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By

E.Johannesen, H. L. Mørk, K. Korsbrekke, R. Wienerroither, E. Eriksen, M. Fossheim and T. de Lange Wenneck

IMR

and

A. Dolgov, T. Prokhorova, and D. Prozorkevich

PINRO

Institute of Marine Research - IMR

Polar Research Institute of Marine Fisheries and Oceanography - PINRO

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AUTHORS:

IMR:
Edda Johannesen, Herdis Langøy Mørk, Knut Korsbrekke, Rupert Wienerroither, Elena Eriksen, Maria Fossheim, Thomas de Lange Wenneck

PINRO:
Andrey Dolgov, Tatiana Prokhorova, Dmitry Prozorkevich

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Contents

Synopsis

The Barents Sea is one of nine shelf ecosystem survey bordering the Arctic Basin. The Arctic region is warming faster than the rest of the world. In the Barents Sea the years since 2000 were the warmest since the onset of regular measurements (1900, Bochkov 1982, ICES 2016) and paleo-records based on foraminifera even suggest that the Atlantic Water flowing into to the Barents Sea area was at its warmest for the last 2000 years (Spielhagen et al. 2011). As a result the extent of Arctic Water with sub-zero temperatures and sea ice is shrinking in the Barents Sea (e.g. ICES 2016). The changes in hydrographic conditions change the conditions for the poorly known Arctic fish fauna in the region. Here we present for the first time results on trends in abundance and distribution of demersal Arctic fishes in the northern Barents Sea.

Here we define an “Arctic shelf ecosystem” as a system with Arctic water masses and Arctic biota. The North-northeastern Barents Sea is such an Arctic shelf ecosystem. The Joint IMR/PINRO ecosystem survey covers the whole Barents Sea shelf including the northern Arctic part. The survey started in 2004, and in October 2016 the 13th survey was completed. Due to its broad area coverage and now 13 years of data this survey is the most extensive survey of an Arctic shelf ecosystem in existence. With ever more years of monitoring amended understanding of the dynamic of the poorly known northern Barents Sea and the fishes found here can be gained. Therefore, abundance and distribution of Arctic fishes from this survey should be reported regularly.

When analyzing trends in occupancy and abundance of Arctic fishes in the northern Barents Sea using data from the ecosystem survey we found that:

- Overall there was a negative trend in occupancy and the number of Arctic fish species caught at each station from 2004-2015 in the Barents Sea
- The decline was most pronounced in the eastern and central part of the area studied here
- Some species declined all over, some decline only in the southern part over the area studied, some decline in the southern part of the study area and increased in the north indicating a displacement, while some did not show any significant change.

We provide an inventory of all fishes caught at the ecosystem survey and discuss problems with species identity and identification as well as limitation due to survey coverage and sampling, and provide recommendations for future work.

2 Zoogeographical classification of Barents Sea fishes

Biogeographical patterns are created by large-scaled historical, phylogenetic processes (Box 1). The range limits maintaining the zoogeographical patterns are due to spatial variation in the environment (including geographical barriers), the ecological traits of the species (their niche), and to what extent these traits are maintained over time (niche conservatisms). There is no approved methodology for marine biogeography and categories can be defined by distribution in relation to temperature regimes or by taxonomic/phylogenetic discreteness defined by the degree of endemism (Dipner 2001). The classification used here (below) is based on with water mass affiliation and include four different categories (CAFF 2013): **Arctic (A)** species are distributed in Arctic waters, spawn solely at sub-zero temperatures and are only infrequently found in temperate waters, **Arctic-boreal (AB)** species are distributed in Arctic and cold temperate waters and may spawn in both sub-zero temperatures and positive temperatures, **Boreal (B)** species are distributed in temperate waters, spawn solely in positive temperatures and are only occasionally found in the border regions of Arctic waters. **Widely Distributed (WD)** species are common both in temperate and subtropical zones and in or below the warm waters of at least two oceans (or are known from the southern hemisphere). They occur only rarely in the Arctic:Many meso- and bathypelagic and migratory species belong to this category.

Box 1. Phylogentic history of the biota in the Arctic Ocean and adjacent seas.
Briggs and Bowen (2012) described the historical development of the world's oceans and the phylogenetic development of marine fishes, the following is adapted from their paper: The Atlantic Ocean and the Arctic Ocean are the youngest of the Oceans, and thus have had the shortest time to develop endemic species. The Atlantic developed around ~165 million years ago. The boreal, cold-temperate species of the North Pacific and Arctic-North Atlantic biotas evolved separately for more than 30 million years until the connection of the seas across the Bering Bridge developed ~5 to 3 million years ago. This allowed a mixing of the Pacific boreal and Atlantic boreal species called the Great Trans-Arctic Interchange. After this a cooling in the Arctic region started 2.9-2.4 million years ago. In this period, due to this cooling the Pacific and Atlantic boreal species were separated once again and endemic boreal species developed in the Northern Pacific and Northern Atlantic. Most of the boreal species were eliminated from the Arctic region and the modern Arctic fauna developed.

Most studies on northern marine biogeography have been carried out by Russian scientists (Briggs and Bowen 2012). Andriashev and Chernova (1995) classified 441 fishes from the Arctic region in their paper "*Annotated list of fishlike vertebrates and fish in the Arctic Seas and adjacent waters*". More recently, in the chapter on Marine fish in the Arctic Biodiversity Assessment (ABA) report (CAFF 2013, under Arctic Council), 633 fishes from the Arctic region (the Arctic Ocean and adjacent Seas) were classified into zoogeographical groups. The classification used in the ABA report was based on Andriashev and Chernova (1994), Karamushko (2008) and Mecklenburg et al. (2011). Here we use the CAFF (2013) classification (see also Mecklenburg et al. 2013, Mecklenburg and Steinke 2015 for update) to group the fishes caught at the ecosystem survey in the Barents Sea 2004-2015 (Table 2.1).

Table 2.1. Species recorded at the ecosystem survey in the entire Barents Sea (marine fish caught by demersal trawl only). Zoogeographical (Zoog.) classification is taken from CAFF 2013. A=Arctic (in bold), B=Boreal, AB=Arctic-boreal and WD=Widely Distributed. In the beginning of the time series a few registrations were recurrent errors of species that are not confirmed from the Barents Sea. These are not shown in the table but include *Dipturus batis, Dipturus oxyrinchus, Leucoraja fullonica, Raja clavata, Argentina sphyraena, Paralepis coregonoides, Gaidropsarus vulgaris* and *Gaidropsarus ensis* (see also comments).

Order	**Family**	**Scientific name**	**Zoog.**	**Comment**
Squaliformes	Dalatiidae	*Etmopterus spinax*	WD	
Squaliformes	Dalatiidae	*Somniosus microcephalus*	AB	
Rajiformes	Arhynchobatidae	*Bathyraja spinicauda*	B	sometimes misidentified as *Dipturus batis*
Rajiformes	**Rajidae**	***Amblyraja hyperborea***	**A**	
Rajiformes	Rajidae	*Amblyraja radiata*	B	
Rajiformes	Rajidae	*Rajella lintea*	B	
Rajiformes	Rajidae	*Rajella fyllae*	B	
Chimaeriformes	Chimaeridae	*Chimaera monstrosa*	B	
Osmeriformes	Argentinidae	*Argentina silus*	B	sometimes misidentified as *Argentina sphyraena*
Osmeriformes	Microstomatidae	*Nansenia groenlandica*	WD	
Aulopiformes	Paralepididae	*Arctozenus risso*	WD	sometimes misidentified as *Paralepis coregonoides*
Gadiformes	Macrouridae	*Macrourus berglax*	B	
Gadiformes	Macrouridae	*Coelorinchus labiatus*	B	
Gadiformes	**Gadidae**	***Eleginus nawaga***	**A**	
Gadiformes	**Gadidae**	***Arctogadus glacialis***	**A**	
Gadiformes	**Gadidae**	***Boreogadus saida***	**A**	
Gadiformes	Gadidae	*Gadiculus argenteus*	B	
Gadiformes	Gadidae	*Gadus morhua*	B	
Gadiformes	Gadidae	*Melanogrammus aeglefinus*	B	
Gadiformes	Gadidae	*Merlangius merlangus*	B	
Gadiformes	Gadidae	*Micromesistius poutassou*	B	
Gadiformes	Gadidae	*Pollachius pollachius*	B	
Gadiformes	Gadidae	*Pollachius virens*	B	
Gadiformes	Gadidae	*Trisopterus esmarkii*	B	
Gadiformes	Lotidae	*Brosme brosme*	B	
Gadiformes	Lotidae	*Enchelyopus cimbrius*	B	
Gadiformes	Lotidae	*Gaidropsarus argentatus*	AB	
Gadiformes	Lotidae	*Molva molva*	B	
Gadiformes	Merlucciidae	*Merluccius merluccius*	B	
Gadiformes	Phycidae	*Phycis blennoides*	B	
Lophiiformes	Lophiidae	*Lophius piscatorius*	B	
Syngnathiformes	Syngnathidae	*Entelurus aequoreus*	B	
Scorpaeniformes	Sebastidae	*Sebastes mentella*	B	young *Sebastes* are often identified to genus level only
Scorpaeniformes	Sebastidae	*Sebastes norvegicus*	B	previously known as *S. marinus*
Scorpaeniformes	Sebastidae	*Sebastes viviparus*	B	
Scorpaeniformes	Cottidae	*Artediellus atlanticus*	AB	
Scorpaeniformes	**Cottidae**	***Artediellus scaber***	**A**	
Scorpaeniformes	**Cottidae**	***Gymnocanthus tricuspis***	**A**	
Scorpaeniformes	**Cottidae**	***Icelus bicornis***	**A**	all *Icelus* are pooled in this report
Scorpaeniformes	Cottidae	*Icelus spatula*	AB	all *Icelus* are pooled in this report
Scorpaeniformes	Cottidae	*Myoxocephalus scorpius*	AB	
Scorpaeniformes	Cottidae	*Triglops murrayi*	B	
Scorpaeniformes	**Cottidae**	***Triglops nybelini***	**A**	
Scorpaeniformes	Cottidae	*Triglops pingelii*	AB	
Scorpaeniformes	Psychrolutidae	*Cottunculus microps*	AB	
Scorpaeniformes	Agonidae	*Leptagonus decagonus*	AB	
Scorpaeniformes	**Agonidae**	***Aspidophoroides olrikii***	**A**	
Scorpaeniformes	Agonidae	*Agonus cataphractus*	B	
Scorpaeniformes	Cyclopteridae	*Cyclopterus lumpus*	B	
Scorpaeniformes	**Cyclopteridae**	***Eumicrotremus derjugini***	**A**	
Scorpaeniformes	**Cyclopteridae**	***Eumicrotremus spinosus***	**A**	

Table 2.1 continued

Order	Family	Scientific name	Zoog.	Comment
Scorpaeniformes	**Liparidae**	***Careproctus derjugini***	**A**	all *Careproctus* are pooled in this report
Scorpaeniformes	**Liparidae**	***Careproctus dubius***	**A**	all *Careproctus* are pooled in this report
Scorpaeniformes	**Liparidae**	***Careproctus macrophthalmus***	**A**	all *Careproctus* are pooled in this report
Scorpaeniformes	**Liparidae**	***Careproctus micropus***	**A**	all *Careproctus* are pooled in this report
Scorpaeniformes	**Liparidae**	***Careproctus reinhardti***	**A**	all *Careproctus* are pooled in this report
Scorpaeniformes	**Liparidae**	***Careproctus solidus***	**A**	all *Careproctus* are pooled in this report
Scorpaeniformes	**Liparidae**	***Careproctus tapirus***	**A**	all *Careproctus* are pooled in this report
Scorpaeniformes	**Liparidae**	***Careproctus telescopus***	**A**	all *Careproctus* are pooled in this report
Scorpaeniformes	Liparidae	*Liparis montagui*	B	
Scorpaeniformes	**Liparidae**	***Liparis fabricii***	**A**	
Scorpaeniformes	**Liparidae**	***Liparis bathyarcticus***	**A**	
Scorpaeniformes	Liparidae	*Liparis liparis*	B	
Scorpaeniformes	**Liparidae**	***Liparis tunicatus***	**A**	
Scorpaeniformes	**Liparidae**	***Paraliparis bathybius***	**A**	
Scorpaeniformes	**Liparidae**	***Rhodichthys regina***	**A**	
Perciformes	**Zoarcidae**	***Gymnelus andersoni***	**A**	all *Gymnelus* are pooled in this report
Perciformes	**Zoarcidae**	***Gymnelus hemifasciatus***	**A**	all *Gymnelus* are pooled in this report
Perciformes	**Zoarcidae**	***Gymnelus retrodorsalis***	**A**	all *Gymnelus* are pooled in this report
Perciformes	**Zoarcidae**	***Gymnelus viridis***	**A**	all *Gymnelus* are pooled in this report
Perciformes	**Zoarcidae**	***Lycenchelys kolthoffi***	**A**	
Perciformes	**Zoarcidae**	***Lycenchelys muraena***	**A**	
Perciformes	Zoarcidae	*Lycenchelys sarsii*	B	
Perciformes	**Zoarcidae**	***Lycodes adolfi***	**A**	
Perciformes	Zoarcidae	*Lycodes esmarkii*	B	
Perciformes	**Zoarcidae**	***Lycodes eudipleurostictus***	**A**	
Perciformes	**Zoarcidae**	***Lycodes frigidus***	**A**	
Perciformes	Zoarcidae	*Lycodes gracilis*	B	
Perciformes	**Zoarcidae**	***Lycodes luetkenii***	**A**	
Perciformes	**Zoarcidae**	***Lycodes paamiuti***	**A**	
Perciformes	Zoarcidae	*Lycodes pallidus*	AB	
Perciformes	**Zoarcidae**	***Lycodes polaris***	**A**	
Perciformes	**Zoarcidae**	***Lycodes reticulatus***	**A**	
Perciformes	**Zoarcidae**	***Lycodes rossi***	**A**	
Perciformes	**Zoarcidae**	***Lycodes seminudus***	**A**	
Perciformes	**Zoarcidae**	***Lycodes squamiventer***	**A**	
Perciformes	**Zoarcidae**	***Lycodonus flagellicauda***	**A**	
Perciformes	Stichaeidae	*Anisarchus medius*	AB	
Perciformes	Stichaeidae	*Leptoclinus maculatus*	AB	
Perciformes	Stichaeidae	*Lumpenus fabricii*	AB	
Perciformes	Stichaeidae	*Lumpenus lampretaeformis*	B	
Perciformes	Anarhichadidae	*Anarhichas denticulatus*	AB	
Perciformes	Anarhichadidae	*Anarhichas lupus*	B	
Perciformes	Anarhichadidae	*Anarhichas minor*	B	
Perciformes	Ammodytidae	*Ammodytes marinus*	B	
Pleuronectiformes	Pleuronectidae	*Glyptocephalus cynoglossus*	B	
Pleuronectiformes	**Pleuronectidae**	***Liopsetta glacialis***	**A**	
Pleuronectiformes	Pleuronectidae	*Hippoglossoides platessoides*	B	
Pleuronectiformes	Pleuronectidae	*Hippoglossus hippoglossus*	B	
Pleuronectiformes	Pleuronectidae	*Limanda limanda*	B	
Pleuronectiformes	Pleuronectidae	*Microstomus kitt*	B	
Pleuronectiformes	Pleuronectidae	*Pleuronectes platessa*	B	
Pleuronectiformes	Pleuronectidae	*Reinhardtius hippoglossoides*	AB	
Pleuronectiformes	Scophthalmidae	*Lepidorhombus whiffiagonis*	B	
Pleuronectiformes	Scophthalmidae	*Zeugopterus norvegicus*	B	

3 Sampling

3.1 Survey coverage and strata system

The ecosystem survey covers the Barents Sea shelf with somewhat variable survey coverage from year to year, due to variation in vessel-days available, ice conditions and other factors (Figure 3.1). The ecosystem survey does not have an established strata system, but with the exception of the slope areas, mostly there is a regular grid allowing flexibility in defining strata *a posteriori* according to the goal of the study. Here we defined eight strata or areas in the north -northeastern Barents Sea (Figure 3.1) and include only stations found within these strata further. These areas were chosen based on the water currents directions, depth intervals and geographic peculiarities of these parts of the Barents Sea, as well as the yearly variation in survey coverage. The survey coverage on the continental slope in the west and north are variable and the results from this area will depend on the distribution of the stations by depth. Dividing the slope region into smaller strata, will result in high variance whereas changes in the distribution stations by depth will discredit the results from this area as a time series. The somewhat variable survey coverage resulted in incomplete coverage in some of the strata some of the years (Table 3.1). Therefore, it is better to calculate the average density per strata (of species, individuals or biomass per nm) rather than a strata total.

Table 3.1. Number of valid hauls per strata. NB there were also stations taken in area 6 in 2013, but these were not available when this report was made.

