

# Geographical species distribution in the Barents Sea under climate change - results from the BarEcoRe project

By Grégoire Certain and Benjamin Planque





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in the Barents Sea under climate change  
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Tromsø, mars 2014

# PROSJEKTRAPPORT



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## Sammendrag (norsk):

Rapporten beskriver en undersøkelse av mulige endringer i ulike arters utbredelse i Barentshavet som kan skyldes framtidige endringer i klimaet i havet. Utbredelsesmodeller for de ulike artene er laget for å beskrive og kvantifisere forholdet mellom tidligere utbredelse og miljøforhold. På bakgrunn av enkle miljøscenarier blir den samme modellen brukt for å forutse mulige endringer i den enkelte arts romlige utbredelse. Arbeidet ble gjennomført under prosjektet BarEcoRe: *Barents Sea Ecosystem Resilience under global environmental change*, finansiert gjennom Norges Forskningsråd.

## Summary (English):

This report presents a study of possible changes in species' spatial distribution in the Barents Sea as a result of possible future changes in the ocean climate. Species Distribution Models (SDMs) are constructed to describe and quantify the relationship between past distribution of species and environmental conditions. On the basis of simple environmental scenarios, the same models are used to project possible changes in individual species' spatial distributions. The work was conducted under the NFR funded project BarEcoRe: *Barents Sea Ecosystem Resilience under global environmental change*.

## Emneord (norsk):

1. Geografisk fordeling
2. Fisk
3. Global oppvarming
4. Barentshavet

## Subject heading (English):

1. Geographical distribution
2. Fish
3. Global warming
4. Barents Sea

Prosjektleder

Faggruppeleder

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## Background

The project BarEcoRe - *Barents Sea Ecosystem Resilience under global environmental change* - was conducted to investigate how the Barents Sea ecosystem can respond to anticipated changes in climate or human pressures. The project was funded by the Norwegian Research Council, the Norwegian Institute of Marine Research and the University of Tromsø and was conducted from June 2010 to May 2013.

The main objective of BarEcoRe was **to evaluate the effects of global environmental change on the future structure and resilience of the Barents Sea ecosystem**. This was studied by investigating the effects of past changes in climate and fisheries on the Barents Sea ecosystem, by developing indicators of ecosystem resilience, diversity and structure, and by forecasting the possible future states of the Barents Sea ecosystem under particular environmental and fisheries scenarios.

The key questions stated at the start of the project were:

1. What are the key characteristics of past temporal and spatial variations in fish and benthos communities and how are these related to past climate variability and fishing pressure?
2. How does climate variability and change propagate through the Barents Sea ecosystem and influences species interactions?
3. How can the combined effects of fisheries and climate modify the spatial distribution of plankton, benthos and fish species in the Barents Sea?
4. What determines vulnerability or resilience of the Barents Sea ecosystem and how will these be affected by possible future changes in climate and fisheries regimes?
5. Can we detect early warning signals and can we evaluate management strategies with regards to ecosystem resilience?

This report presents some of the results of BarEcoRE that are of particular relevance for the spatial distribution of marine species under climate change (question 3 above).

## Expected changes in temperature and salinity

The IPCC<sup>1</sup> projects that increases in atmospheric temperature will be most pronounced in the Arctic regions (ACIA 2005). Modelling work (Slagstad et al. 2011) predicts that this could lead to ocean warming by 2-3 degrees by 2050-2060 and to a reduction of sea surface salinity due to ice melting and increased precipitations. There remain great uncertainties in the outputs of current climate models run under various scenarios of human activities, but despite these there is a dominant consensus that water temperature will increase and that surface salinity will be slightly reduced in the future.

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<sup>1</sup> International Panel on Climate Change

## **Potential change in geographical distributions of individual species - method**

The Barents Sea is home of more than 100 fish species, many of which are commercially exploited. Changes in the geographical distribution of species may directly affect the fishing industry and indirectly modify the dynamic of the Barents Sea ecosystem through regional modification of species assemblages. In BarEcoRe, we developed Species Distribution Models (SDMs) to investigate the relationship between past distribution of species and the environmental conditions.

We constructed SDMs for the 59 most frequently sampled fish taxa using Generalized Additive Models (GAMs, Guisan et al. 2002). The environmental drivers considered in the models included: bottom depth, slope, bottom and surface temperature and salinity, surface chlorophyll a, primary production, mixed layer depth and ice coverage. Models were fitted using the following sequence. First, the dataset was split in two training and evaluation sets. The training set was composed of years 2004-2008, while the evaluation set was composed of years 2009-2012. Model selection and fitting was carried out using the training set. Ten forward model selections were carried out successively. Each time, the training set was randomly split in two parts, termed A and B for convenience. Models were fitted with part A, and then used to predict part B. The maximization of the coefficient of correlation between model prediction and data in part B was the criteria used to retain covariates during model selection. After model selection, the predictive power of the final model was evaluated similarly, but using the evaluation dataset that had been set aside from the model selection process. For each species, a set of ten “final models” was identified. They were averaged to produce predicted distribution for today’s situation and under environmental change scenarios.

Environmental scenarios were built by modifying today’s temperature and salinity fields in the Barents Sea. In a preliminary step, we set up two models using GAMs. One model linked sea bottom temperature (SBT) to sea surface temperature (SST), and the other one linked sea bottom salinity (SBS) to sea surface salinity (SSS). The three environmental scenarios first modified uniformly SST and SSS with the following values: Scenario 1 SST+1, SSS-0.1. Scenario 2: SST+2, SSS-0.2. Scenario 3: SST+4, SSS-0.5. Then, fields of SBT and SBS were predicted for each scenarios from the two models set up in the preliminary stage. That way, we ensure that our scenarios conserve the statistical relationships between SST and SBT and between SSS and SBS. Maps of SST, SBT, SSS and SBS for today and environmental scenarios are presented in appendix 1.

We used SDMs predictions under environmental scenarios to answer two main questions:

Q1: How much of the distribution of each species can be predicted by environmental parameters?

Q2: What type of modification in species distribution could be expected under environmental change scenarios?

To answer Q1, we looked at the predictive power of the SDMs, expressed by the correlation coefficient between model prediction and the evaluation dataset. To answer Q2, we compared species distribution maps predicted for today and for scenario 3. The comparison was achieved through two indices, termed “change potential”  $C_p$  and “expansion value”  $E_v$ . Both are related, but they express a slightly different phenomenon. Let us denote  $t_i$  the set of model prediction for today situation at any location  $i$ , and  $s_i$  the corresponding set of model prediction for scenario 3. The locations  $i$  are the grid cells over which predictions are computed.

$$C_p = \sum_i |s_i - t_i|$$

$$E_v = \sum_i s_i - \sum_i t_i$$

Under these formulations,  $C_p$  represents the average pixel-to-pixel change between today’s situation and scenario 3. In other word, the more different are the two maps, the higher is  $C_p$ .  $E_v$  compare the distribution of species at the scale of the whole Barents Sea. It will be positive if the species is more widespread in scenario 3, and it will be negative if the species distribution is reduced. To put it simply,  $C_p$  is a measure of local change, at the scale of the pixel, while  $E_v$  measures change at the scale of the whole Barents Sea.

## Potential change in geographical distributions of individual species – results

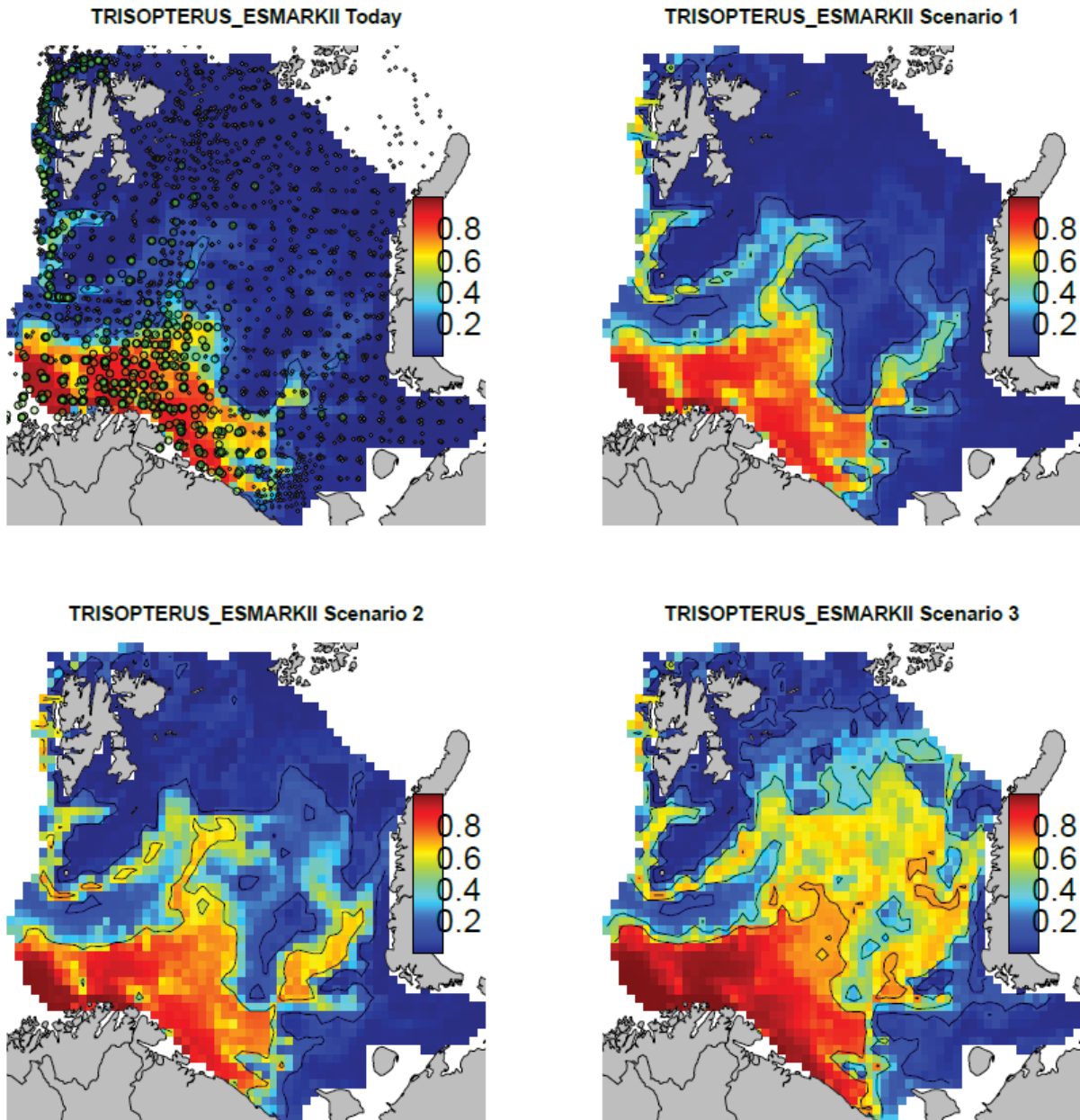
Table 1 shows for each species the predictive performance of the SDMs, together with  $C_p$  and  $E_v$ . Plots showing the spatial distribution for each species are provided in appendix 2. For each species there are four maps which display the current spatial distribution and the projected distributions under three environmental change scenarios. Figure 1 shows an example of prediction maps for *Trisopterus esmarkii*, for which a good model is available and for which an increase in distribution is projected.

To synthesize our answer to our two questions, we plotted the position of each species according to the predictive power of the model,  $C_p$  and  $E_v$  (Figure 2). The figure shows clearly that for about 2/3 of species, models based on environmental parameters performed rather poorly (predictive power <0.3) and therefore, expectations concerning the effect of global change on the distribution of these species are difficult to draw. Still, models performed rather well for some species, and a few of them predicted strong changes in species distribution when modifying temperature and salinity fields in the Barents Sea. Most of these changes take the form of Northward and Eastward migration as temperature increases through the scenarios, that can be spectacular in the model outputs as in the case of the Haddock *Melanogrammus aeglefinus*, a species distributed in the south-west of the Barents Sea but for which the model predicts a large increase in distribution over the whole area in Scenario 3.



**Table 1.** List of Fish species for which SDMs have been build, together with the predictive power of the models (corr.eval), change potential (Cp) and Expansion value (Ev). Species are ranked according to model predictive power (best models on the bottom).

species name	corr.eval	Cp	Ev
<i>CYCLOPTERUS LUMPUS</i>	0.01	351	351
<i>MAUROLICUS MUELLERI</i>	0.03	95	76
<i>CLUPEA HARENGUS</i>	0.04	1020	1020
<i>GYMNELUS</i>	0.05	295	-202
<i>LYCENCHELYS KOLTHOFFI</i>	0.07	4	4
<i>LYCODES EUDIPLUROSTICTUS</i>	0.09	524	-256
<i>LYCODES ROSSI</i>	0.09	3863	-3863
<i>POLLACHIUS VIRENS</i>	0.10	1971	1971
<i>ANISARCHUS MEDIUS</i>	0.11	849	613
<i>BATHYRAJA SPINICAUDA</i>	0.11	55	-54
<i>AMMODYTES</i>	0.13	500	499
<i>TRIGLOPS PINGELII</i>	0.14	1406	-1402
<i>LYCODES POLARIS</i>	0.14	428	-147
<i>SCORPAENIDAE</i>	0.14	2379	-1433
<i>ENCHELYOPUS CIMBRIUS</i>	0.15	688	450
<i>GYMNOCANTHUS TRICUSPIS</i>	0.15	570	495
<i>GASTEROSTEUS ACULEATUS</i>	0.16	3359	3160
<i>TRIGLOPS MURRAYI</i>	0.16	2867	199
<i>COTTUNCULUS SADKO</i>	0.16	1540	-1404
<i>ANARHICHAS MINOR</i>	0.18	2909	-1441
<i>ICELUS BICORNIS</i>	0.18	2587	-2587
<i>CAREPROCTUS</i>	0.19	1755	-1414
<i>RAJELLA FYLLAE</i>	0.19	1274	1254
<i>LYCODES ESMARKII</i>	0.19	184	-179
<i>LIMANDA LIMANDA</i>	0.23	5327	4554
<i>EUMICROTREMUS SPINOSUS</i>	0.23	1068	23
<i>ARCTOZENUS RISSO</i>	0.24	803	-613
<i>GADUS MORHUA</i>	0.26	1140	-509
<i>MACROURUS BERGLAX</i>	0.26	227	192
<i>SEBASTES MARINUS</i>	0.26	1847	-1621
<i>ANARHICHAS DENTICULATUS</i>	0.26	1580	-1545
<i>AMBLYRAJA HYPERBOREA</i>	0.26	901	-849
<i>ICELUS SPATULA</i>	0.28	1967	-1967
<i>LYCODES RETICULATUS</i>	0.30	2782	-2782
<i>LYCODES SEMINUDUS</i>	0.30	1646	-1638
<i>ANARHICHAS LUPUS</i>	0.32	5977	5794
<i>HIPPOGLOSSOIDES PLATESSOIDES</i>	0.34	1106	-41
<i>LUMPENUS LAMPRETAEFORMIS</i>	0.36	4515	1190
<i>MALLOTUS VILLOSUS</i>	0.37	4548	-4548
<i>ARTEDIELLUS ATLANTICUS</i>	0.38	2929	-2202
<i>ULCINA OLRIKII</i>	0.38	1847	700
<i>LEPTOCLINUS MACULATUS</i>	0.38	1107	-608
<i>LYCODES PALLIDUS</i>	0.42	1748	-1506
<i>AMBLYRAJA RADIATA</i>	0.43	5277	2993
<i>SEBASTES MENTELLA</i>	0.44	5617	974
<i>BROSME BROSME</i>	0.45	1120	1032
<i>LIPARIS</i>	0.48	2566	1989
<i>GADICULUS ARGENTEUS</i>	0.52	3347	3347
<i>SEBASTES VIVIPARUS</i>	0.53	723	435
<i>PLEURONECTES PLATESSA</i>	0.53	1274	1207
<i>MICROMESISTIUS POUTASSOU</i>	0.54	4027	-4027
<i>LEPTAGONUS DECAGONUS</i>	0.55	9969	-9969
<i>LYCODES GRACILIS</i>	0.59	7823	4044
<i>ARGENTINA SILUS</i>	0.61	709	397
<i>TRISOPTERUS ESMARKII</i>	0.65	6779	6779
<i>REINHARDTIUS HIPPOGLOSSOIDES</i>	0.66	7340	-5114
<i>MELANOGRAMMUS AEGLEFINUS</i>	0.70	12408	12408
<i>TRIGLOPS NYBELINI</i>	0.73	2967	-2521
<i>BOREGADUS SAIDA</i>	0.73	3411	48



**Figure 1.** Species Distribution Model (SDM) for the Norway pout (*Trisopterus esmarkii*). Top left: modelled spatial distribution of Norway pout today. Dots are showing the localization of trawling samples where the Norway pout was present (large green dot) or absent (small yellow dot). Top right and bottom left and right: modelled spatial distribution of the Norway pout under scenario 1, 2 and 3. The colour scale indicate the probability of presence (blue=0, red=1).



## Discussion

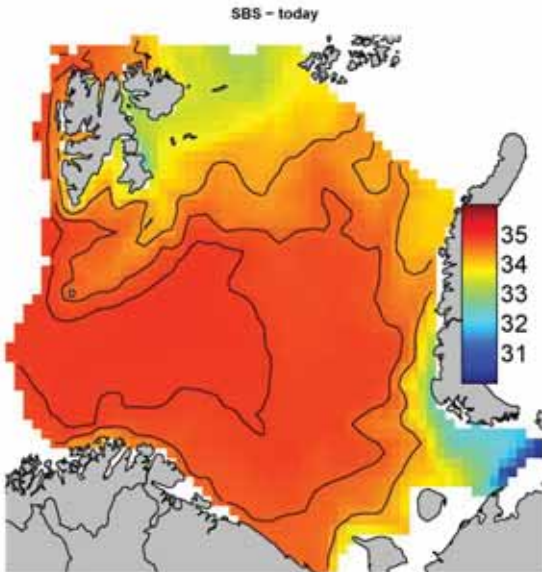
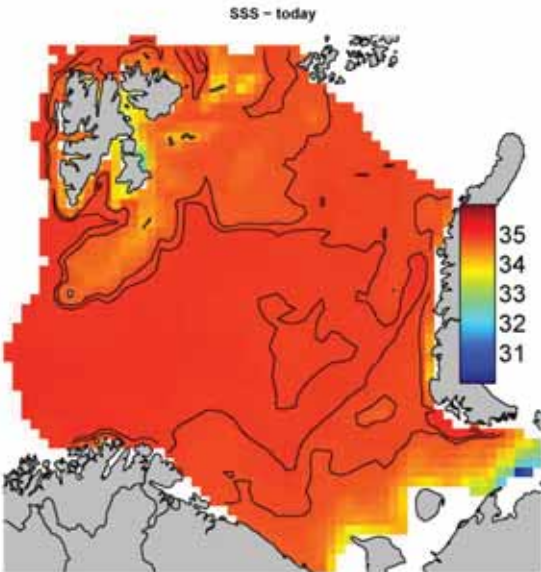
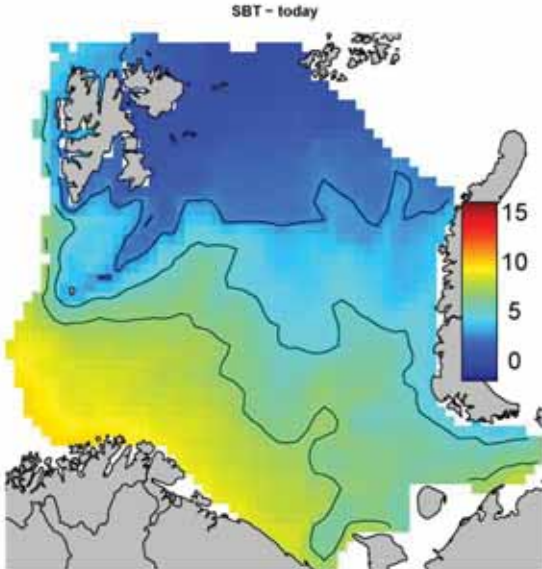
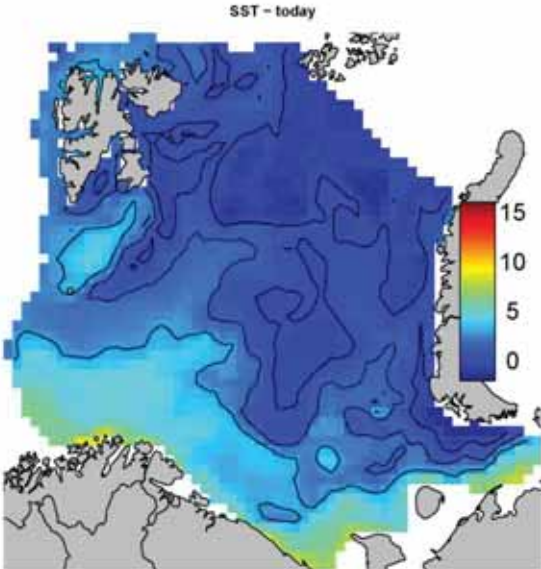
Words of caution are necessary in front of these results. Even if a spectacularly change is predicted by a robust model, such as in the case of haddock, this remains uncertain simply because of the ecological processes such as predation or competition that are not explicitly considered in our study. Furthermore, our scenarios are based on a simplistic representation of the oceanography of the Barents Sea.

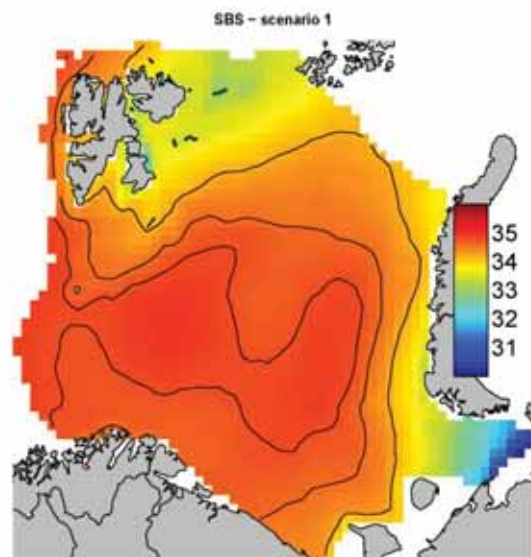
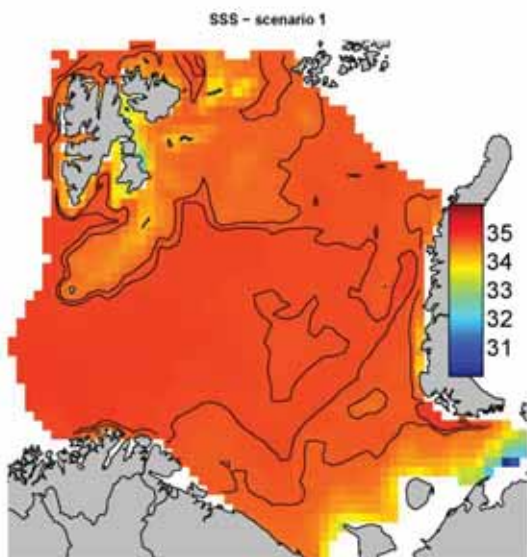
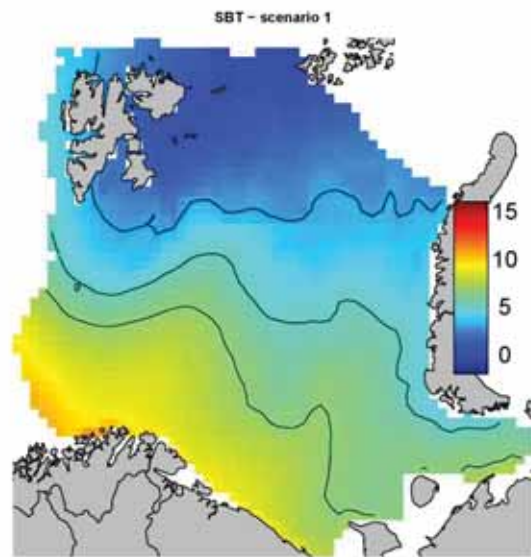
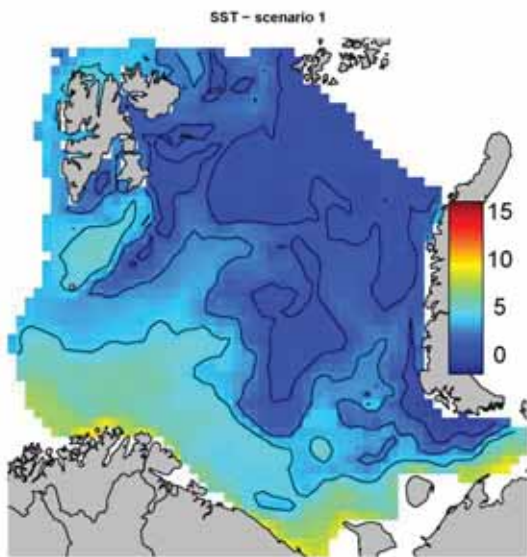
This said, two conclusions can be drawn from our study. First, species which distribution is tightly coupled to environmental parameters have been identified. If changes in oceanographic conditions are observed at the scale of the Barents Sea, these species are the most likely to respond quickly to these changes. Second, for a large number of species, either no good model linking their distribution to environmental parameters could be identified, or they do not respond strongly to change in temperature and salinity. For these species, one can hypothesizes that effects due to global change may be slower, and probably mediated through changes in trophic flows along the food web, rather than triggered by a direct response of the population to change in temperature or salinity.

