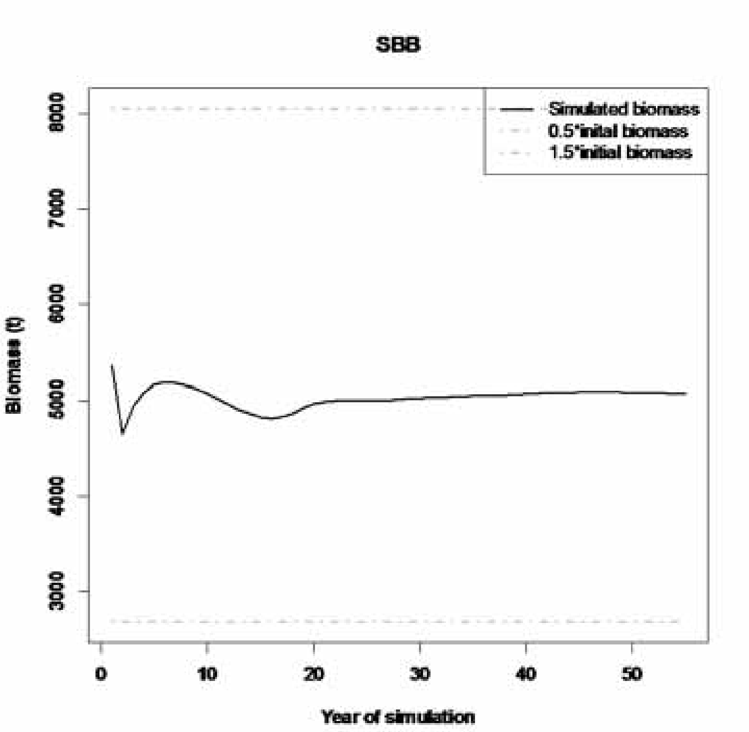

Figure 12: Biomass of boreal seabirds (SBB) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

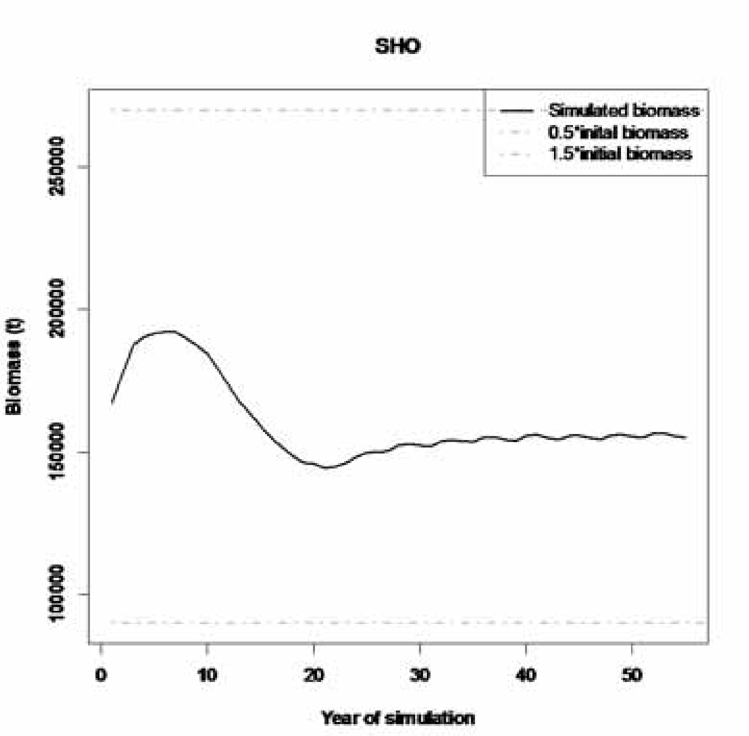

Figure 13: Biomass of other sharks (SHO) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

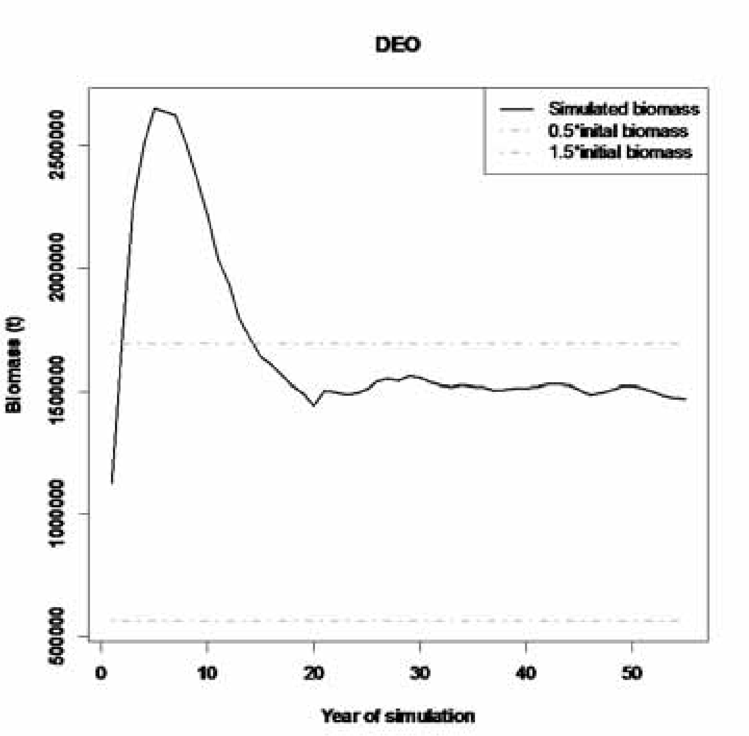

Figure 14: Biomass of other demersals (DEO) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

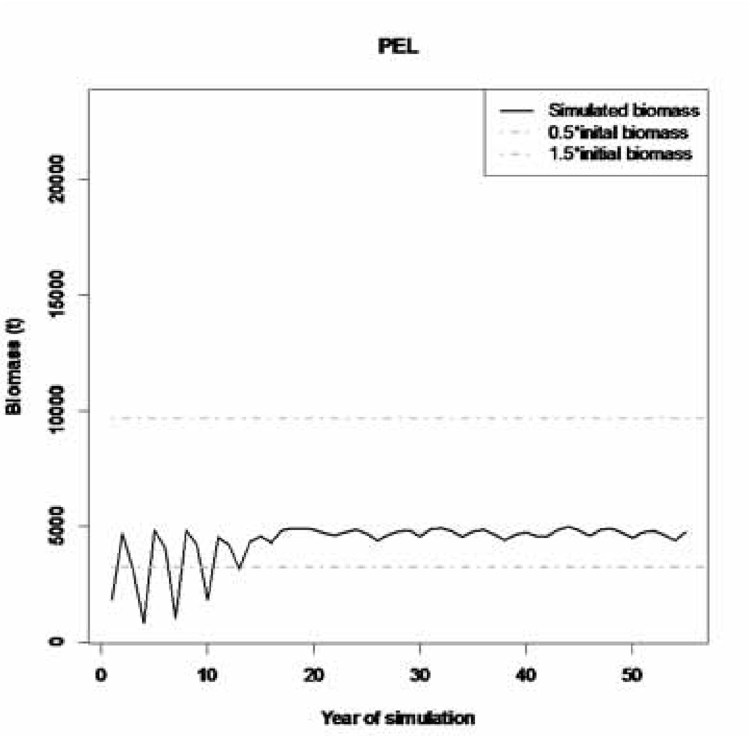

Figure 15: Biomass of large pelagics (PEL) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

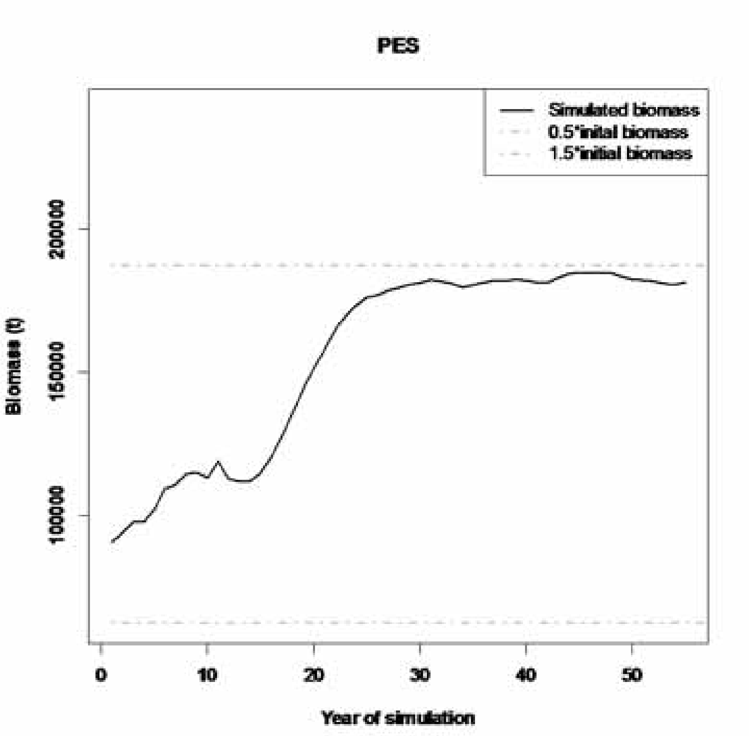

Figure 16: Biomass of small pelagics (PES) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