Strata	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1 Central Bank	85	78	104	94	53	57	63	62	66	66	65	52
2 Novaya Zemlya	54	59	67	53	58	57	58	59	64	61	63	56
3 Svalb/Spitsb East	118	125	70	90	30	28	38	57	61	58	15	46
4 Central North	9	16	7	18	8	21	14	15	16	23	18	24
5 Franz Josef	22	32	13	38	22	25	21	14	24	26	0	20
6 Kara Sea North	0	0	0	0	0	27	23	21	0	2	0	1
7 Svalb/Spitsb West	59	61	56	48	53	24	11	29	34	37	19	13
8Svalb/Spitsb North	87	34	44	37	26	25	2	22	42	36	11	12

3.2 Catchability and sub-sampling

The results presented here, are based on valid demersal trawl hauls from Campelen 1800 shrimp trawl (for details see e.g. Eriksen et al. 2014). The mesh size is relatively small, still some smaller fishes might escape capture. The current procedure is to sort all catch and identify all fish to the species level. However, sub-sampling was a problem on the Norwegian boats, especially in earlier years. When only a fraction of the catch is sorted, the proportion of each species in the sorted part of the catch is multiplied with the total catch. This creates a problem with the data (either 0 or unrealistically high numbers) especially for the rare species, and is the reason why e.g. Byrkjedal and Høines (2009) and Johannesen et al. (2012) used presence/absence data in their analyses. We do not deal with this problem here, other than calculating abundance indices only for the most common species.

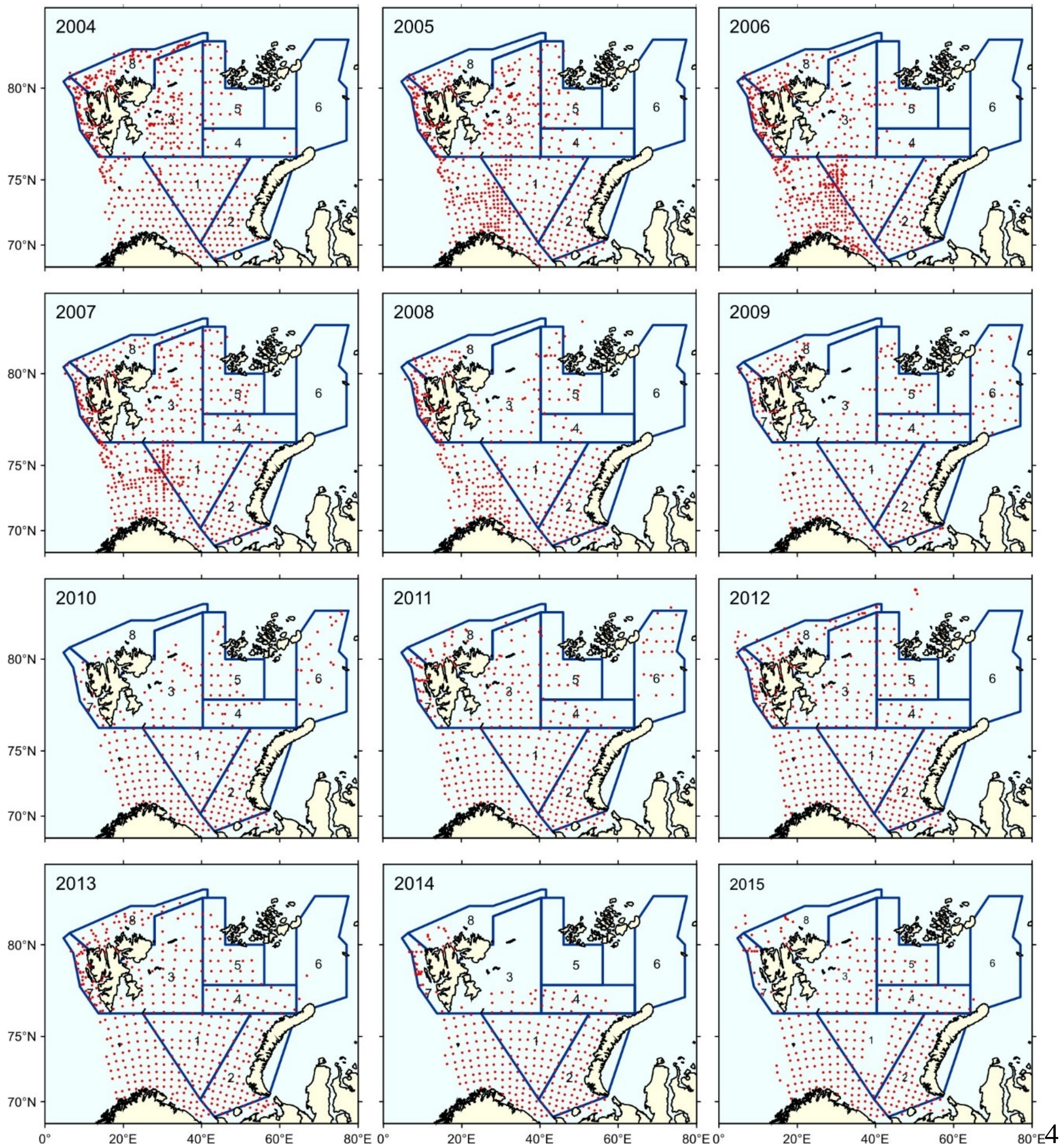


Figure 3.1. Annual maps of bottom trawl stations (red dots) used in the report. The strata system used in the data analysis is shown in blue. Strata 1: Central Bank, Strata 2: Novaya Zemlya, Strata 3: Svalbard/Spitsbergen East, Strata 4: Central North, Strata 5: Franz Josef, Strata 6: Kara Sea North, Strata 7: Svalbard/Spitsbergen West and Strata 8: Svalbard/Spitsbergen North. There were more stations taken in Strata 6 in 2013 than shown in the figure, but they were not available when making this report.

4 Species identification

4.1 Procedures for species identification of fishes at IMR and PINRO

IMR/PINRO surveys are primarily fishery surveys targeting commercial species for stock assessment. However, with the introduction of the ecosystem approach to management, the value of monitoring other aspects of the ecosystem, including non-targeted fishes, has been recognized. At PINRO, improvement in fish identification started in 1995-1998, and at IMR in the early 2000's spurred by an increased cooperation between IMR and the University Museum of Bergen. A couple of measures significantly improved the species identification at IMR. Annual workshops in species identification are held since 2004, and own dichotomous identification keys, based on drawings and pictures, have been prepared, used, and refined. This simplifies species identification and ensures a consistent use of the same characters, independent of vessel or staffing. In 2008, a routine of freezing specimens from problematic groups for later identification ashore started at IMR. All this resulted in a significantly improved species identification of traditionally problematic groups like e.g. skates and eelpouts.

Harmonization of species identification between IMR and PINRO has been addressed by workshops and meetings in Bergen in 2008, 2009, 2010, 2011 and 2013, and in Murmansk in 2015, as well as under the preparation of the Atlas of the Barents Sea fishes (Wienerroither et al 2011). Identification keys have been exchanged and used on frozen material. Knowledge on species only occurring in Russian or Norwegian areas has been exchanged, drawing the attention to the taxonomic characters of uncommon or locally distributed species in the Barents Sea, like e.g. *Eleginus nawaga*.

4.2 Description of the families with Arctic fishes, and issues related to identification

During the ecosystem survey 2004-2015, 42 species of Arctic fish were caught (Table 2.1). Below a short description of the Arctic fish species in the Barents Sea is given, with focus on taxonomic issues and species that are commonly or easily confused.

4.2.1 Rajidae

Species identification of skates has significantly improved since the beginning of the time series. Misidentifications of skates in the Barents Sea were quite common, but have stopped after the above mentioned measures have been implemented. Four species are registered in the data set, three of them boreal, and one arctic: *Amblyraja hyperborea*.

4.2.2 Gadidae

Of the eleven species in the dataset, three are Arctic and eight boreal. The Arctic *Eleginus nawaga* is only distributed in the southeastern Russian area of the Barents Sea. The other two species, *Arctogadus glacialis* and *Boreogadus saida*, might seem very similar, but the overall differences in habitus are striking when both species are present in the catch. *B. saida* is much more abundant, therefore subsampling may cause that *A. glacialis* is overlooked.

4.2.3. Cottidae

Sculpins (Cottidae) are a large family of small bottom-dwelling fish found primarily in Arctic to temperate waters. The data set includes nine species, four Arctic, four Arctic-boreal, and one boreal, the Arctic species *Artediellus scaber* is only found in the Russian part of the Barents Sea.

Small specimens of *Triglops* are more difficult to differentiate, and 37 specimens in the dataset were identified to genus level only. Some of the southwestern recordings of *T. nybelini* and *T. pingelii* dating from the beginning of the time series are likely misidentified *T. murrayi*.

The two species of genus *Icelus* are difficult to separate, and *I. spatula* is recorded on Russian vessels only. The taxonomic characters like shape and extension of the lateral line scales, commonly used in identification literature are controversial. Males can more easily also be distinguished by the shape of the urogenital papilla, but on Norwegian vessels no male *I. spatula* has been verified so far.

4.2.4 Agonidae

There are three species of poachers (Agonidae) in the Barents Sea, but only *Aspidophoroides olrikii* is considered Arctic (the other two being Arctic-boreal and boreal, respectively). *Aspidophoroides olrikii* is found in the easternmost part of the Barents Sea, only a few specimens were taken in the Norwegian part, or on Norwegian vessels respectively. There are no special issues related to species identification.

4.2.5 Cyclopteridae

Of the three species in the dataset one is boreal and two are Arctic. Small specimens of *Eumicrotremus* need a closer look but there are no issues related to species identification.

4.2.6 Liparidae

Snailfishes (Liparidae) are one of the most diverse and abundant fish families that dwell in polar and deep-sea habitats (Chernova 1991, 2005a), but the biology of many of these species is poorly studied. The number of species in general and in the Barents Sea, is not known as their taxonomy is subject to extensive revisions, especially for the genus *Careproctus* (e.g Chernova 2005b). These revisions are not without controversy, and until they are resolved IMR and PINRO take the conservative approach and identify according to the accepted taxonomy prior to these revisions. This applies mainly to genus *Careproctus*, where IMR distinguishes based on characters like the length of the lower pectoral fin lobe, although no taxonomic species name has been given to these different forms. Some of the *Careproctus* specimens in the data set were identified by dr. Chernova, but she had no chance to do this for all specimens or all years.

Freezing specimens for verifying identification on land has proven to be beneficial for many groups. However, it does not work very well for liparids in general and genus *Liparis* in particular. Due to their gelatinous consistency, they easily disintegrate and important taxonomic characters like size of gill openings and nostrils are lost. This is another reason why specimens are not registered at a lower taxonomic level.

All *Careproctus* species are classified as Arctic, of the other seven liparid species, five are Arctic and only two are boreal.

4.2.7 Zoarcidae

The taxonomy of eelpouts (Zoarcidae) is problematic as they have a great degree of character plasticity (Mecklenburg et al 2011). Good identification keys and experience with eelpouts were lacking in the beginning of the time series. Around 2007 the species identification improved, especially on Norwegian boats, where difficult specimens were frozen onboard and identified on land by taxonomists. During the surveys 2004-2015, 21 zoarcid species were identified, most of them are Arctic, except three boreal and one Arctic-boreal species. Almost 40% of the eelpout catches were identified as the boreal *Lycodes gracilis,* and less than 1% of the specimens were identified to the family level only. The biggest challenge is posed by young specimens of *Lycodes rossi* and *Lycodes reticulatus*. While they easily can be distinguished based on coloration from a size of about 15 cm, smaller ones are very similar. The number of pectoral fin rays is the only character to separate the species, unfortunately there is an overlap: 17-19 in *L. rossi* and 19-21 in *L. reticulatus*.

4.2.8 Pleuronectidae

There are ten species in the data set, all are boreal except one Arctic-boreal and the Arctic species *Liopsetta glacicalis*, which is found in shallow areas in the southeastern Barents Sea. It most closely resembles *Pleuronectes platessa*, differing in the presence and shape of bony tubercles behind the eyes, the number of dorsal and anal fin rays, and the coloration. *Liopsetta glacialis* has never been registered on Norwegian vessels.

5 Results

5. 1 Overall trend

There were 105 species of marine fish caught in the ecosystem survey 2004-2015 (Table 2.1), 14 Arctic-boreal, 47 Boreal, three Widely Distributed species, and 42 Arctic species in the entire Barents Sea. Due to issues with taxonomy and species identity and identification, we pooled 16 of the Arctic species to the genus level (*Icelus*, *Careproctus* and *Gymnelus*) leaving 32 taxa (three genera and 29 species) in our data set. Of the Arctic species, almost 90% of the individuals caught were polar cod (Figure 5.1). The second most abundant species was *Triglops nybelini* (6% of the individuals) and third most common was *Liparis fabricii* (2%).

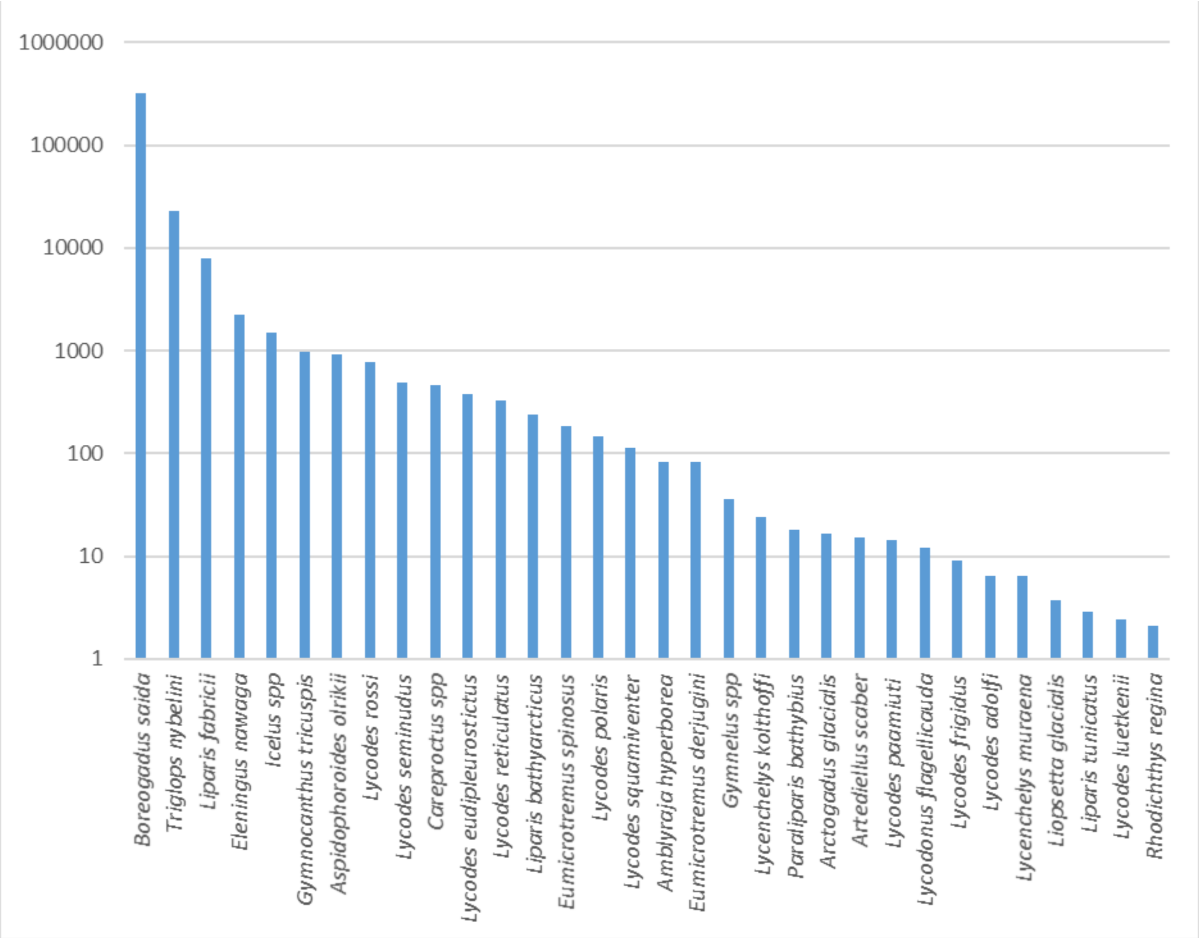


Figure 5.1 Species rank plotted against log abundance.

A decline of polar cod abundance from 2004-2015 has been shown in e.g. ICES (2016), and maps of distributions and acoustic estimates of polar cod are provided each year in the survey reports from the ecosystem survey. Therefore, our main concern is the remaining Artic species. The number of Arctic species per station and the total catches (individuals per nautical mile) of Arctic species (excluding polar cod per station) is shown in Figure 5.2.