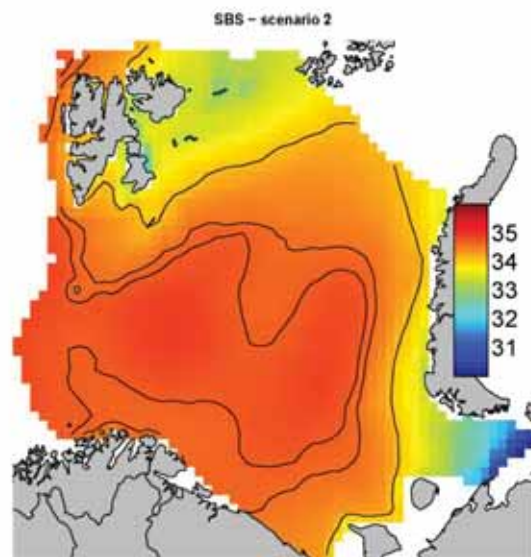
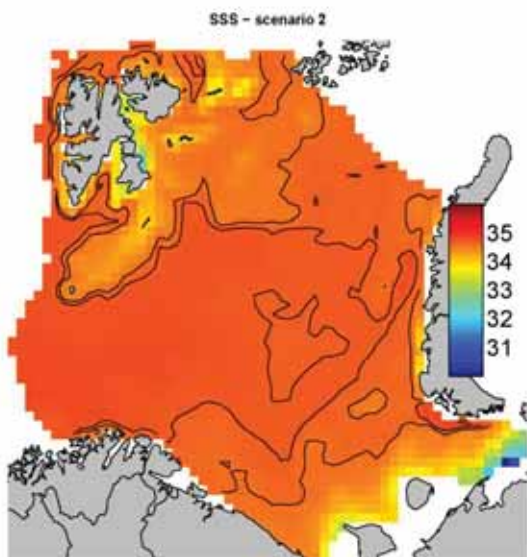
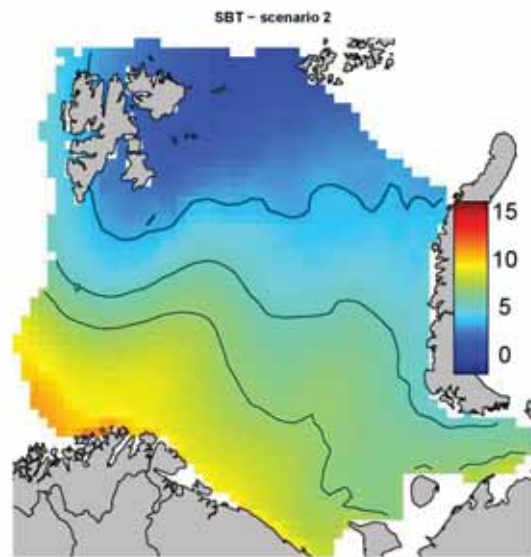
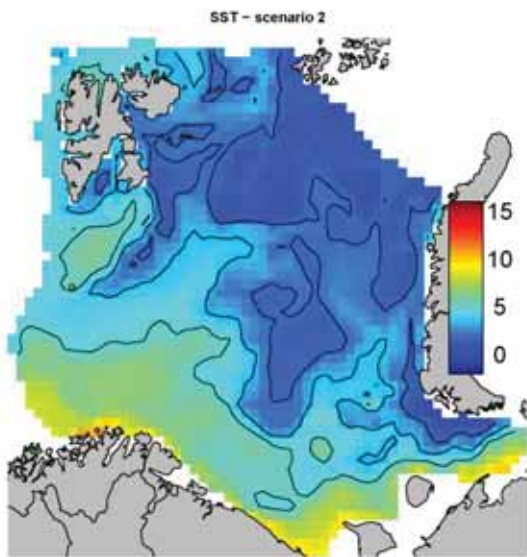
## References

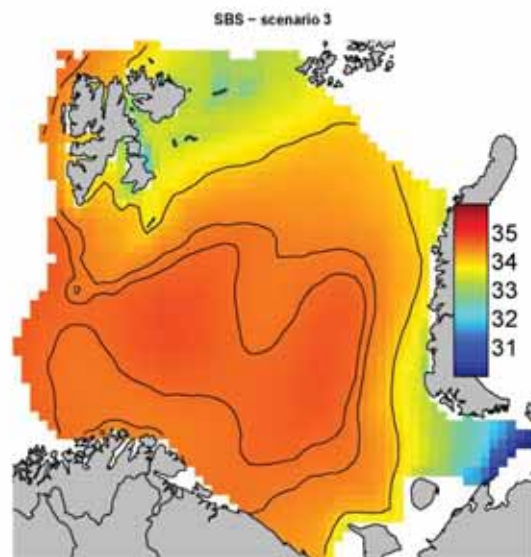
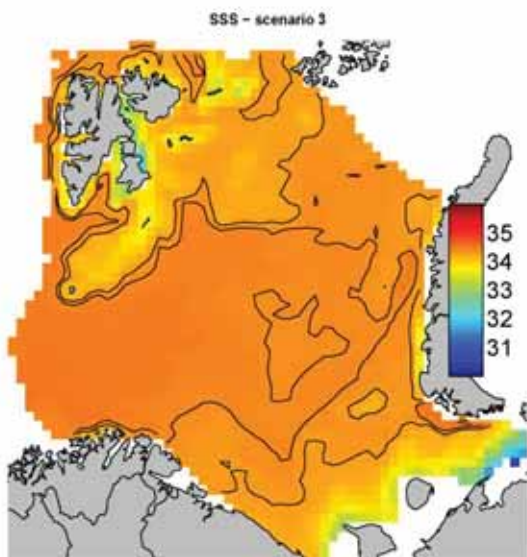
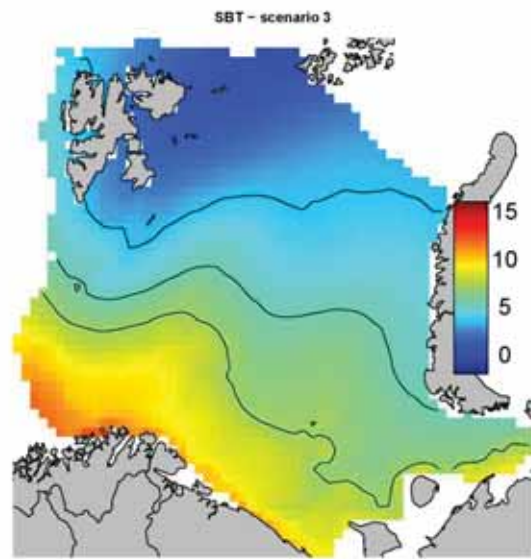
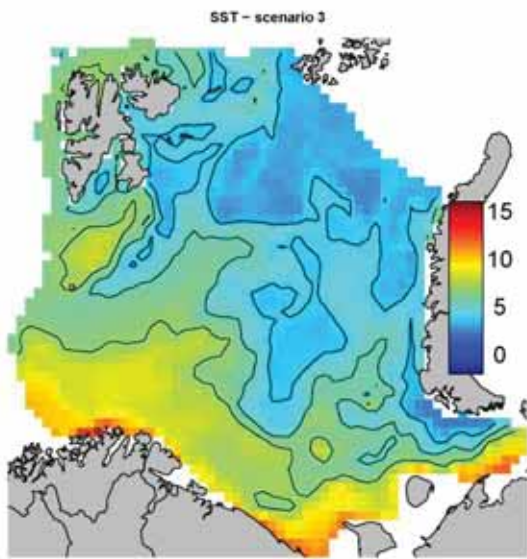
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Appendix 1. Climate scenarios



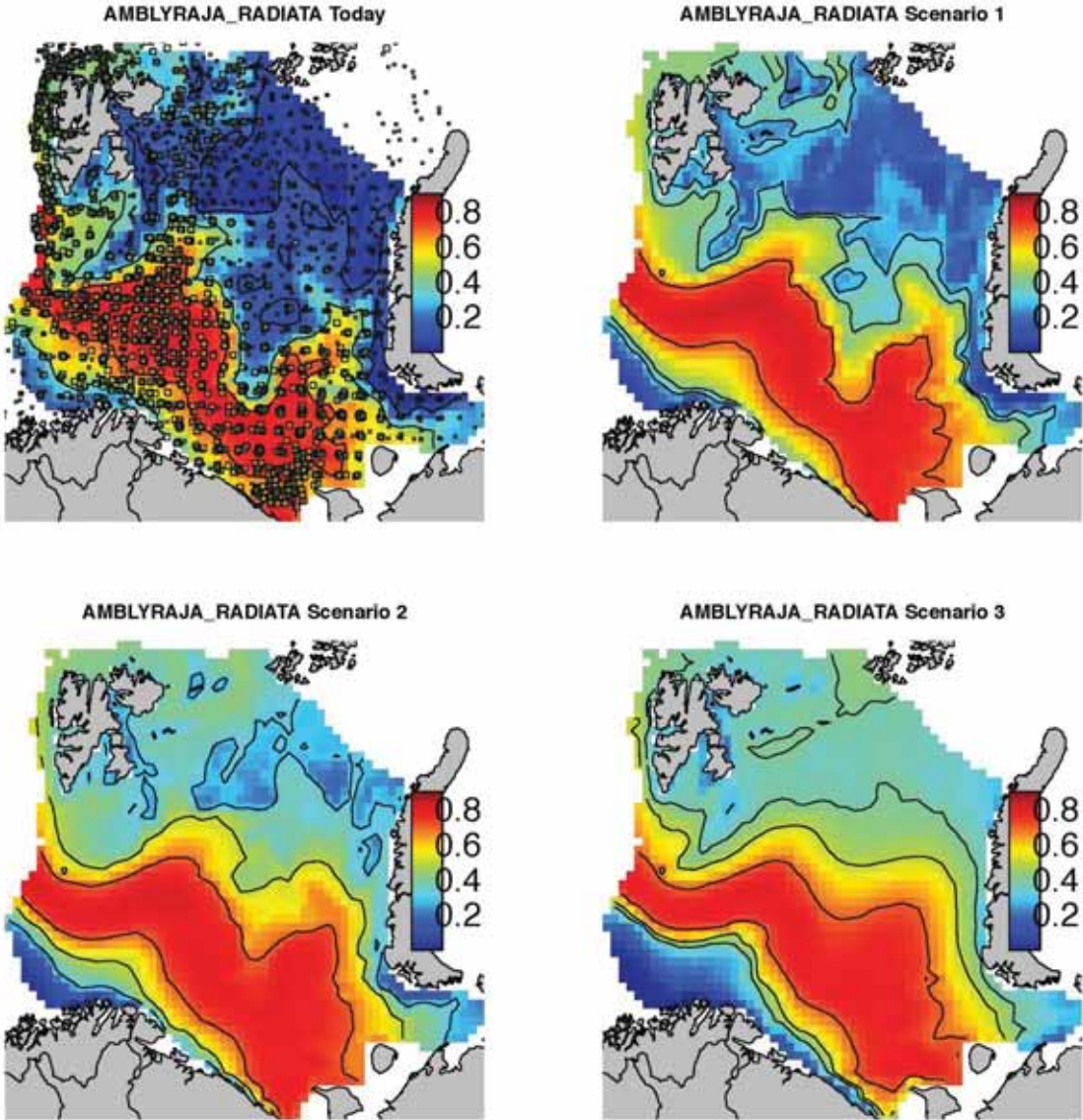




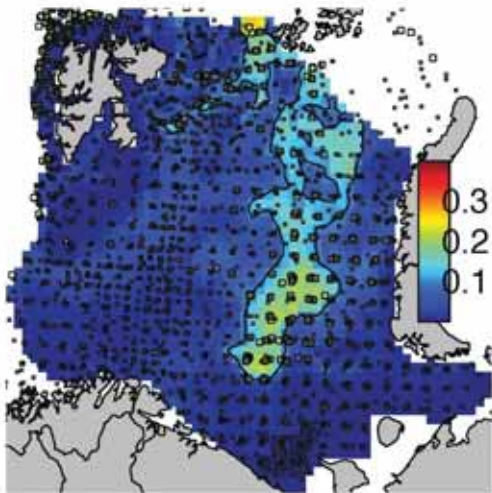




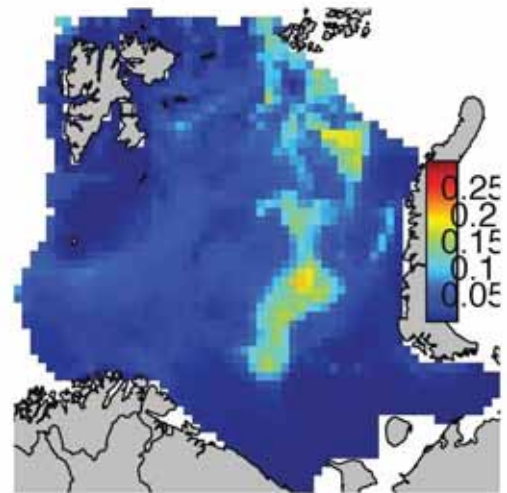
Appendix 2. Species distribution model outputs



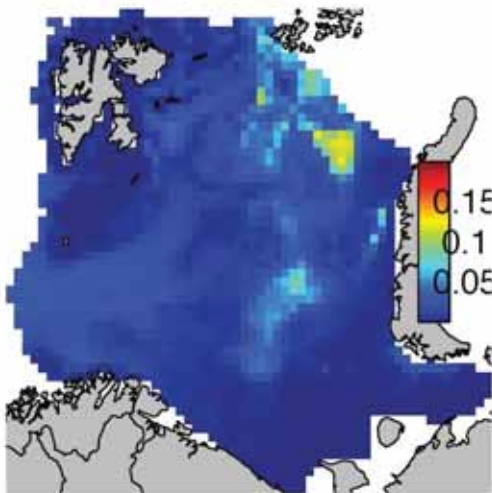
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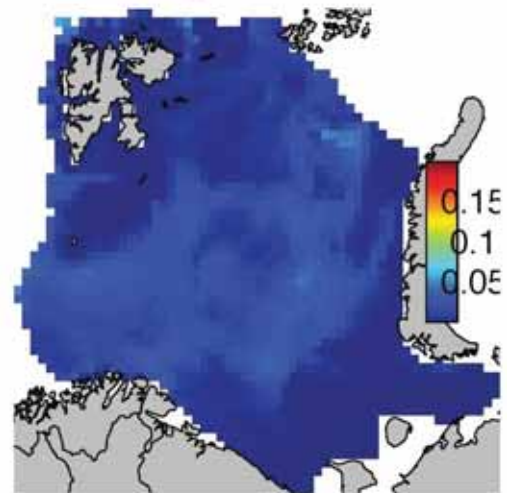
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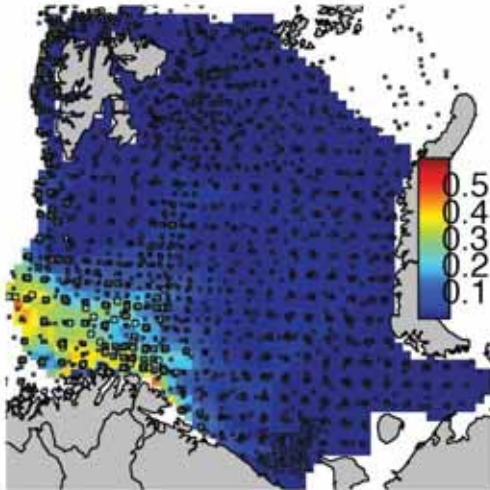
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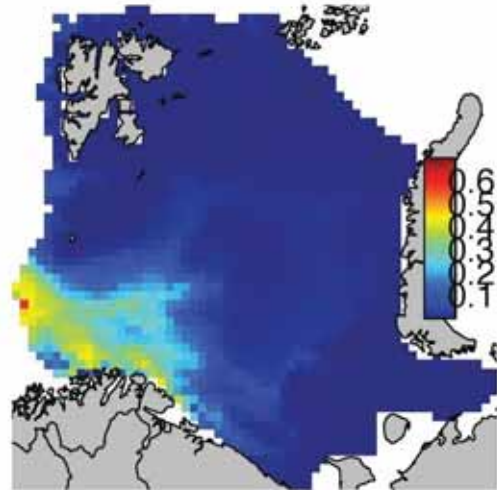
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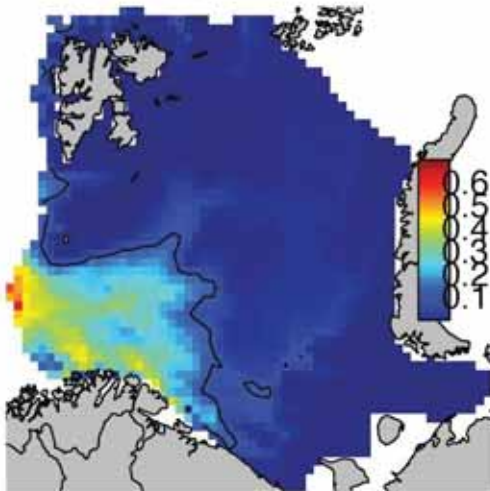
RAJELLA\_FYLLAE Today



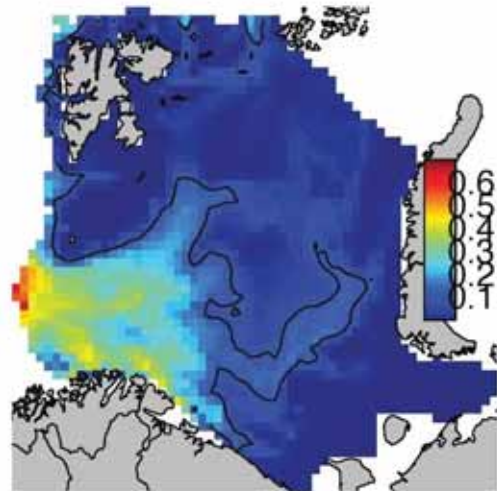
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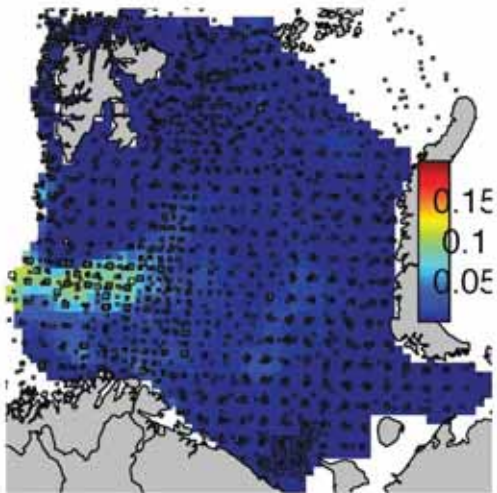
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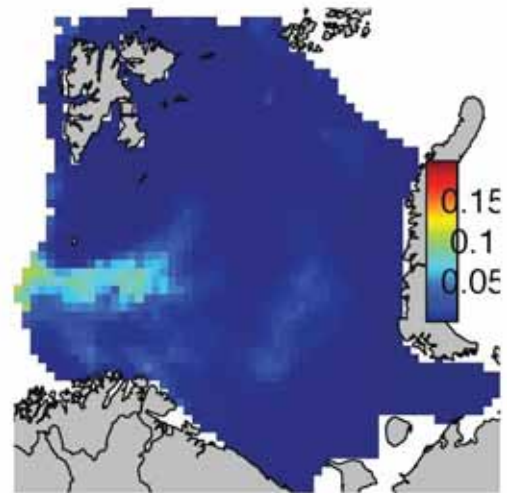
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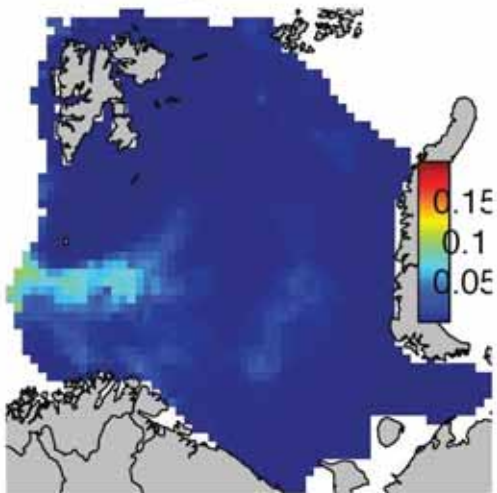
BATHYRAJA\_SPINICAUDA Today



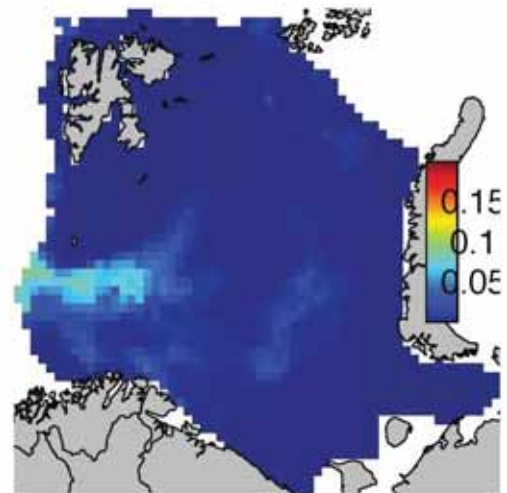
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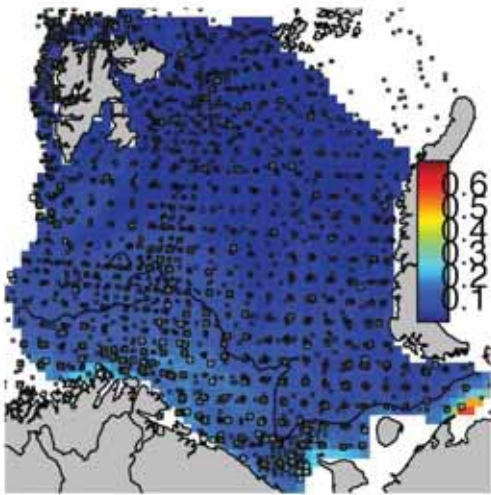
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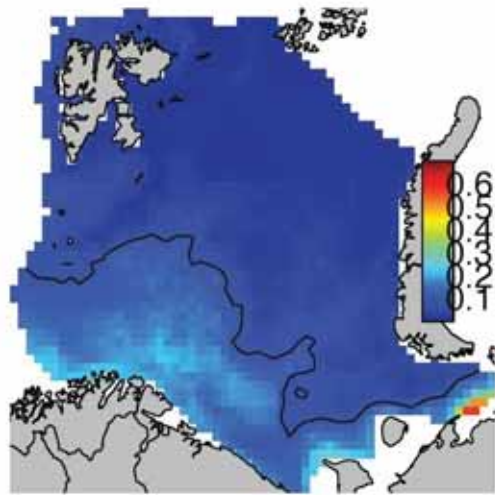
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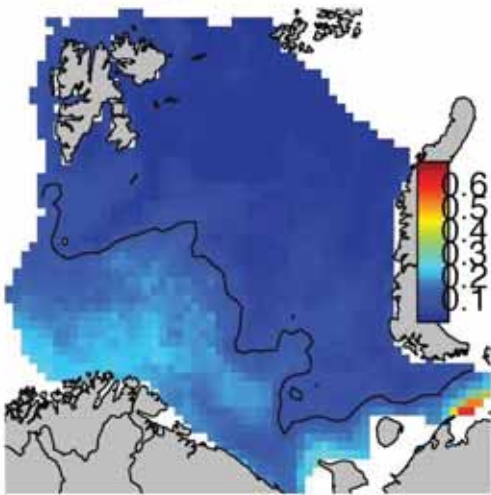
CLUPEA\_HARENGUS Today