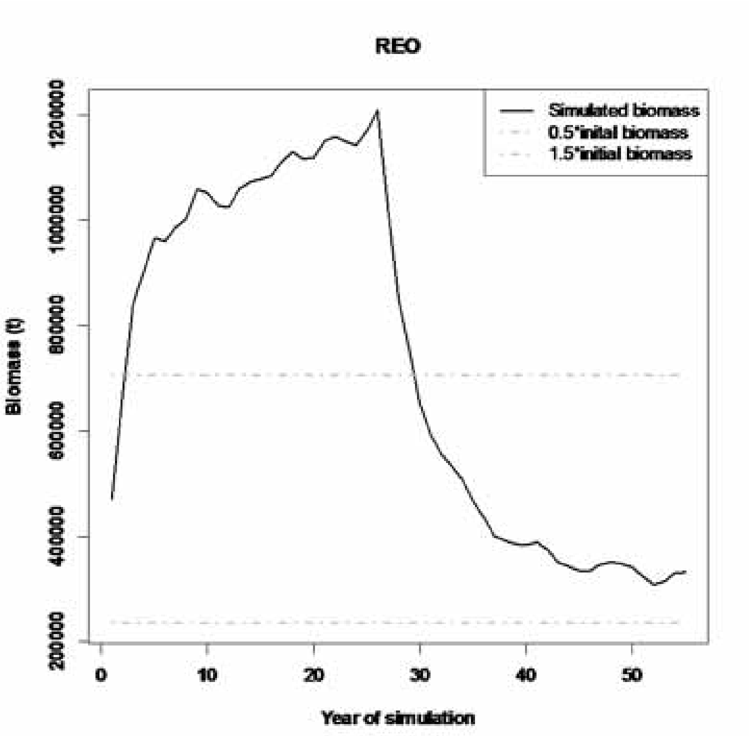

Figure 17: Biomass of other redfish (REO) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

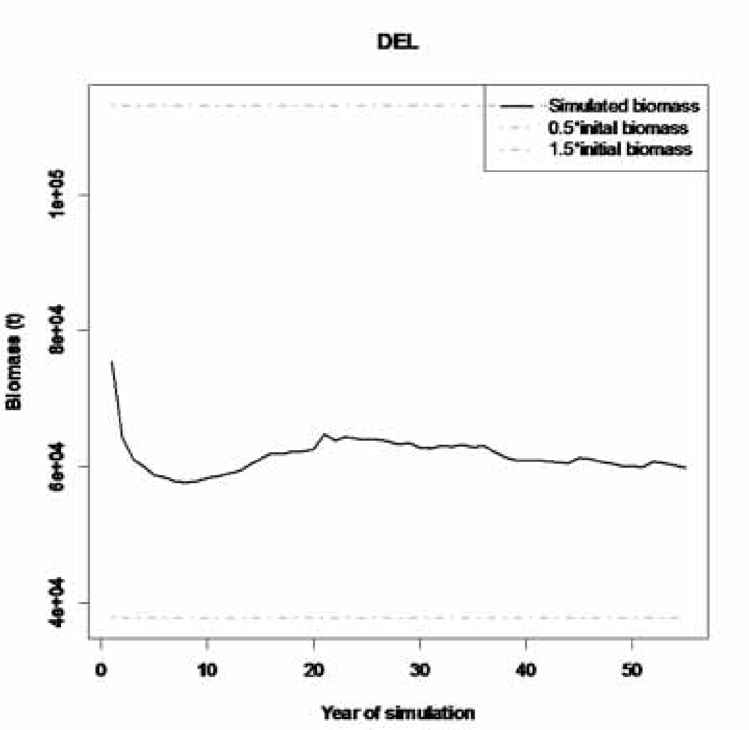

Figure 18: Biomass of large demersals (DEL) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

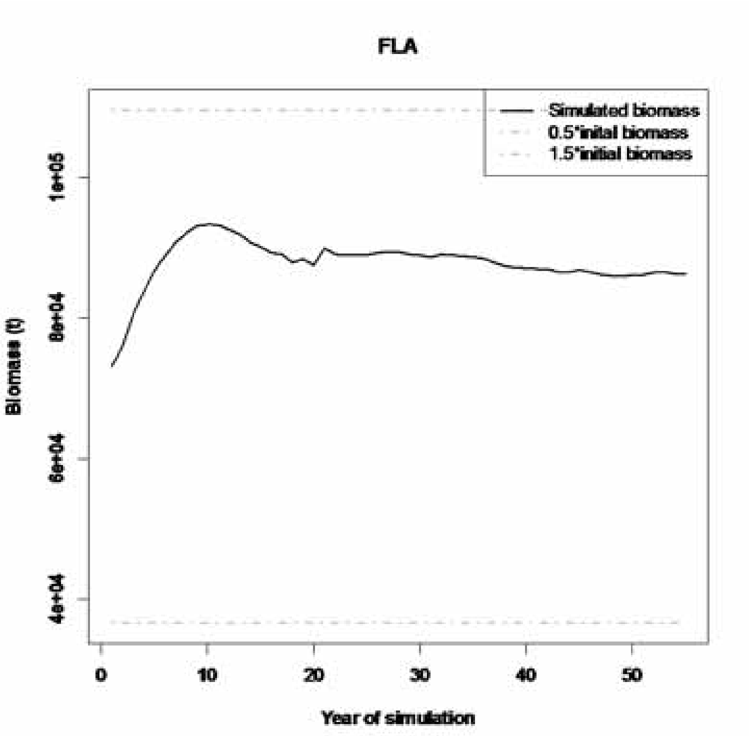

Figure 19: Biomass of flatfish (FLA) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

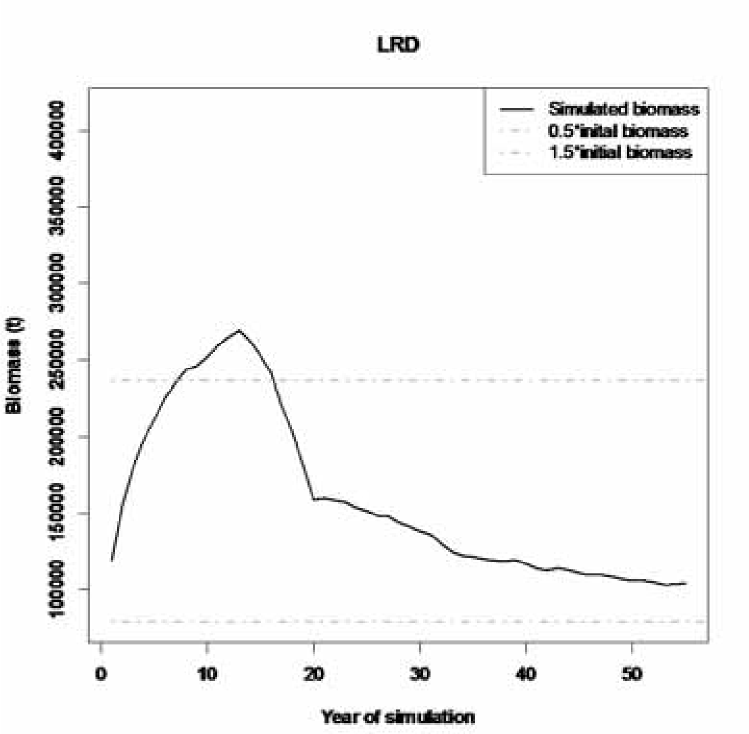

Figure 20: Biomass of long rough dab (LRD) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

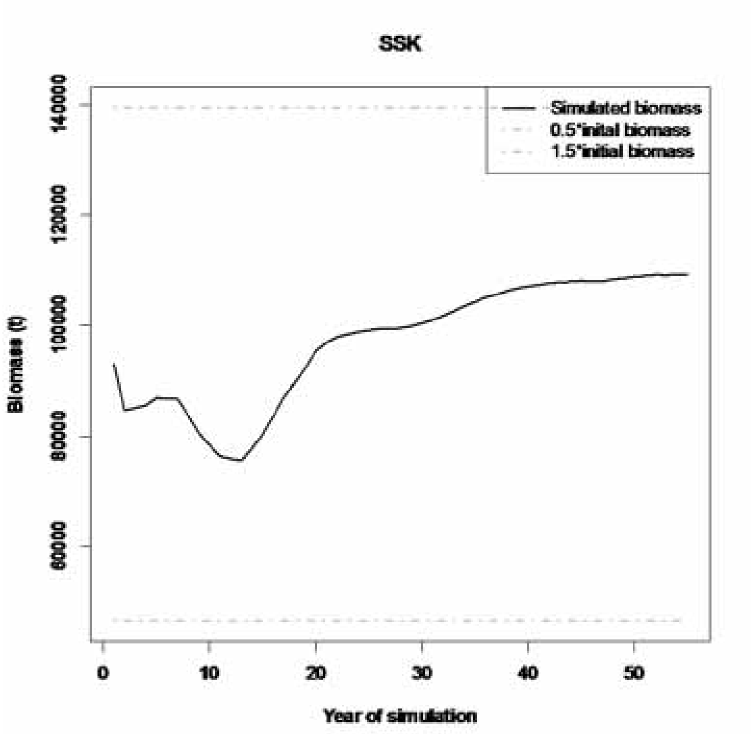

Figure 21: Biomass of skates and rays (SSK) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