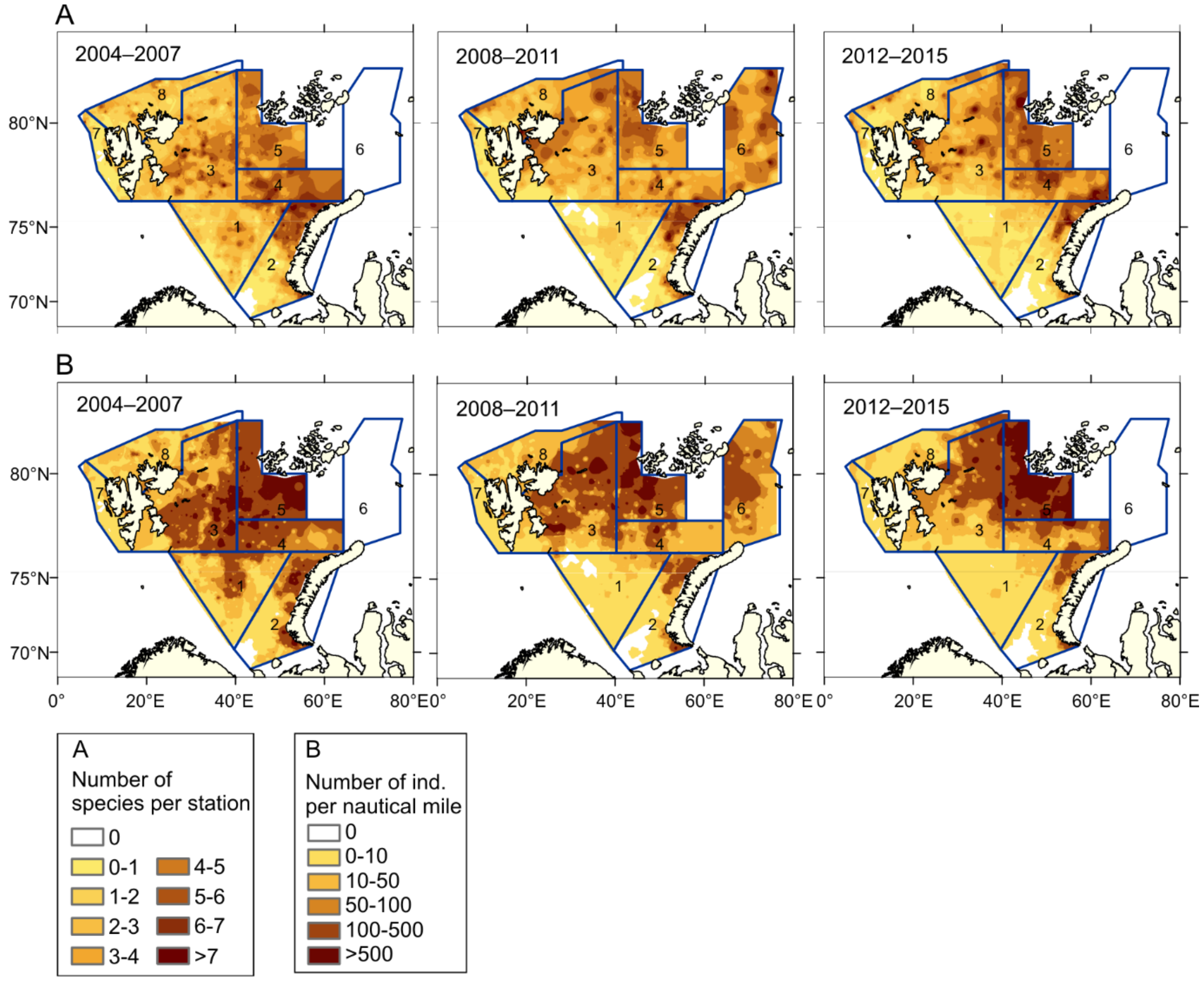
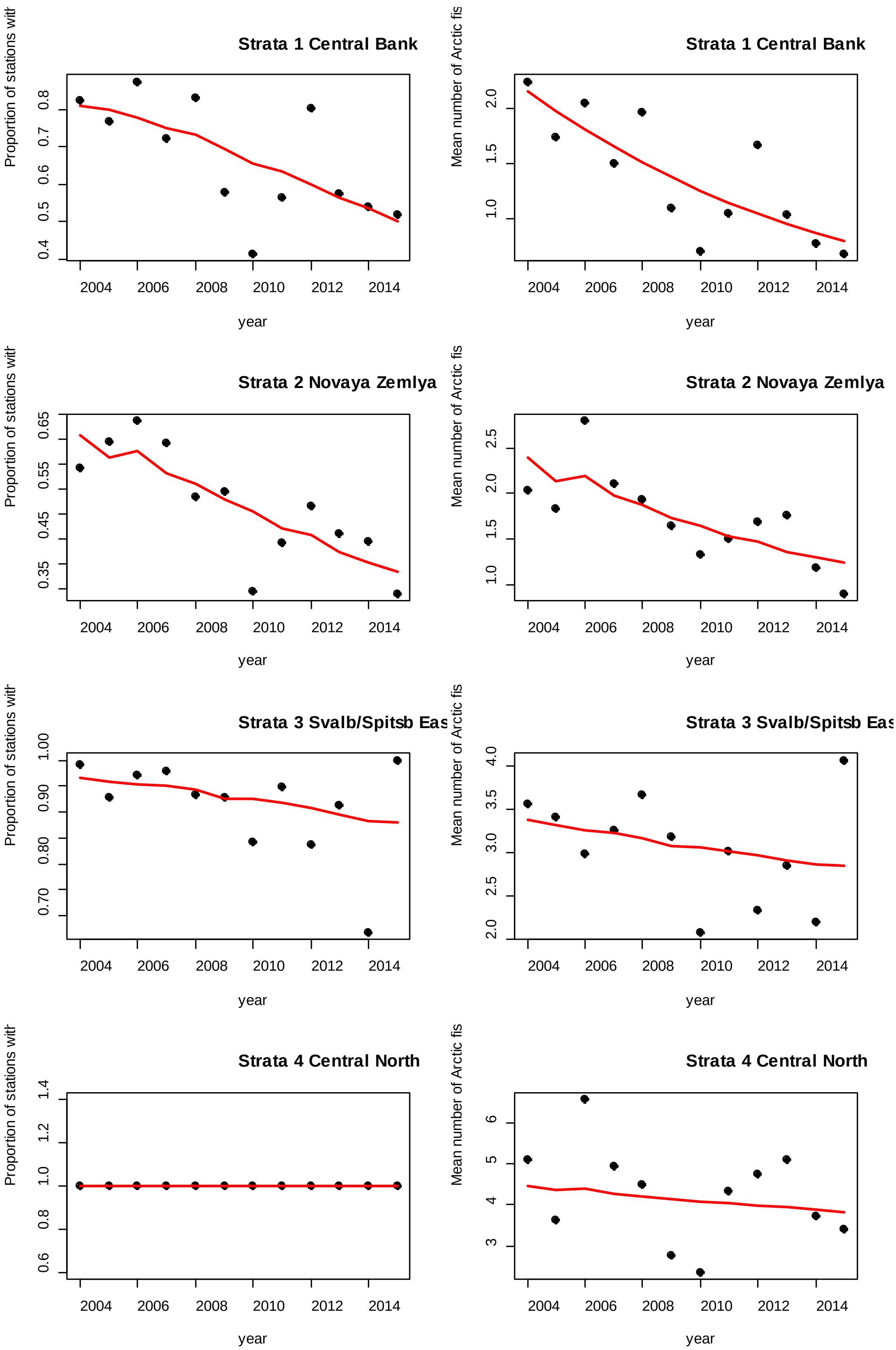


Figure 5.2 Maps of A: number of Arctic species per station and B: total number of individuals of all Arctic species per stations. Left 2004-2007, middle: 2008-2011, right: 2012-2015. The maps are made in ArcGIS Spatial Analyst with IDW interpolation on a 10 km by 10 km grid using the 6 nearest stations. There were no data for strata 6 in 2004-2007 and 2012-2015. Survey data from 2013 exist but was not available when this report was made.

An overall decline of the Arctic fishes was evident from our data. Excluding polar cod, there was a significant decline in the proportion of stations with Arctic species over time and the number of Arctic species caught per station ($p<0.0001$, Figure 5.3). The decline was found mainly in the southern part of the study area, the Central Bank and Novaya Zemlya. The Central Bank area and Novaya Zemlya have a current system with northward movement of warmer currents and this system provide clear patterns. Strata 7, 8 and 5 have a more complex current system (mix of cold water from south and warm water from north), so patterns in these areas are not so clear.



Strata 1 Central Bank
Proportion of stations witr
Strata 1 Central Bank
Mean number of Arctic fis
Strata 2 Novaya Zemlya
Proportion of stations witr
Strata 2 Novaya Zemlya
Mean number of Arctic fis
Strata 3 Svalb/Spitsb Eas
Proportion of stations witr
Strata 3 Svalb/Spitsb Eas
Mean number of Arctic fis
Strata 4 Central North
Proportion of stations witr
Strata 4 Central North
Mean number of Arctic fis
year
2004 2006 2008 2010 2012 2014

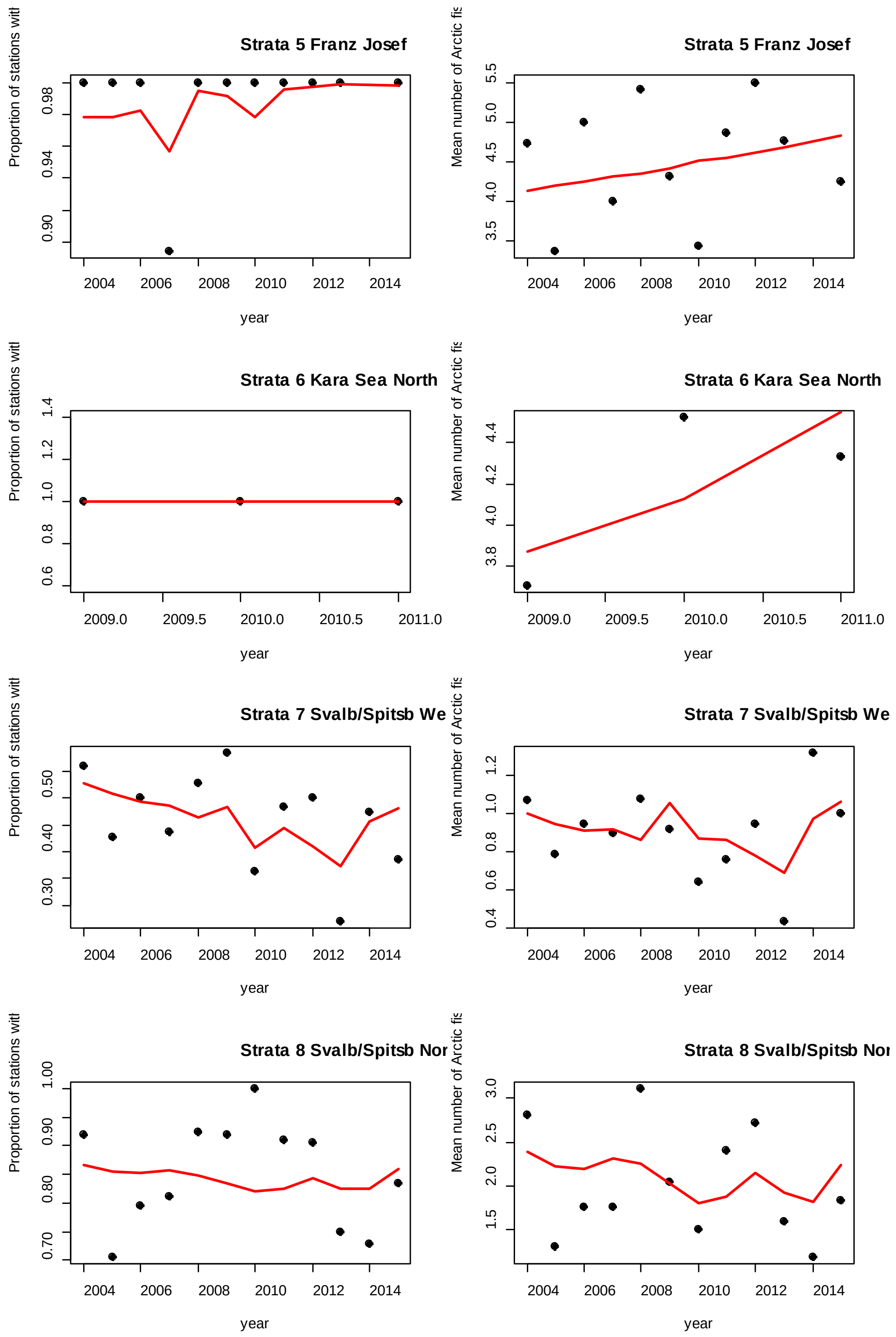


Figure 5.3. Left: proportion of stations with Arctic species. Right: average of number of Arctic species per station 2004-2005. The red line is the estimated trend. The fitted model includes year as continuous variable and bottom depth as a covariate to account for variable sampling by depth from year to year. Logistic regression was used for occurrence and log link and Poisson error was used for the number of species per station. The model was fitted to each strata separately. When fitting the model to all data, there was a significant effect of depth, year as a trend and strata (p<0.0001) for both occurrence and mean number of species.

There was significant interaction between year and strata for mean number of species but not for occurrence. There were 17 taxa (species or genera) caught all years (Table 5.1), all the remaining (15) that were not caught every year had restricted distributions (Figure 5.4). They were found either along the shelf break around Svalbard/Spitsbergen and around Franz Josef Land (11 species: *Arctogadus glacialis, Lycenchelys kolthoffi, Lycenchelys muraena, ,Lycodes adolfi, Lycodes frigidus, Lycodes luetkenii*, *Lycodes paamiutiLycodes squamiventer, Lycodonus flagellicauda, Paraliparis bathybius Rhodichthys regina,*), or in the shallow, brackish water in southeastern Barents Sea (three species: *Artediellus scaber, Eleginus nawaga, Liopsetta glacialis*), or in shallow waters around Bear Island (one species: *Liparis tunicatus*). These species that were not sampled every year appear to have too restricted distributions to be properly sampled by the survey and to assess trends.

Table 5.1. Number of years (yrs) with catches of the species at the ecosystem survey and the number hauls with species by the strata included in the current study. The species are sorted according to number of years they are recorded and the total number of hauls contacting the species, from common to rare. Strata 1 CB: Central Bank, Strata 2 NZ: Novaya Zemlya, Strata 3 SE: Svalbard/Spitsbergen East, Strata 4 CN: Central North, Strata 5: FJ Franz Josef, Strata 6: KN Kara North, Strata 7: Svalbard/Spitsbergen West, Strata 8: Svalbard/Spitsbergen North.

Species	Yrs *	CB 1	NZ 2	SE 3	CN 4	FJ 5	KN6	SW 7	SN 8	Comment
Boreogadus saida	12	488	372	658	186	252	74	302	356	
Triglops nybelini	12	108	31	566	151	245	69	19	103	
Careproctus spp.	12	266	72	216	81	135	34	72	83	
Liparis fabricii	12	47	90	318	86	236	73	22	51	
Lycodes rossi	12	257	68	297	86	82	7	32	37	
Icelus spp.	12	88	168	190	102	101	11	9	18	
Lycodes reticulatus	12	92	70	214	75	82	14	4	25	
Lycodes seminudus	12	87	39	157	46	129	31	10	50	
Liparis bathyarcticus	12	50	97	107	55	18	9	27	21	
Amblyraja hyperborea	12	97	41	23	12	43	18	61	52	
Aspidophoroides olrikii	12	14	236	9	21	2	4	0	0	
Lycodes eudipleurostictus	12	57	1	27	2	4	12	67	90	
Gymnocanthus tricuspis	12	9	160	12	12	0	0	5	50	
Eumicrotremus spinosus	12	4	36	76	0	10	0	9	80	
Gymnelus spp.	12	18	25	45	15	17	1	1	17	
Lycodes polaris	12	11	71	5	18	7	9	0	1	
Eumicrotremus derjugini	12	0	16	27	3	3	1	1	1	
Arctogadus glacialis	11	0	0	23	2	15	6	3	18	Slope
Lycenchelys kolthoffi	11	4	3	9	5	6	7	7	36	Slope
Eleningus nawaga	10	0	0	3	0	0	0	0	0	Kara -South
Lycodes squamiventer	10	0	0	0	0	1	6	9	22	Slope
Lycodonus flagellicauda	10	0	0	0	0	0	0	13	14	Slope
Paraliparis bathybius	9	0	0	1	0	0	0	9	18	Slope
Lycenchelys muraena	8	0	0	0	0	0	0	8	8	Slope
Lycodes luetkenii	7	0	0	0	0	1	3	2	4	Slope
Lycodes paamiuti	7	0	0	0	0	0	0	6	6	Slope
Lycodes adolfi	6	0	0	0	0	0	0	0	9	Slope
Artediellus scaber	5	1	4	0	0	0	4	0	0	Kara -South
Liopsetta glacialis	5	0	0	0	0	0	0	0	0	Kara -South
Rhodichthys regina	5	0	1	1	0	0	0	1	6	Slope
Lycodes frigidus	4	5	0	3	0	0	0	4	4	Slope/
Liparis tunicatus	3	1	2	0	1	0	0	0	1	Coast
**years apply to the all demersal stations taken at the ecosystem survey, therefor the number of non-zero recordings does not add up to the years*										