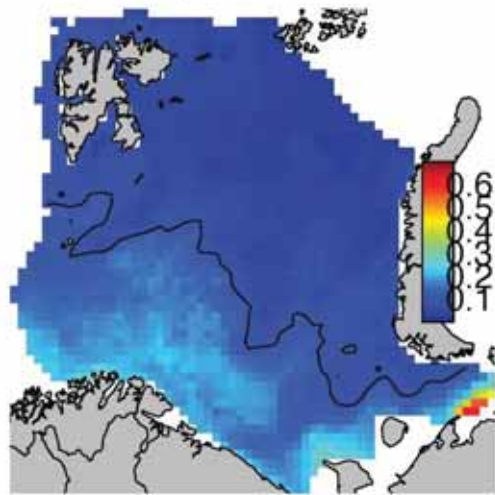
CLUPEA\_HARENGUS Scenario 1



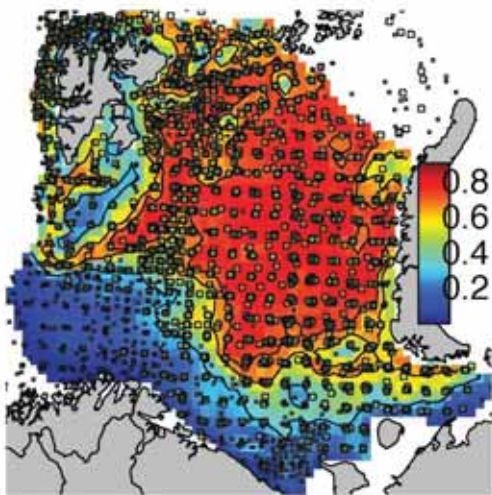
CLUPEA\_HARENGUS Scenario 2



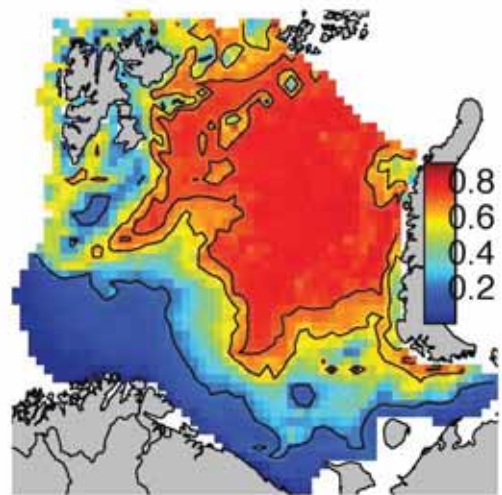
CLUPEA\_HARENGUS Scenario 3



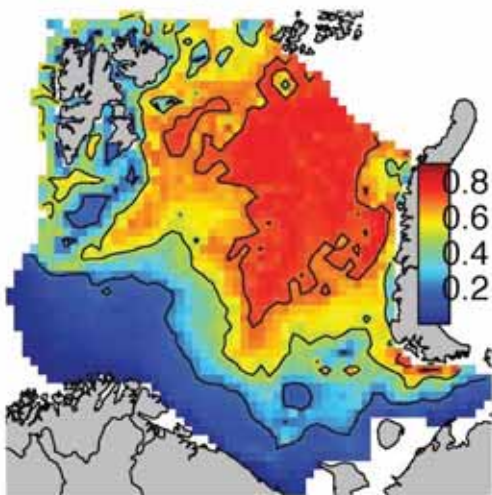
MALLOTUS\_VILLOSUS Today



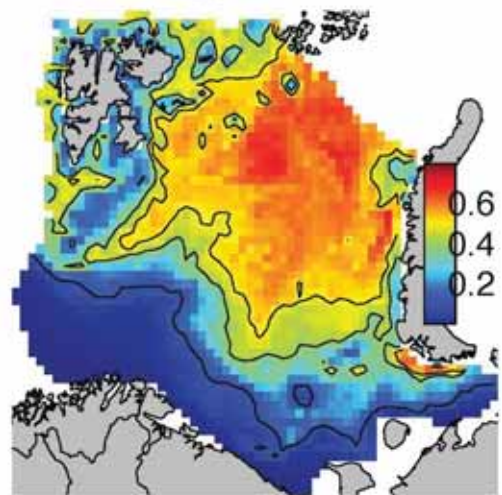
MALLOTUS\_VILLOSUS Scenario 1



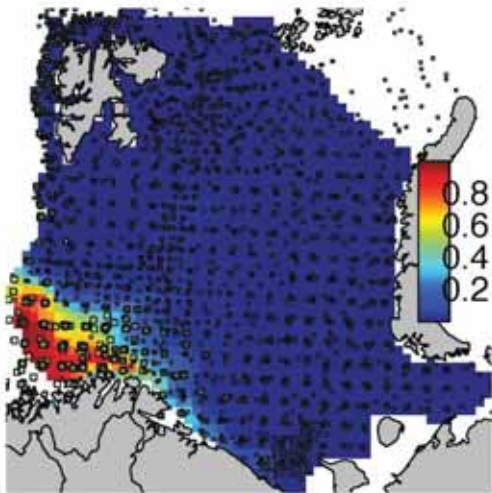
MALLOTUS\_VILLOSUS Scenario 2



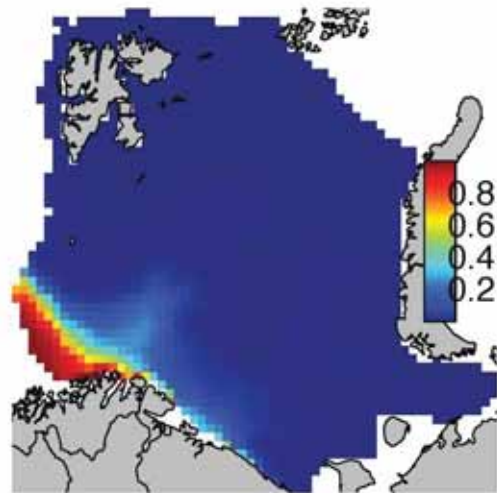
MALLOTUS\_VILLOSUS Scenario 3



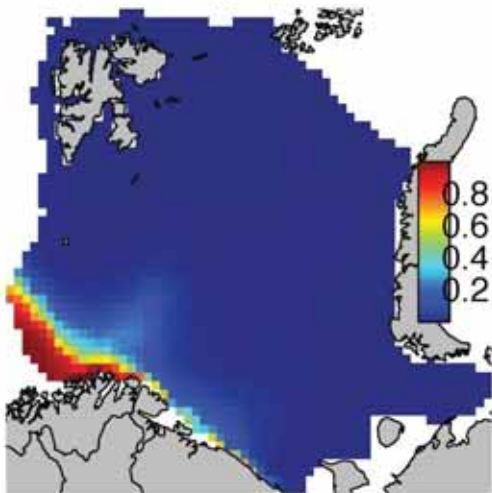
ARGENTINA\_SILUS Today



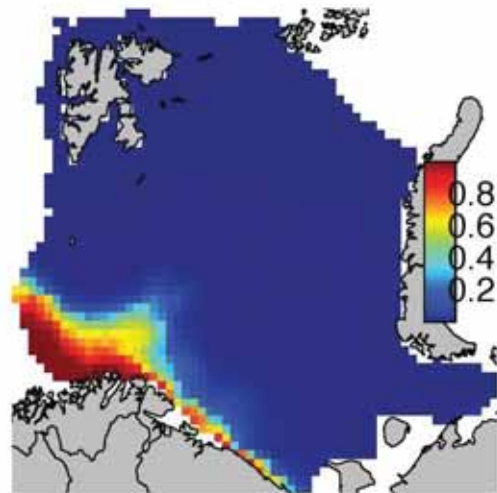
ARGENTINA\_SILUS Scenario 1



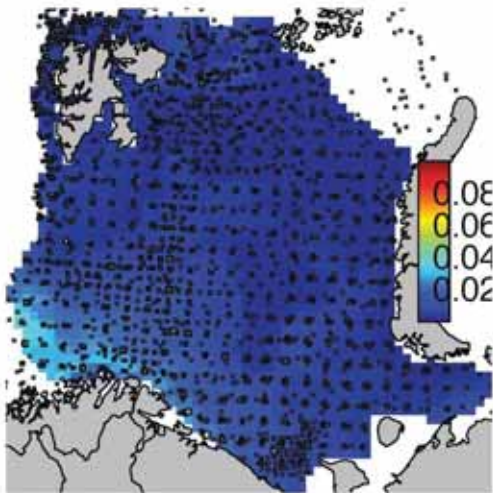
ARGENTINA\_SILUS Scenario 2



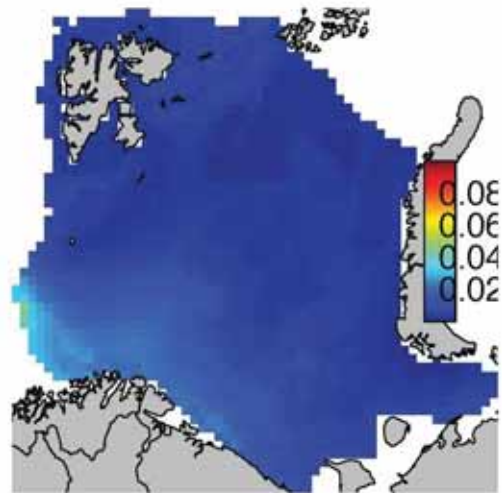
ARGENTINA\_SILUS Scenario 3



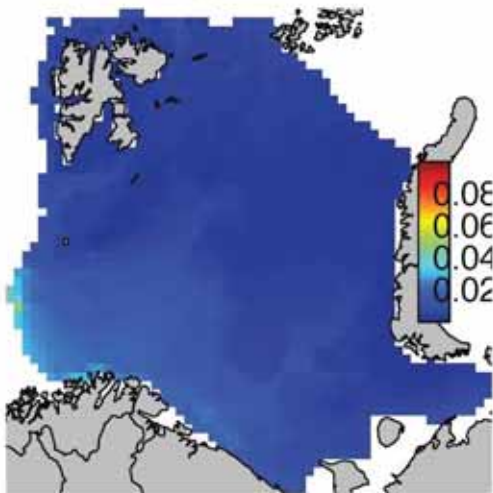
MAUROLICUS\_MUELLERI Today



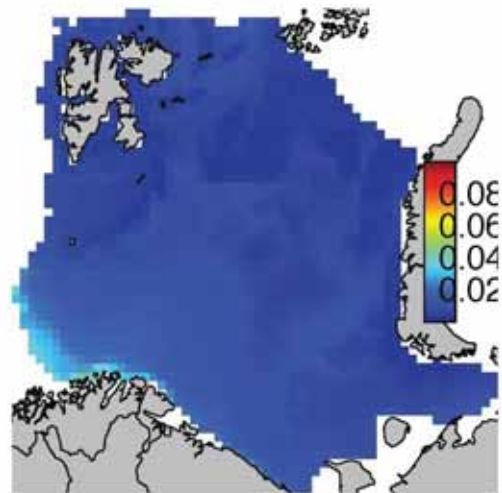
MAUROLICUS\_MUELLERI Scenario 1



MAUROLICUS\_MUELLERI Scenario 2

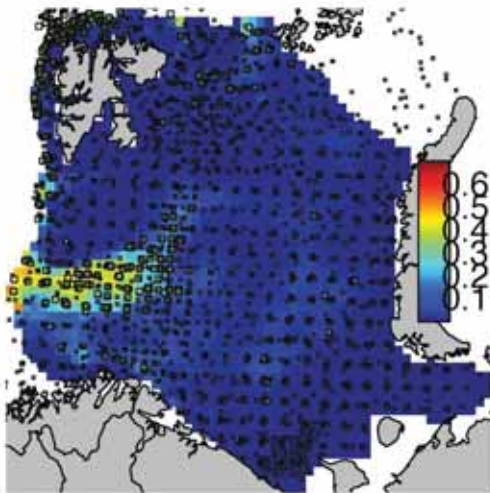


MAUROLICUS\_MUELLERI Scenario 3

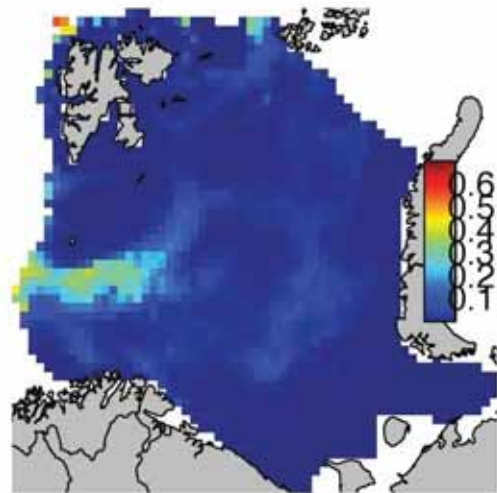




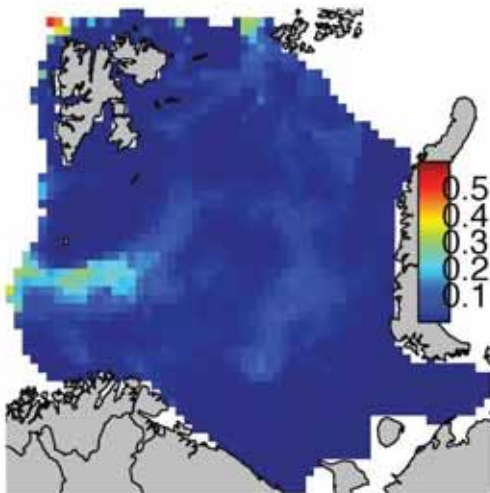
ARCTOZENUS\_RISSO Today



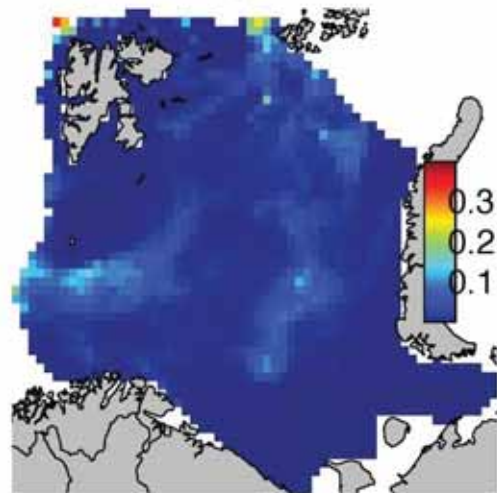
ARCTOZENUS\_RISSO Scenario 1



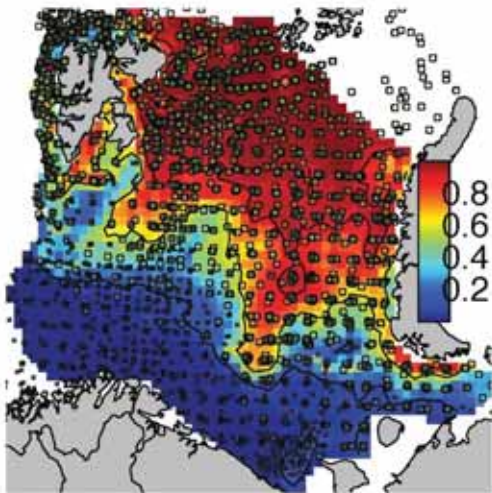
ARCTOZENUS\_RISSO Scenario 2



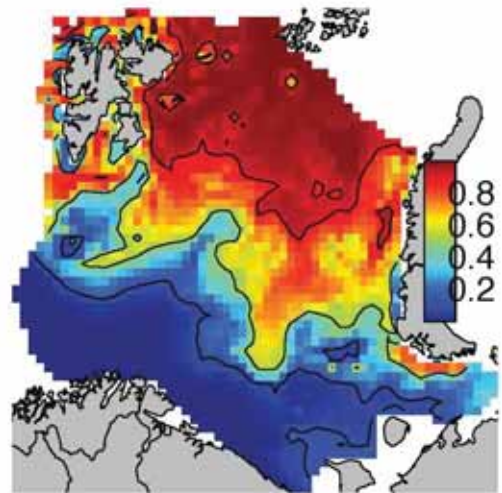
ARCTOZENUS\_RISSO Scenario 3



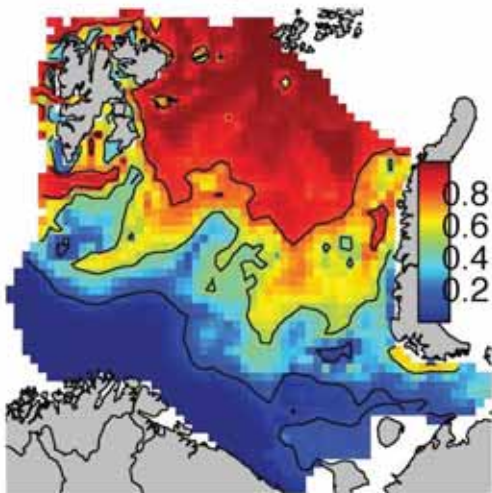
BOREGADUS\_SAIDA Today



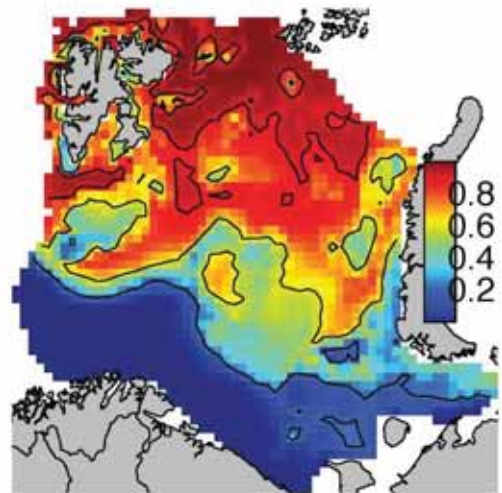
BOREGADUS\_SAIDA Scenario 1



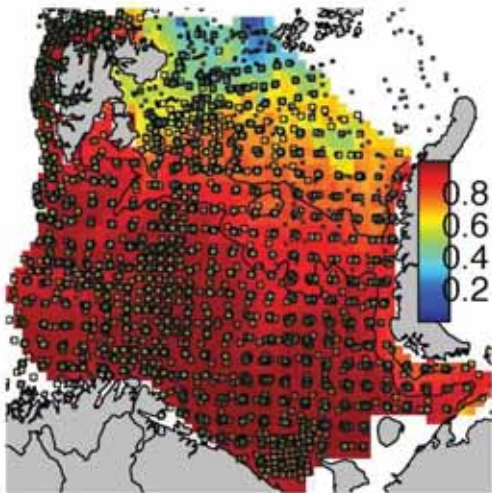
BOREGADUS\_SAIDA Scenario 2



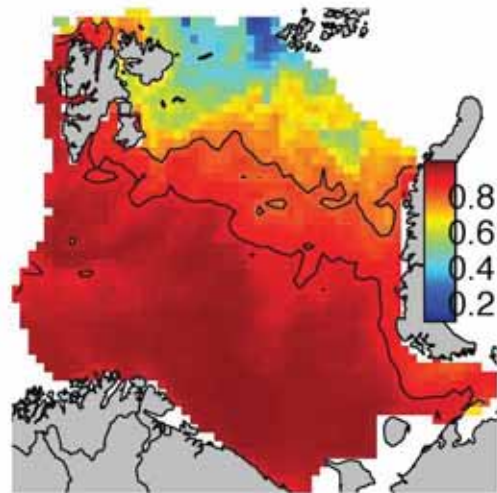
BOREGADUS\_SAIDA Scenario 3



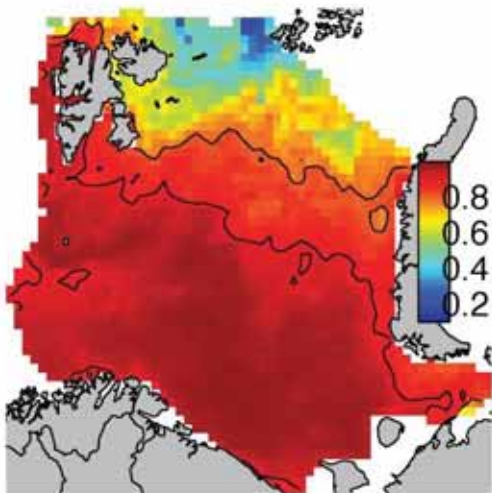
GADUS\_MORHUA Today



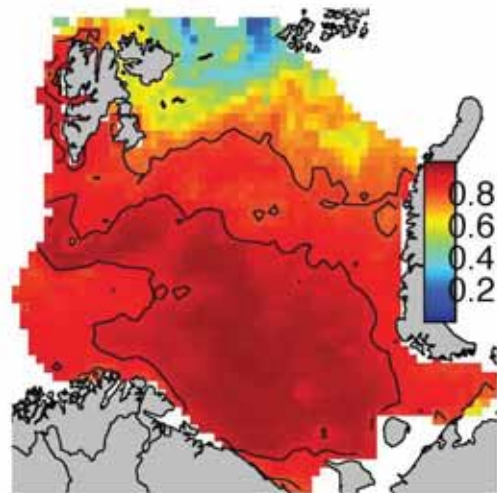
GADUS\_MORHUA Scenario 1



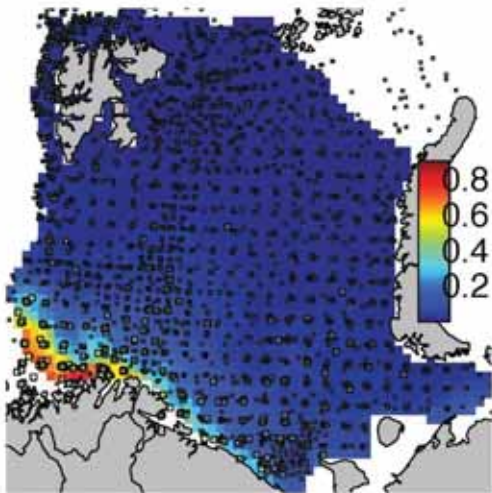
GADUS\_MORHUA Scenario 2



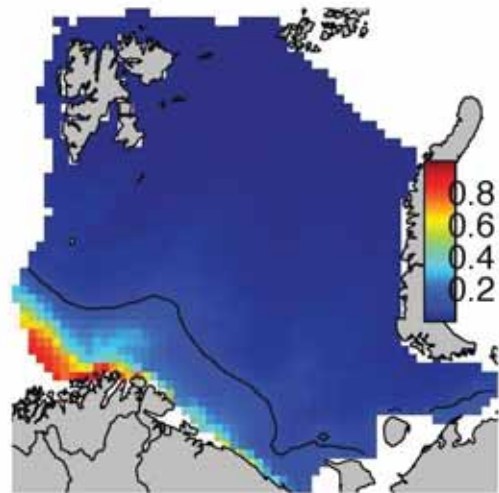
GADUS\_MORHUA Scenario 3



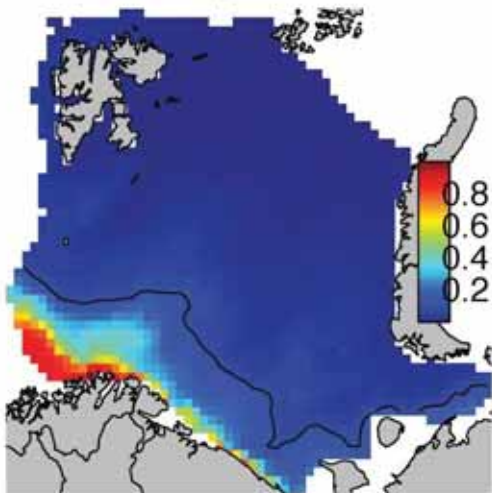
POLLACHIUS\_VIRENS Today



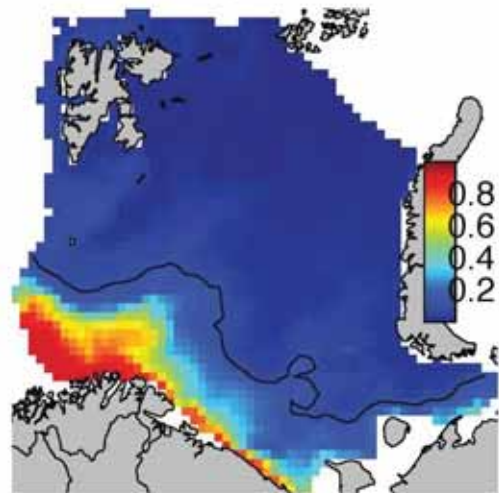
POLLACHIUS\_VIRENS Scenario 1



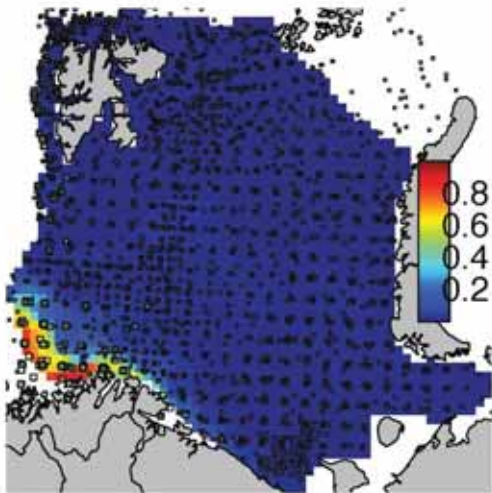
POLLACHIUS\_VIRENS Scenario 2



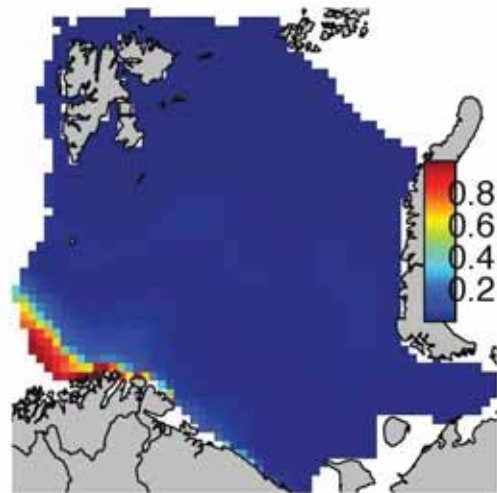
POLLACHIUS\_VIRENS Scenario 3



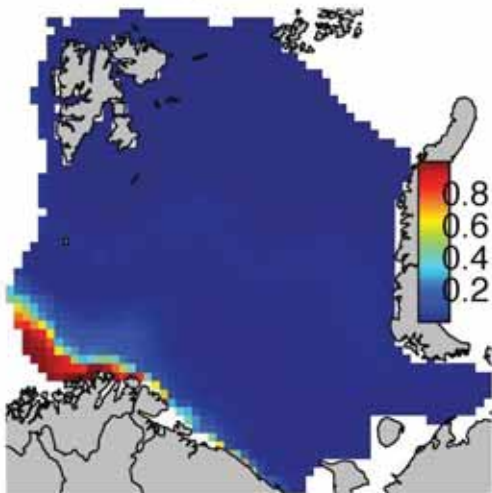
BROSME\_BROSME Today



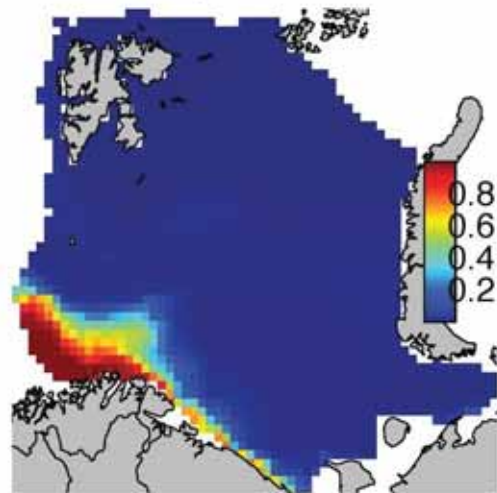
BROSME\_BROSME Scenario 1



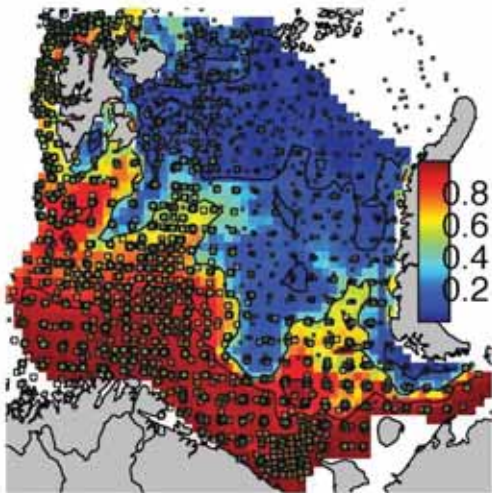
BROSME\_BROSME Scenario 2



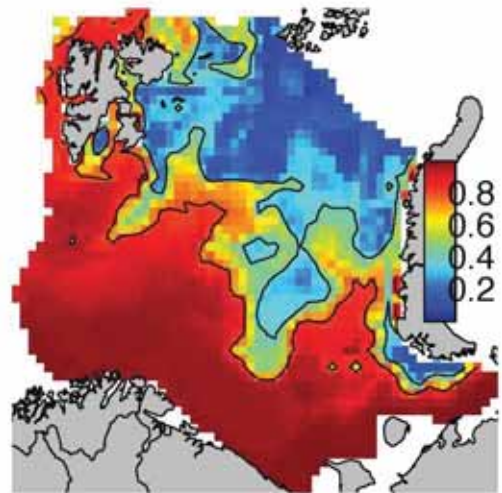
BROSME\_BROSME Scenario 3



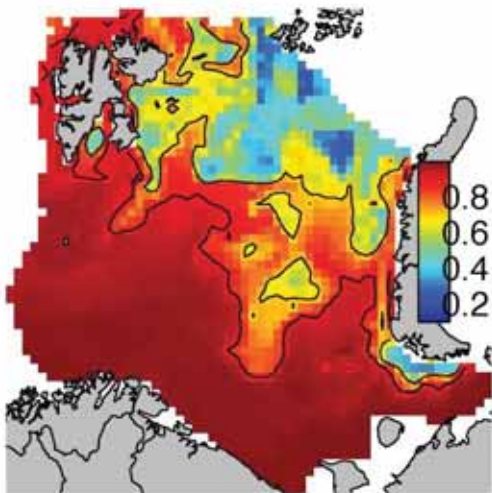
MELANOGRAMMUS\_AEGLEFINUS Today



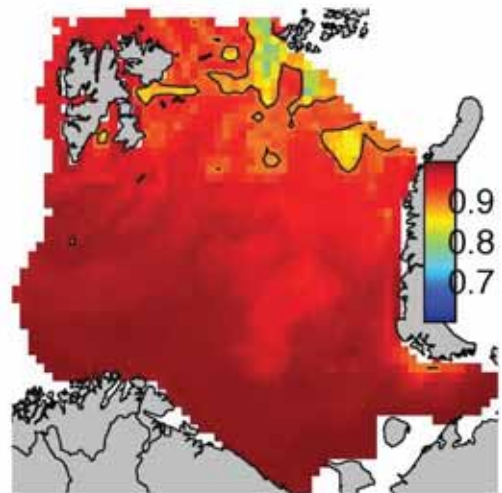
MELANOGRAMMUS\_AEGLEFINUS Scenario 1



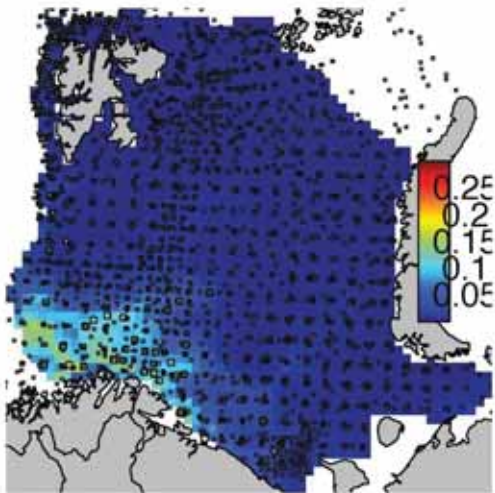