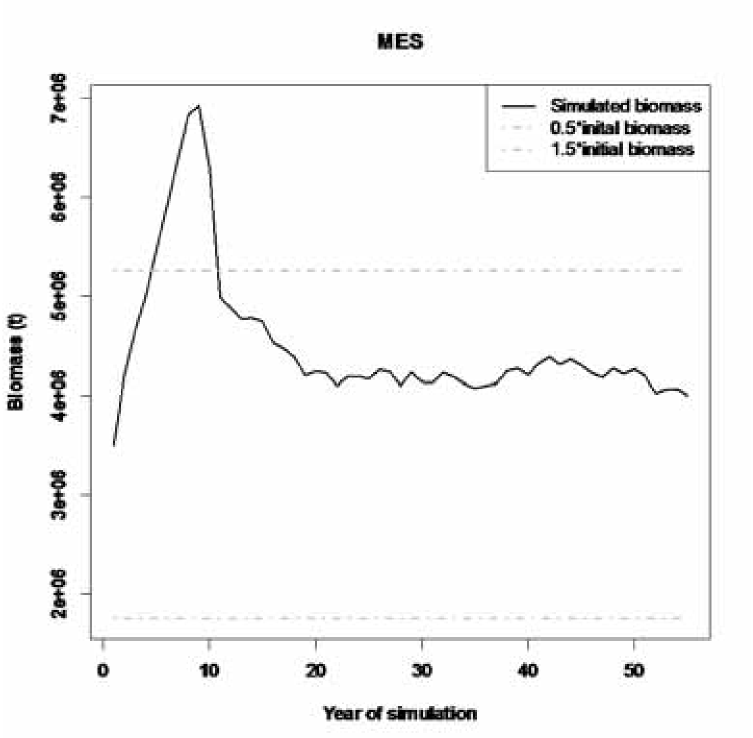

Figure 22: Biomass of mesopelagic fish (MES) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

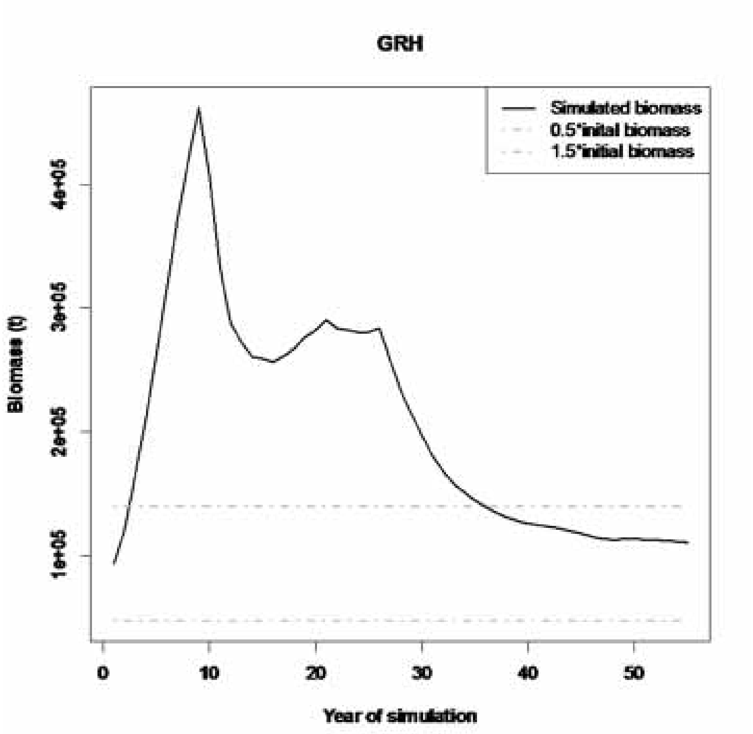

Figure 23: Biomass of Greenland halibut (GRH) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

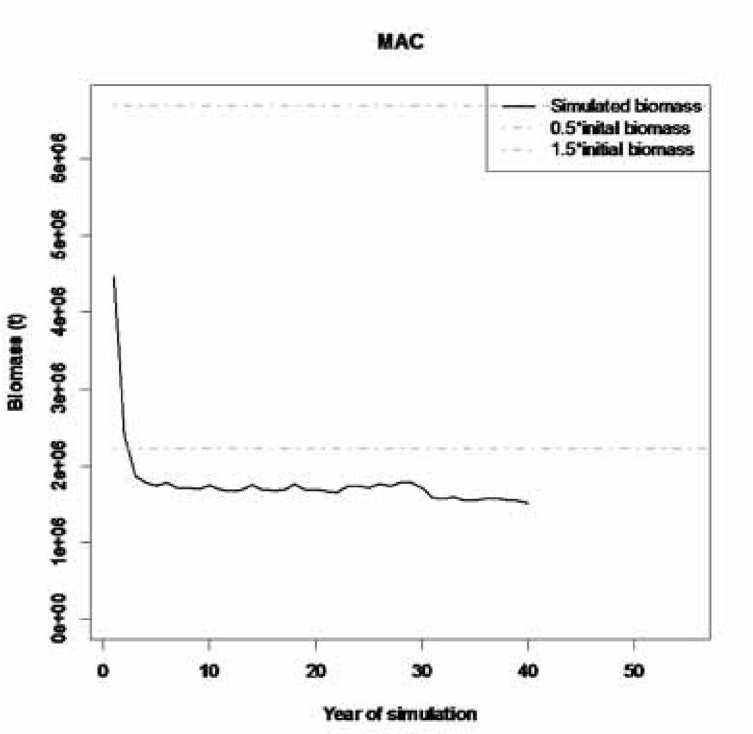

Figure 24: Biomass of mackerel (MAC) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

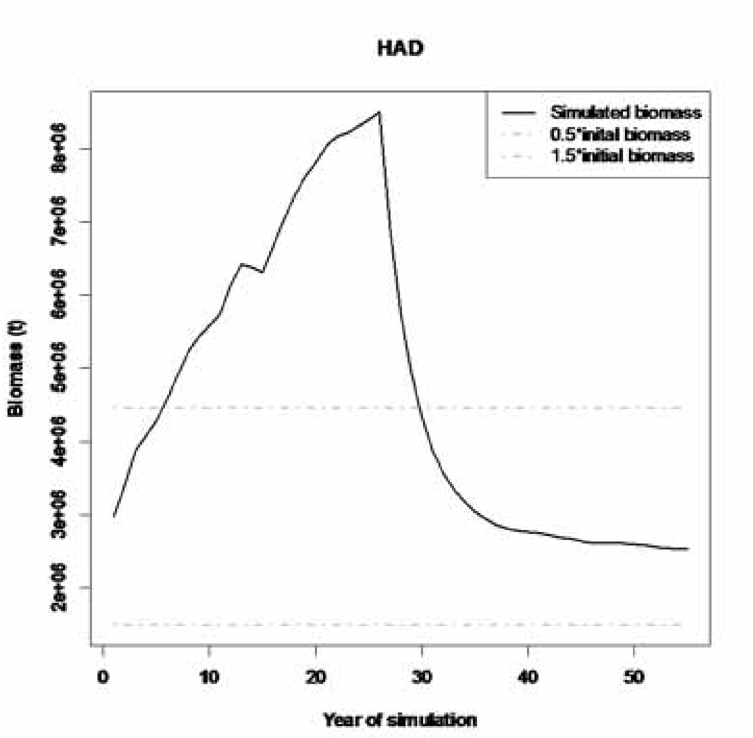

Figure 25: Biomass of haddock (HAD) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

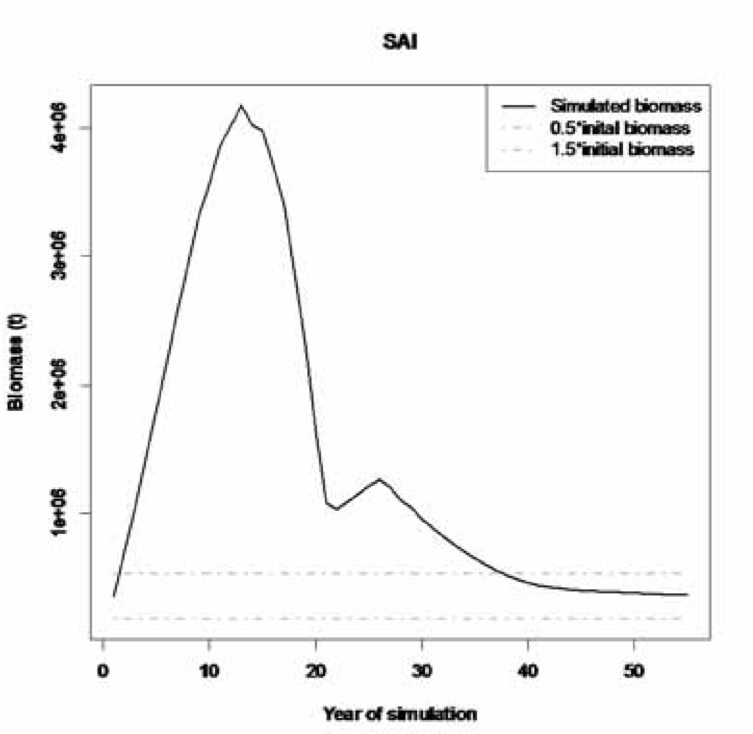

Figure 26: Biomass of saithe (SAI) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