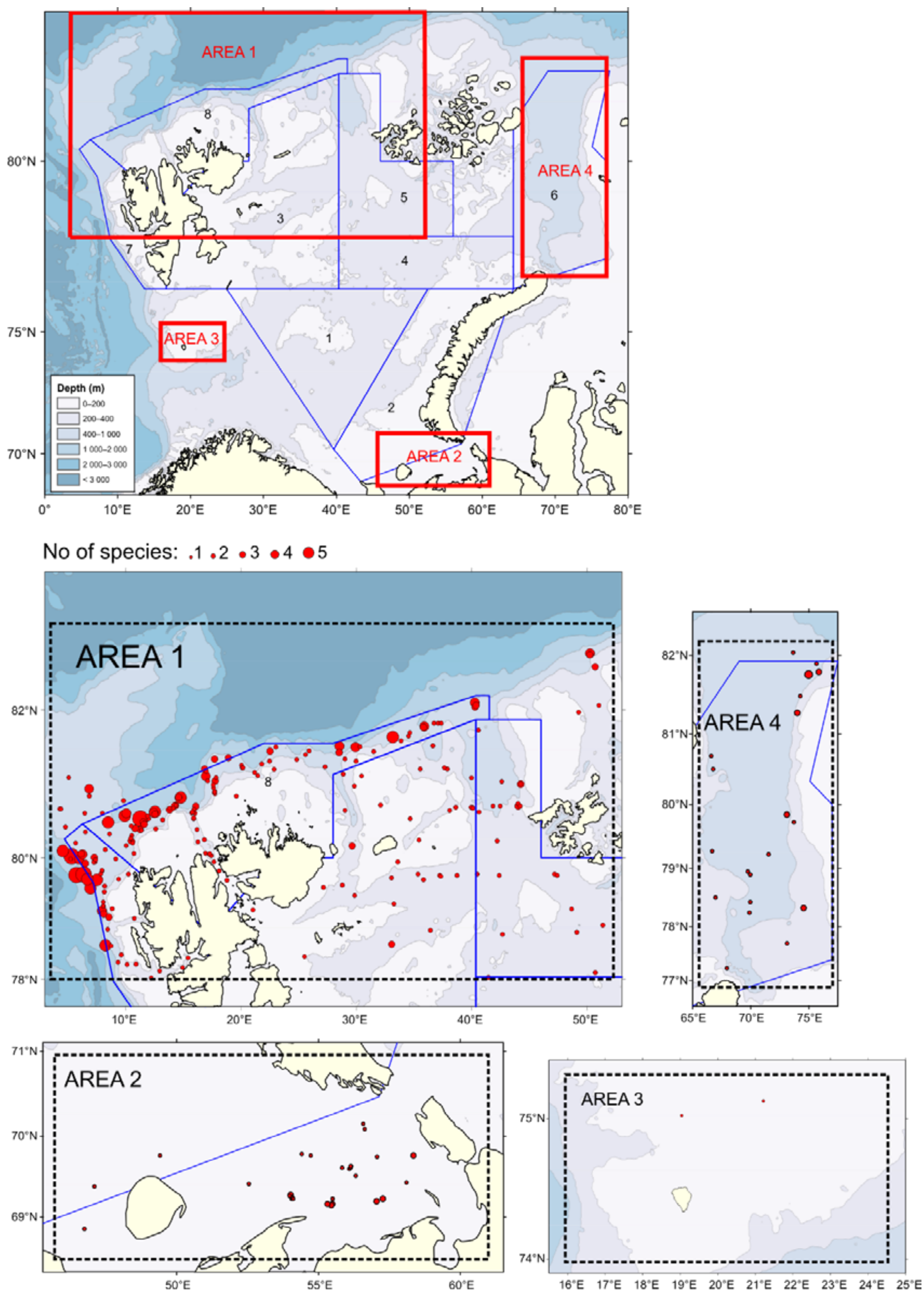


Figure 5.4. Map of catches of species with restricted distributions. Area 1: Arctogadus glacialis, Lycenchelys kolthoffi, Lycodes squamiventer, Lycodonus flagellicauda, Paraliparis bathybius, Lycenchelys muraena, Lycodes luetkenii, Lycodes paamiuti, Lycodes adolfi, Rhodichthys regina, Lycodes frigidus. Area 2: Liopsetta glacialis, Artediellus scaber, and Eleningus nawaga. Area 3: Two stations with Liparis tunicatus north of Bear Island in shallow water. Area 4: Arctogadus glacialis, Lycenchelys kolthoffi, Lycodes squamiventer, Lycodes luetkenii. There are a few catches of these species outside these areas (see table 5.1), most likely misidentifications.

5.2 Trends by species

Of the species caught every year, seven appear to be rare and/or poorly sampled by our sampling gear (Table 5.1). Trends in occupancy for these species were further assessed by logistic regression, whereas trends for the more abundant species were both assessed using logistic regression and the free StoX software under development at IMR.

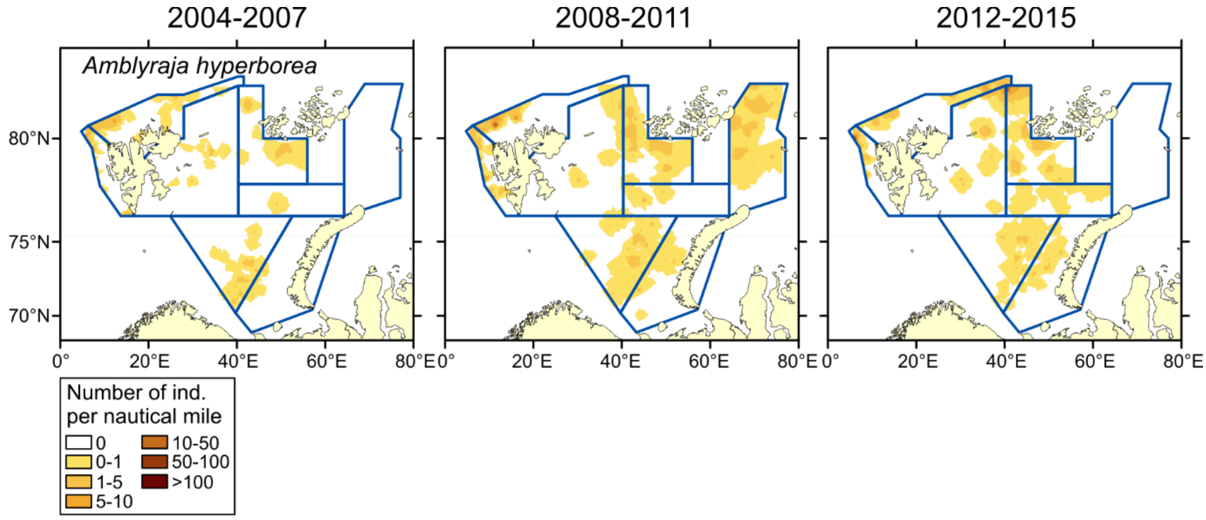
A negative relationship between year and occupancy was found for fourteen of the sixteen species assessed, but the relationship was significant for only eight of the species. Interactions between strata and year were significant for eight species, indicating that the temporal trend differed between strata (Figures 5.2.1-5.2.15a). Below we group the species according to the overall change over time and by area.

Five species had an overall decline in occurrence in all/most of the strata. These include the most common Arctic species after Polar cod, *Liparis fabricii* and *Triglops nybelini*, as well as *Lycodes seminudus*, *Liparis bathyarcticus* and *Careproctus* spp.

Six species appear to have an overall decline in occurrence in Strata 2 (Novaya Zemlya) and an increase in the strata to the north of strata 2, strata 4 (Central North) indicating a northwards shift of these species. These species include *Aspidophoroides olrikii* and *Gymnocanthus tricuspis*, two species that are almost exclusively restricted to the shallow waters around Novaya Zemlya in the Eastern Barents Sea. In addition, *Icelus* spp. and the eelpouts *Lycodes reticulatus*, *L. rossi* and *L. eudipleurostictus* fall in this category.

Three species did not show any clear trends or shifts. This includes the small bodied cyclopterids *Eumicrotremus derjugini* and *E. spinosus* and the eelpout *L. polaris.* The last two, *Amblyraja hyperborea* and genus *Gymnelus* spp. showed an increase over time. The trend for the latter was insignificant.

5.2.1. Amblyraja hyperborean



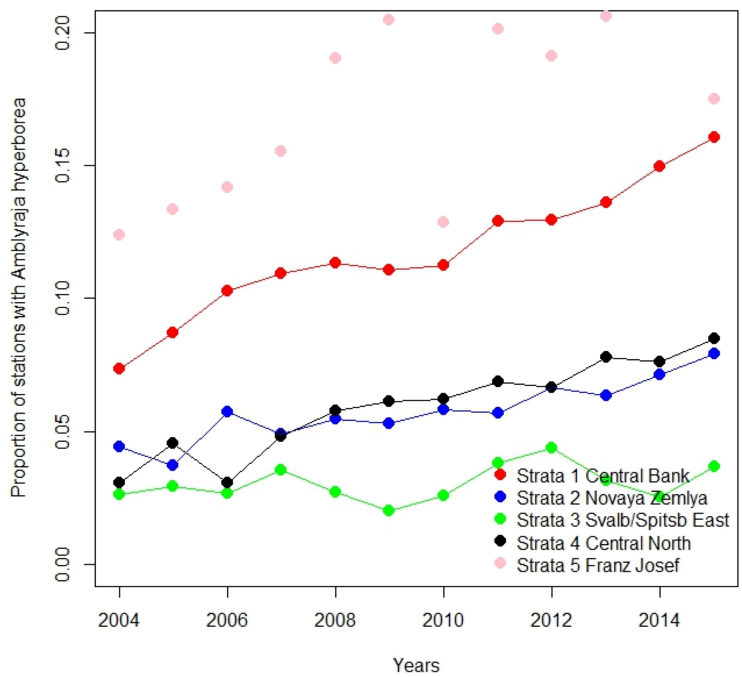
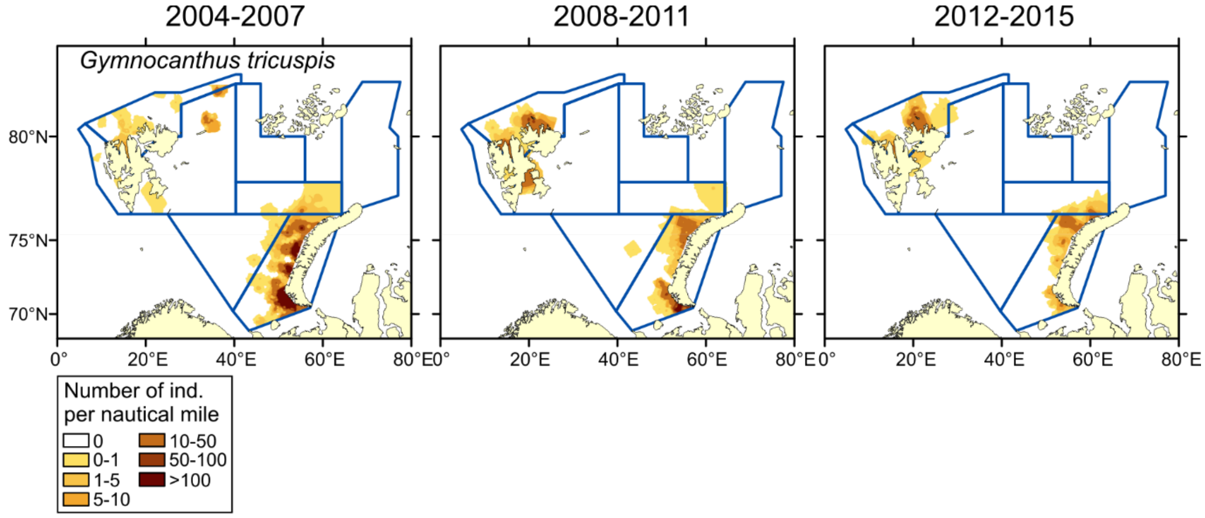


Figure 5.2.1. Temporal development in occupancy of *Amblyraja hyperborea* by strata. Estimated from logistic regression with year as a continuous variable (significant), strata (significant) and depth (significant). Interaction between year and strata was not significant.

5.2.2 Gymnocanthus tricuspis



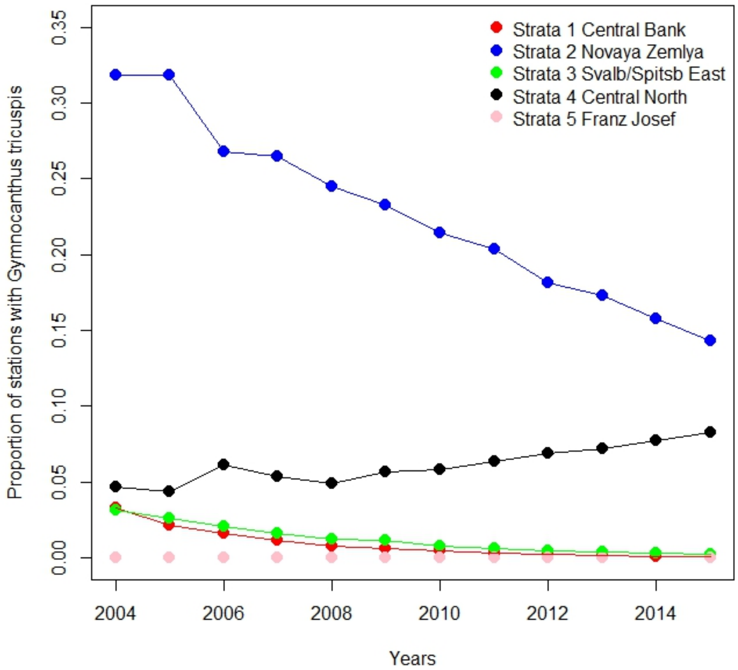
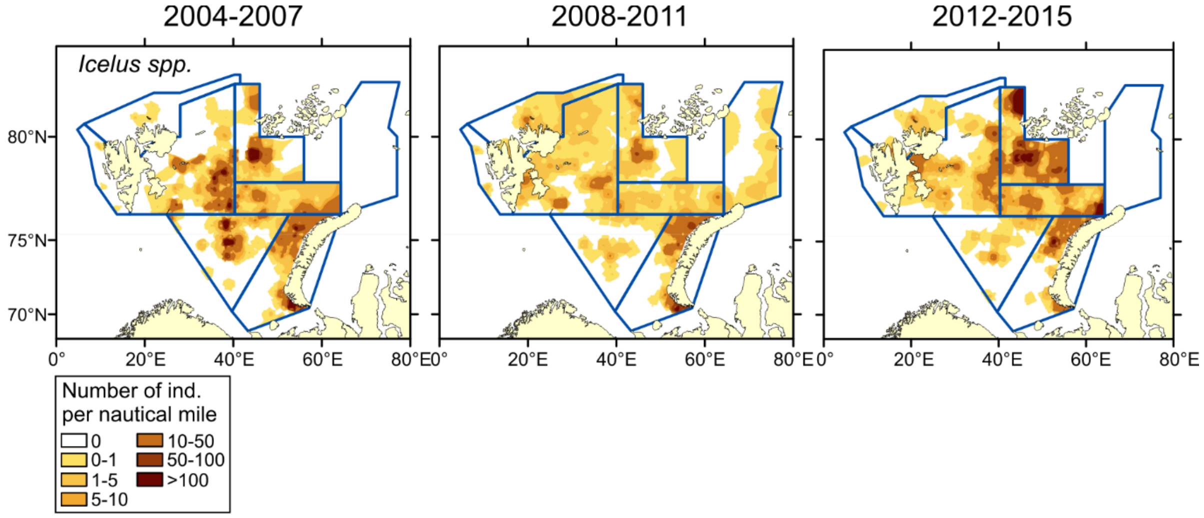


Figure 5.2.2 Temporal development in occupancy of *Gymnocanthus triscupis* by strata. Estimated from logistic regression with year as a continuous variable (significant), strata (significant), depth (significant) and interaction between year and strata (significant).