MELANOGRAMMUS\_AEGLEFINUS Scenario 2



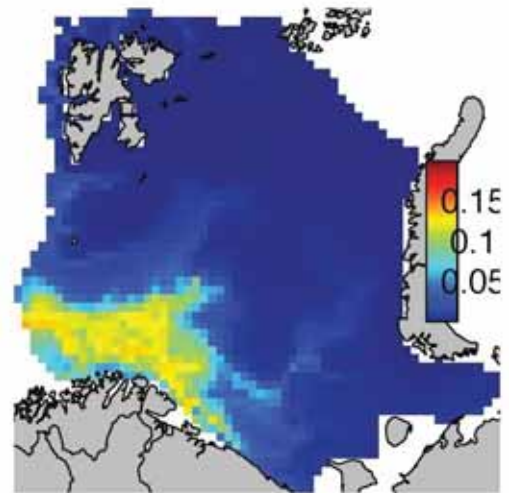
MELANOGRAMMUS\_AEGLEFINUS Scenario 3



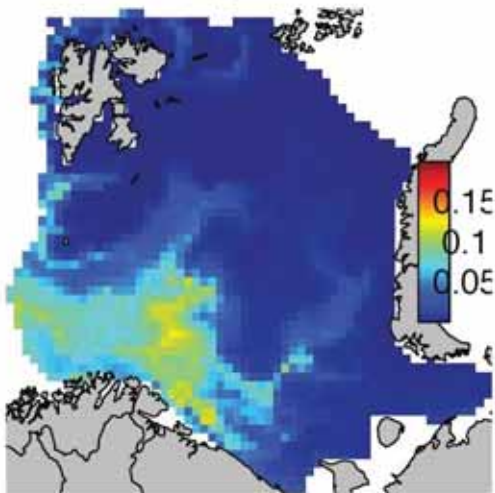
ENCHELYOPUS\_CIMBRIUS Today



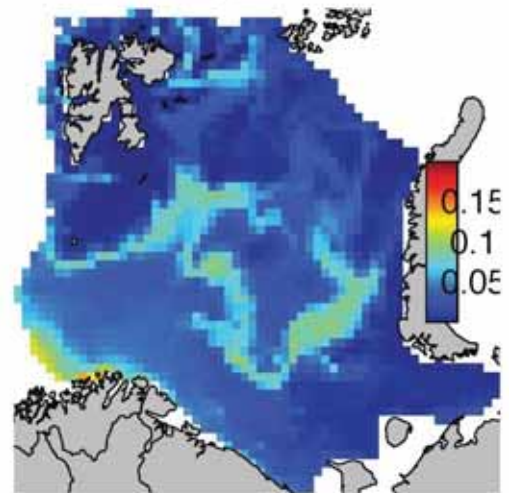
ENCHELYOPUS\_CIMBRIUS Scenario 1



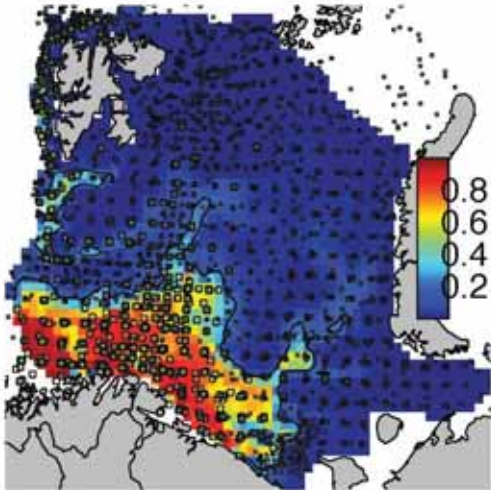
ENCHELYOPUS\_CIMBRIUS Scenario 2



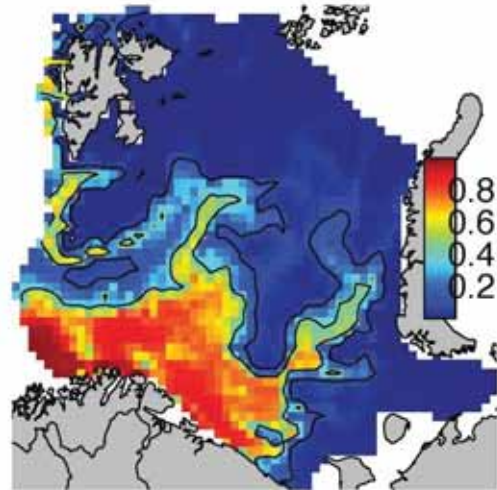
ENCHELYOPUS\_CIMBRIUS Scenario 3



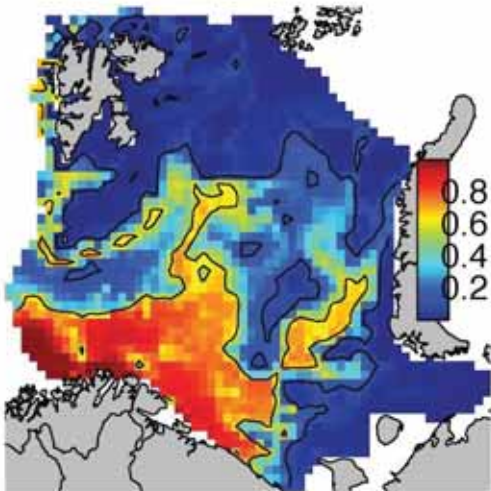
TRISOPTERUS\_ESMARKII Today



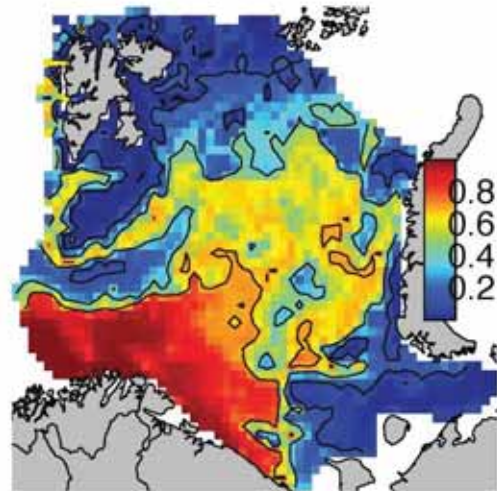
TRISOPTERUS\_ESMARKII Scenario 1



TRISOPTERUS\_ESMARKII Scenario 2

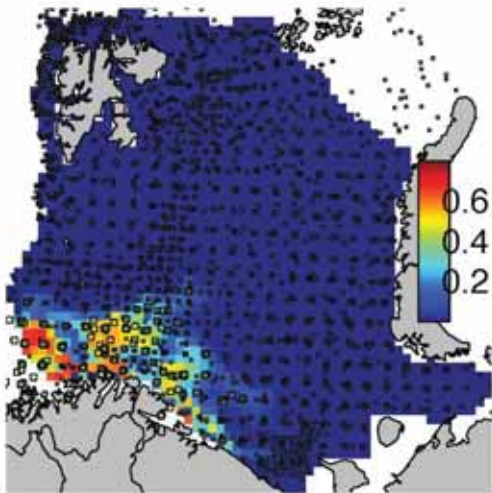


TRISOPTERUS\_ESMARKII Scenario 3

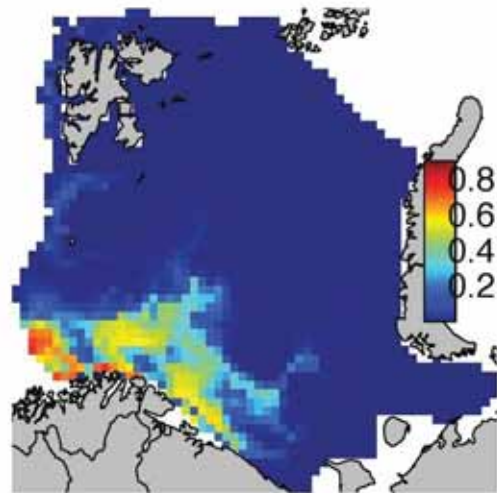




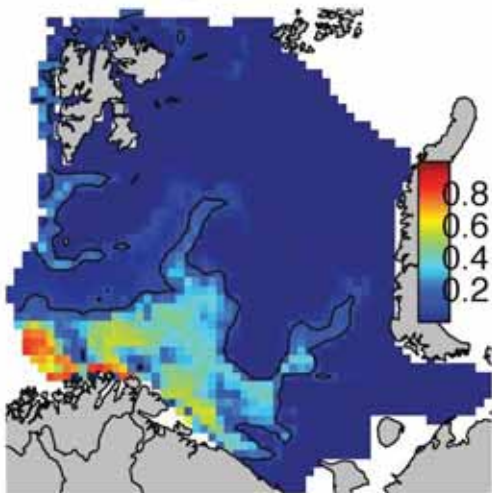
GADICULUS\_ARGENTEUS Today



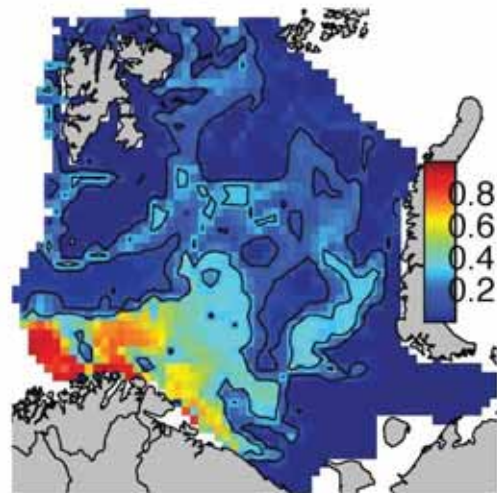
GADICULUS\_ARGENTEUS Scenario 1



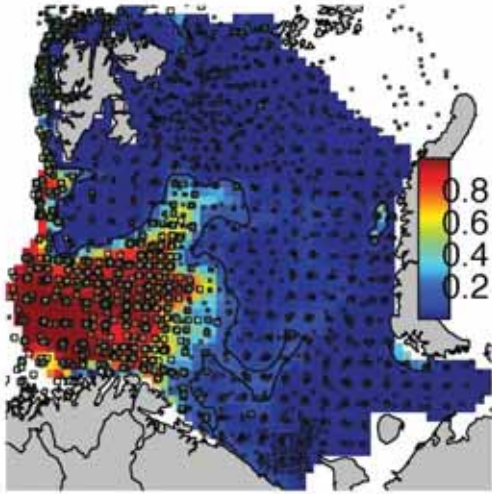
GADICULUS\_ARGENTEUS Scenario 2



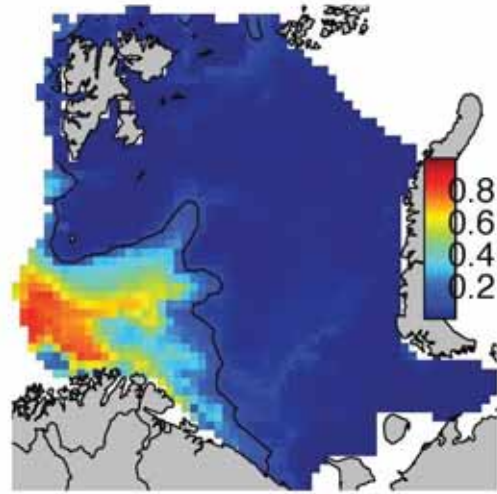
GADICULUS\_ARGENTEUS Scenario 3



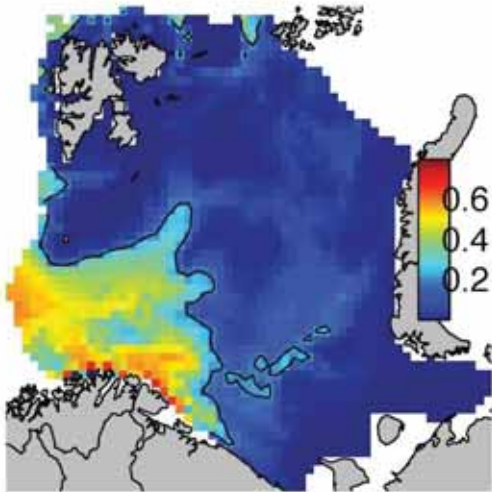
MICROMESISTIUS\_POUTASSOU Today



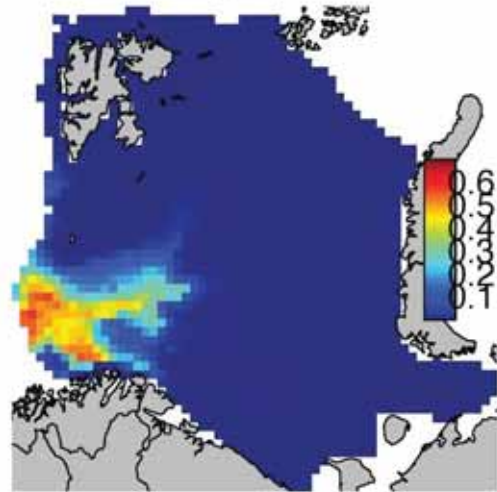
MICROMESISTIUS\_POUTASSOU Scenario 1



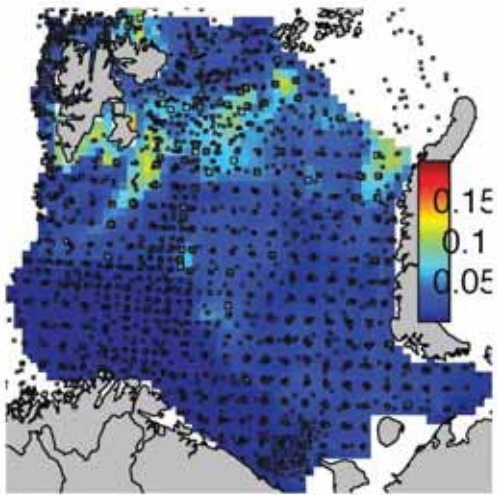
MICROMESISTIUS\_POUTASSOU Scenario 2



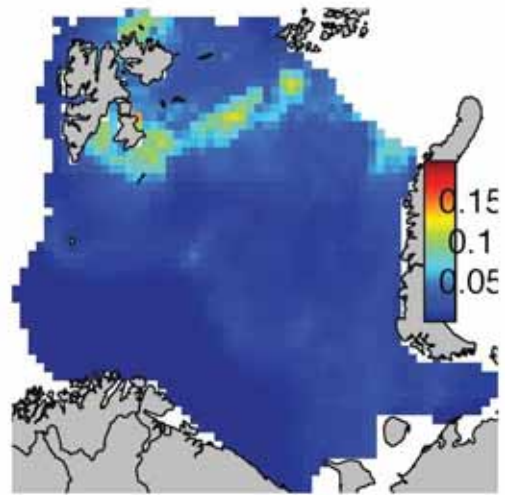
MICROMESISTIUS\_POUTASSOU Scenario 3



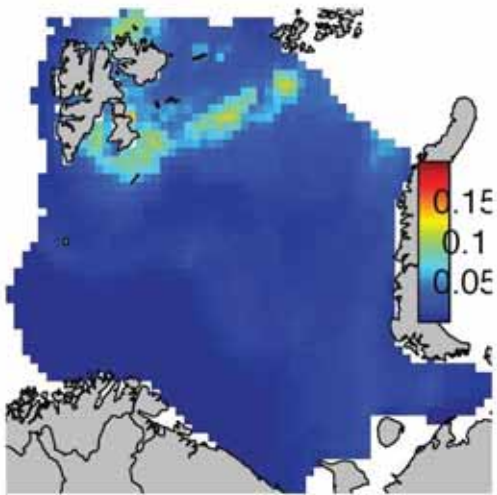
GYMNELUS Today



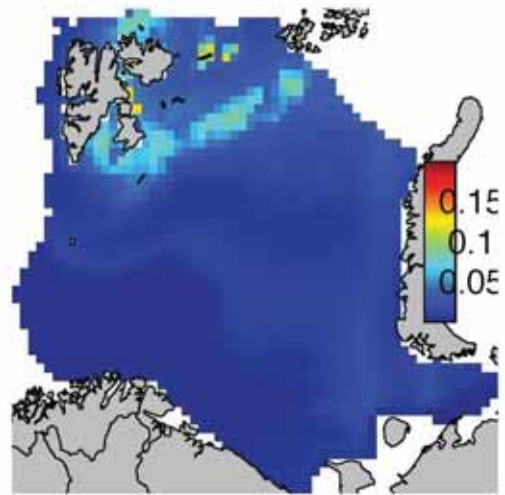
GYMNELUS Scenario 1



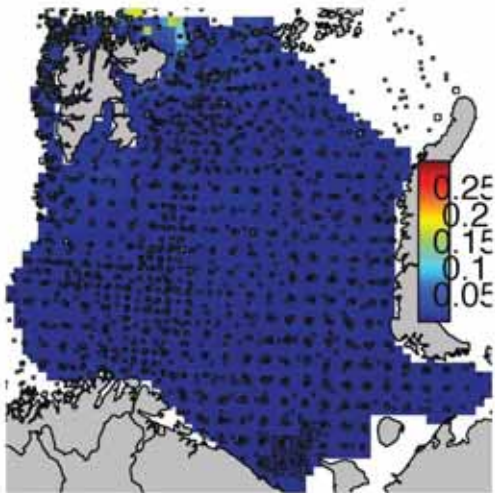
GYMNELUS Scenario 2



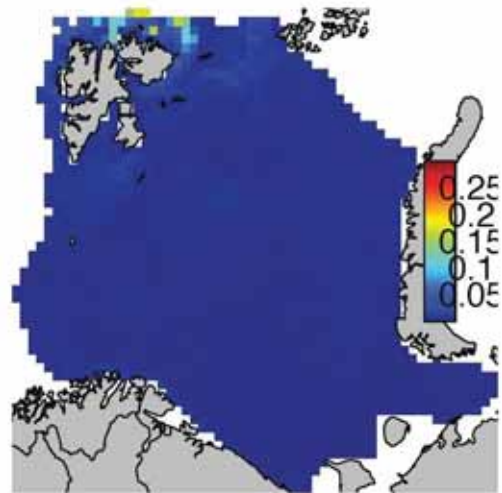
GYMNELUS Scenario 3



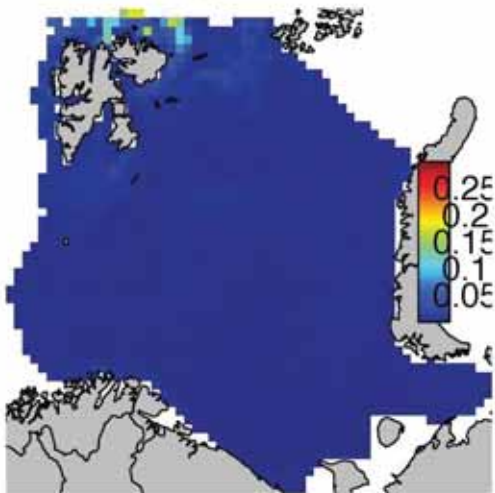
LYCENCHELYS\_KOLTHOFFI Today



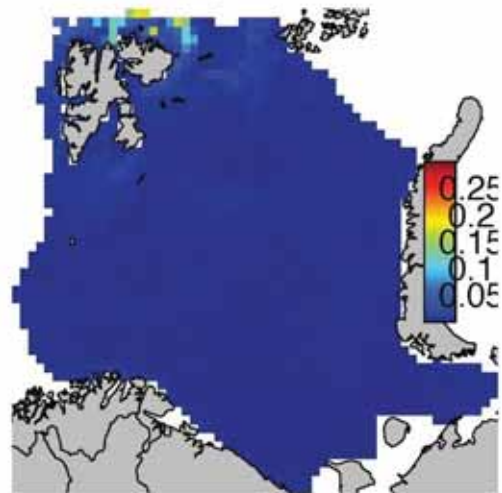
LYCENCHELYS\_KOLTHOFFI Scenario 1



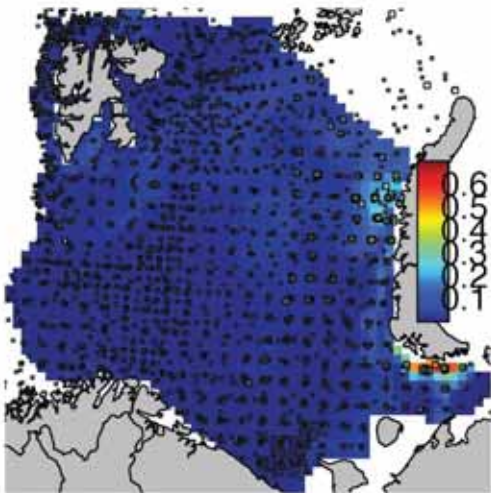
LYCENCHELYS\_KOLTHOFFI Scenario 2



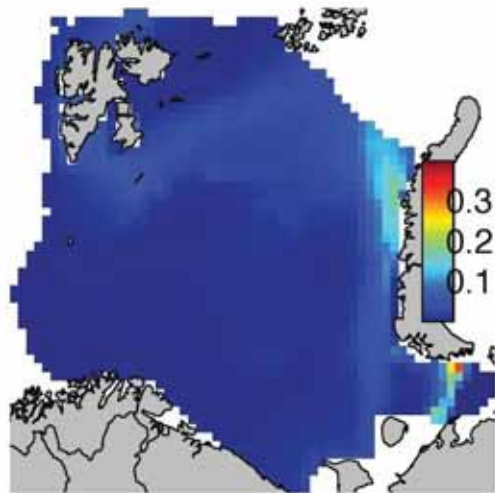
LYCENCHELYS\_KOLTHOFFI Scenario 3



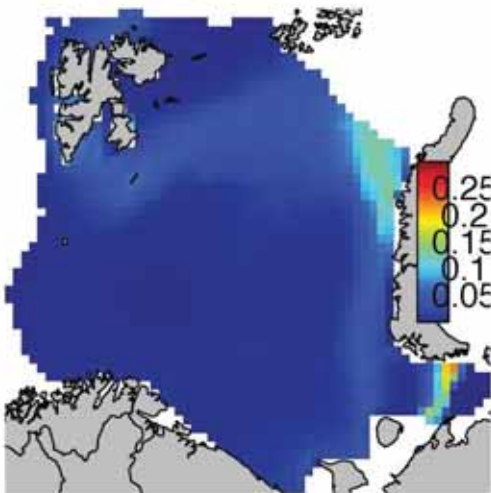
LYCODES\_POLARIS Today



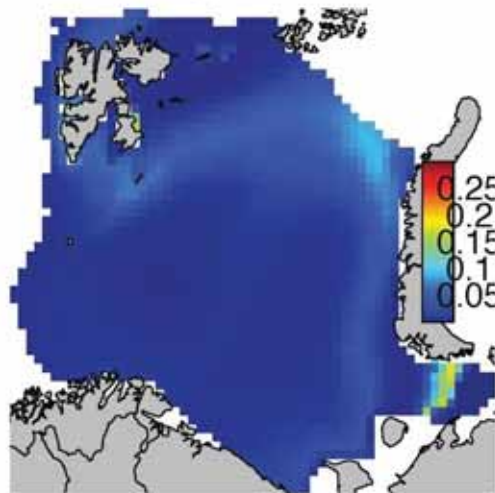
LYCODES\_POLARIS Scenario 1



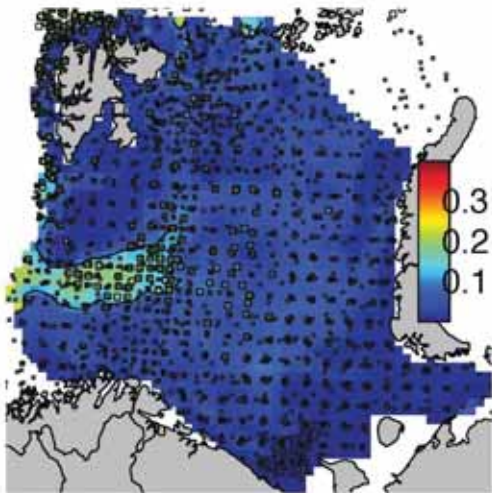
LYCODES\_POLARIS Scenario 2



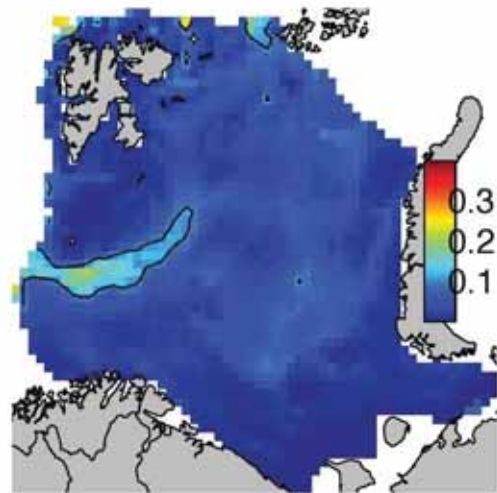
LYCODES\_POLARIS Scenario 3



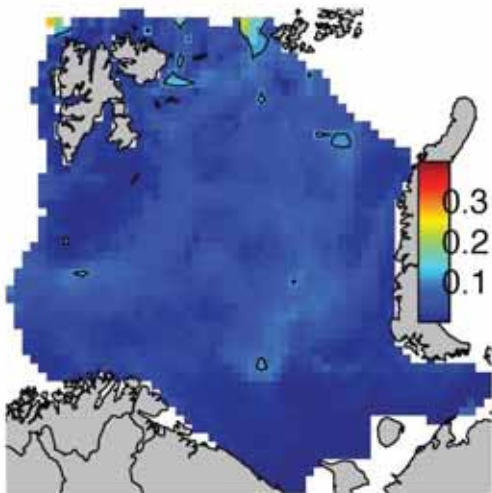
LYCODES\_EUDIPLEUROSTICTUS Today



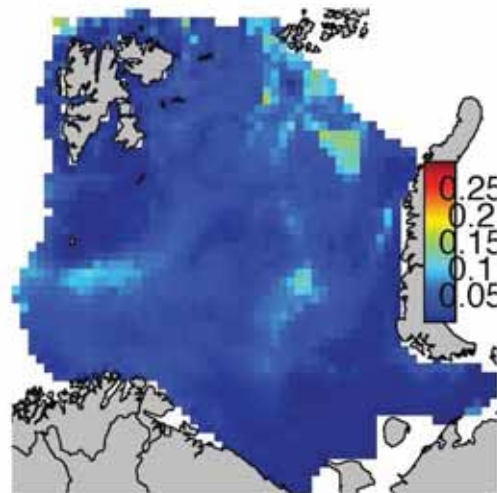
LYCODES\_EUDIPLEUROSTICTUS Scenario 1



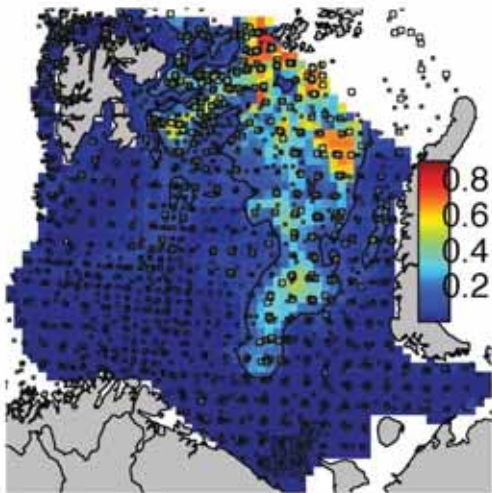
LYCODES\_EUDIPLEUROSTICTUS Scenario 2



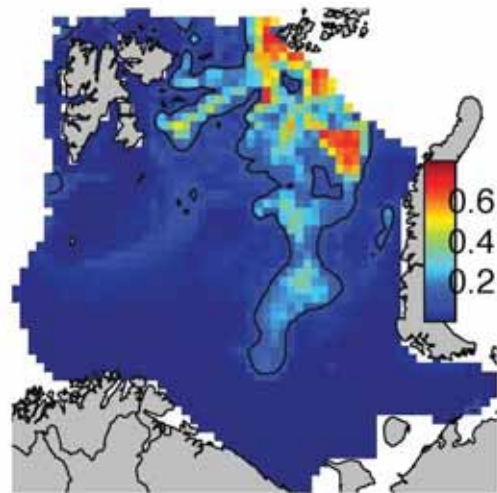
LYCODES\_EUDIPLEUROSTICTUS Scenario 3



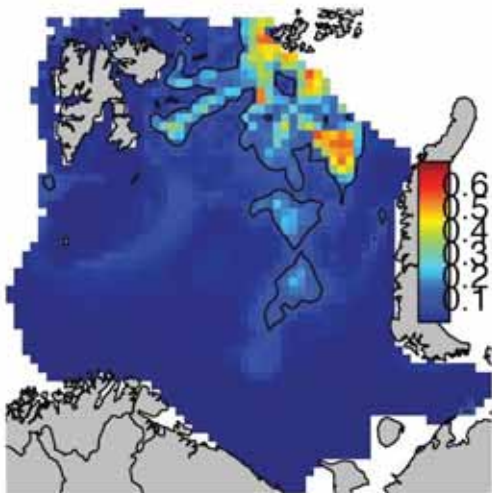
LYCODES\_SEMINUDUS Today



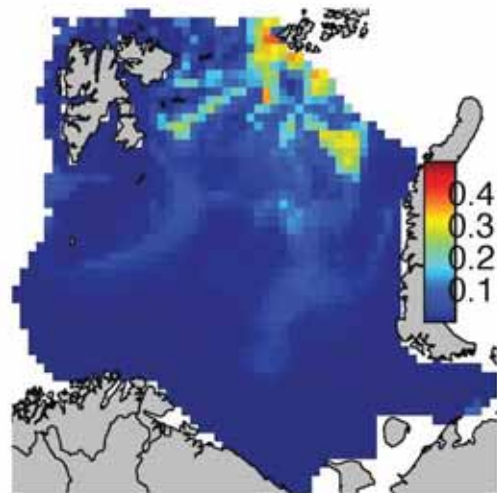
LYCODES\_SEMINUDUS Scenario 1