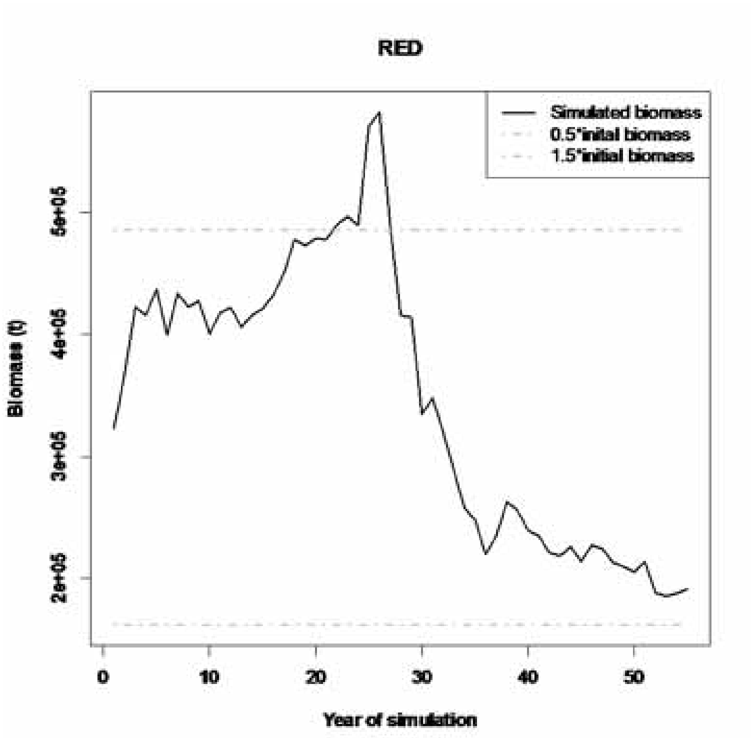

Figure 27: Biomass of redfish (RED) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

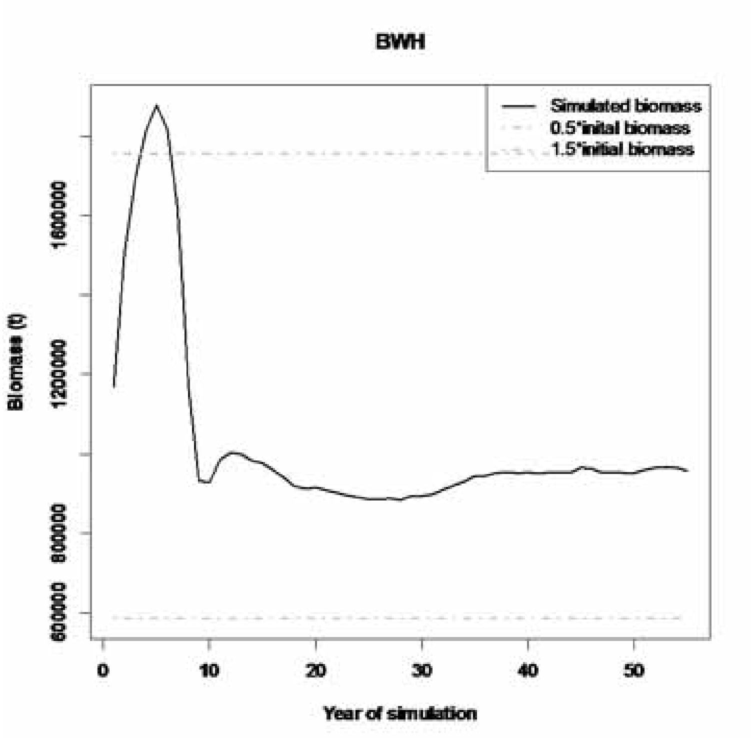

Figure 28: Biomass of blue whiting (BWH) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

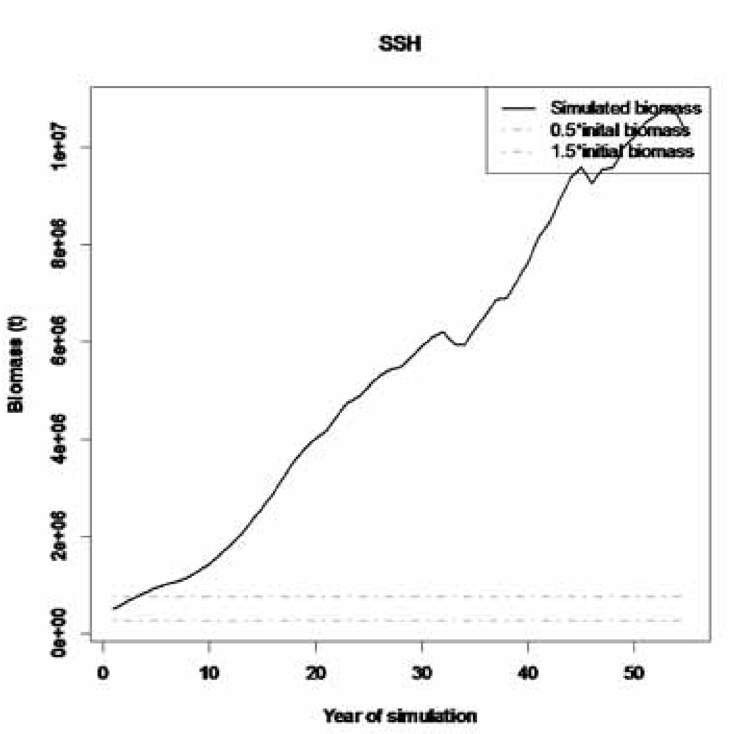

Figure 29: Biomass of Norwegian spring spawning herring (SSH) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

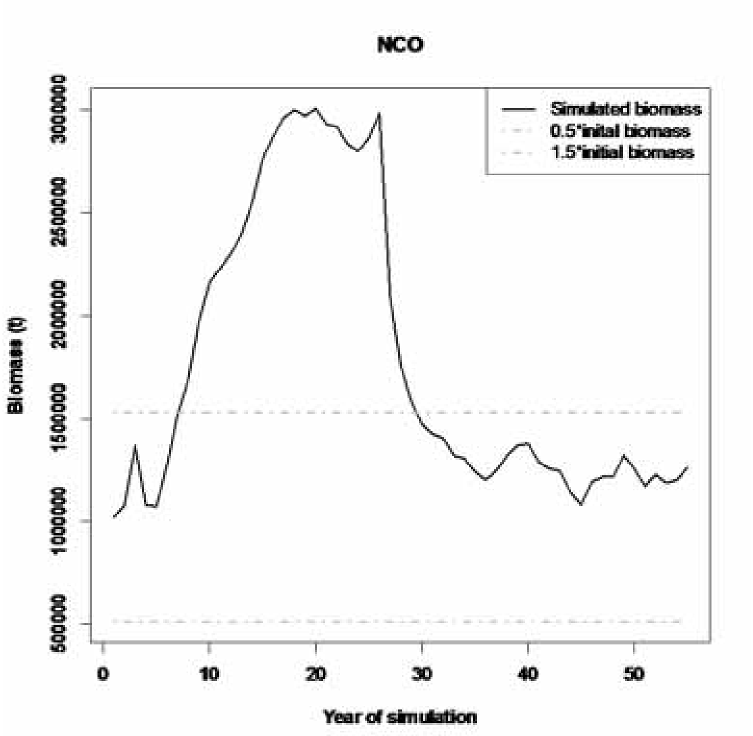

Figure 30: Biomass of Northeast arctic cod (NCO) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

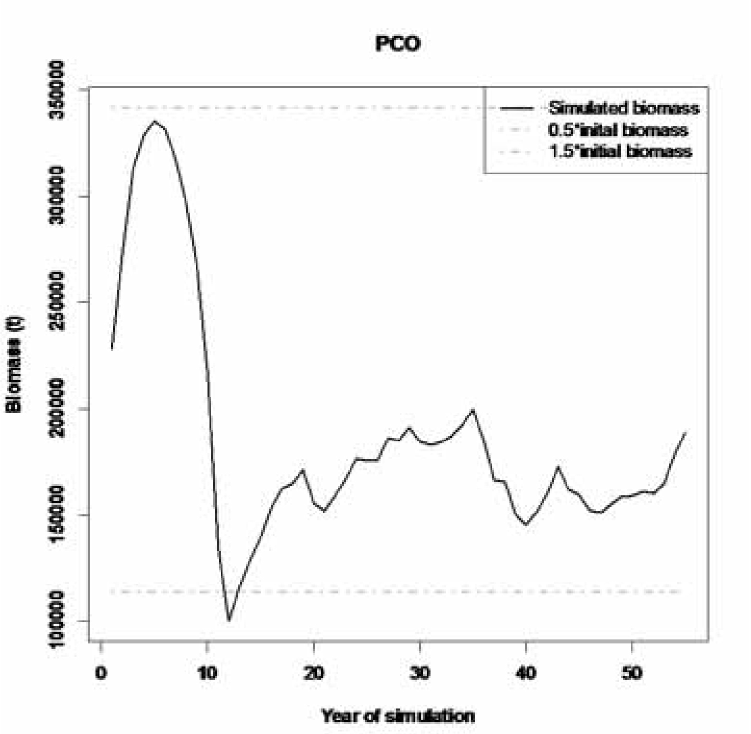

Figure 31: Biomass of polar cod (PCO) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