Table 5.2.2 Estimated densities of *G. triscupis* (individuals per nautical mile squared, rounded to individual). Slope of the regression log (estimated density) is given for strata with estimates for ten or more years. Significant codes: *** 0.001, ** 0.01, * 0.05

Year	Strata 1	Strata 2	Strata 3	Strata 4	Strata 5
2004	NA	318	46	NA	NA
2005	5	NA	1	12	NA
2006	3	2240	NA	13	NA
2007	NA	1404	NA	103	NA
2008	NA	1108	NA	NA	NA
2009	NA	163	77	NA	NA
2010	2	242	NA	6	NA
2011	NA	107	NA	NA	NA
2012	NA	226	NA	NA	NA
2013	NA	184	5	32	NA
2014	NA	65	NA	NA	NA
2015	NA	52	NA	15	NA
Slope		-0.29**			

5.2.3 Icelus spp.



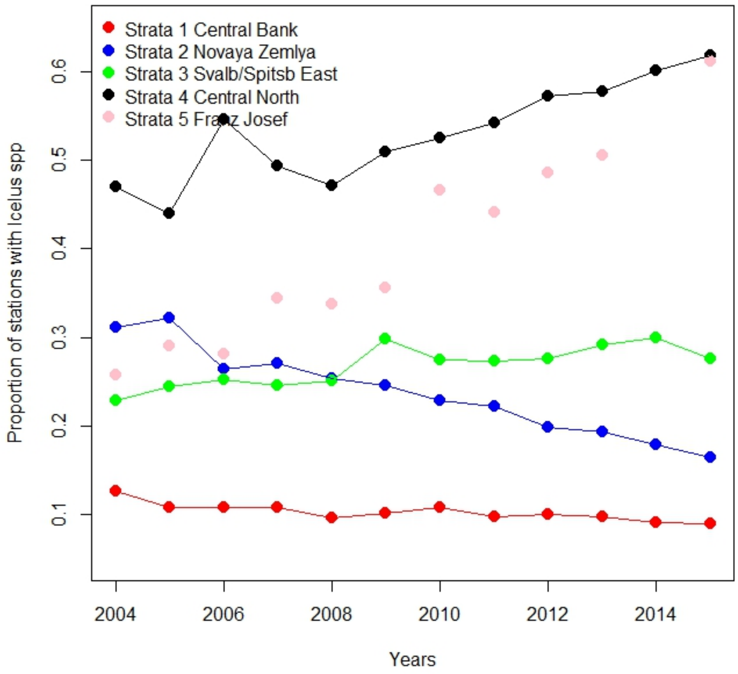
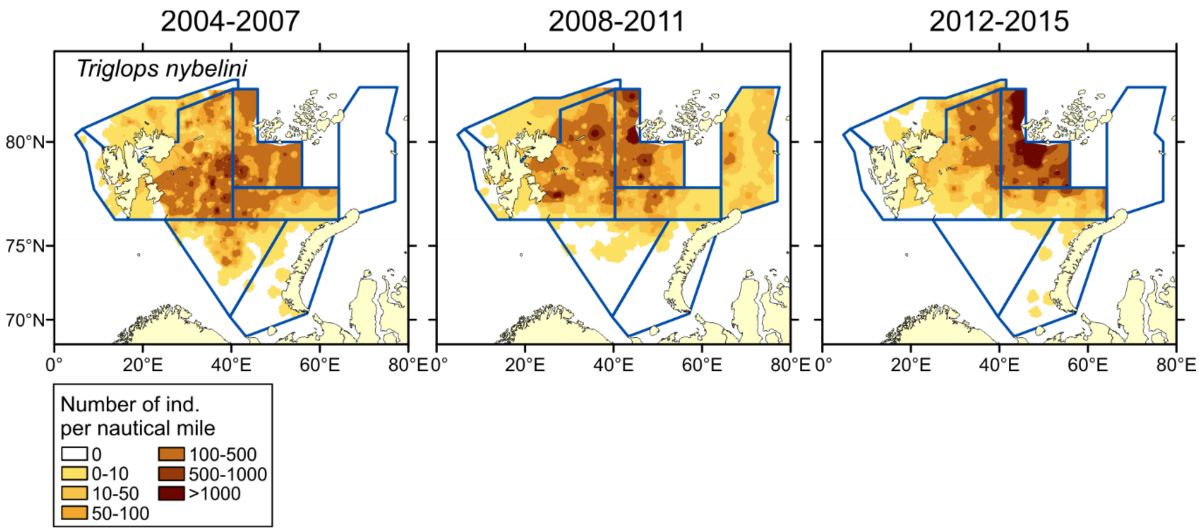


Figure 5.2.3. Temporal development in *Icelus* spp. Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy of *Icelus* spp. by strata. Estimated from logistic regression with year as a continuous variable (not significant), strata (significant), depth (significant) and interaction between year and strata (significant).

5.2.4 Triglops nybelini



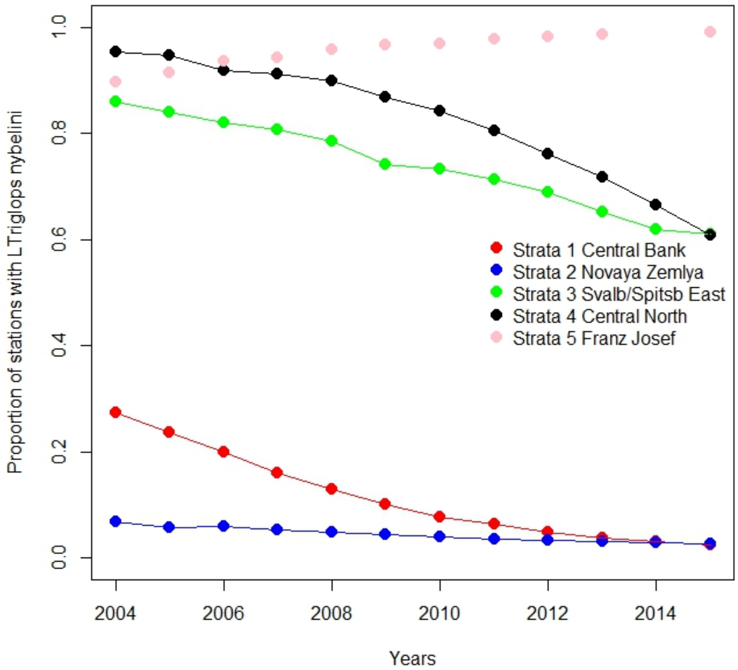
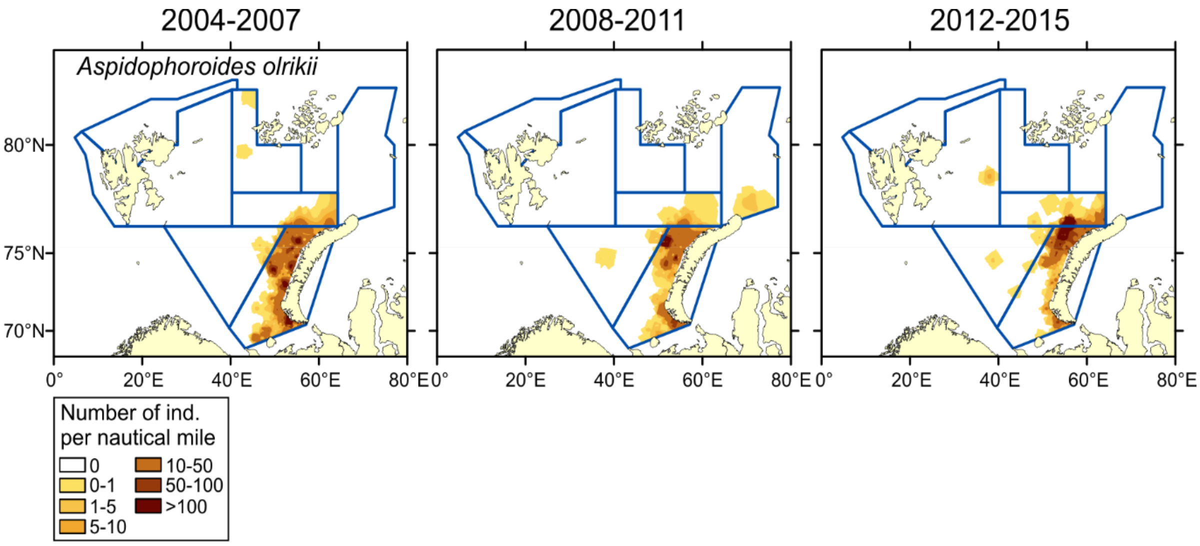


Figure 5.2.4. Temporal development in *Triglops nybelini.* Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy of *T. nybelini* by strata. Estimated from logistic regression with year as a continuous variable (significant), strata (significant), depth (significant) and interaction between year and strata (significant).

Table 5.2.4 Estimated densities of *T. nybelini* (individuals per nautical mile squared, rounded to individual). Slope of the regression log (estimated density) is given for strata with estimates for ten or more years. Significant codes: *** 0.001, ** 0.01, * 0.05

Year	Strata 1	Strata 2	Strata 3	Strata 4	Strata 5
2004	1506	19	17334	8890	16651
2005	1514	NA	17149	9437	19795
2006	1158	15	8817	10591	8679
2007	793	31	10965	14708	14495
2008	534	8	20278	8689	19106
2009	484	57	5235	3468	11583
2010	16	2	4199	2308	16986
2011	39	3	10489	5402	82188
2012	29	123	9124	5094	126410
2013	18	5	3123	2691	26532
2014	1	1	407	1977	NA
2015	NA	10	4259	705	9672
Year	-0.66***	-0.14	-0.21*	-0.21***	0.7

5.2.5 Aspidophoroides olrikii



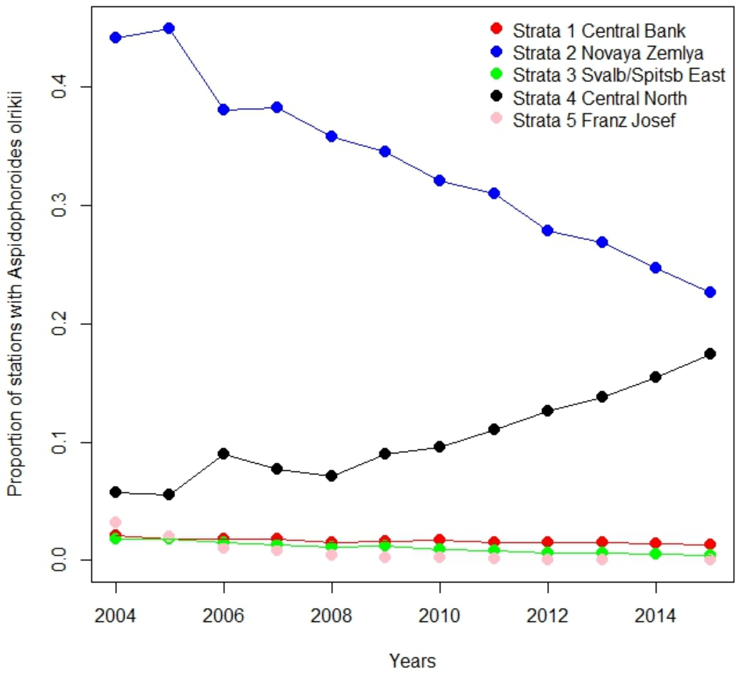
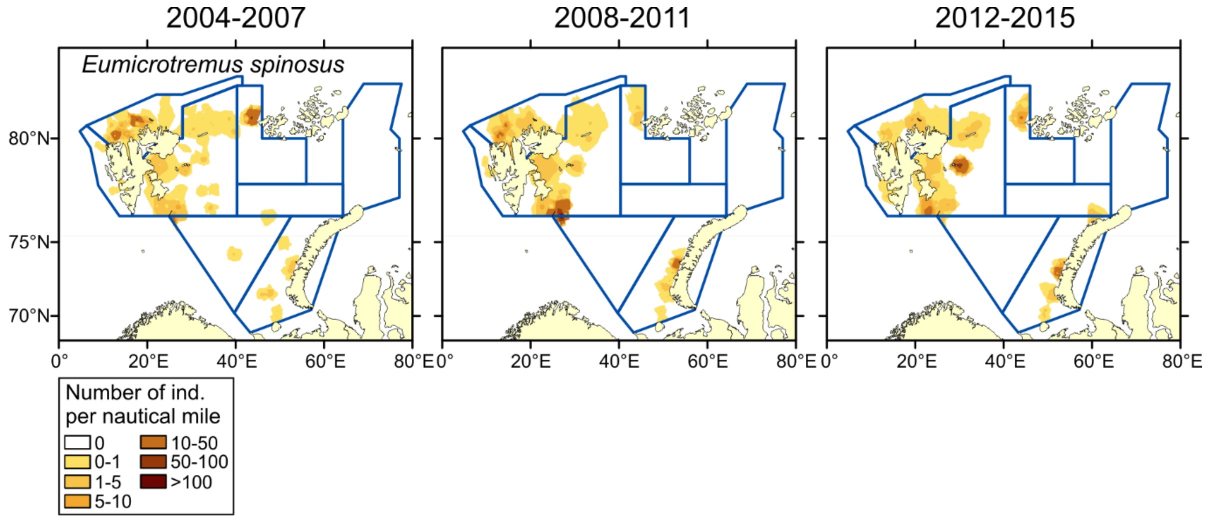


Figure 5.2.5. Temporal development in *Aspidophoroides olrikii.* Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy of *A. olrikii* by strata. Estimated from logistic regression with year as a continuous variable (significant), strata (significant), depth (significant) and interaction between year and strata (significant).

Table 5.2.5. Estimated densities of *A. olrikii* (individuals per nautical mile squared, rounded to individual). Slope of the regression is given for strata with estimates for ten or more years. Slope of the regression log (estimated density) is given for strata with estimates for ten or more years. Significant codes: *** 0.001, ** 0.01, * 0.05

	Strata 1	Strata 2	Strata 3	Strata 4	Strata 5
2004	NA	458	NA	NA	NA
2005	NA	1411	NA	NA	NA
2006	5	1060	NA	NA	NA
2007	NA	1171	NA	NA	3
2008	10	356	NA	49	7
2009	3	662	NA	129	NA
2010	2	NA	NA	61	NA
2011	NA	635	NA	80	NA
2012	1	563	NA	29	NA
2013	3	1528	NA	2347	NA
2014	4	407	NA	118	NA
2015	NA	NA	11	984	NA
Slope		-0.05			

5.2.6 Eumicrotremus derjugini



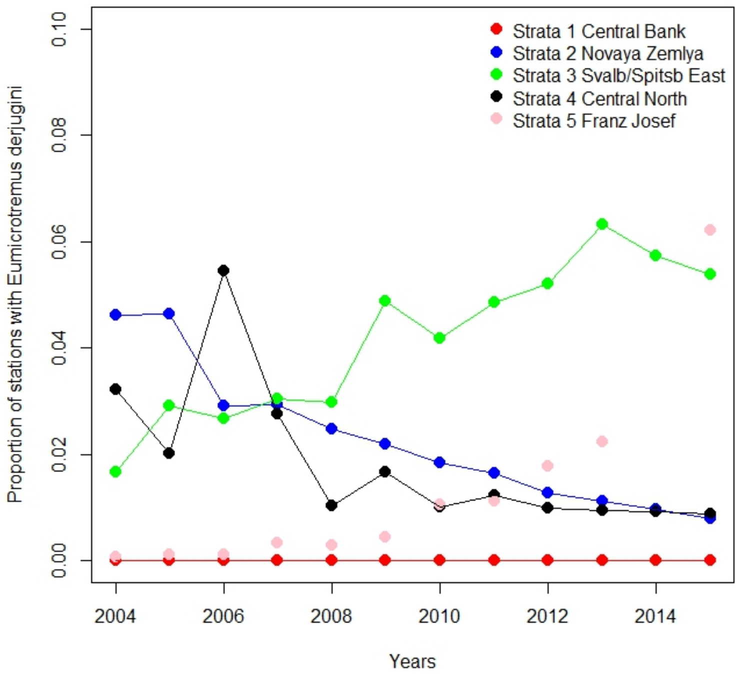


Figure 5.2.6. Temporal development in *Eumicrotremus derjugini.* Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy of *E. derjugini* by strata. Estimated from logistic regression with year as a continuous variable (not significant), strata (significant), depth (significant) and interaction between year and strata (significant).

5.2.7 Eumicrotremus spinosus

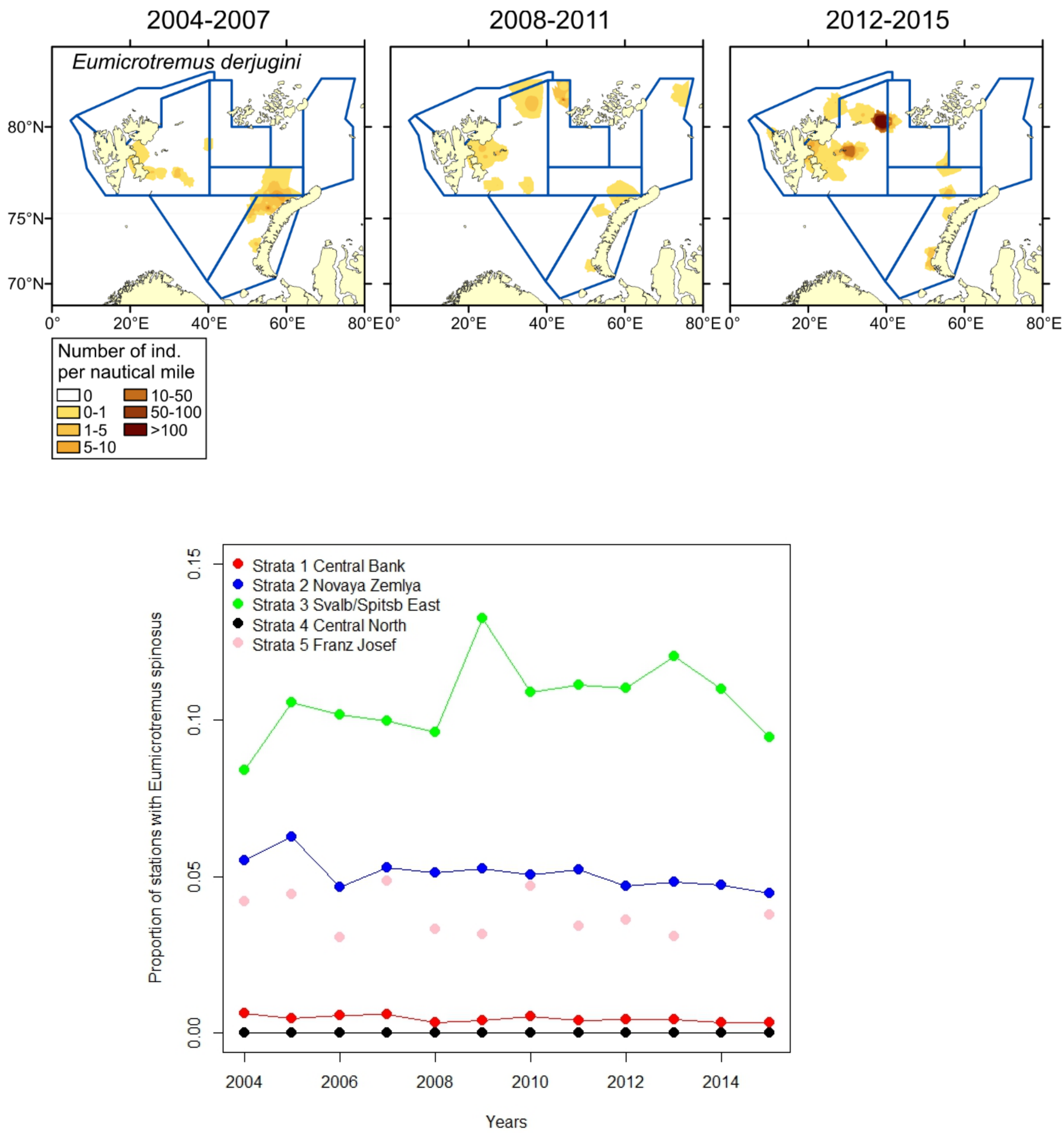


Figure 5.2.7. Temporal development in *Eumicrotremus spinosus.* Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy of *E. spinosus* by strata. Estimated from logistic regression with year as a continuous variable (not significant), strata (significant) and depth (significant).