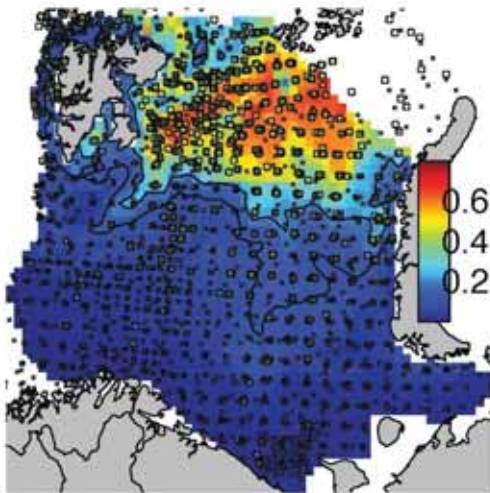
LYCODES\_SEMINUDUS Scenario 2



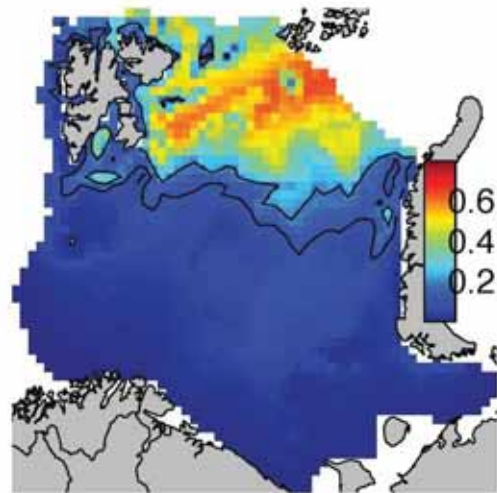
LYCODES\_SEMINUDUS Scenario 3



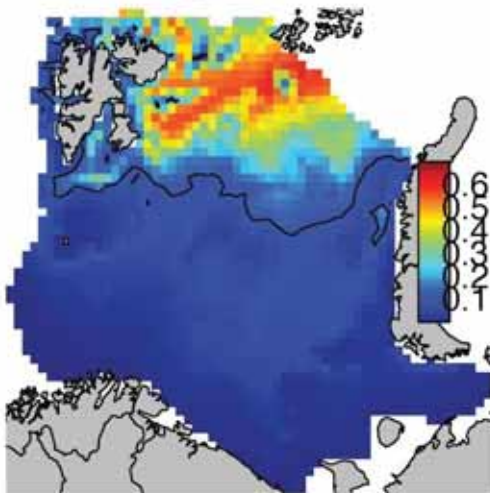
LYCODES\_PALLIDUS Today



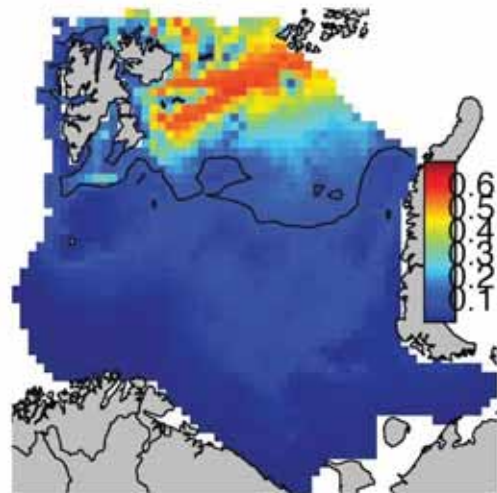
LYCODES\_PALLIDUS Scenario 1



LYCODES\_PALLIDUS Scenario 2

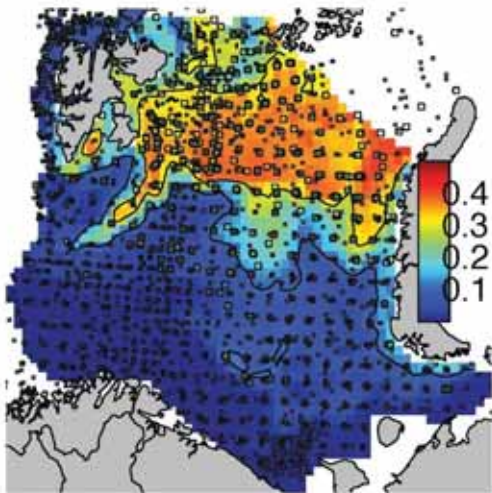


LYCODES\_PALLIDUS Scenario 3

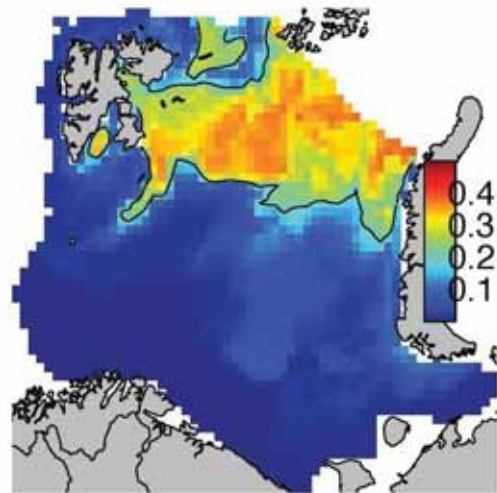




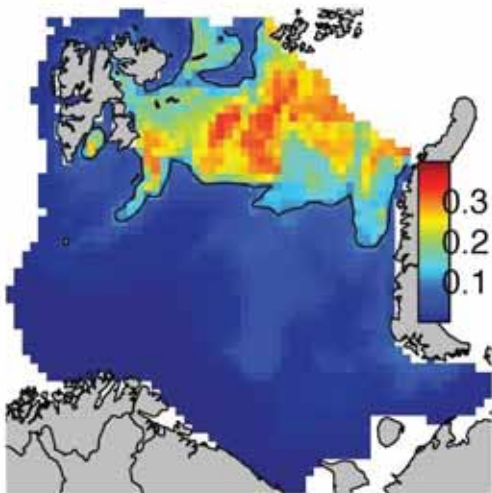
LYCODES\_RETICULATUS Today



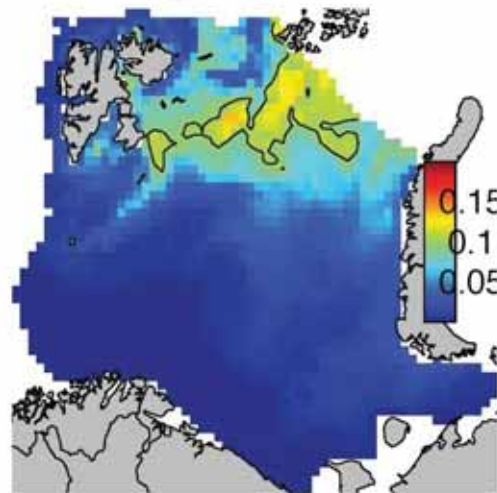
LYCODES\_RETICULATUS Scenario 1



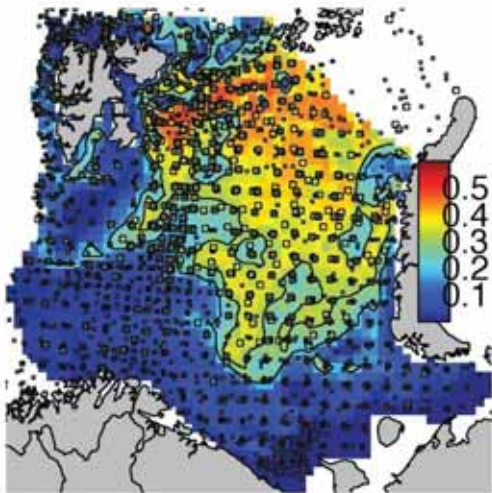
LYCODES\_RETICULATUS Scenario 2



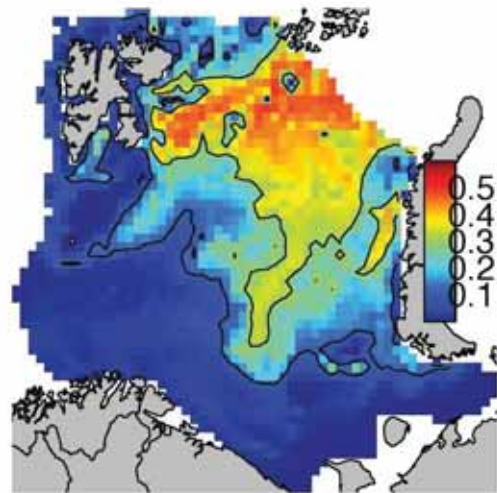
LYCODES\_RETICULATUS Scenario 3



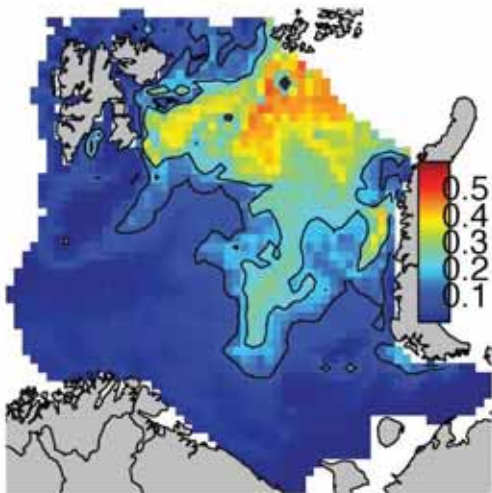
LYCODES\_ROSSI Today



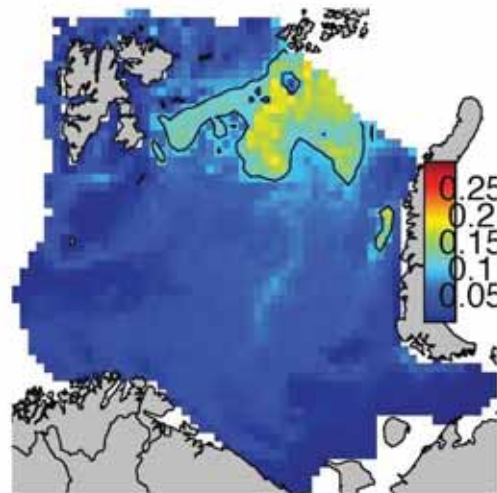
LYCODES\_ROSSI Scenario 1



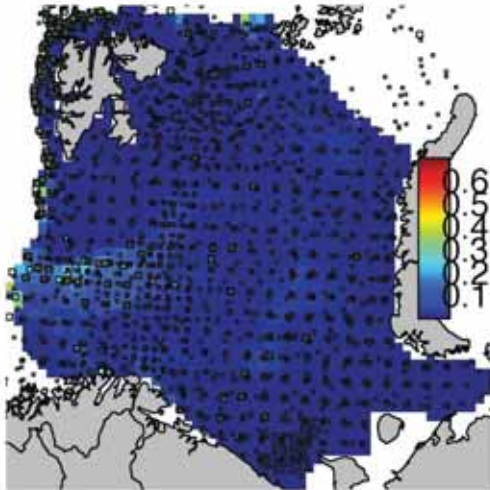
LYCODES\_ROSSI Scenario 2



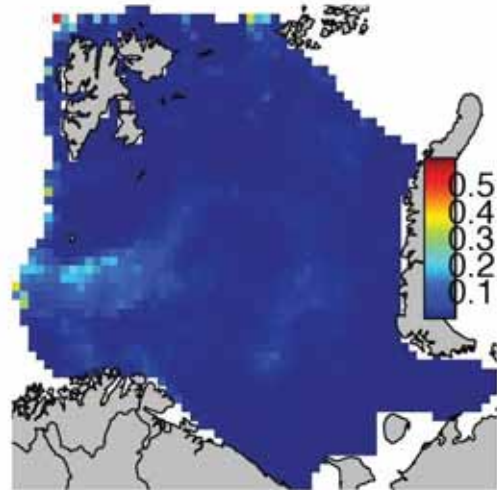
LYCODES\_ROSSI Scenario 3



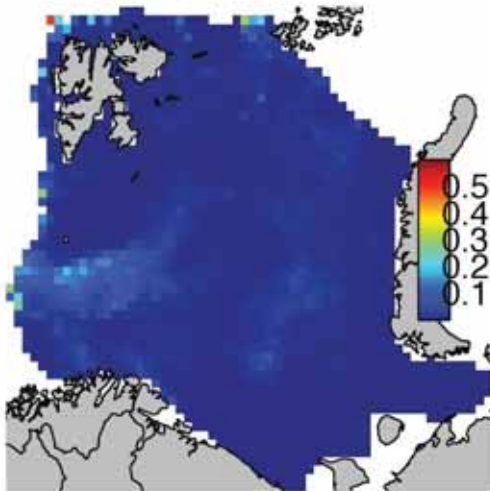
LYCODES\_ESMARKII Today



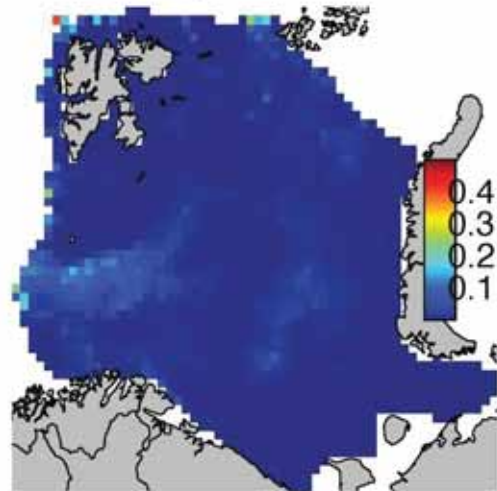
LYCODES\_ESMARKII Scenario 1



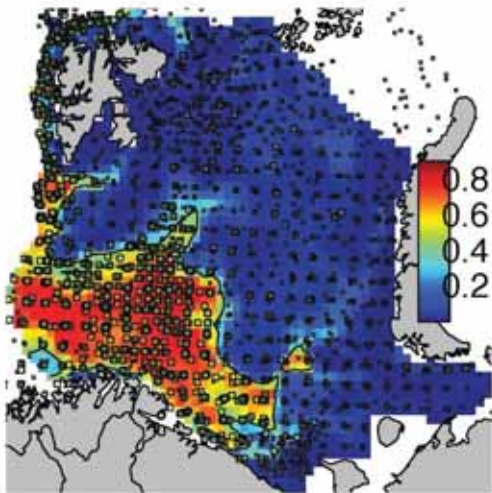
LYCODES\_ESMARKII Scenario 2



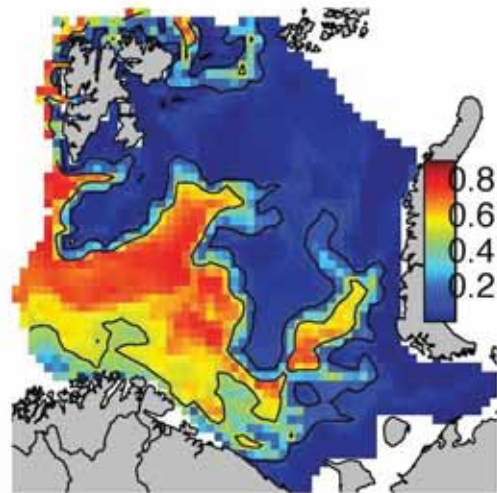
LYCODES\_ESMARKII Scenario 3



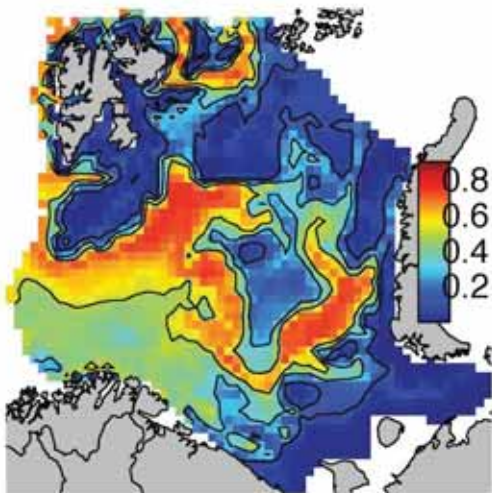
LYCODES\_GRACILIS Today



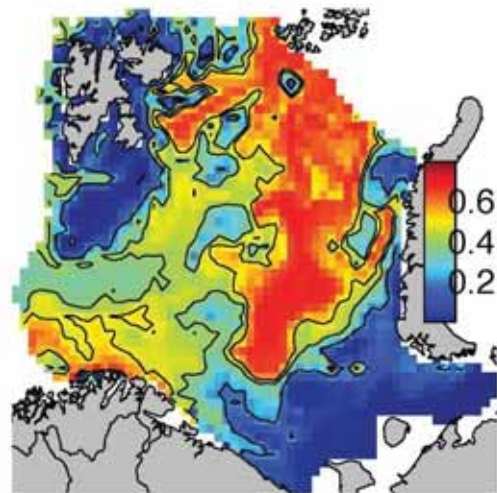
LYCODES\_GRACILIS Scenario 1



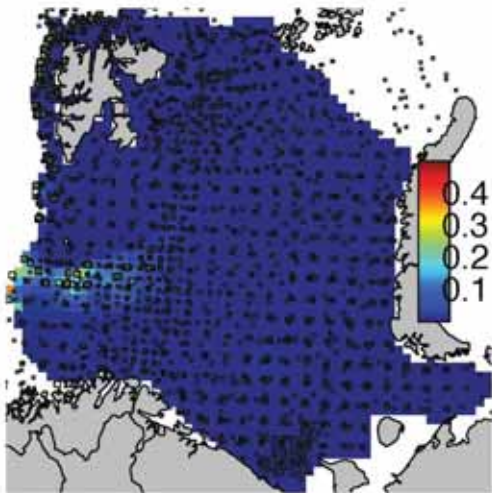
LYCODES\_GRACILIS Scenario 2



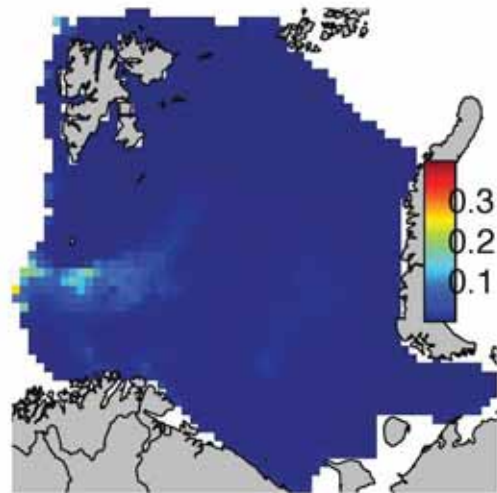
LYCODES\_GRACILIS Scenario 3



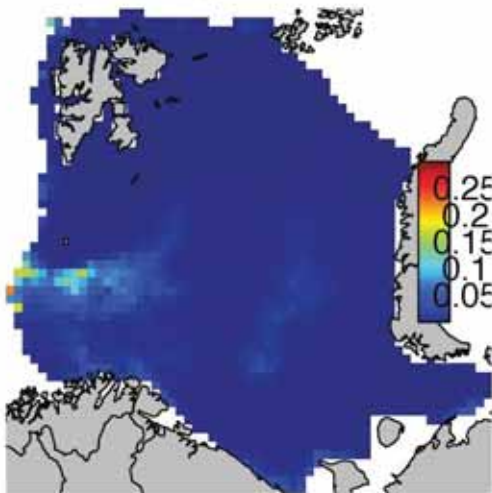
MACROURUS\_BERGLAX Today



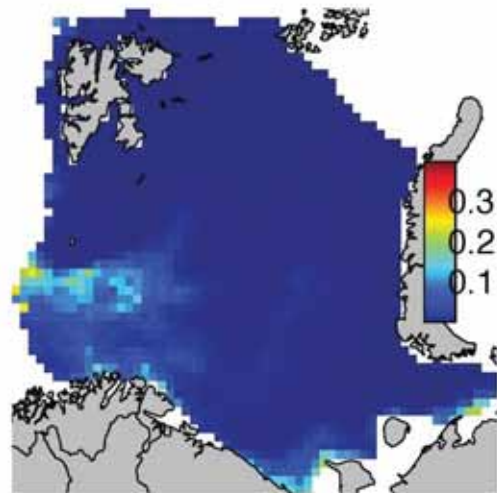
MACROURUS\_BERGLAX Scenario 1



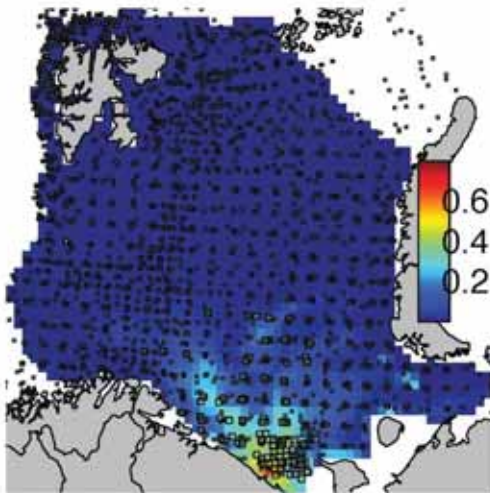
MACROURUS\_BERGLAX Scenario 2



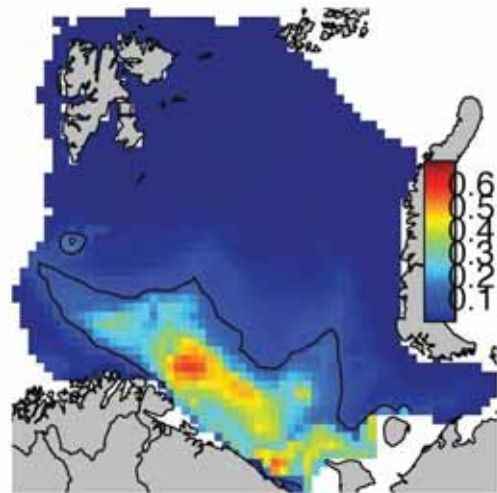
MACROURUS\_BERGLAX Scenario 3



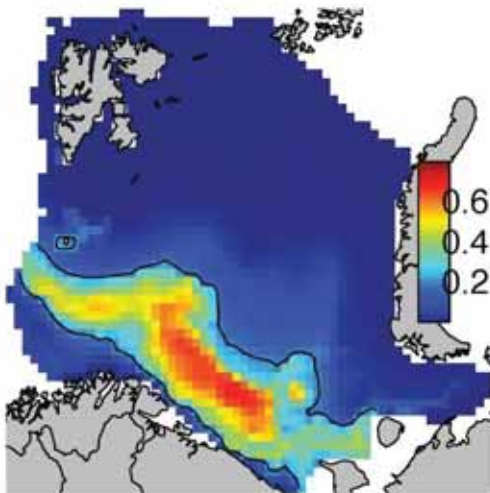
GASTEROSTEUS\_ACULEATUS Today



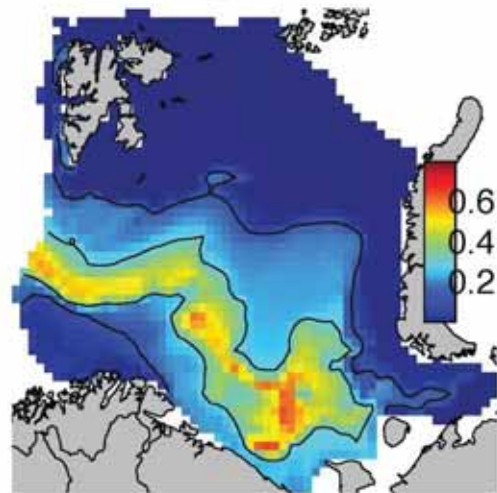
GASTEROSTEUS\_ACULEATUS Scenario 1



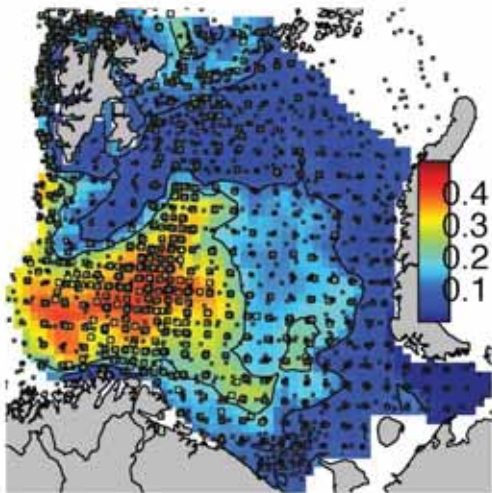
GASTEROSTEUS\_ACULEATUS Scenario 2



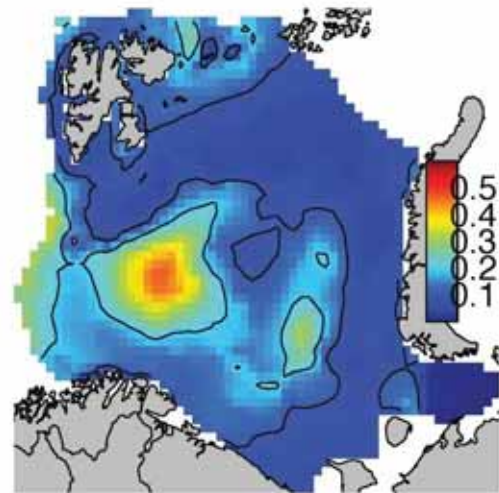
GASTEROSTEUS\_ACULEATUS Scenario 3



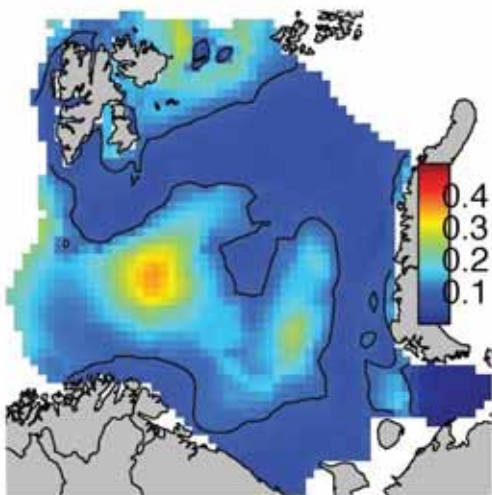
SCORPAENIDAE Today



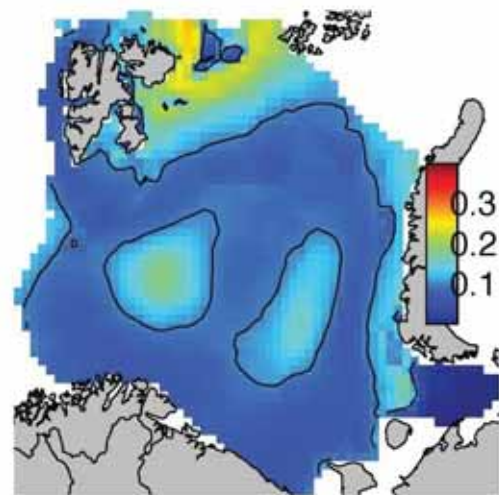
SCORPAENIDAE Scenario 1



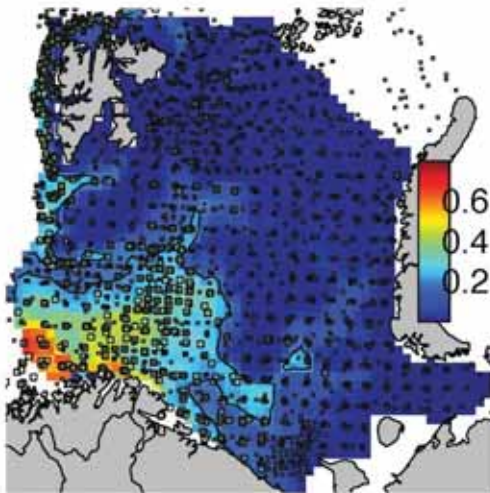
SCORPAENIDAE Scenario 2



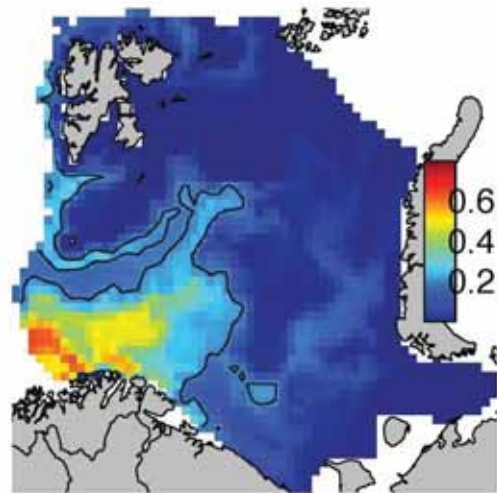
SCORPAENIDAE Scenario 3



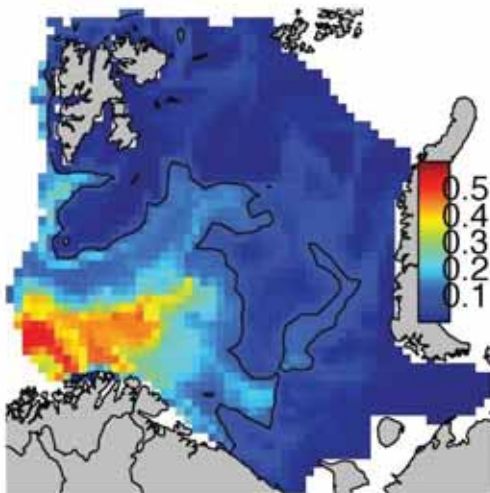
SEBASTES\_MARINUS Today



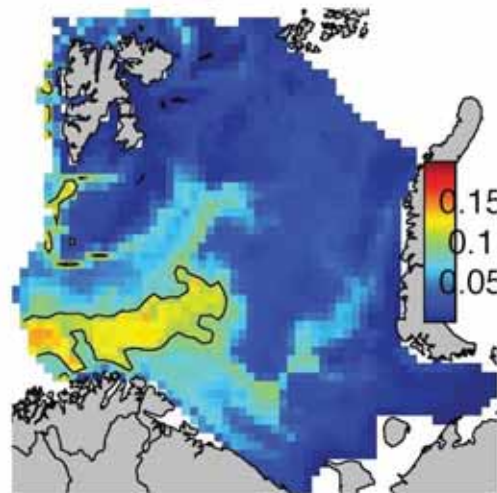
SEBASTES\_MARINUS Scenario 1



SEBASTES\_MARINUS Scenario 2

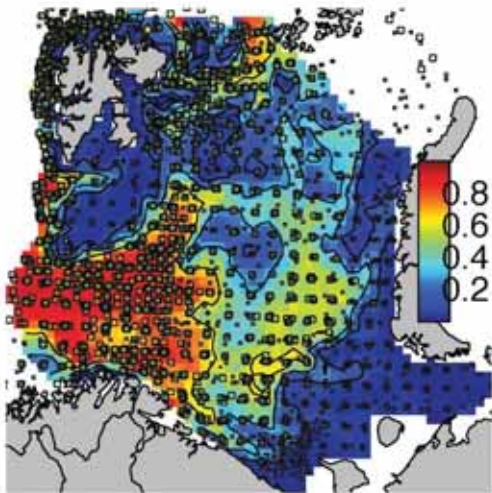


SEBASTES\_MARINUS Scenario 3