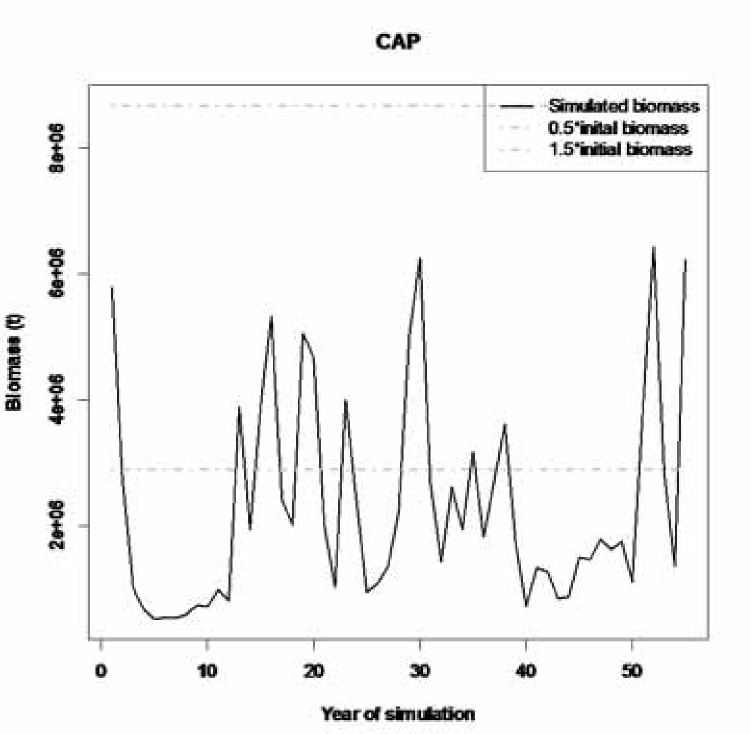

Figure 32: Biomass of capelin (CAP) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

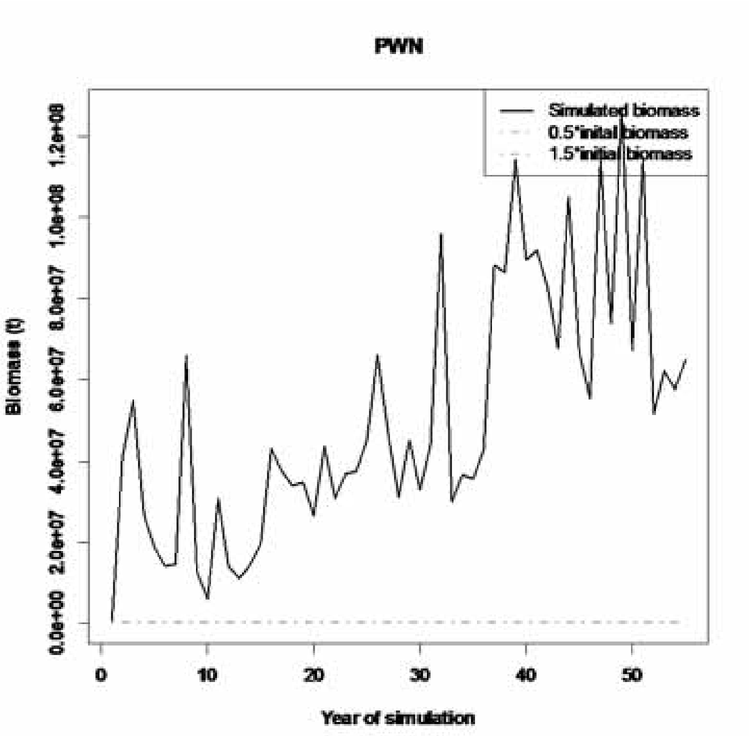

Figure 33: Biomass of shrimps (PWN) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

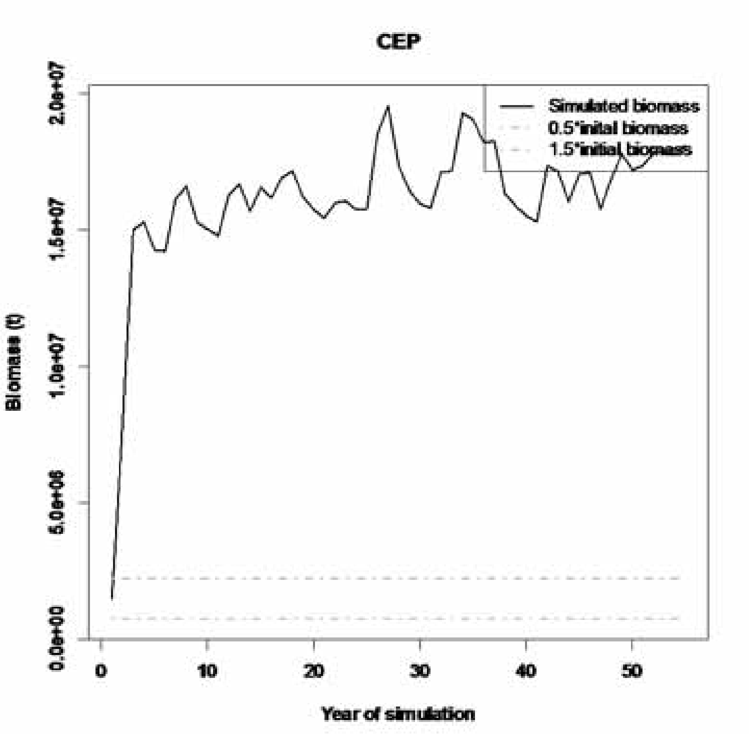

Figure 34: Biomass of squid (CEP) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

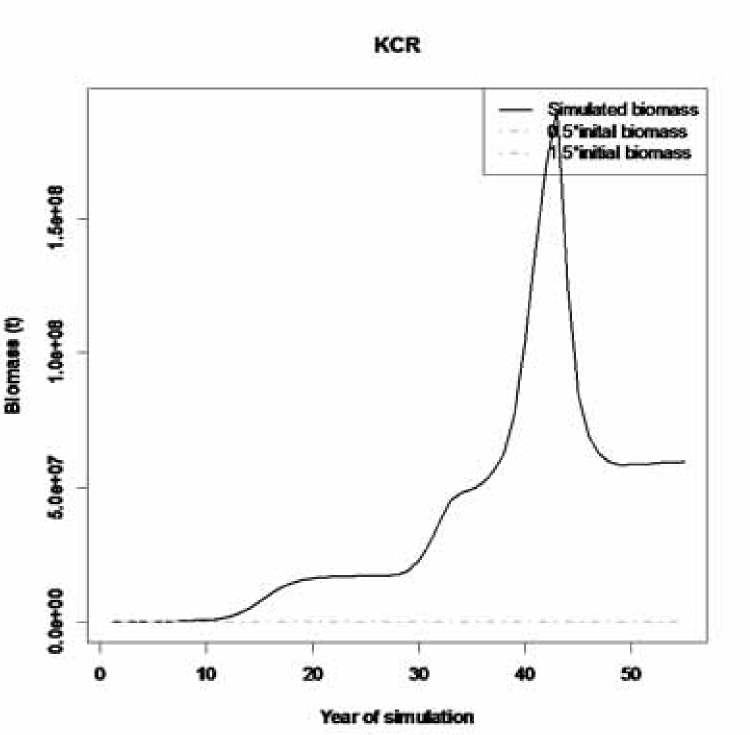

Figure 35: Biomass of red king crab (KCR) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