5.2.8 *Careproctus* spp.

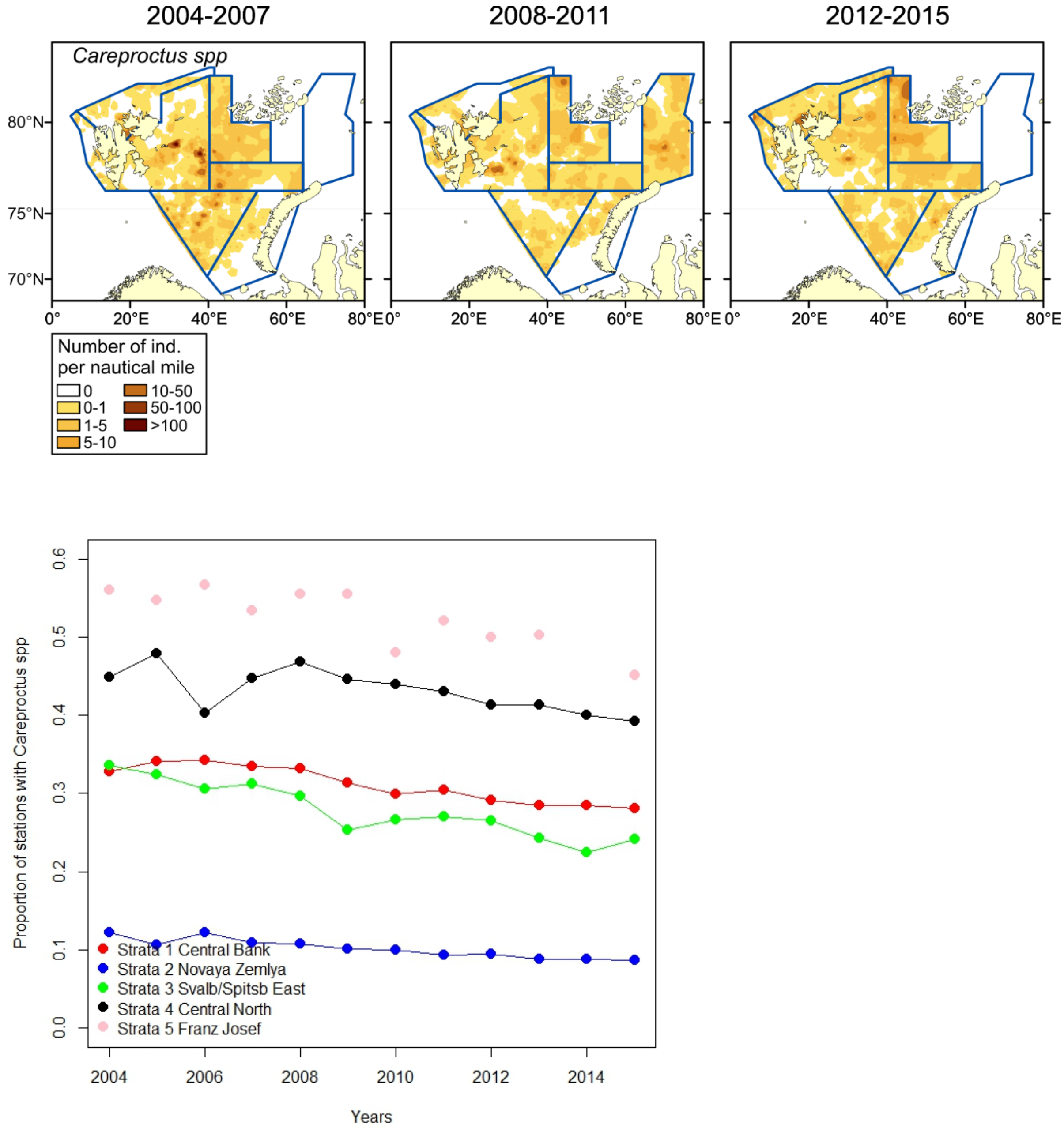
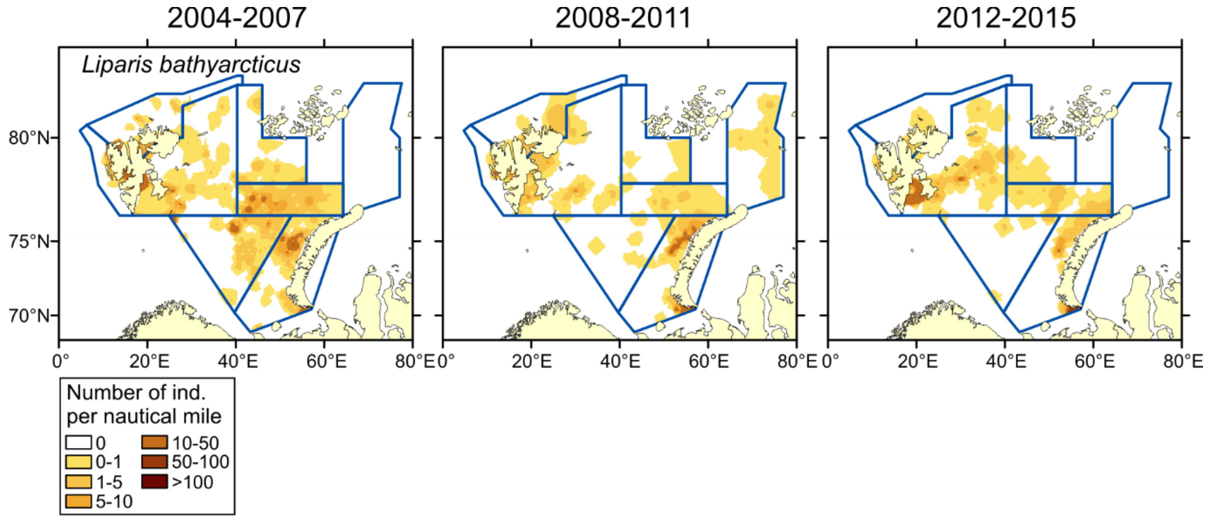


Figure 5.2.8 Temporal development in *Careproctus* spp. Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy of *Careproctus* spp. by strata. Estimated from logistic regression with year as a continuous variable (not significant, p<0.052), strata (significant) and depth (significant).

5.2.9 Liparis bathyarcticus



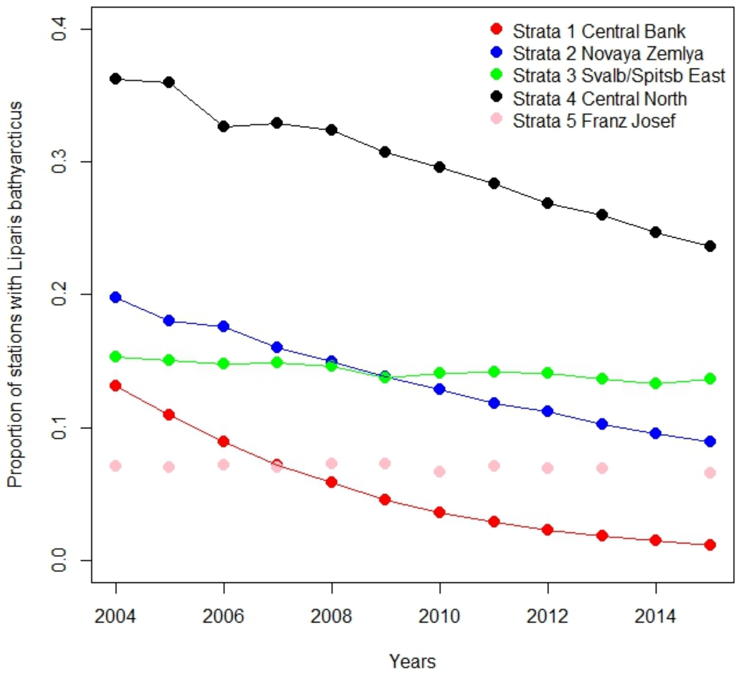


Figure 5.2.9 Temporal development in *Liparis bathyarcticus.* Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy of *L. bathyarcticus* by strata. Estimated from logistic regression with year as a continuous variable (significant), strata (significant), depth (significant) and interaction between year and strata (significant).

5.2.10 Liparis fabricii

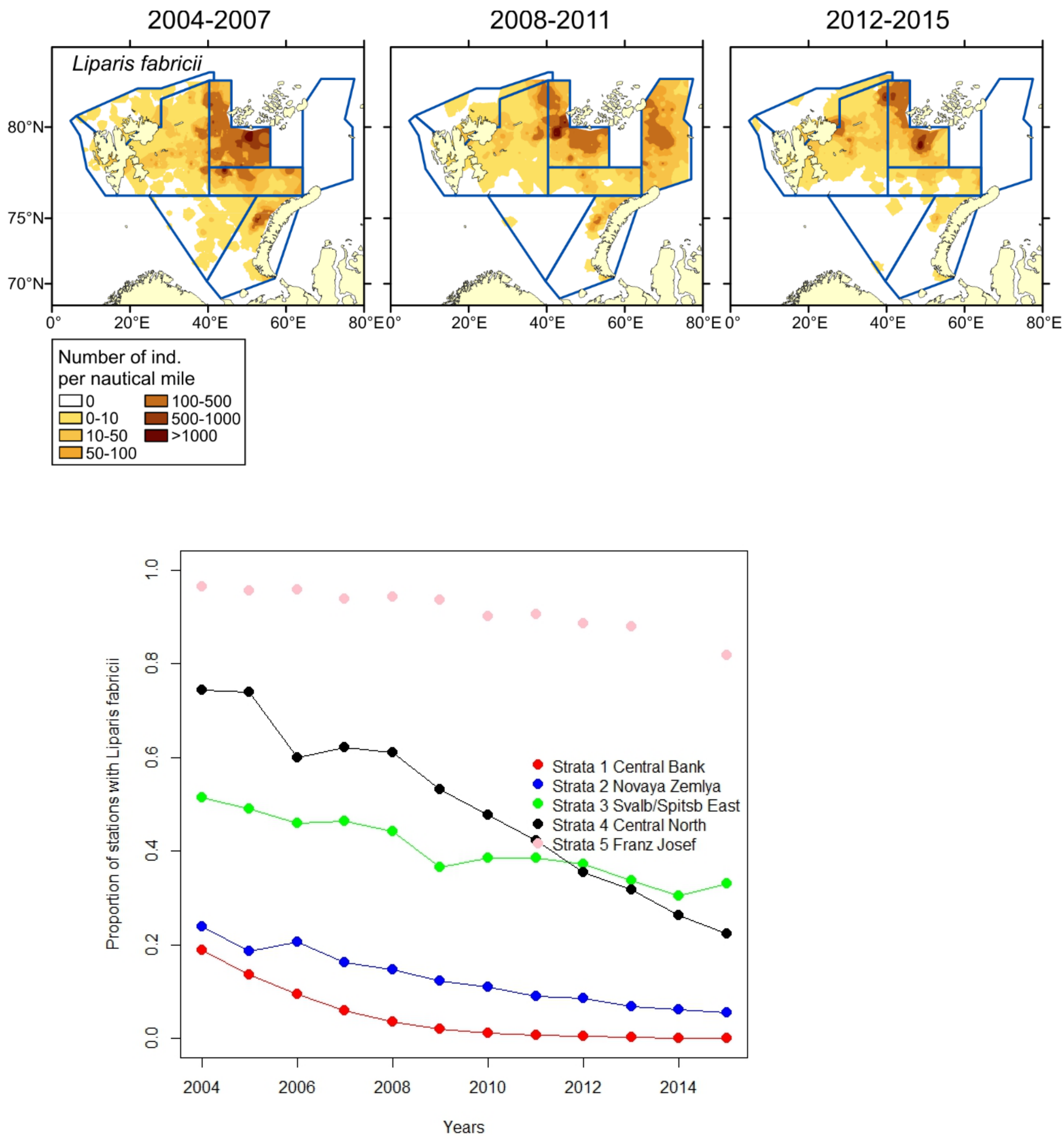


Figure 5.2.10 Temporal development in *Liparis fabricii.* Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy of *L. fabricii* by strata. Estimated from logistic regression with year as a continuous variable (significant), strata (significant), depth (significant) and interaction between year and strata (significant).

Table 5.2.10. Estimated densities of *L. fabricii* (individuals per nautical mile squared, rounded to individual). Slope of the regression log (estimated density) is given for strata with estimates for ten or more years. Significant codes: *** 0.001, ** 0.01, * 0.05

Year	Strata 1	Strata 2	Strata 3	Strata 4	Strata 5
2004	245	253	3450	7130	22491
2005	5356	887	1607	2554	13272
2006	54	6727	1915	11169	71463
2007	83	1578	3298	14523	59651
2008	NA	973	850	891	7762
2009	4	63	197	189	6566
2010	NA	197	1390	514	16680
2011	NA	96	1214	1088	30122
2012	2	47	1448	571	15996
2013	3	269	258	121	2434
2014	NA	24	18	442	NA
2015	NA	7	2536	303	4537
Slope		-0.41**	-0.20	-0.34**	-0.17

5.2.11 Gymnelus spp.

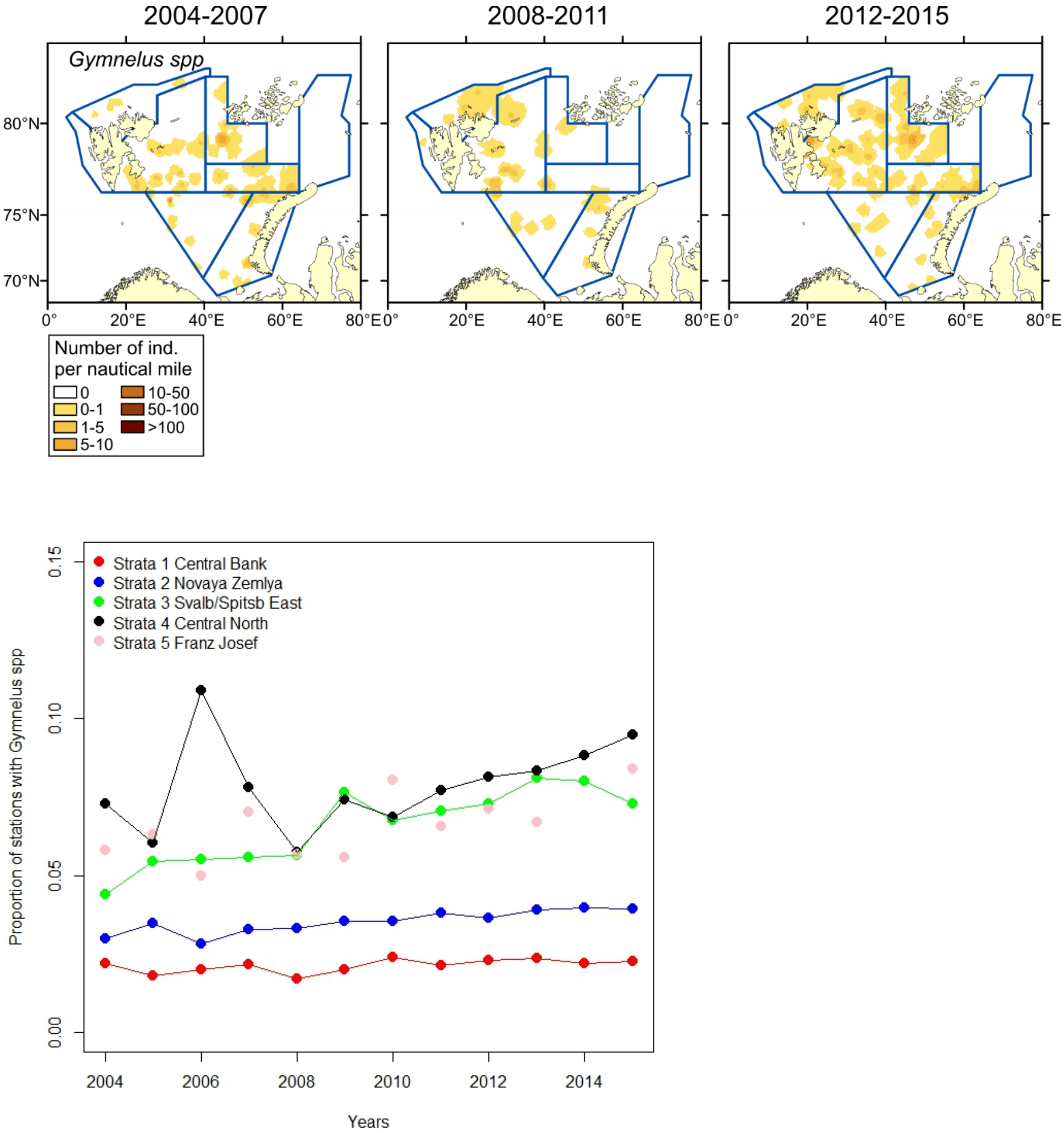
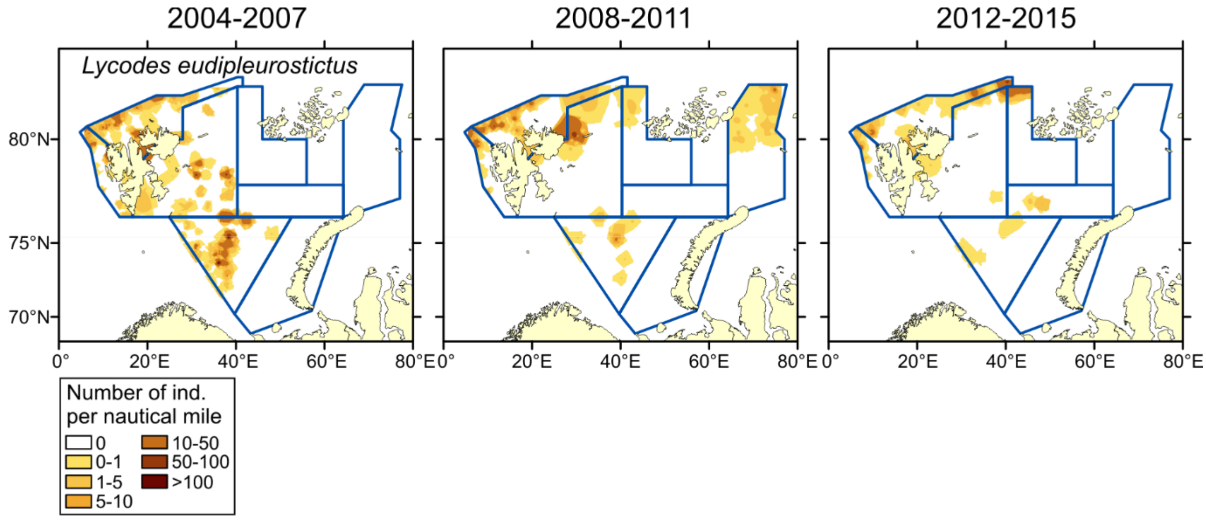