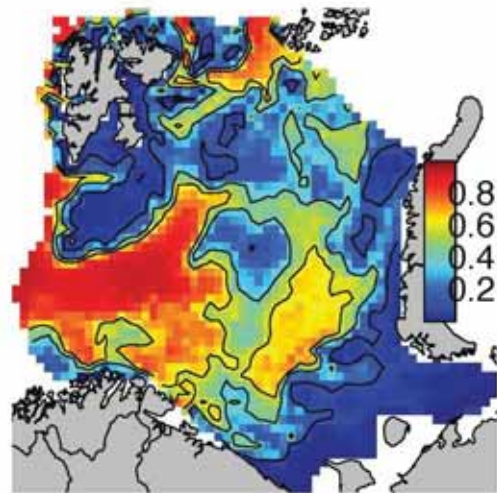




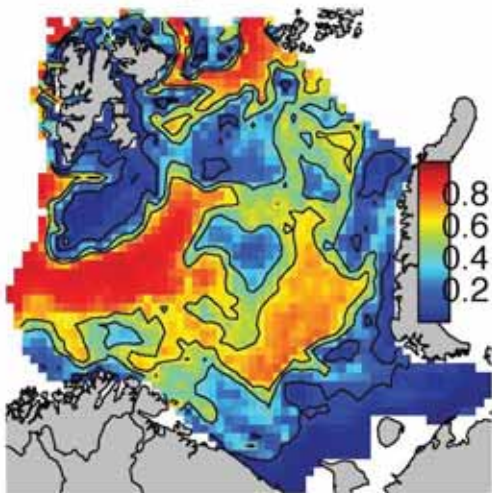
SEBASTES\_MENTELLA Today



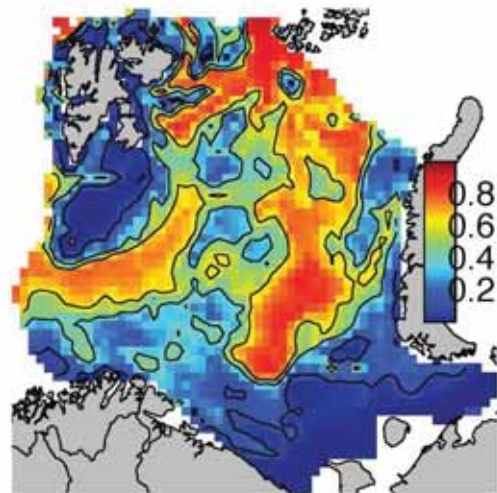
SEBASTES\_MENTELLA Scenario 1



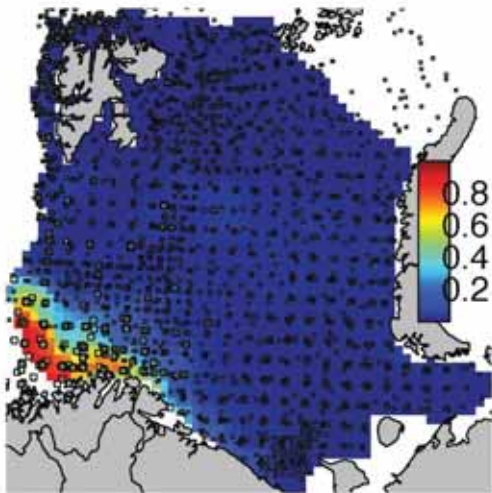
SEBASTES\_MENTELLA Scenario 2



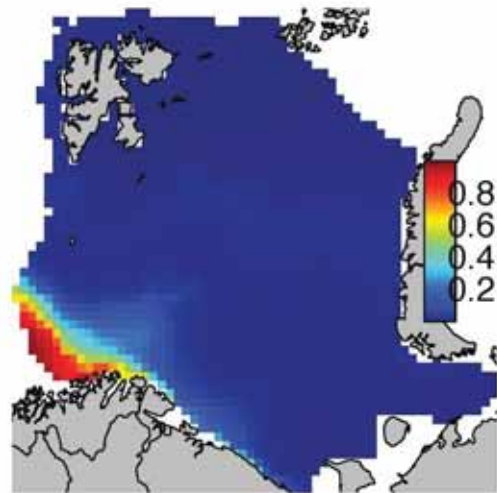
SEBASTES\_MENTELLA Scenario 3



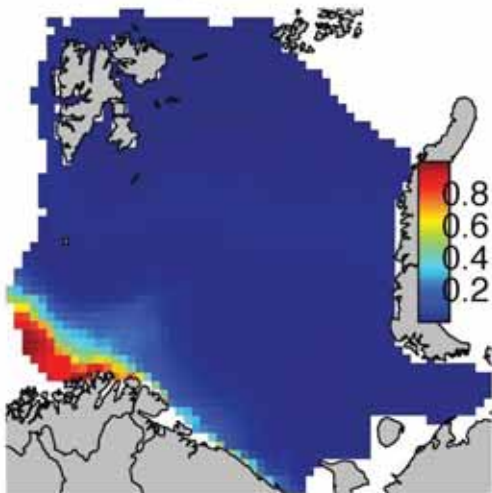
SEBASTES\_VIVIPARUS Today



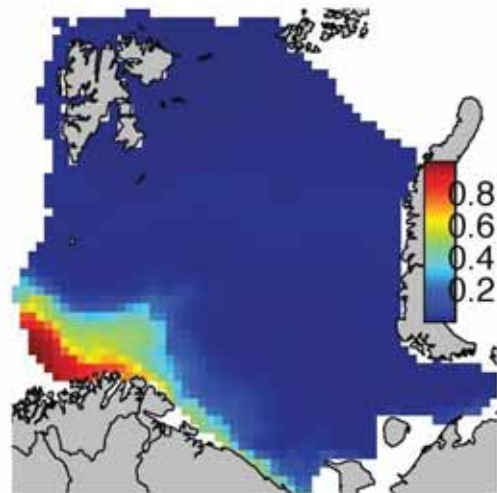
SEBASTES\_VIVIPARUS Scenario 1



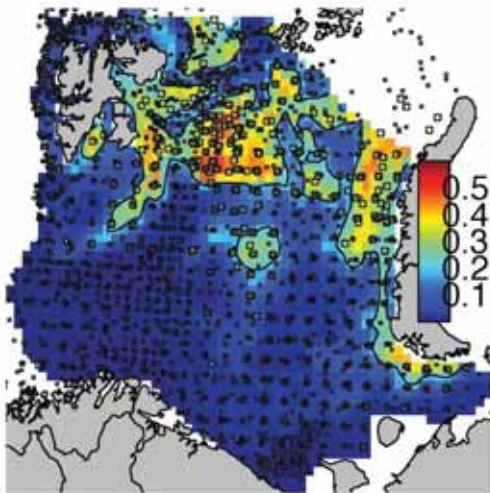
SEBASTES\_VIVIPARUS Scenario 2



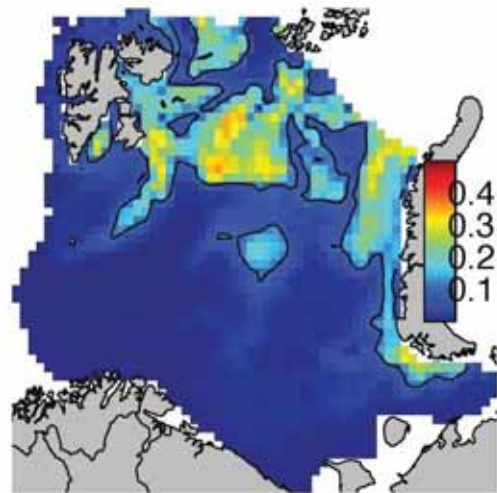
SEBASTES\_VIVIPARUS Scenario 3



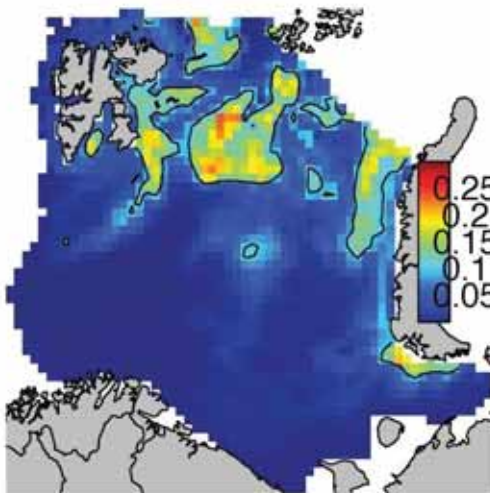
ICELUS\_BICORNIS Today



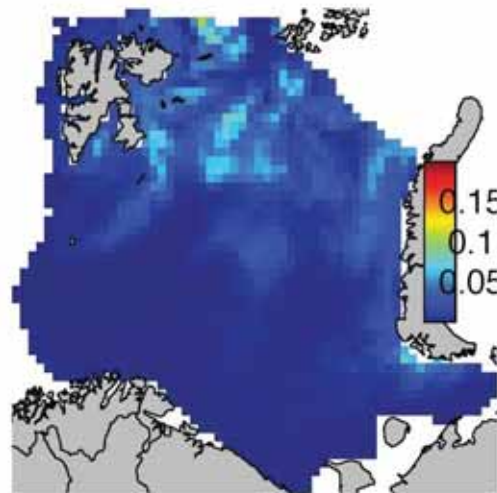
ICELUS\_BICORNIS Scenario 1



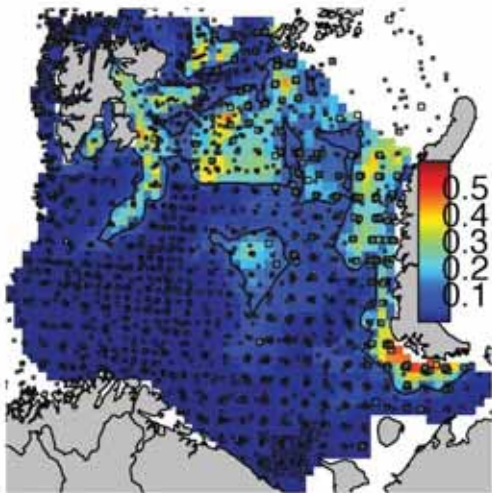
ICELUS\_BICORNIS Scenario 2



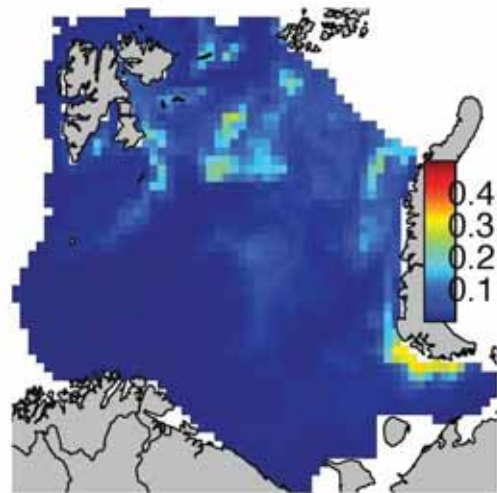
ICELUS\_BICORNIS Scenario 3



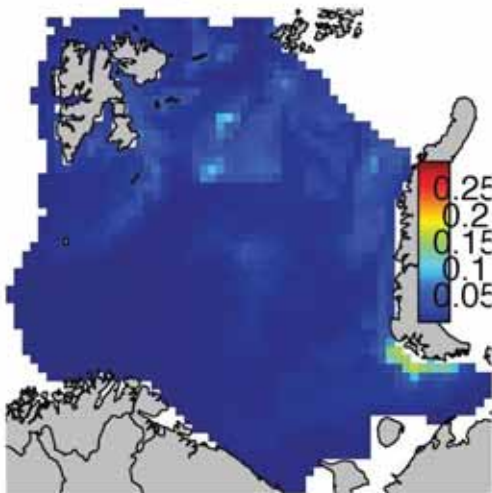
ICELUS\_SPATULA Today



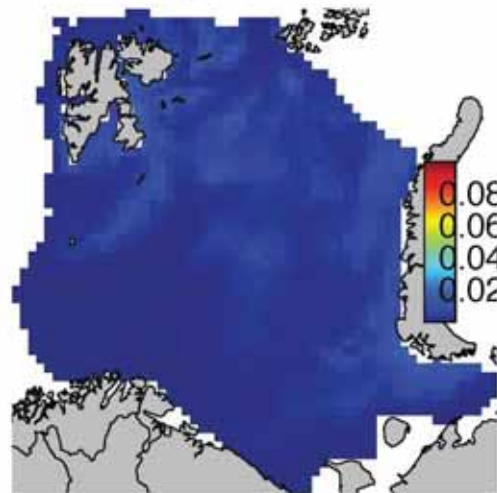
ICELUS\_SPATULA Scenario 1



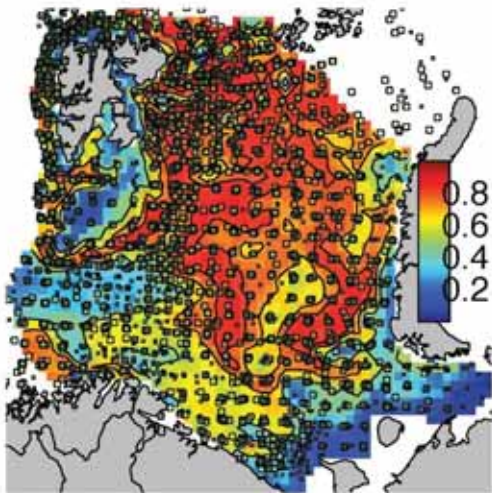
ICELUS\_SPATULA Scenario 2



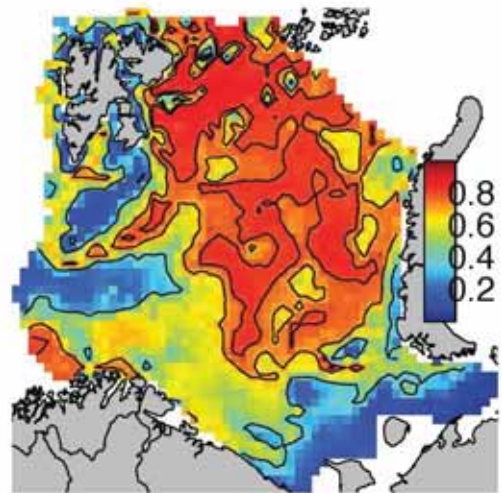
ICELUS\_SPATULA Scenario 3



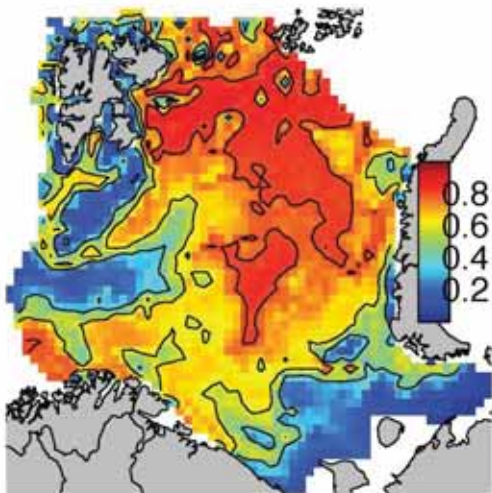
ARTEDIELLUS\_ATLANTICUS Today



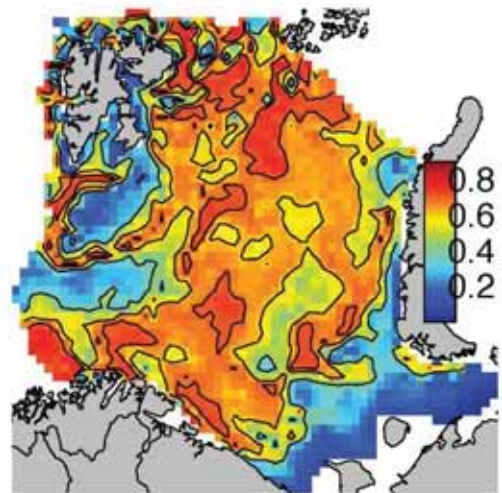
ARTEDIELLUS\_ATLANTICUS Scenario 1



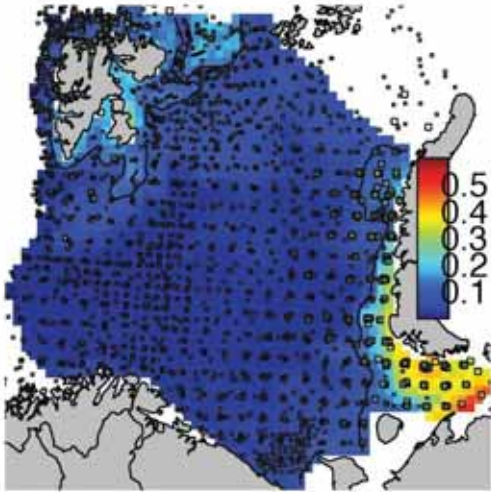
ARTEDIELLUS\_ATLANTICUS Scenario 2



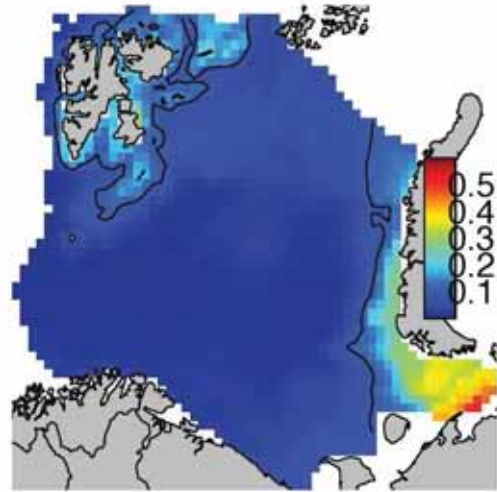
ARTEDIELLUS\_ATLANTICUS Scenario 3



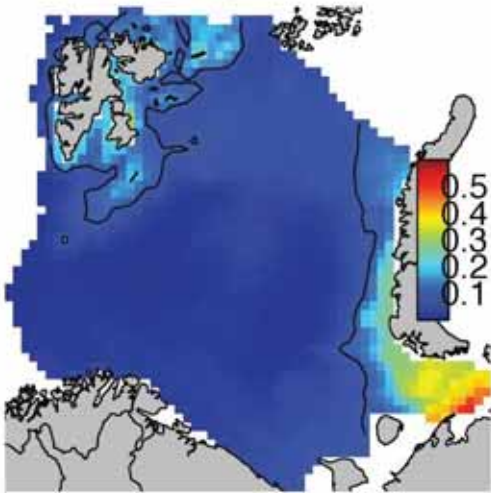
GYMNOCANTHUS\_TRICUSPIS Today



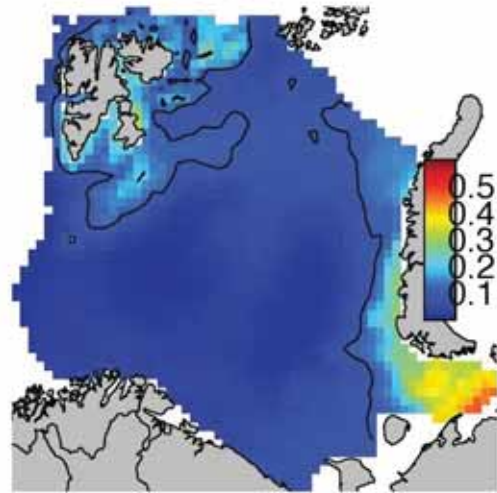
GYMNOCANTHUS\_TRICUSPIS Scenario 1



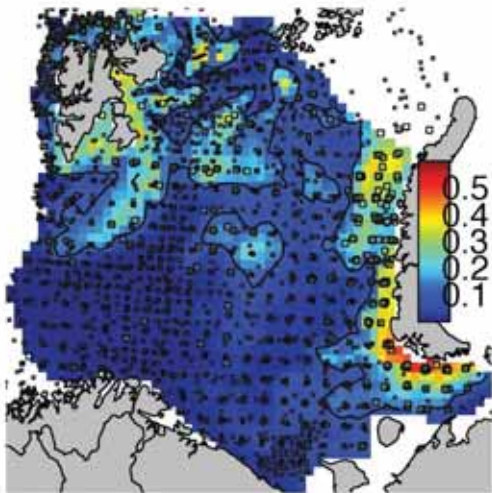
GYMNOCANTHUS\_TRICUSPIS Scenario 2



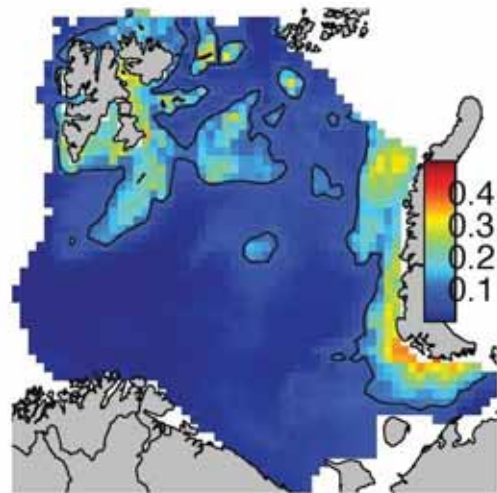
GYMNOCANTHUS\_TRICUSPIS Scenario 3



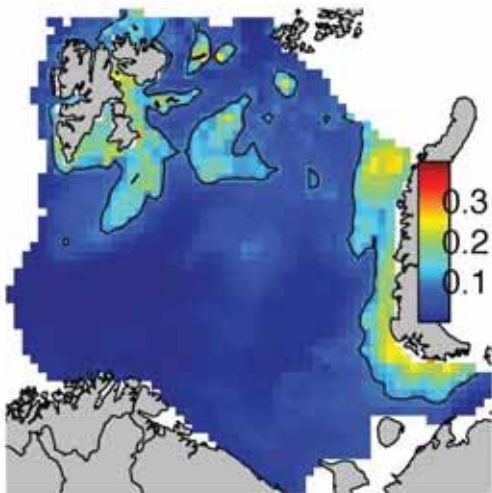
TRIGLOPS\_PINGELII Today



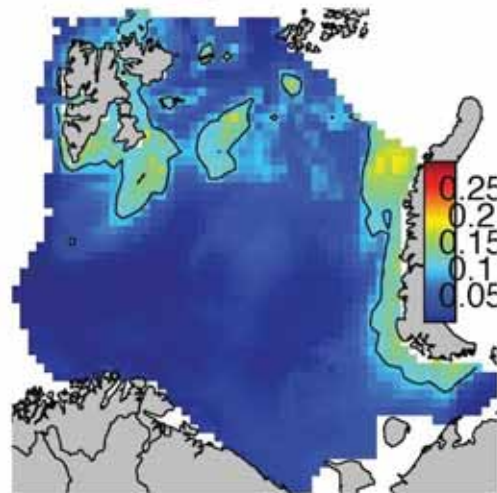
TRIGLOPS\_PINGELII Scenario 1



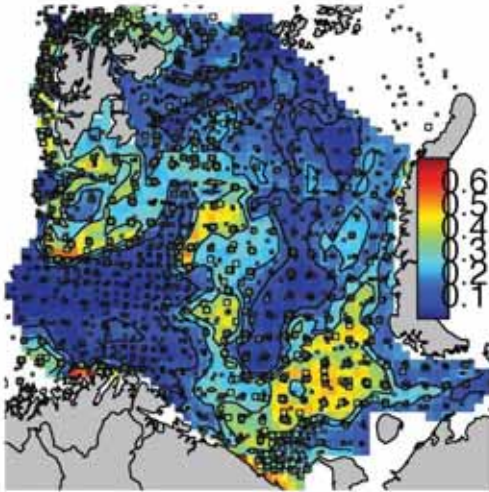
TRIGLOPS\_PINGELII Scenario 2



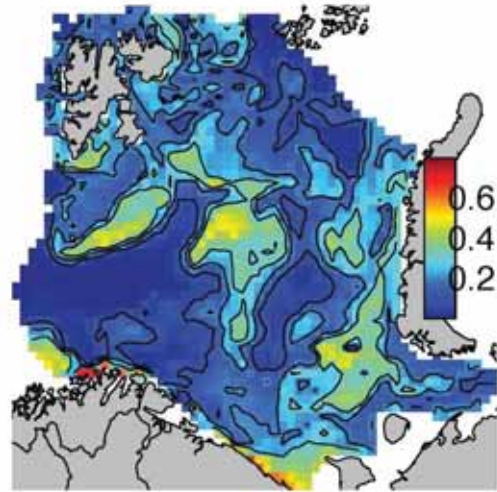
TRIGLOPS\_PINGELII Scenario 3



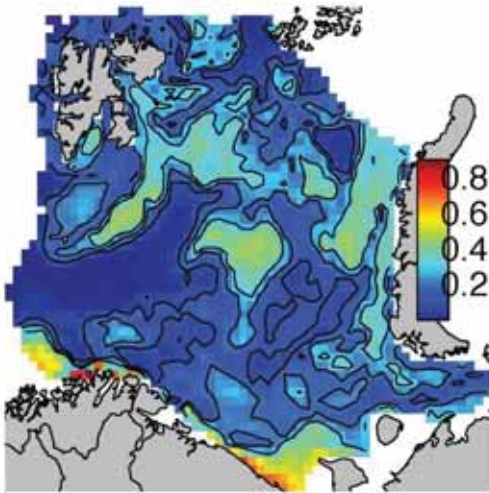
TRIGLOPS\_MURRAYI Today



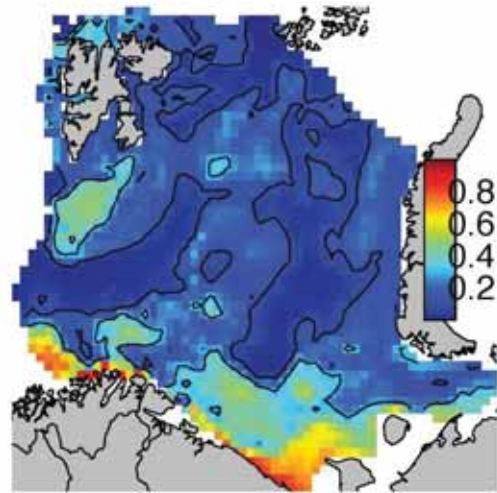
TRIGLOPS\_MURRAYI Scenario 1



TRIGLOPS\_MURRAYI Scenario 2

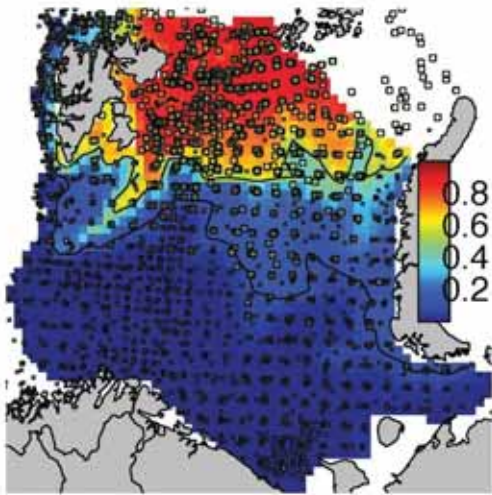


TRIGLOPS\_MURRAYI Scenario 3

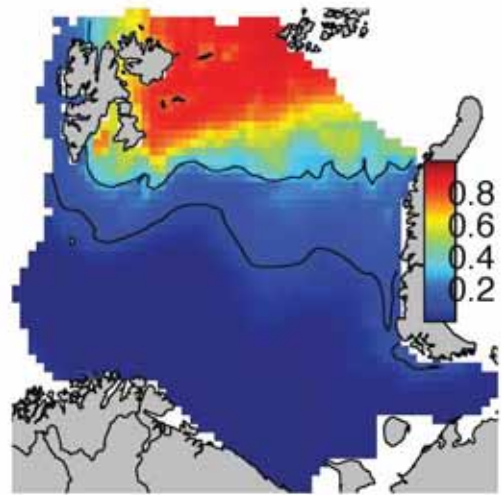




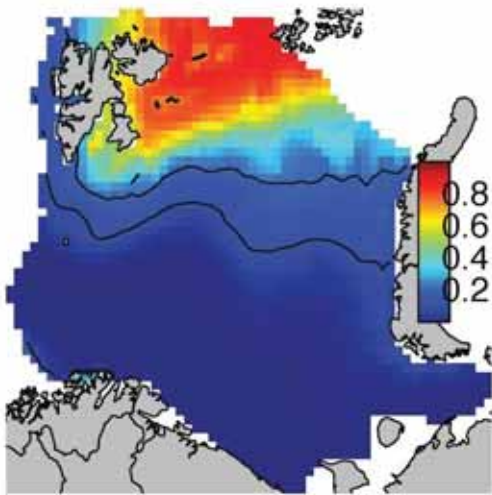
TRIGLOPS\_NYBELINI Today



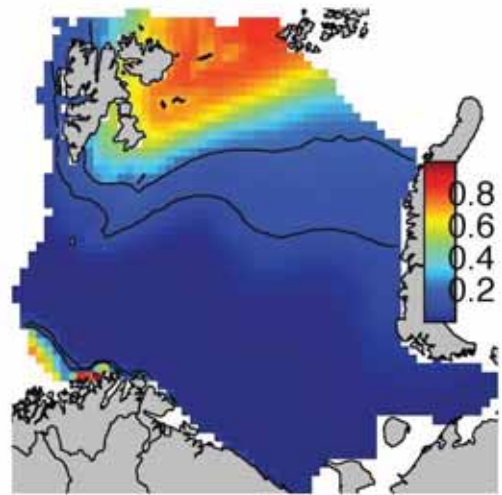
TRIGLOPS\_NYBELINI Scenario 1



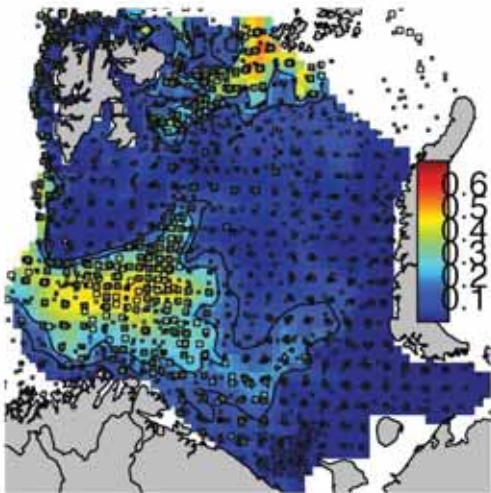
TRIGLOPS\_NYBELINI Scenario 2



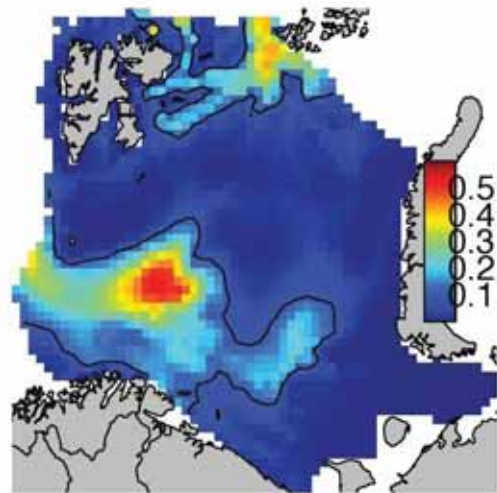
TRIGLOPS\_NYBELINI Scenario 3