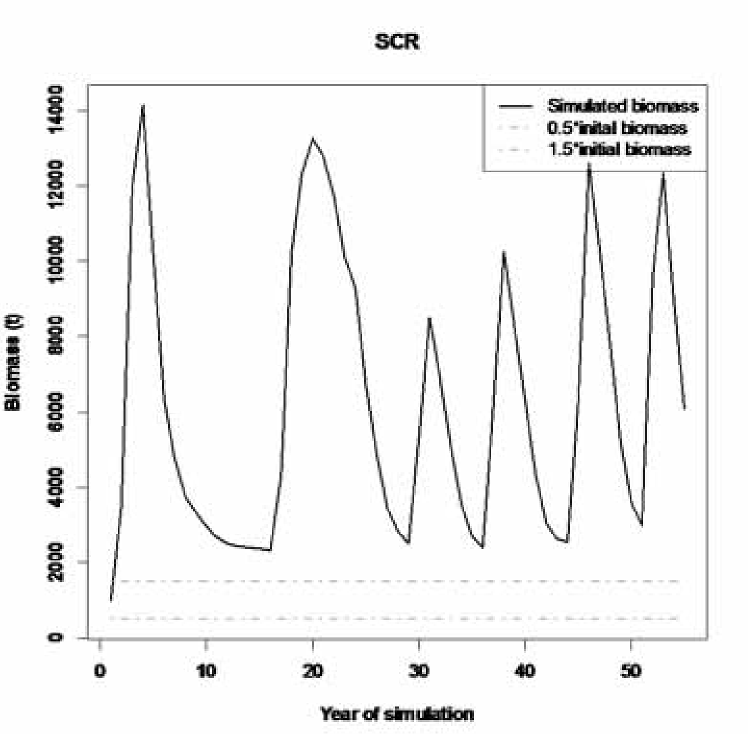

Figure 36: Biomass of snowcrab (SCR) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

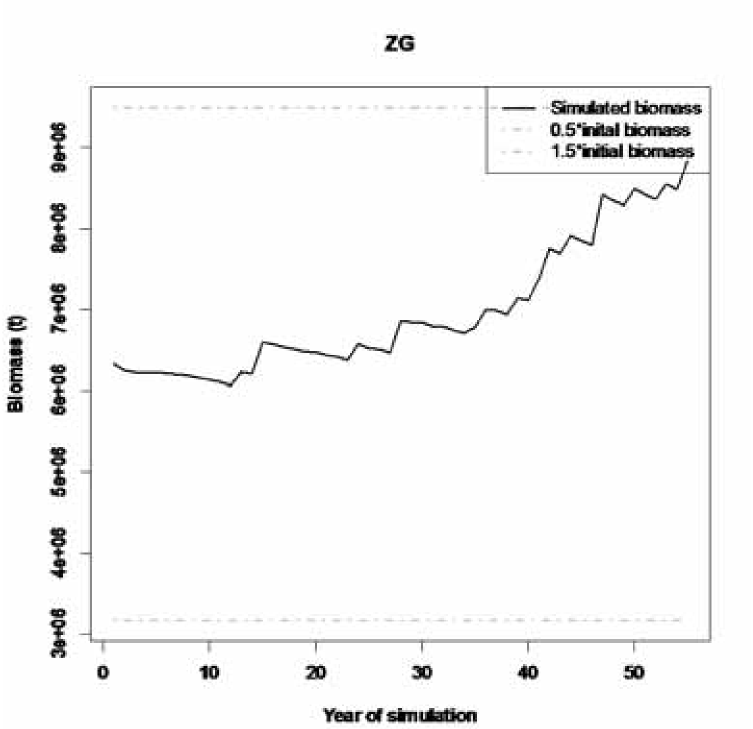

Figure 37: Biomass of gelatineous zooplankton (ZG) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

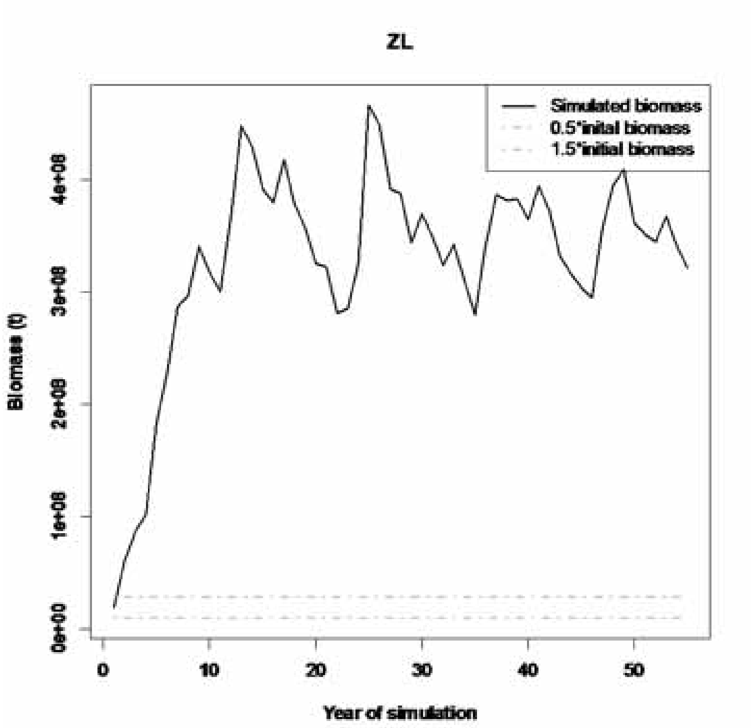

Figure 38: Biomass of large zooplankton (ZL) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

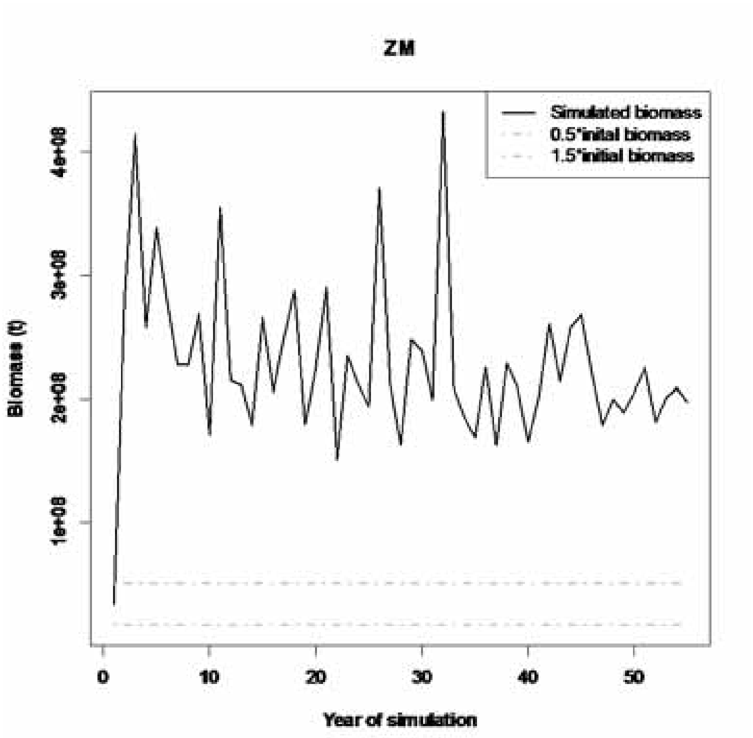

Figure 39: Biomass of medium zooplankton (ZM) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

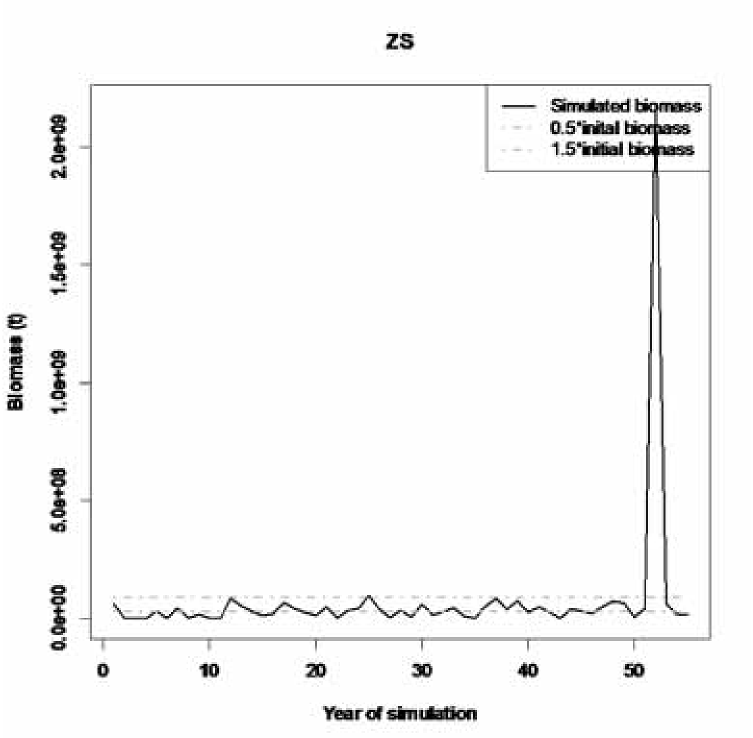

Figure 40: Biomass of small zooplankton (ZS) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