Figure 5.2.11 Temporal development in *Gymnelus* spp. Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy of *Gymnelus* spp. by strata. Estimated from logistic regression with year as a continuous variable (non significant), strata (significant), and depth (significant).

5.2.12 Lycodes eudipleurostictus



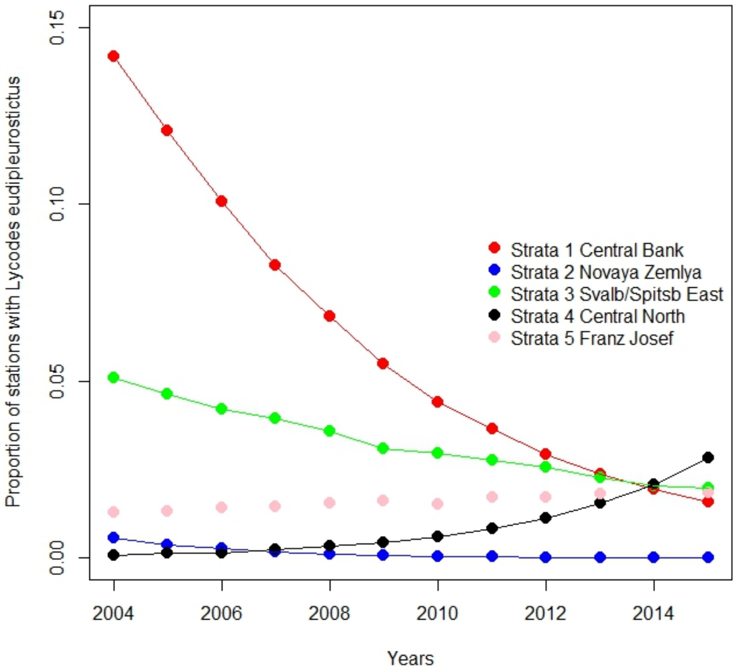
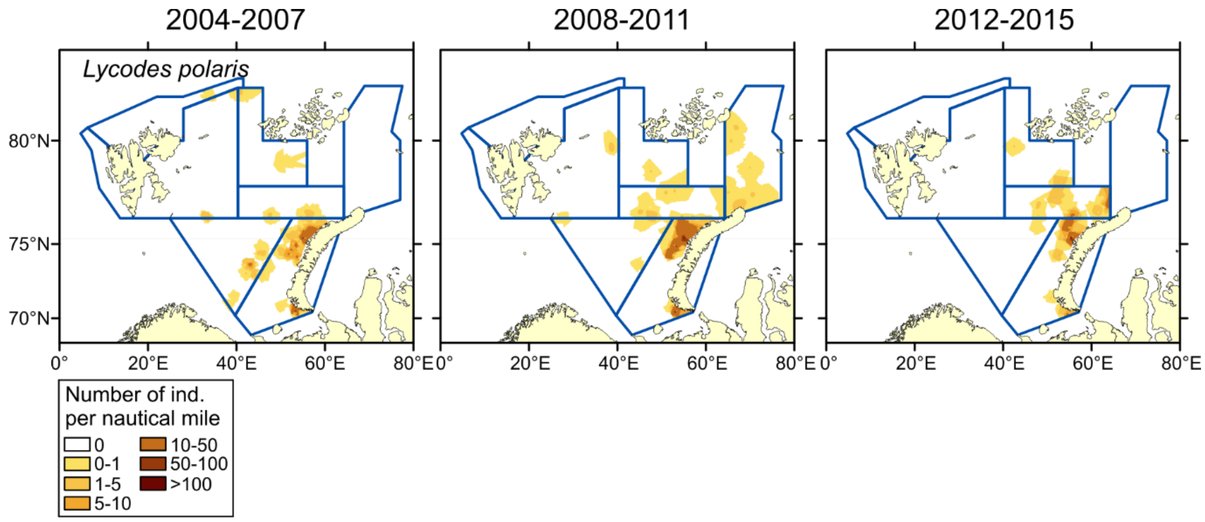


Figure 5.2.12 Temporal development in *Lycodes eudipleurostictus.* Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy of *L. eudipleurostictus* by strata. Estimated from logistic regression with year as a continuous variable (significant), strata (significant), depth (significant) and interaction between year and strata (significant).

Table 5.2.12 Estimated densities of *L. eudipleurostictus* (individuals per nautical mile squared, rounded to individual).

	Strata 1	Strata 2	Strata 3	Strata 4	Strata 5
2004	370	NA	47	NA	8
2005	49	NA	2	NA	NA
2006	149	NA	198	NA	NA
2007	14	NA	7	NA	NA
2008	NA	NA	NA	NA	14
2009	11	NA	NA	NA	6
2010	NA	NA	9	NA	NA
2011	33	NA	137	NA	NA
2012	3	NA	3	NA	73
2013	NA	NA	2	46	NA
2014	4	NA	NA	NA	NA
2015	4	NA	NA	NA	NA

5.2.13 Lycodes polaris



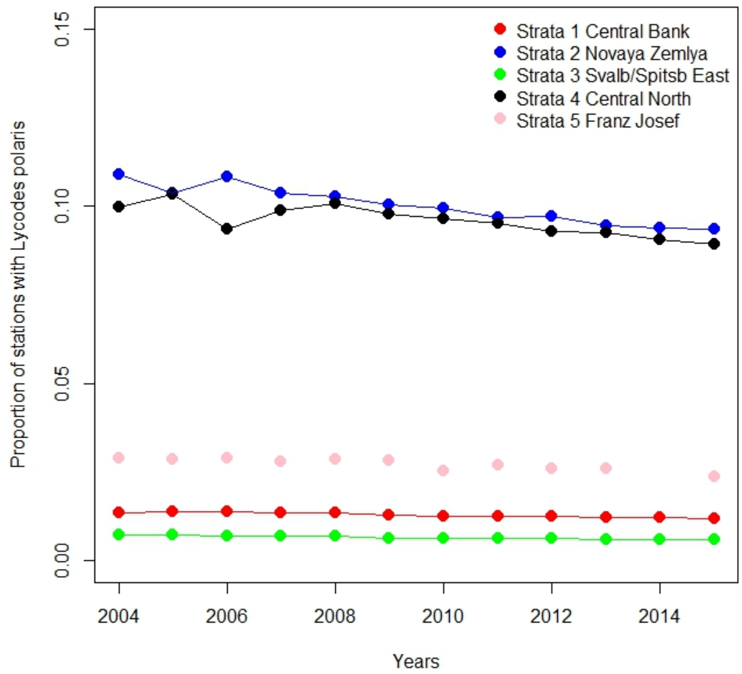
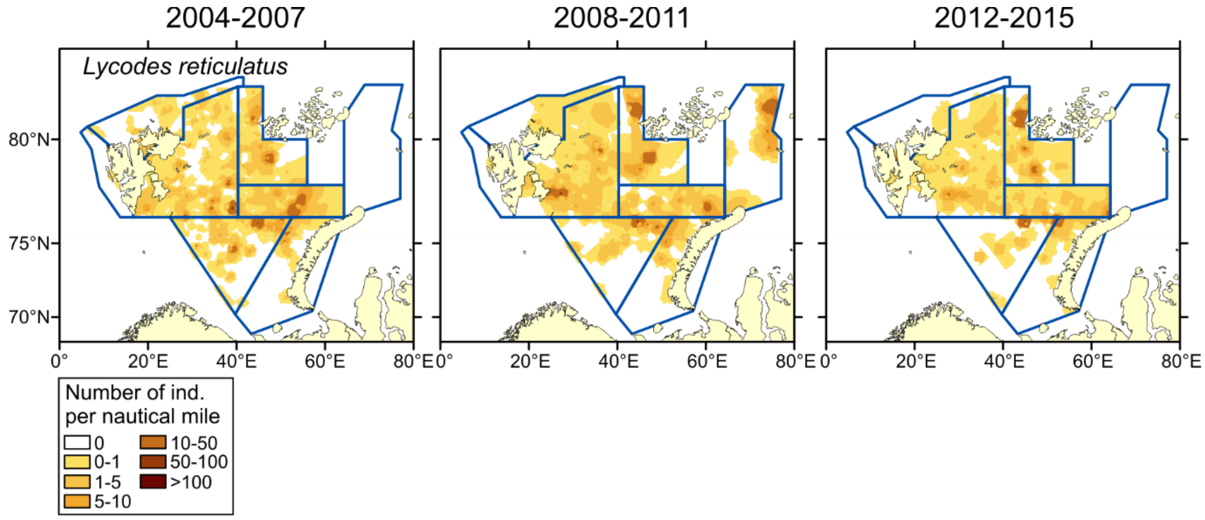


Figure 5.2.13 Temporal development in *Lycodes polaris.* Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy *L. polaris* by strata. Estimated from logistic regression with year as a continuous variable (not significant), strata (significant) and depth (significant).

5.2.14 Lycodes reticulatus



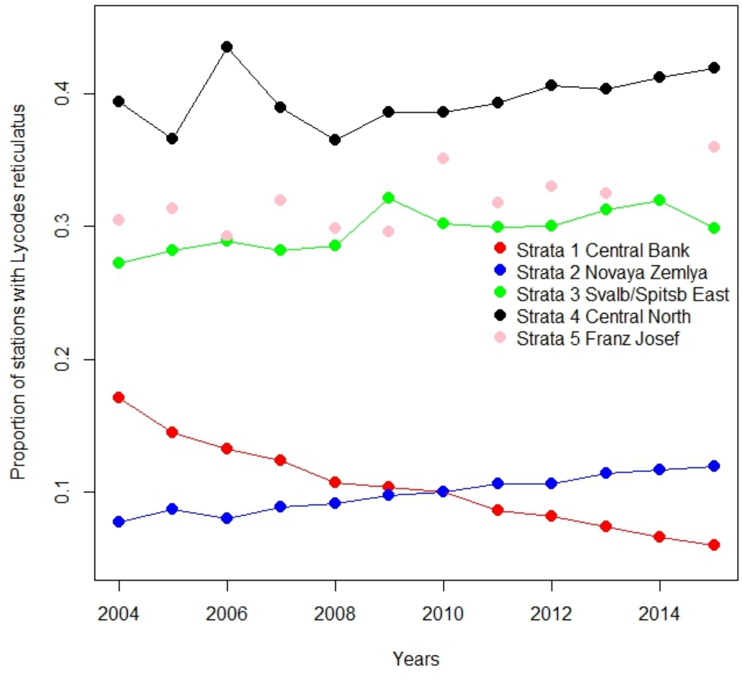
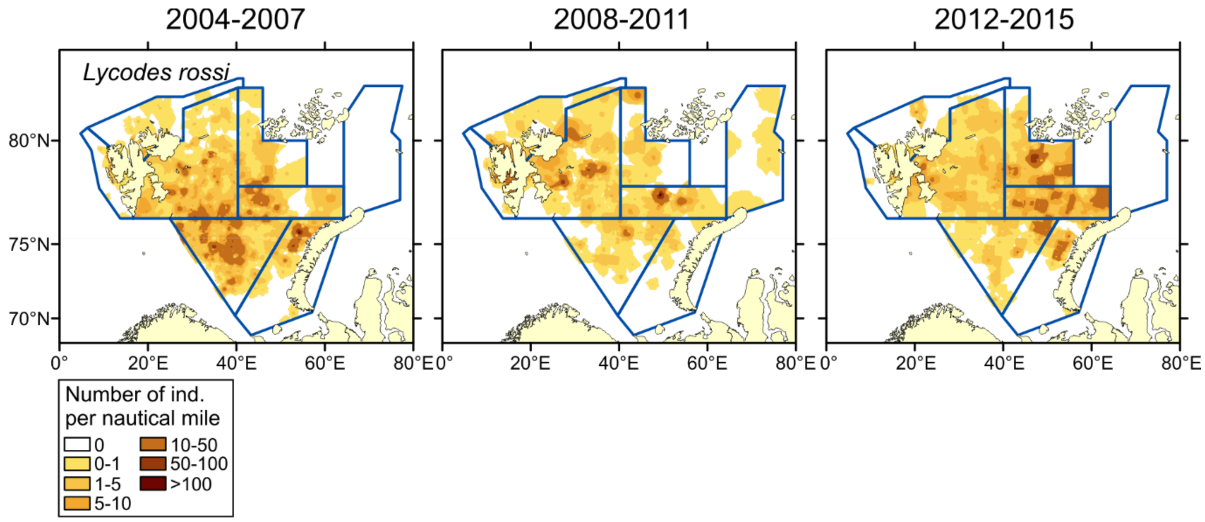


Figure 5.2.14. Temporal development in *Lycodes reticulatus.* Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy of *L. reticulatus* by strata. Estimated from logistic regression with year as a continuous variable (not significant), strata (significant), depth (significant) and interaction between year and strata (significant).