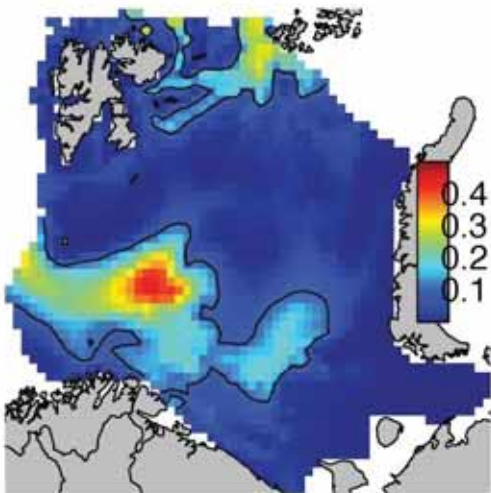
COTTUNCULUS\_SADKO Today



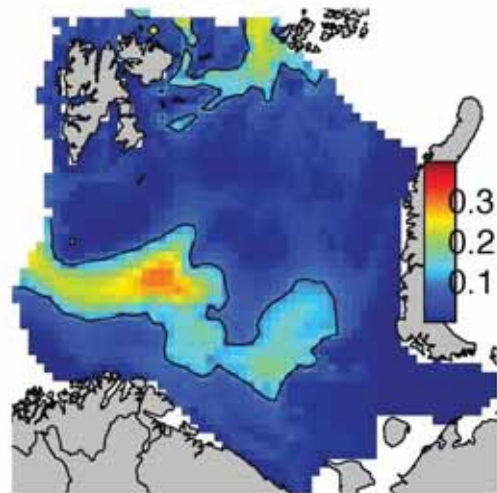
COTTUNCULUS\_SADKO Scenario 1



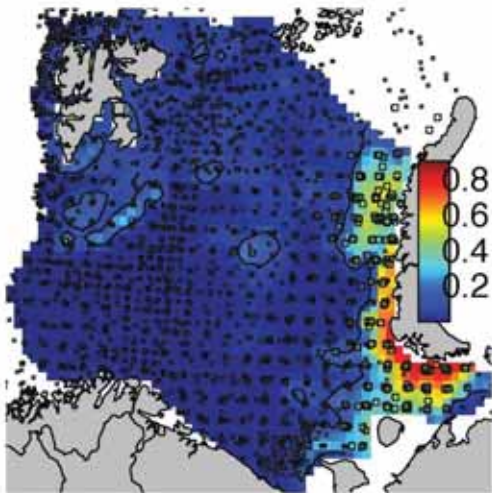
COTTUNCULUS\_SADKO Scenario 2



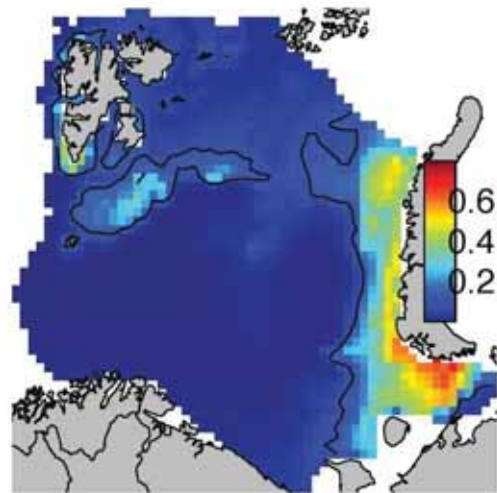
COTTUNCULUS\_SADKO Scenario 3



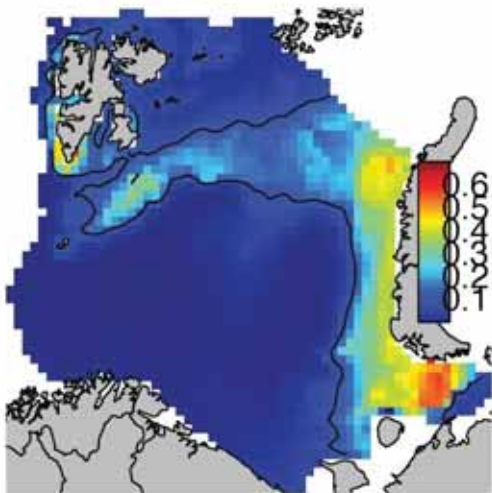
ULCINA\_OLRIKII Today



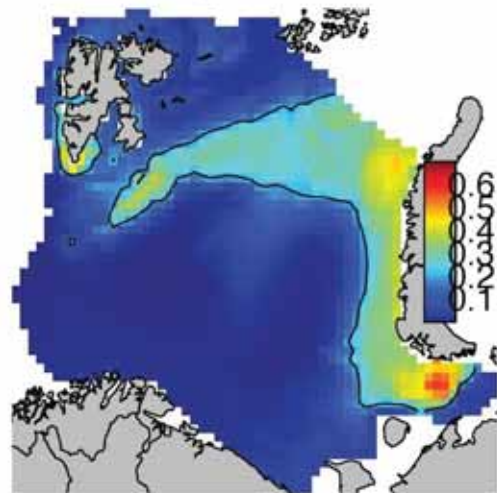
ULCINA\_OLRIKII Scenario 1



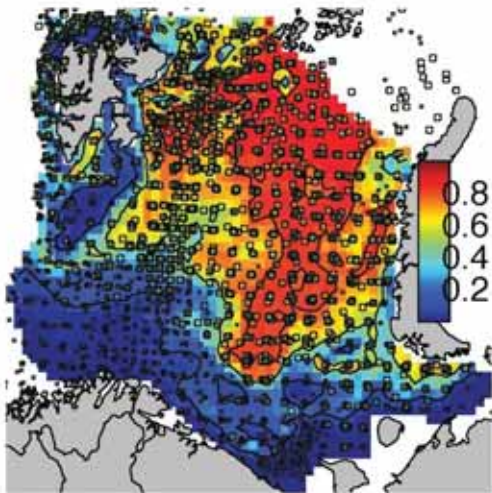
ULCINA\_OLRIKII Scenario 2



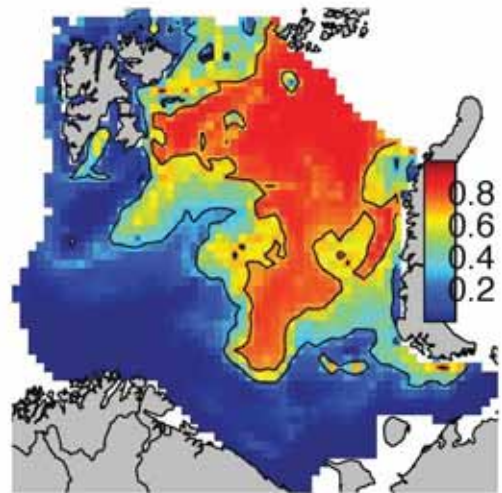
ULCINA\_OLRIKII Scenario 3



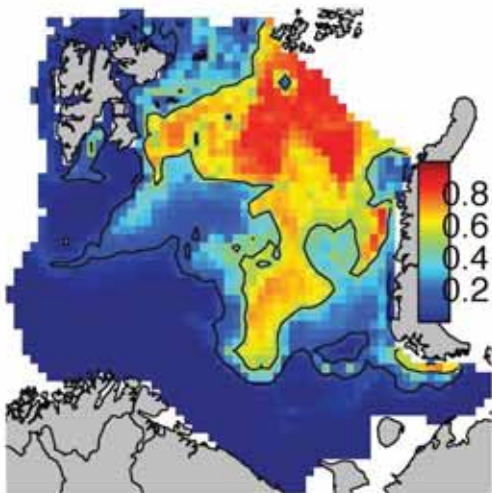
LEPTAGONUS\_DECAGONUS Today



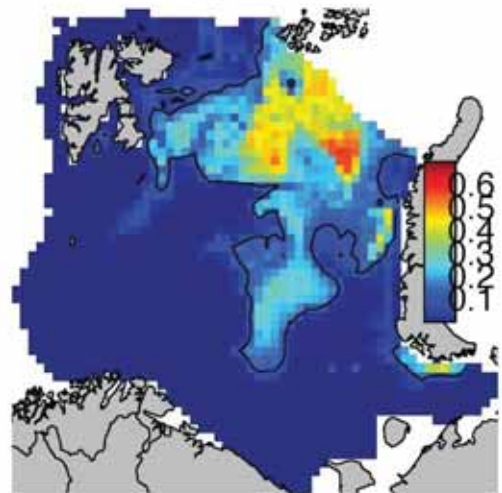
LEPTAGONUS\_DECAGONUS Scenario 1



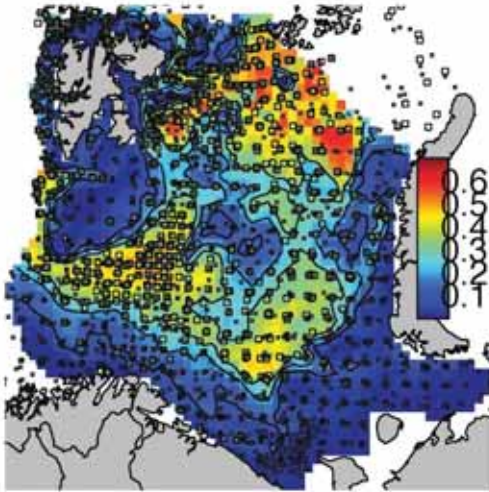
LEPTAGONUS\_DECAGONUS Scenario 2



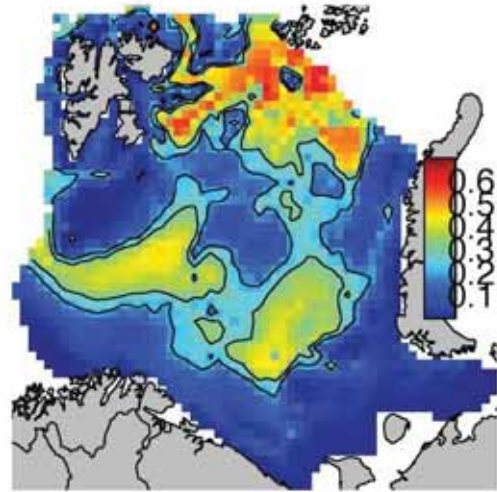
LEPTAGONUS\_DECAGONUS Scenario 3



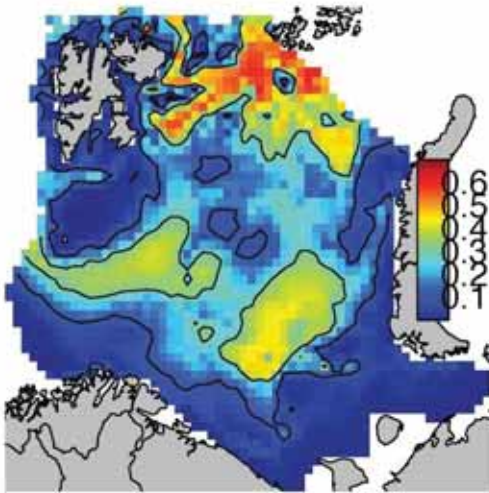
CAREPROCTUS Today



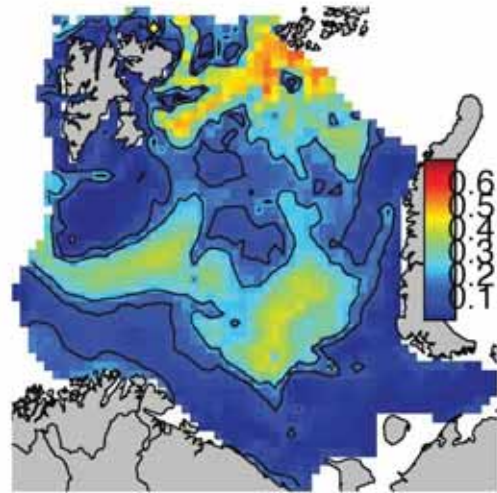
CAREPROCTUS Scenario 1



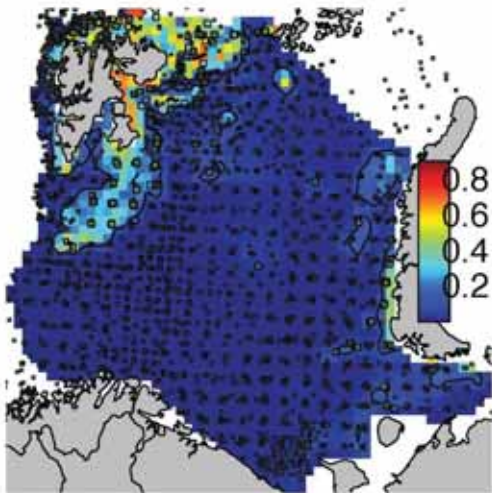
CAREPROCTUS Scenario 2



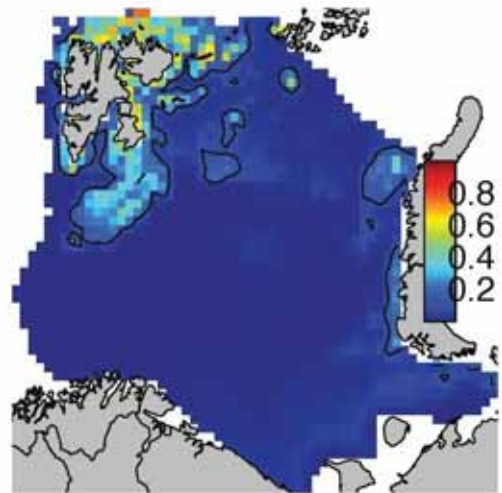
CAREPROCTUS Scenario 3



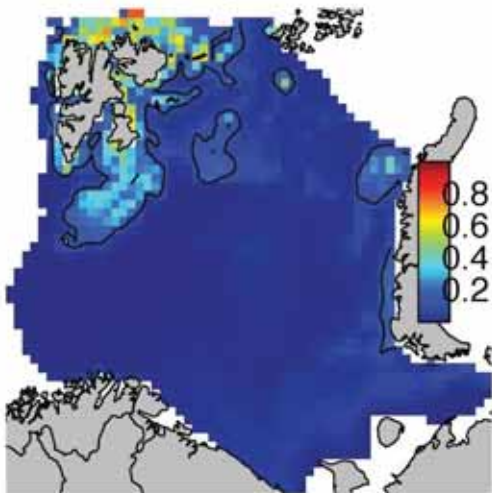
EUMICROTREMUS\_SPINOSUS Today



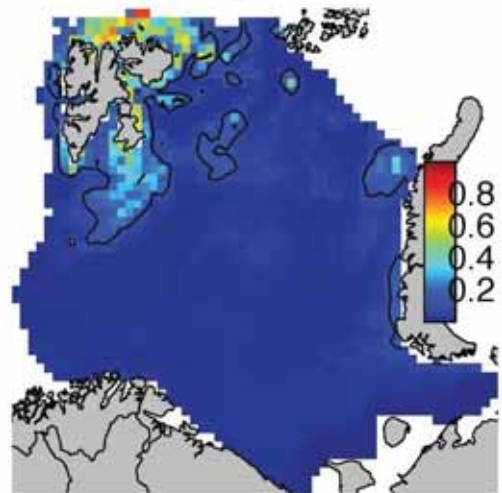
EUMICROTREMUS\_SPINOSUS Scenario 1



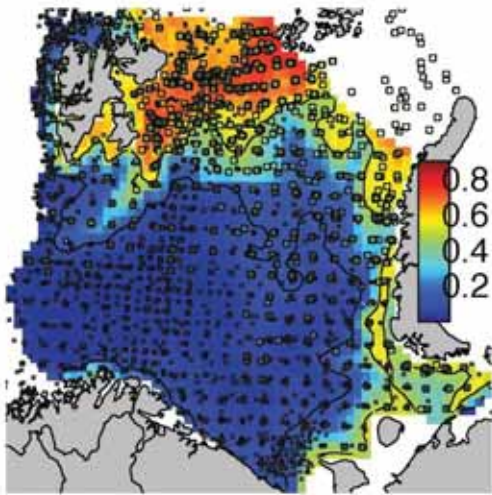
EUMICROTREMUS\_SPINOSUS Scenario 2



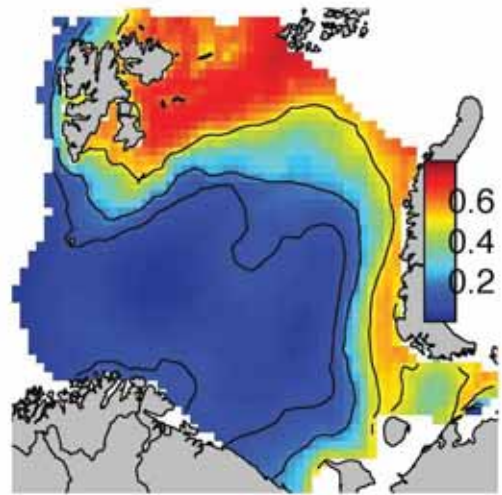
EUMICROTREMUS\_SPINOSUS Scenario 3



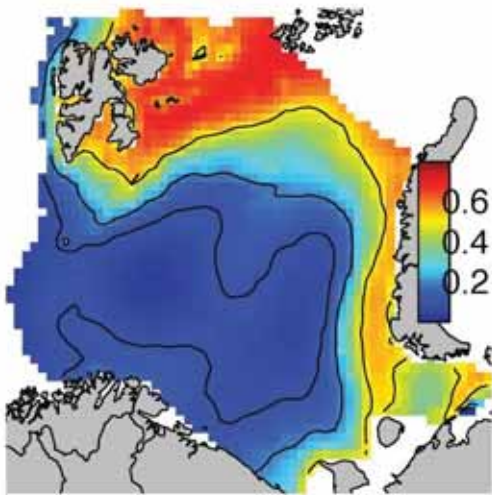
LIPARIS Today



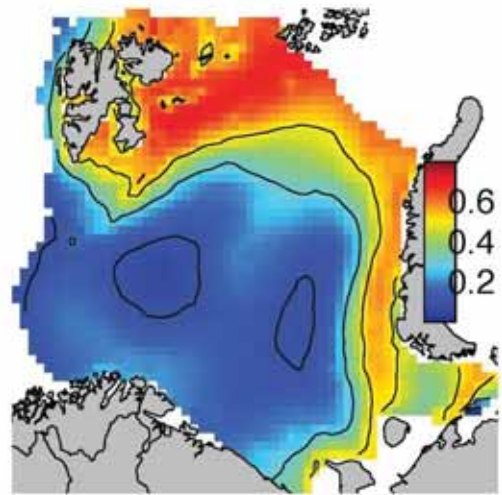
LIPARIS Scenario 1



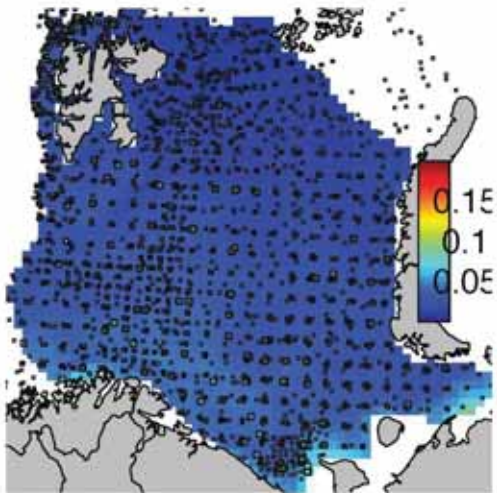
LIPARIS Scenario 2



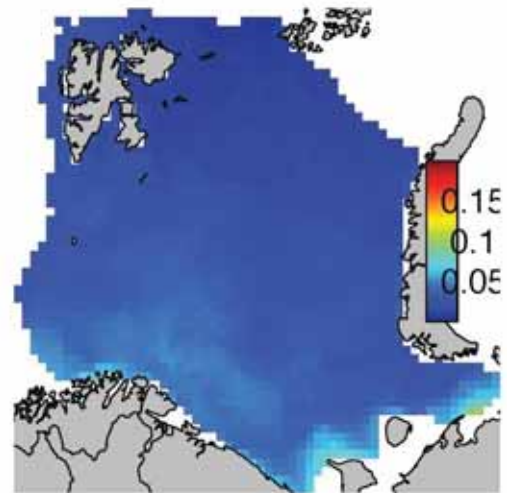
LIPARIS Scenario 3



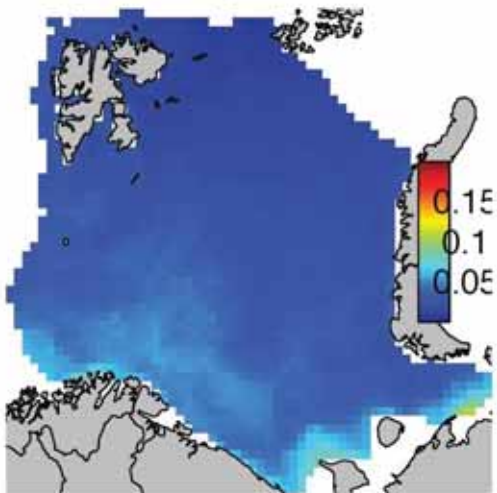
CYCLOPTERUS\_LUMPUS Today



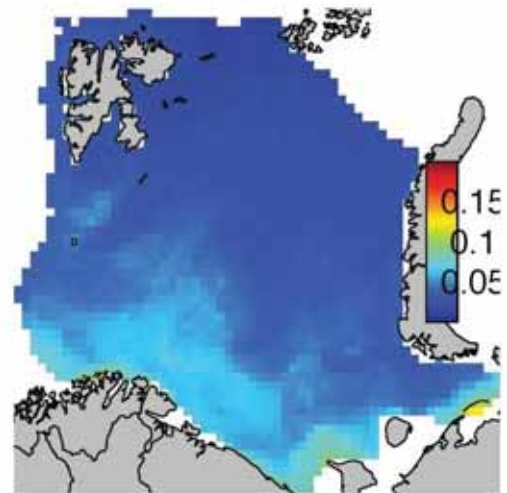
CYCLOPTERUS\_LUMPUS Scenario 1



CYCLOPTERUS\_LUMPUS Scenario 2

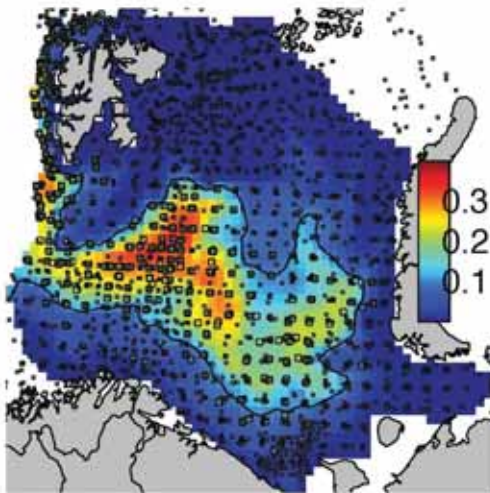


CYCLOPTERUS\_LUMPUS Scenario 3

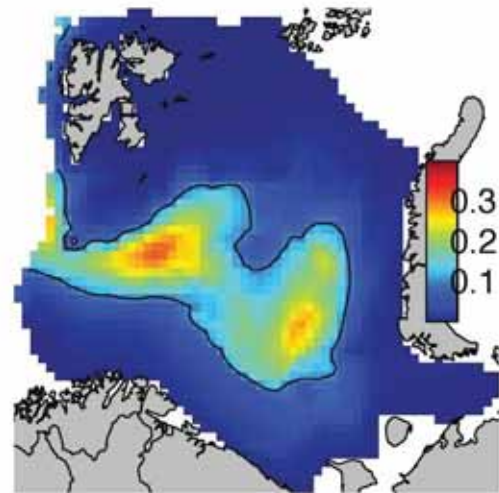




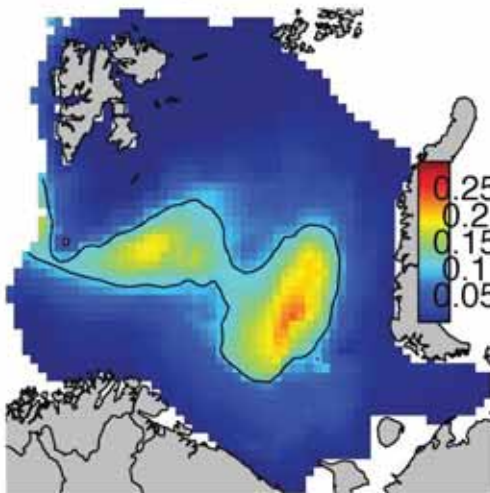
ANARHICHAS\_DENTICULATUS Today



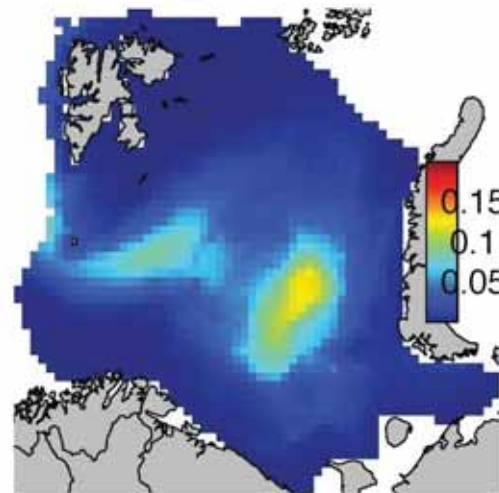
ANARHICHAS\_DENTICULATUS Scenario 1



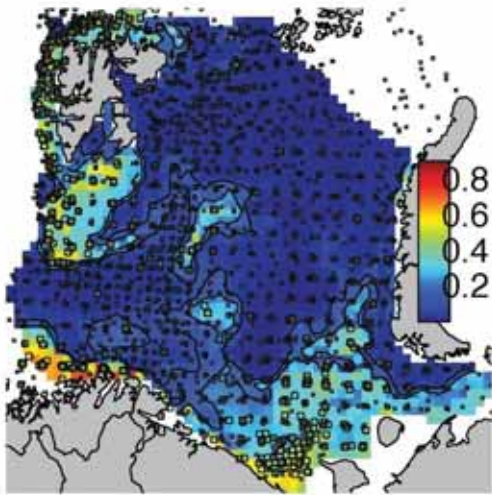
ANARHICHAS\_DENTICULATUS Scenario 2



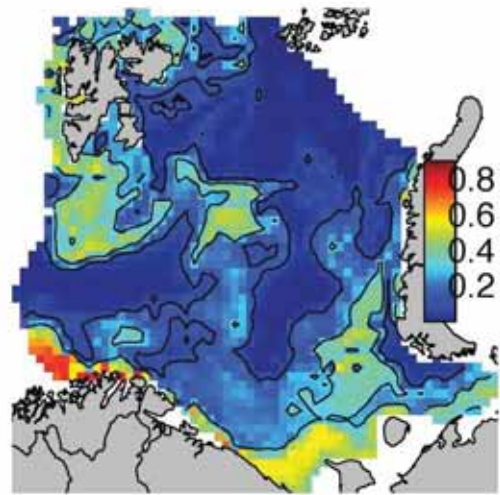
ANARHICHAS\_DENTICULATUS Scenario 3



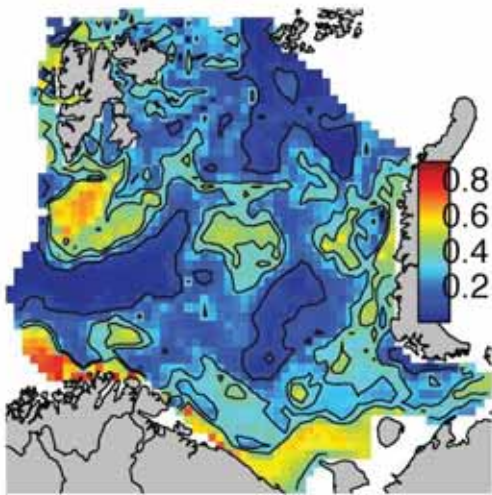
ANARHICHAS\_LUPUS Today



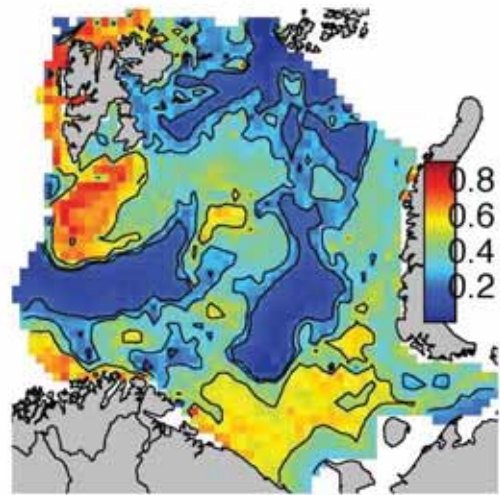
ANARHICHAS\_LUPUS Scenario 1



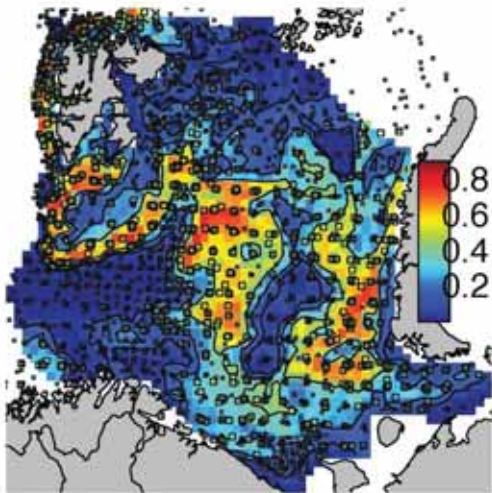
ANARHICHAS\_LUPUS Scenario 2



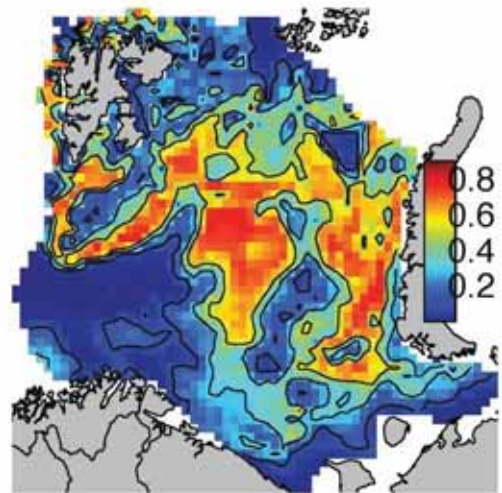
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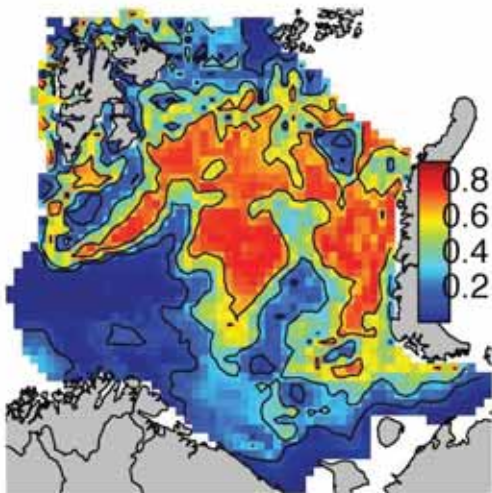
LUMPENUS\_LAMPRETAEFORMIS Today