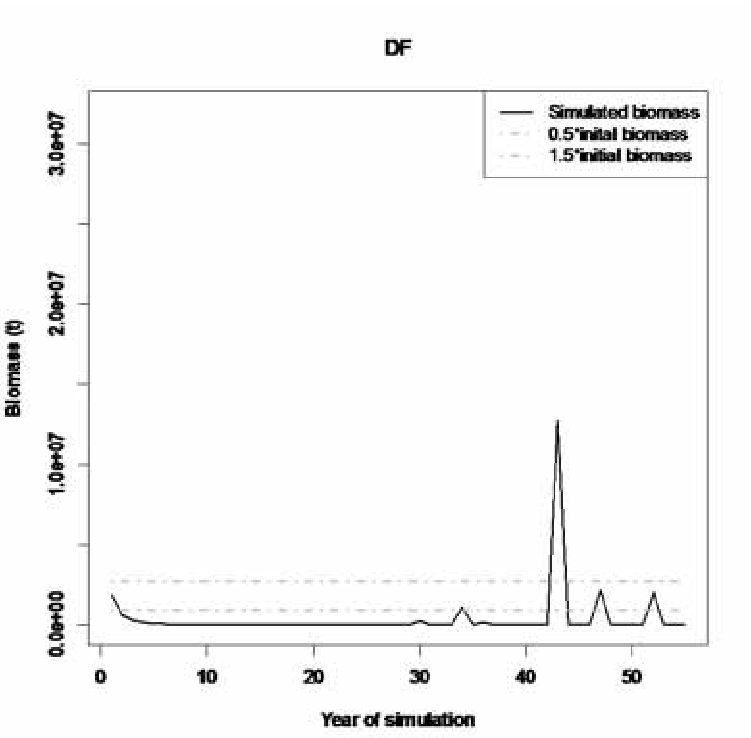

Figure 41: Biomass of dinoflagellates (DF) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

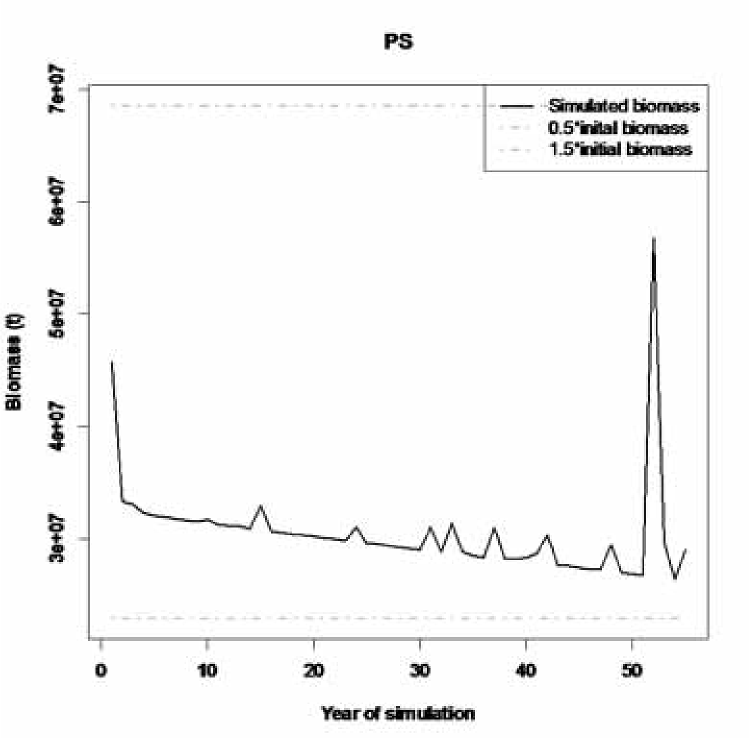

Figure 42: Biomass of small phytoplankton (PS) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

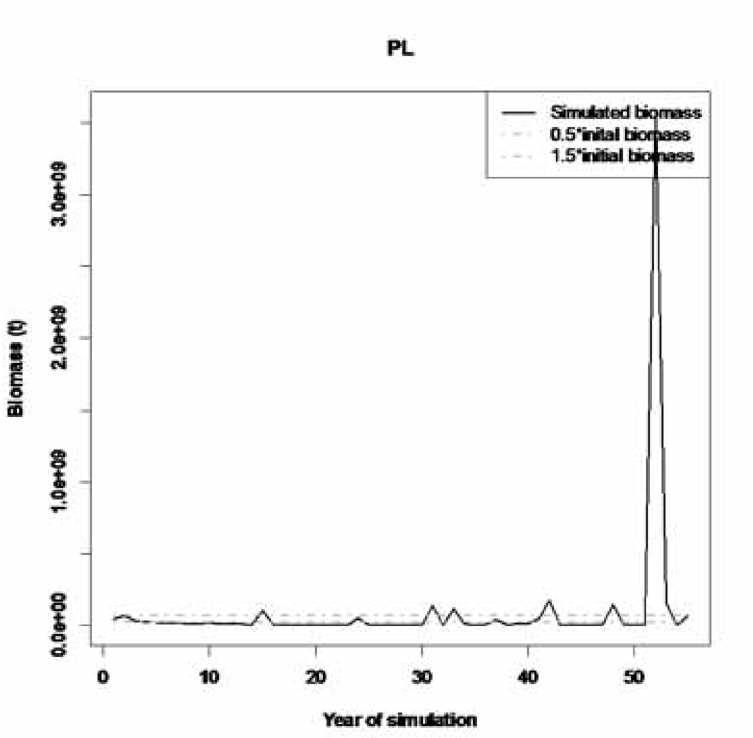

Figure 43: Biomass of large phytoplankton (PL) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

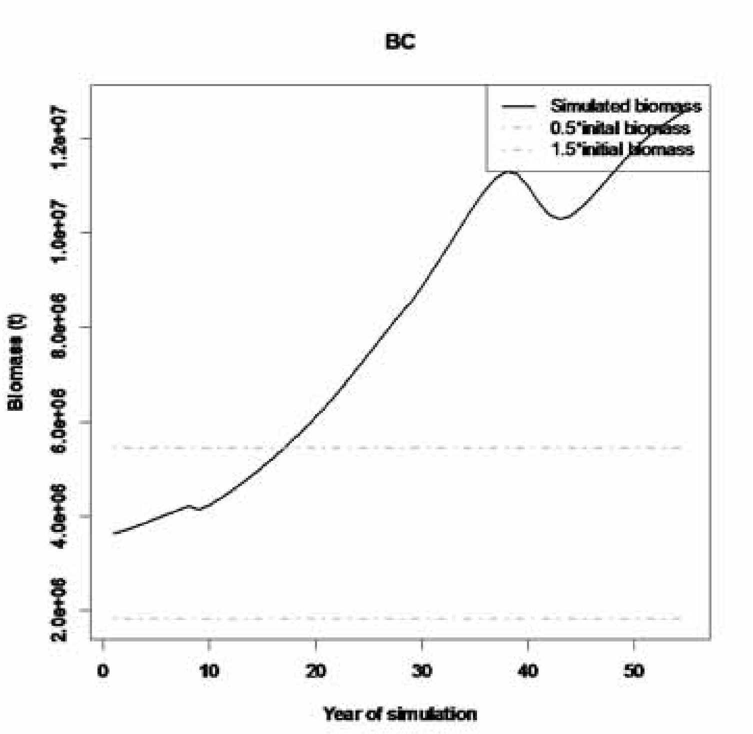

Figure 44: Biomass of carnivore benthos (BC) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

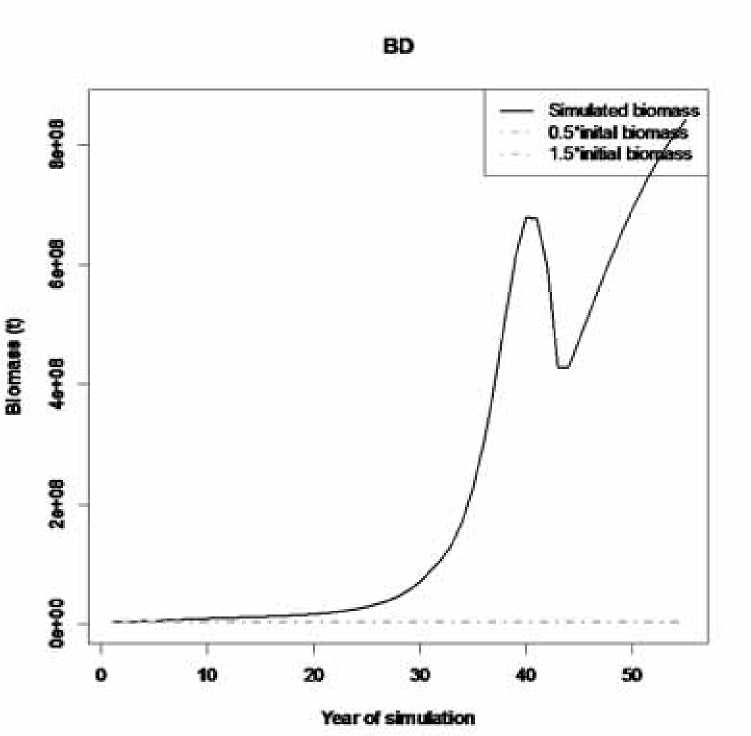

Figure 45: Biomass of detrivore benthos (BD) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