Table 5.2.14 Estimated densities of *L. reticulatus* (individuals per nautical mile squared, rounded to individual). Slope of the regression log (estimated density) is given for strata with estimates for ten or more years. Significant codes: *** 0.001, ** 0.01, * 0.05

Year	Strata 1	Strata 2	Strata 3	Strata 4	Strata 5
2004	58	NA	150	170	107
2005	84	5	60	47	91
2006	52	23	39	67	64
2007	153	35	138	267	164
2008	224	67	424	121	371
2009	39	33	179	148	113
2010	35	37	59	12	427
2011	24	37	69	95	172
2012	60	73	22	58	120
2013	86	49	38	163	178
2014	21	32	126	43	NA
2015	3	6	154	90	229
Slope	-0.17*	0.03	-0.03	-0.04	0.07

5.2.15 Lycodes rossi



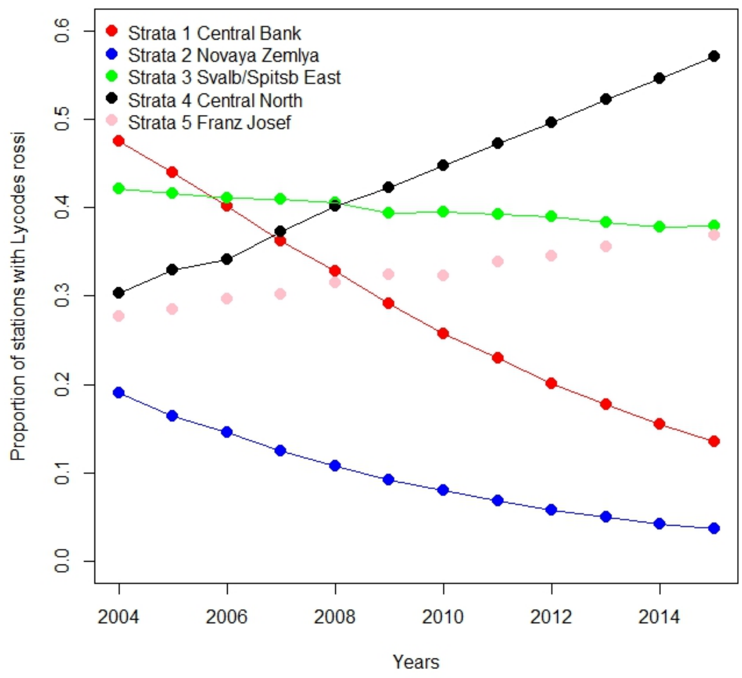
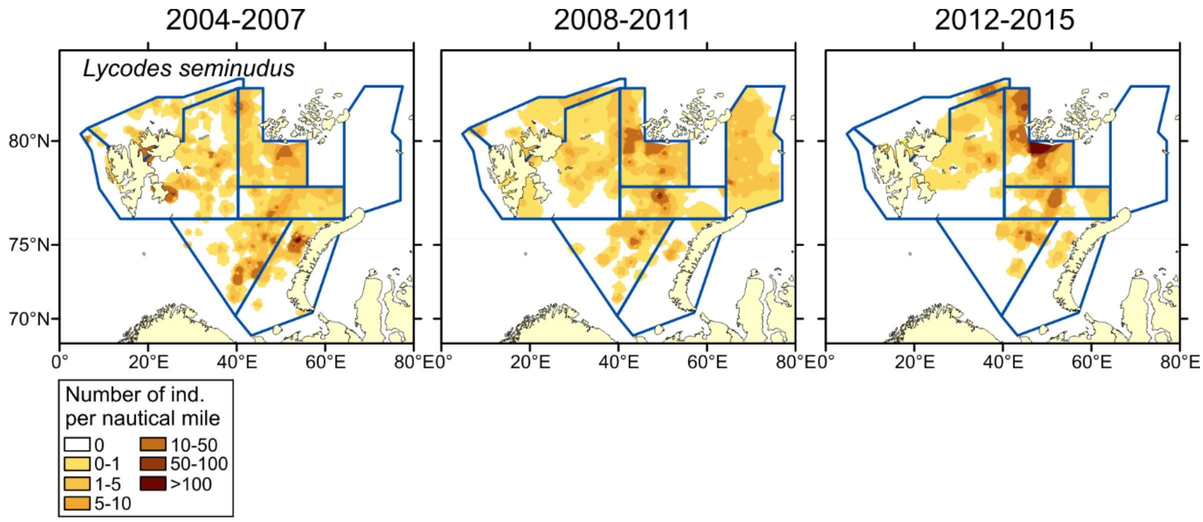


Figure 5.2.15 Temporal development in *Lycodes rossi*. Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy of *L. rossi* by strata. Estimated from logistic regression with year as a continuous variable (significant), strata (significant), depth (significant) and interaction between year and strata (significant).

Table 5.2.15. Estimated densities of *L. rossi* (individuals per nautical mile squared, rounded to individual). Slope of the regression log (estimated density) is given for strata with estimates for ten or more years. Significant codes: *** 0.001, ** 0.01, * 0.05

	Strata 1	Strata 2	Strata 3	Strata 4	Strata 5
2004	731	37	377	991	353
2005	359	8	338	473	92
2006	279	380	282	1151	197
2007	276	59	107	155	34
2008	70	8	604	139	85
2009	80	3	224	5	57
2010	21	NA	64	19	22
2011	35	15	93	1021	57
2012	221	208	177	1190	906
2013	134	69	119	716	418
2014	28	12	113	108	NA
2015	26	NA	182	128	188
Slope	-0.24**	-0.003	-0.10	-0.08	0.06

5.2.16 Lycodes seminudus



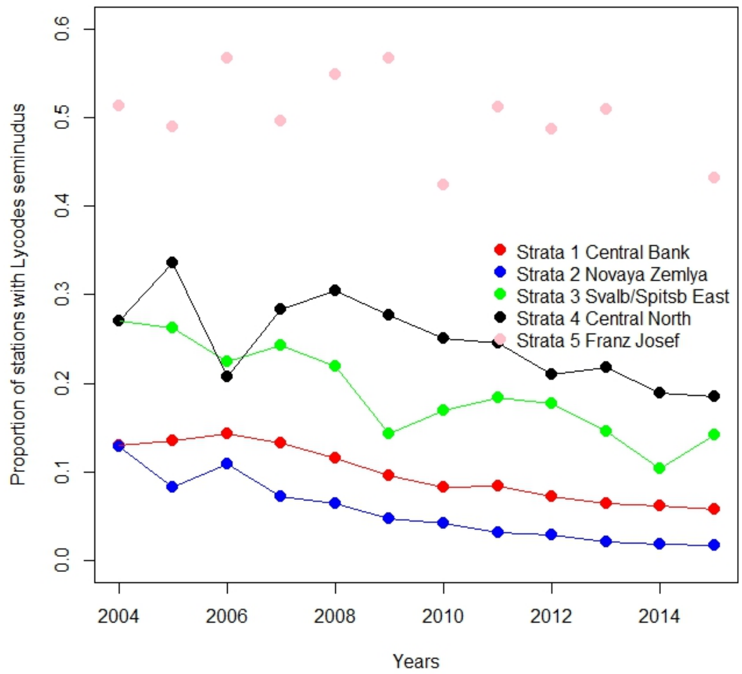


Figure 5.2.16. Temporal development in *Lycodes seminudus*. Upper: Interpolated maps of catches left 2004-2007, middle 2008-2011 and right 2012-2015, for details see Figure 5.2. Lower: Temporal development in occupancy of *L. seminudus* by strata. Estimated from logistic regression with year as a continuous variable (significant), strata (significant), depth (significant) and interaction between year and strata (significant).

Table 5.2.16 Estimated densities of *L. seminudus* (individuals per nautical mile squared, rounded to individual). Slope of the regression log (estimated density) is given for strata with estimates for ten or more years. Significant codes: *** 0.001, ** 0.01, * 0.05.

Year	Strata 1	Strata 2	Strata 3	Strata 4	Strata 5
2004	76	39	174	NA	199
2005	18	5	92	53	87
2006	210	432	81	635	112
2007	157	98	106	176	264
2008	173	30	102	336	673
2009	8	2	29	44	173
2010	48	13	46	25	62
2011	16	1	49	674	730
2012	171	13	84	196	2847
2013	28	2	25	262	119
2014	6	6	6	268	NA
2015	NA	2	13	3	115
slope	-0.16	-0.31*	-0.22***	-0.13	0.06

5. 3 Coeffiecients of Variation

Coefficients of variation were estimated in StoX with 500 bootstraps of each station in each of the strata. These are provided in table 5.3 overall the CV was high, median 0.52 ranging from 0.13 to 1.06.

Table 5.3. CV estimates from stoX.

	Stratum	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Gymnocanthus tricuspis	1	NA	0.65	0.53	NA	NA	NA	0.99	NA	NA	NA	NA	NA
	2	0.55	0.45	0.34	0.6	0.61	0.53	0.67	0.3	0.38	0.39	0.77	0.4
	3	0.72	0.97	NA	NA	NA	1.02	NA	NA	NA	1.03	NA	NA
	4	NA	0.88	0.93	0.71	NA	NA	1.01	NA	NA	0.55	NA	0.46
	5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Triglops nybelini	1	0.43	0.25	0.38	0.45	0.44	0.57	0.6	0.51	0.73	0.78	1.02	NA
	2	0.77	NA	0.79	0.49	0.97	0.94	0.95	0.71	0.97	0.56	0.96	0.79
	3	0.15	0.14	0.24	0.3	0.39	0.34	0.55	0.28	0.27	0.36	0.69	0.29
	4	0.69	0.26	0.32	0.32	0.37	0.34	0.72	0.77	0.27	0.36	0.54	0.69
	5	0.25	0.34	0.31	0.2	0.26	0.34	0.39	0.73	0.21	0.25	0	0.33
Aspidophoroides olrikii	1	NA	NA	0.56	NA	1.09	1.08	0.98	NA	1.04	1.04	0.75	NA
	2	0.51	0.35	0.31	0.71	0.39	0.41	0.67	0.34	0.34	0.41	0.35	0.59
	3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.97
	4	NA	NA	0.95	0.74	NA	0.91	NA	0.94	0.83	0.94	0.96	0.59
	5	NA	1.02	0.97	NA	NA	NA	NA	NA	NA	NA	NA	NA
Liparis fabricii	1	0.38	0.97	0.37	0.8	NA	0.97	NA	NA	0.95	0.68	NA	NA
	2	0.74	0.89	0.56	0.46	0.6	0.62	0.91	0.5	0.82	0.91	0.63	0.58
	3	0.33	0.27	0.36	0.2	0.54	0.45	0.67	0.48	0.91	0.54	0.7	0.37
	4	0.42	0.62	0.52	0.55	0.72	0.31	0.63	0.65	0.55	0.49	0.66	0.67
	5	0.27	0.23	0.18	0.13	0.28	0.25	0.54	0.38	0.46	0.4	NA	0.4
Lycodes eudipleurostictus	1	0.5	0.53	0.36	0.67	NA	0.47	NA	0.67	0.7	NA	0.7	0.67
	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	3	0.67	0.98	0.45	0.61	NA	NA	0.72	0.86	0.68	0.96	NA	NA
	4	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.76	NA	NA
	5	0.99	NA	NA	NA	0.67	0.97	NA	NA	0.94	NA	NA	NA
Lycodes reticulatus	1	0.44	0.49	0.81	0.39	0.55	0.4	0.41	0.46	0.51	0.91	1.05	0.73
	2	NA	0.74	0.79	0.42	0.47	0.54	0.45	0.54	0.68	0.38	0.44	0.48
	3	0.28	0.28	0.37	0.29	0.44	0.57	0.32	0.19	0.37	0.24	0.63	0.3
	4	0.48	0.41	0.48	0.53	0.57	0.49	0.65	0.62	0.5	0.26	0.33	0.41
	5	0.75	0.74	0.45	0.52	0.47	0.52	0.58	0.37	0.87	0.82	NA	0.49
Lycodes rossi	1	0.26	0.21	0.17	0.33	0.26	0.64	0.37	0.37	0.38	0.33	0.31	0.5
	2	0.54	0.49	0.48	0.73	0.6	1.02	NA	0.53	0.46	0.75	0.97	NA
	3	0.23	0.16	0.4	0.24	0.47	0.44	0.4	0.41	0.24	0.28	0.54	0.26
	4	0.65	0.58	0.35	0.65	0.38	0.99	0.53	0.7	0.28	0.38	0.35	0.41
	5	0.41	0.57	0.35	0.51	0.55	0.72	0.62	0.5	0.54	0.27	NA	0.59
Lycodes seminudus	1	0.35	0.47	0.31	0.46	0.46	0.57	0.38	0.53	0.4	0.65	0.6	NA
	2	0.56	0.69	0.59	0.71	0.7	0.99	0.99	1.01	0.79	0.96	0.61	0.95
	3	0.38	0.22	0.28	0.32	0.4	0.4	0.4	0.37	0.42	0.58	0.98	0.42
	4	NA	0.67	0.71	0.37	0.32	0.81	0.64	0.87	0.44	0.55	0.7	0.94
	5	0.27	0.42	0.31	0.31	0.28	0.23	0.43	0.34	0.65	0.29	NA	0.54

5.4 Conclusions

Our analysis of distribution and occupancy patterns of non-target Arctic fishes in the cold-water parts of the Barents Sea during 2004-2015 showed that overall the distribution areas and abundance of Arctic fishes has decreased and there has been a northeastern shift in distribution for some of them under the current warming in Arctic.

Unfortunately, the knowledge on the ecology and biology of most Arctic fishes is poor and therefore we do not understand the main mechanisms and key drivers of their dynamics. It is therefore difficult to evaluate the impact of further warming and the expansion of boreal fishes into the Arctic part of the Barents Sea on the resident Arctic fishes, but a continued decline could be expected.

Further investigations of fishes in Arctic parts of the Barents Sea, their communities as well as interspecies and trophic relationships are needed to provide a more in depth understanding their role in the Arctic ecosystem.

6 Recommendations

Recommendations to IMR and PINRO:

- Maintain an adequate and consistent (given ice conditions) spatial coverage of the northern Barents Sea at the ecosystem survey
- Continue to improve and harmonize species identification with joint PINRO IMR workshops, exchange of identification keys etc
- Improve survey design of the ecosystem survey along the continental slope to account for the depth gradient while considering the needs for coverage for assessment of *Pandalus borealis* and Greenland halibut
- Implement a suitable strata system for the ecosystem survey to allow swept area abundance estimation of species caught with bottom trawls at the survey
- Implements statistical methods suitable for rare species in the StoX software
- Develop the annual reporting on non-commercial fishes from the ecosystem survey, including Arctic fishes to the ICES Working Group of Integrated assessments of the Barents Sea (WGIBAR)

General recommendation for future research on fishes in the Arctic:

- Prioritize research on taxonomy of Arctic fishes to resolve issues related to species identity
- Prioritize research of biology of Arctic fishes and especially their role in the Arctic food web
- Prioritize research of the drivers of changes in abundance and distribution of Arctic fishes

7 References

Andriyashev AP and Chernova NV (1995) Annotated list of fish-like vertebrates and fishes of the Arctic Seas and adjacent waters. J Icthyology34:435-456

Bochkov YA (1982) Water temperature in the 0-200m layer in the Kola-Meridian section in the Barents Sea, 1900-1981. Sb. Nauchn. Trud. PINRO 46: 113-122 (in Russian).

Briggs, JC and Bowen BW (2012) A realignment of marine biogeographic provinces with particular reference to fish distributions. Journal of Biogeography 39:12-30.

Byrkjedal I and Høines Å (2007) Distribution of demersal fish in the south-western Barents Sea. Polar Research 26: 135-151.

CAFF 2013. http://www.arcticbiodiversity.is/index.php/the-report.

Chernova NV (1991) Liparovye ryby Evroaziatskoi Arktiki (Snailfishes of Eurasian Arctic), Apatity: Kolsk. Nauchn. Tsentr, Akad. Nauk SSSR, 1991. (in Russian)

Chernova NV (2005a) Review of Careproctus (Liparidae) of the North Atlantic and adjacent Arctic, including the generic type C. reinhardti, with rehabilitation of C. gelatinosus (Pallas) from Kamchatka. J. Ichthyol. 45(suppl. 1): 1–22.

Chernova NV (2005b) New species of *Careproctus* (Liparidae) from the Barents Sea and adjacent waters *Careproctus* (Liparidae) J. Ichthyol. 45(6): 725–736. (in Russian)

Dipner WP (2001). Biography of the OSPAR Maritime Area. A synopsis and synthesis of Biogeographical Distribution Patterns described for the North-East Atlantic. Federal Agency for Nature Conservation, Bonn Germany. 130 pp. ISBN: 3-7843-3818-6.

Eriksen, E. (Ed.). 2014. Survey report from the joint Norwegian/Russian ecosystem survey in the Barents Sea and adjacent waters, August-October 2014. IMR/PINRO Joint Report Series, No. 1/2015, 153 pp. ISSN 1502-8828.

ICES. 2016. Final Report of the Working Group on the Integrated Assessments of the Barents Sea (WGIBAR), 22-26 February 2016, Murmansk, Russia. ICES CM 2016/SSGIEA:04. 126 pp.

Johannesen E, Høines ÅS, Dolgov AV, Fossheim M (2012) Demersal Fish Assemblages and Spatial Diversity Patterns in the Arctic-Atlantic Transition Zone in the Barents Sea. PLoS ONE 7(4): e34924. doi:10.1371/journal.pone.0034924.

Karamushko OV (2008) Species composition an structure of the Ichtyofauna of the Barents Sea. Journal of Ichthyology/Voprosy Ikhtiologii [J. ICHTHYOL.; VOPR. IKHTIOL.] 48: p. 293-308.

Mecklenburg CM, Møller PR, Steinke B (2011) Biodiversity of arctic marine fishes:taxonomy of zoogeography. Mar Biodiv 41:109-140

Mecklenburg, C.W., I. Byrkjedal, J.S. Christiansen, O.V. Karamushko, A. Lynghammar and P. R. Møller. 2013. List of marine fishes of the arctic region annotated with common names and zoogeographic characterizations. Conservation of Arctic Flora and Fauna, Akureyri, Iceland.

http://www.caff.is/monitoring-series/257-list-of-marine-fishes-of-the-arctic-region-annotated-with-common-names-and-zoogeographic characterizations

Mecklenburg CW and Steinke D (2015). Ichthyofaunal Baselines in the Pacific Arctic Region and RUSALCA Study Area. Oceanography 28 http://dx.doi.org/10.5670/oceanog.2015.64

Spielhagen RF, Werner K, Sørensen SA, Zamelczyk K, Kandiano E, Budeus G, Husum K, Marchitto TM, Hald M (2011). Enhanced Modern Heat Transfer to the Arctic by Warm Atlantic Water. Science 331:450-453.

Wienerroither R, Johannesen E, Dolgov AV, Byrkjedal I, Bjelland O, Drevetnyak K, Eriksen KB, Høines Å, Langhelle G, Langøy H, Prokhorova T, Prozorkevich D, Wenneck T (2011) Atlas of the Barents Sea Fishes. IMR/PINRO Joint Report Series 1-2011

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Institute of Marine Research
Nordnesgaten 50,
5817 Bergen
Norway

Polar Research Institute of Marine Fisheries and Oceanography (PINRO)
6 Knipovich Street,
183763 Murmansk
Russia