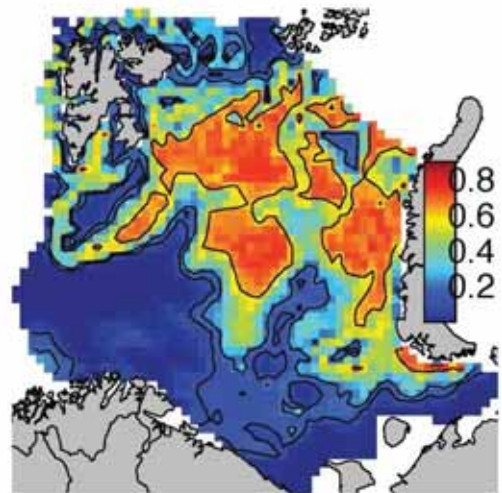
LUMPENUS\_LAMPRETAEFORMIS Scenario 1



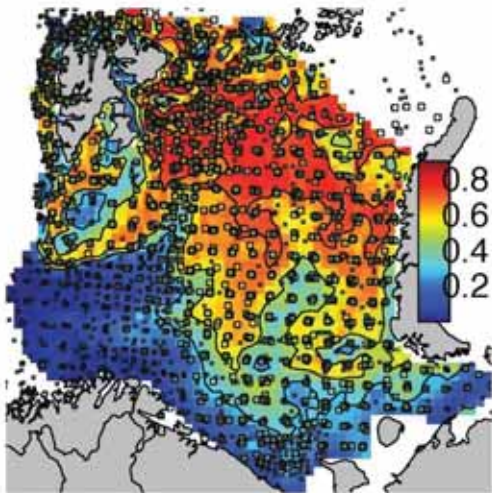
LUMPENUS\_LAMPRETAEFORMIS Scenario 2



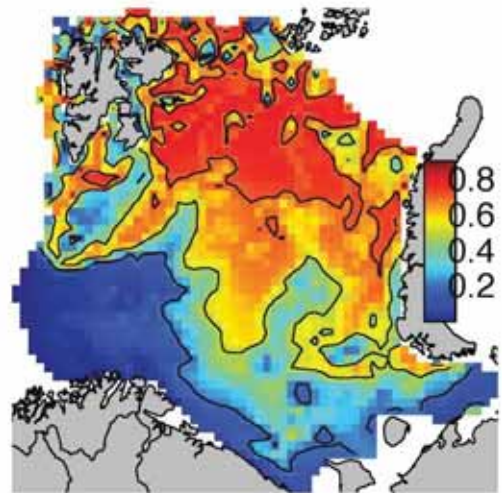
LUMPENUS\_LAMPRETAEFORMIS Scenario 3



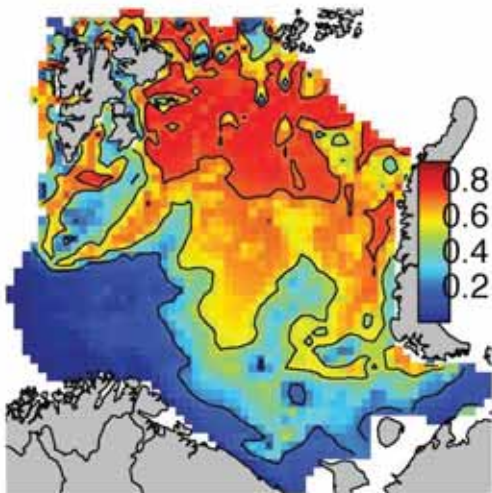
LEPTOCLINUS\_MACULATUS Today



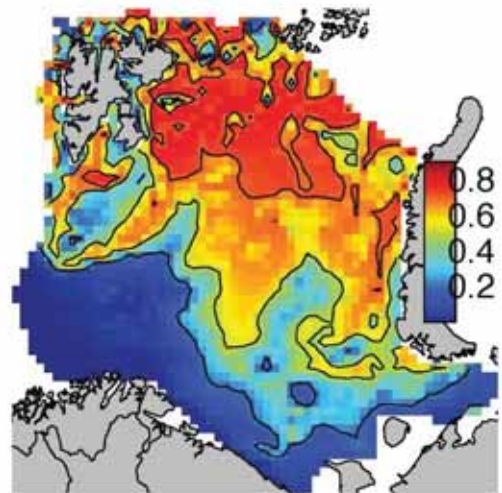
LEPTOCLINUS\_MACULATUS Scenario 1



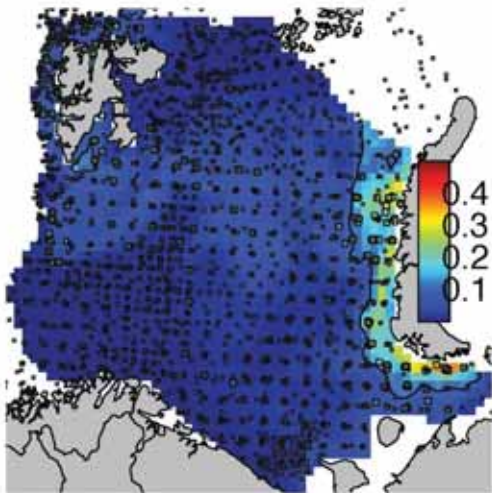
LEPTOCLINUS\_MACULATUS Scenario 2



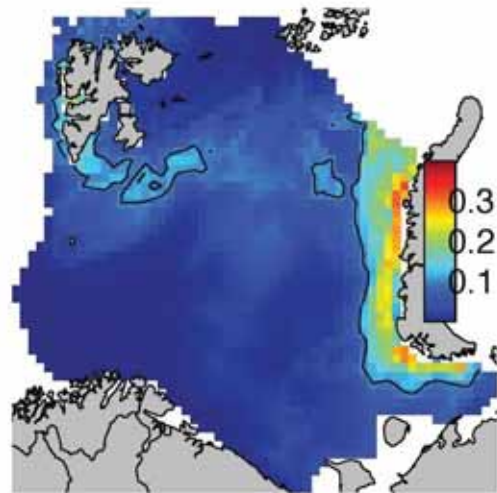
LEPTOCLINUS\_MACULATUS Scenario 3



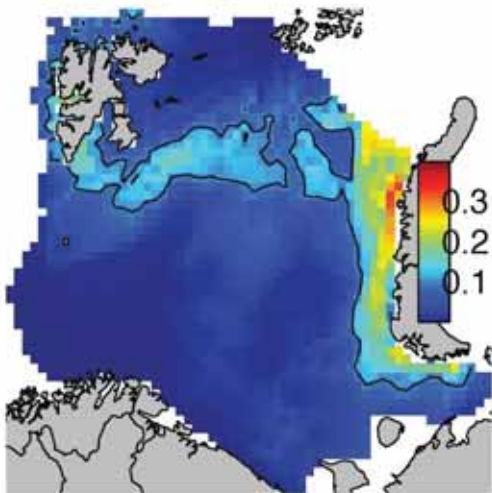
ANISARCHUS\_MEDIUS Today



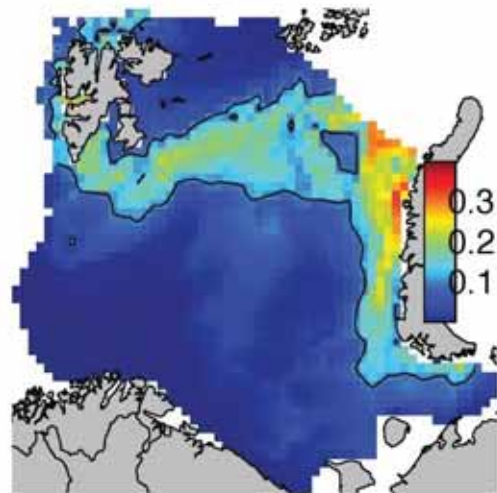
ANISARCHUS\_MEDIUS Scenario 1



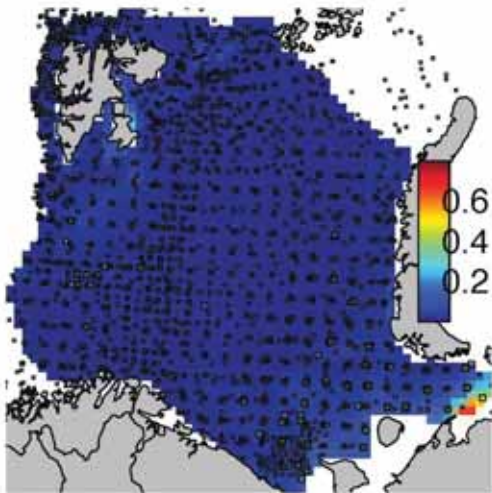
ANISARCHUS\_MEDIUS Scenario 2



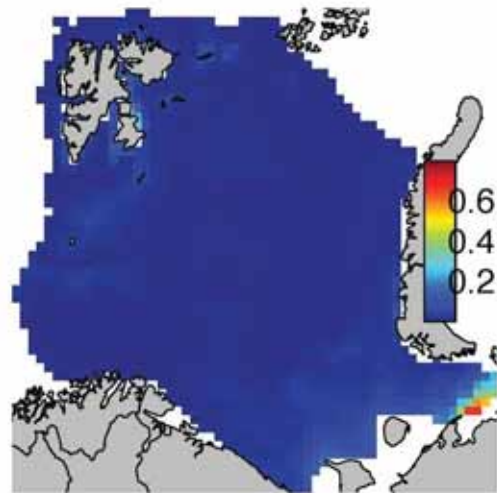
ANISARCHUS\_MEDIUS Scenario 3



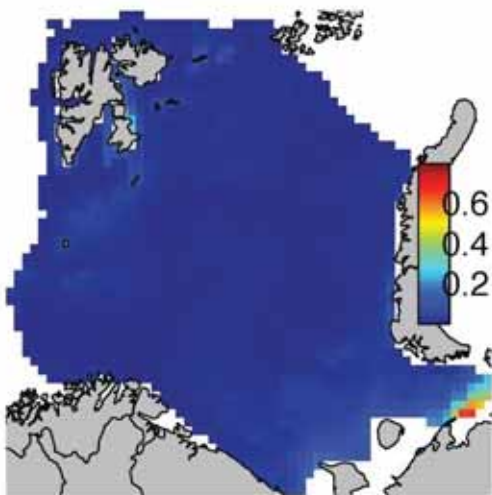
AMMODYTES Today



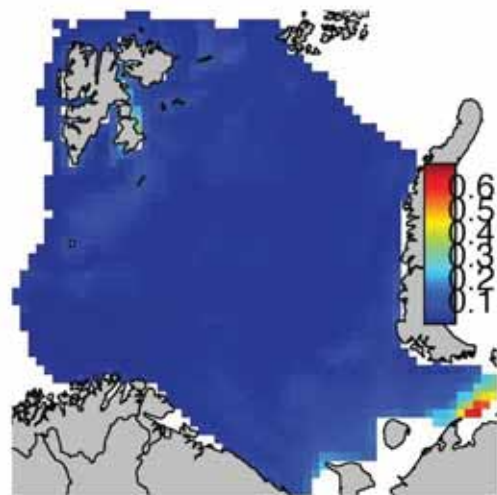
AMMODYTES Scenario 1



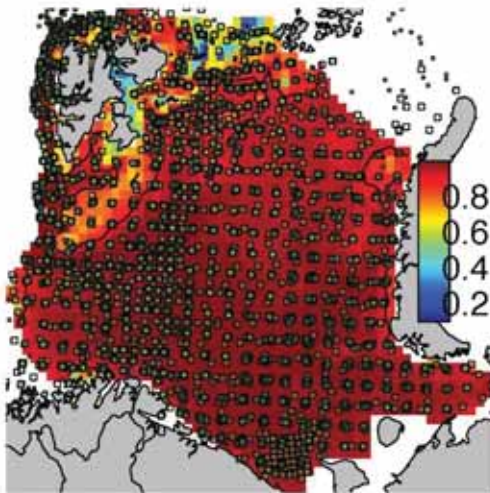
AMMODYTES Scenario 2



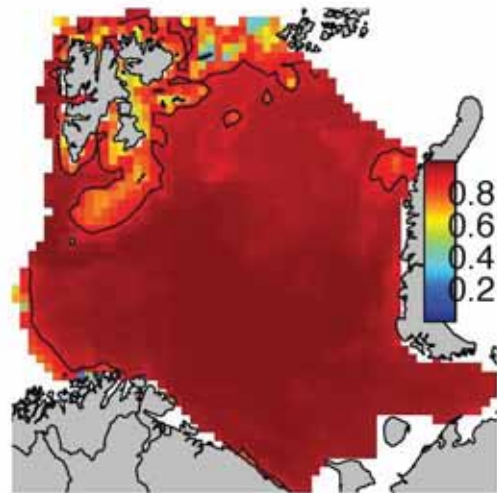
AMMODYTES Scenario 3



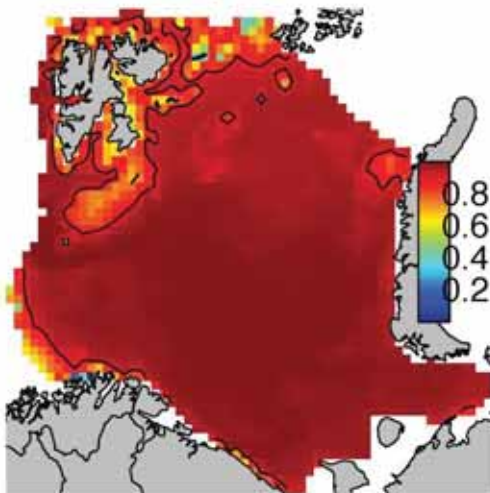
HIPPOGLOSSOIDES\_PLATESSOIDES Today



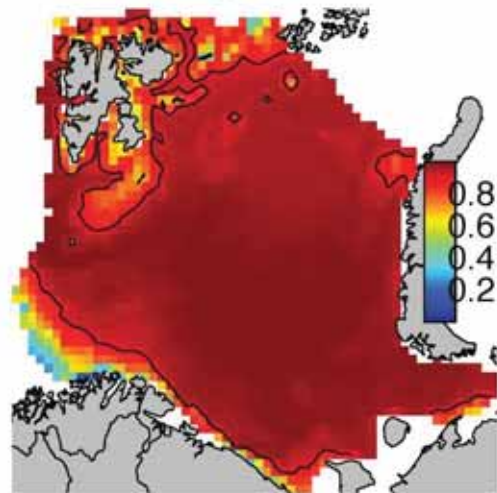
HIPPOGLOSSOIDES\_PLATESSOIDES Scenario 1



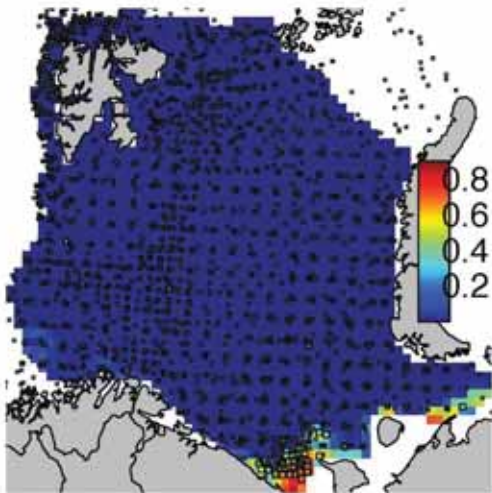
HIPPOGLOSSOIDES\_PLATESSOIDES Scenario 2



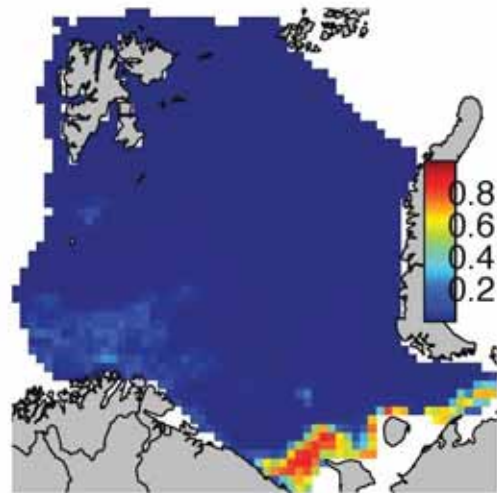
HIPPOGLOSSOIDES\_PLATESSOIDES Scenario 3



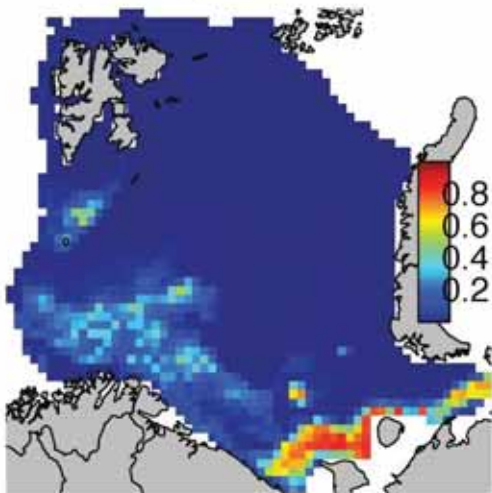
LIMANDA\_LIMANDA Today



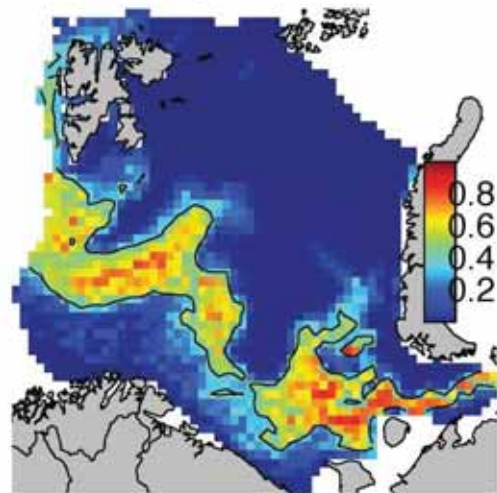
LIMANDA\_LIMANDA Scenario 1



LIMANDA\_LIMANDA Scenario 2

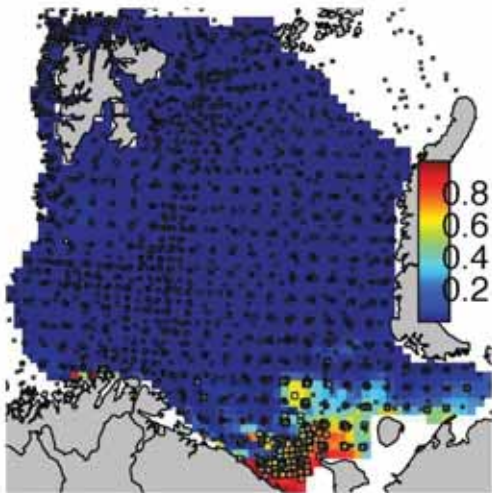


LIMANDA\_LIMANDA Scenario 3

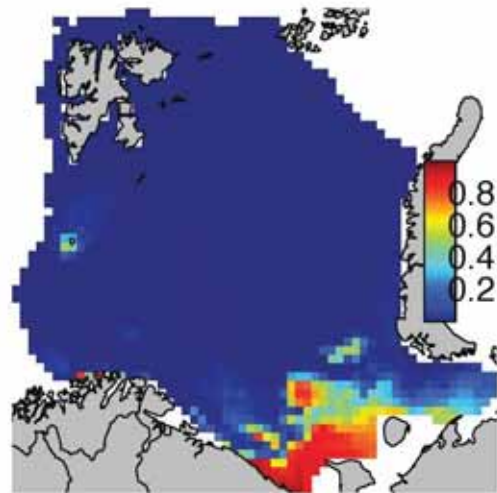




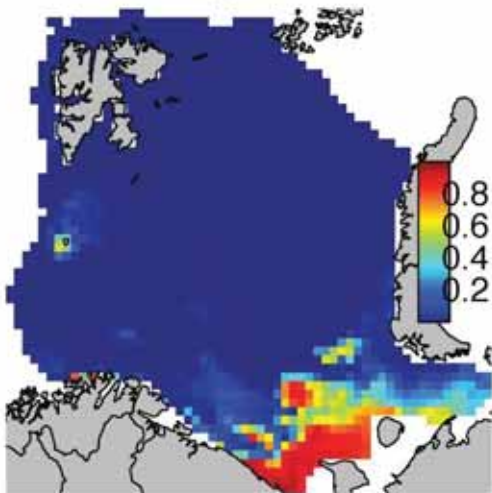
PLEURONECTES\_PLATESSA Today



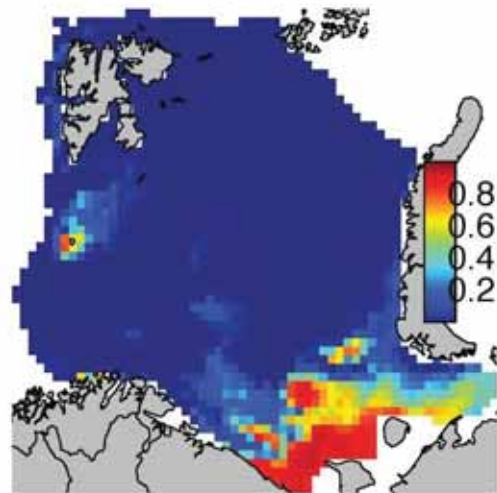
PLEURONECTES\_PLATESSA Scenario 1



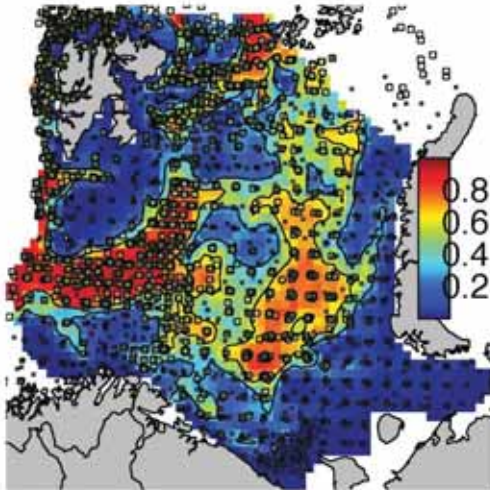
PLEURONECTES\_PLATESSA Scenario 2



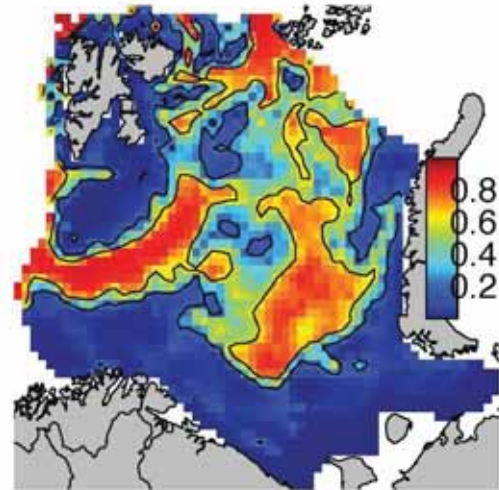
PLEURONECTES\_PLATESSA Scenario 3



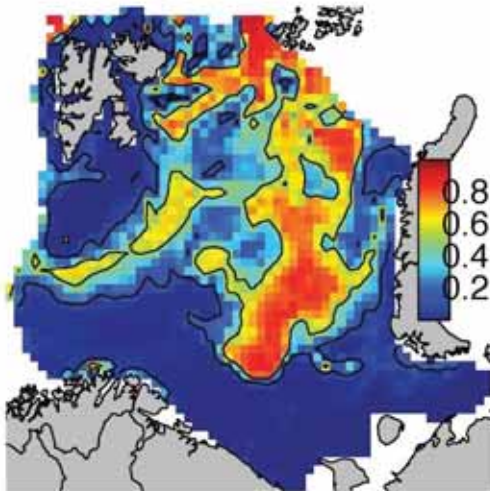
REINHARDTIUS\_HIPPOGLOSSOIDES Today



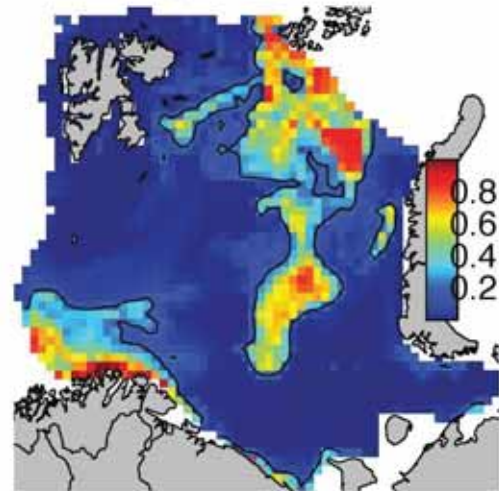
REINHARDTIUS\_HIPPOGLOSSOIDES Scenario 1



REINHARDTIUS\_HIPPOGLOSSOIDES Scenario 2



REINHARDTIUS\_HIPPOGLOSSOIDES Scenario 3





Retur: Havforskningsinstituttet, Postboks 1870 Nordnes, NO-5817 Bergen



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