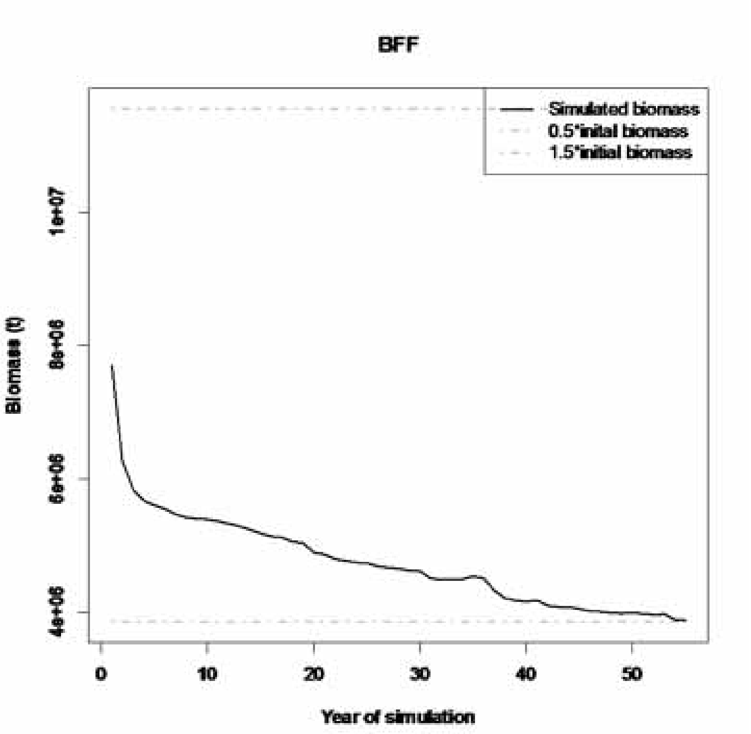

Figure 46: Biomass of benthic filter feeders (BFF) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

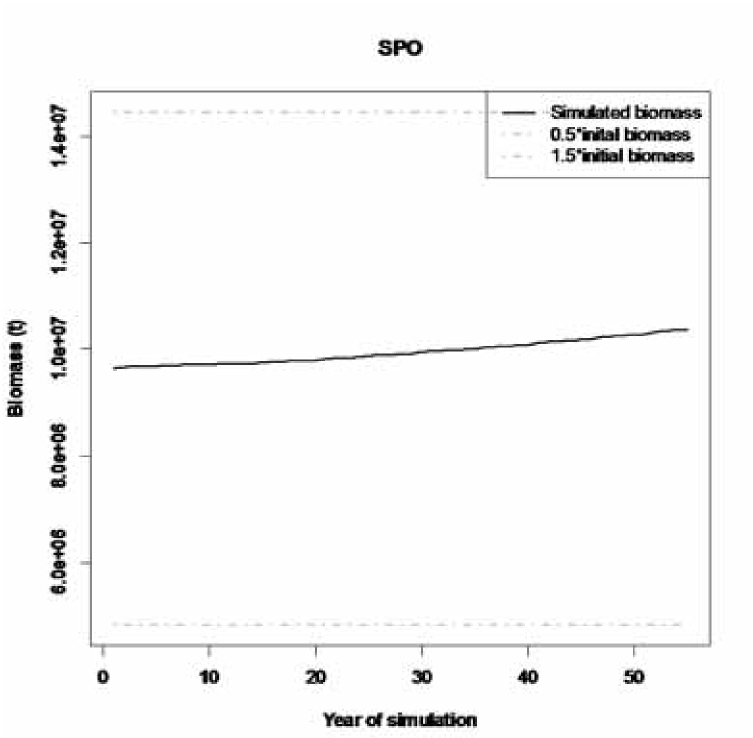

Figure 47: Biomass of sponges (SPO) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

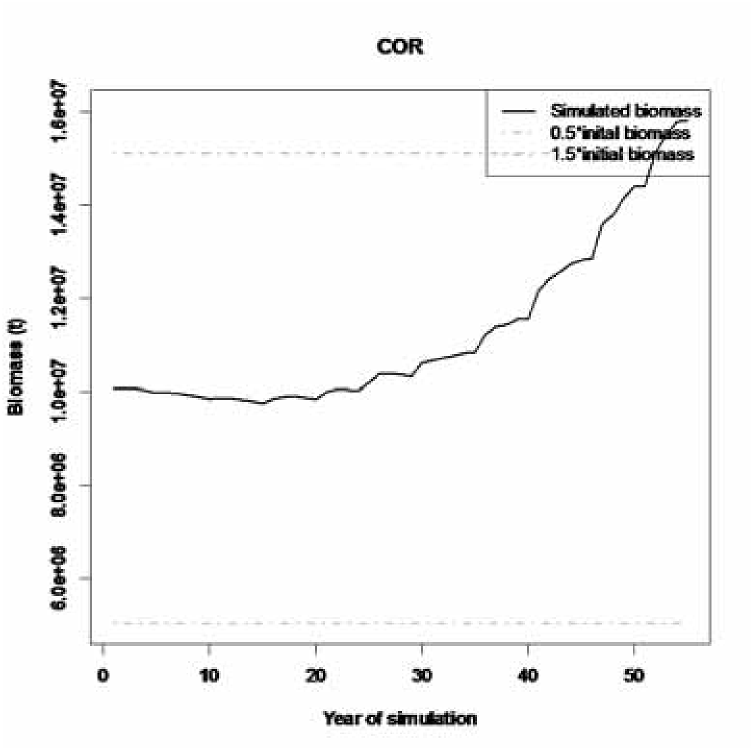

Figure 48: Biomass of corals (COR) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

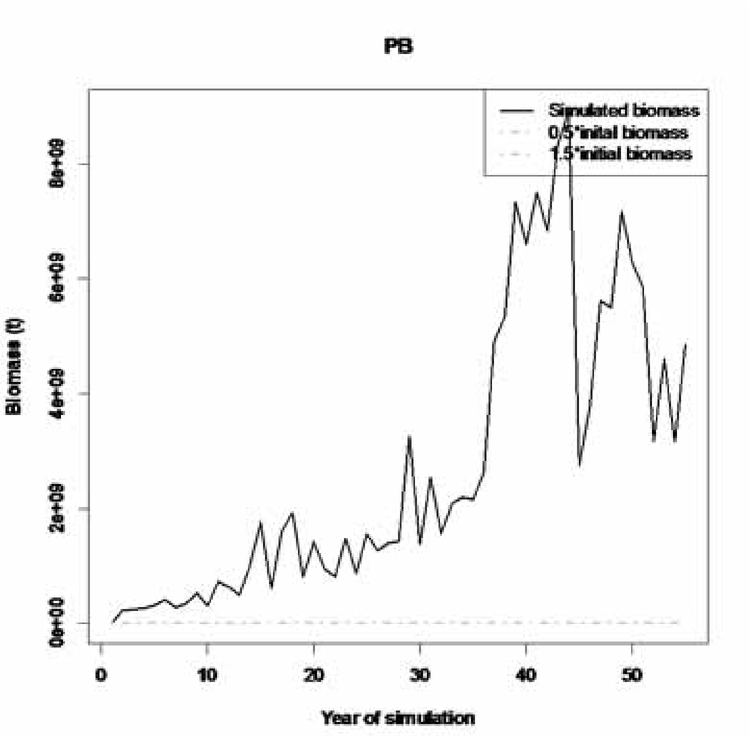

Figure 49: Biomass of pelagic bacteria (PB) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

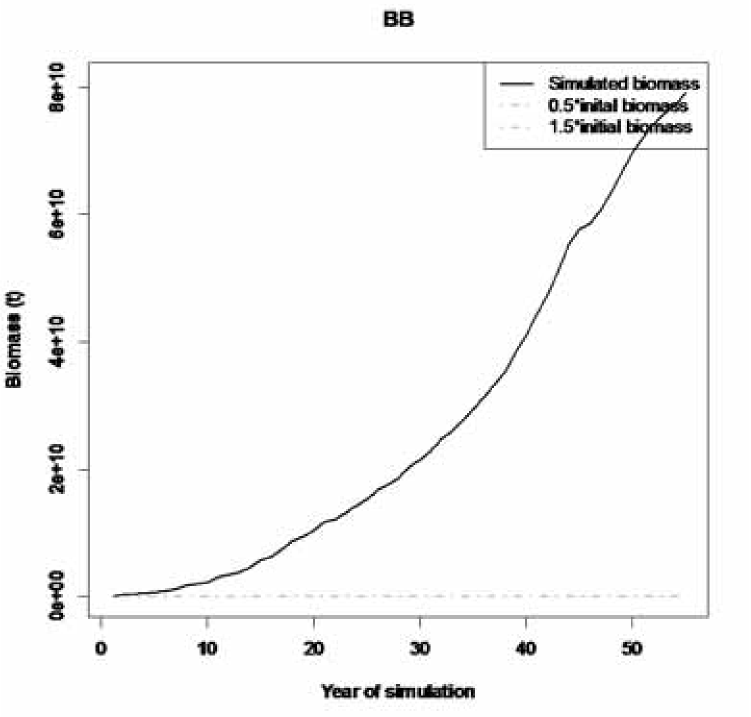

Figure 50: Biomass of benthic bacteria (BB) over the last 35 years of the simulation (whole black line). Grey lines indicate the boundaries for 0.5 and 1.5 times the initial conditions.

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