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National Institute of Aquatic Resources

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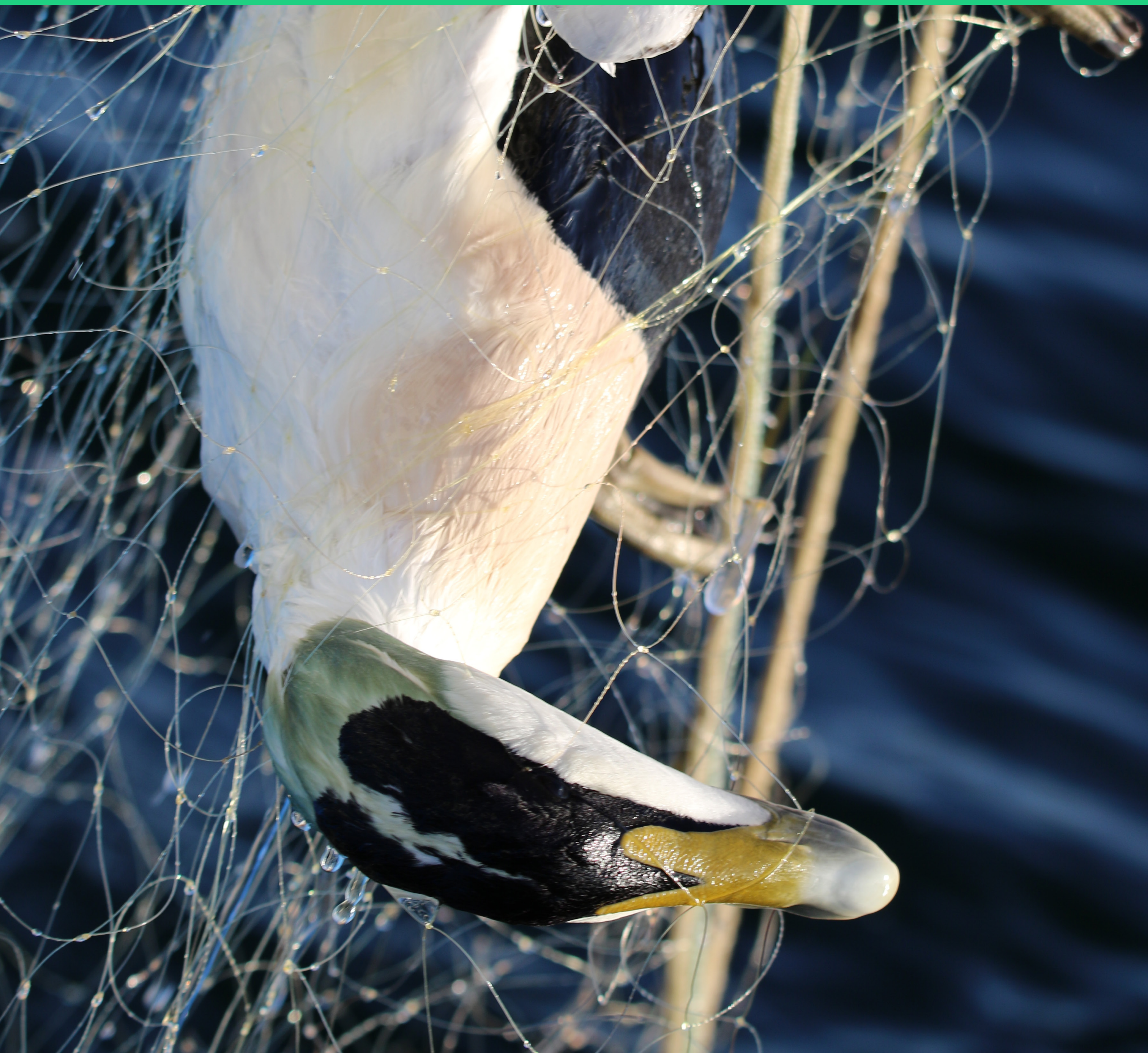
DTU Aqua Report no. 408-2022



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Colophon

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Preface

The project was commissioned by the Danish Environmental Protection Agency and is a part of the overall data collection for the Danish Marine Strategy. Researchers from DTU Aqua have made the report.

Gildas Glemarec
Kgs. Lyngby, August 2022

Content

Purpose of the report

The report is divided into two: 1) an assembly of bycatch data for seabirds, marine mammals and estimates of total bycatch numbers in the Danish gillnet fishery, and 2) an assembly of data on population size and bycatch of non-commercially exploited fish.

1. Bycatch of seabirds and marine mammals

Bycatch of air-breathing animals in commercial fisheries is documented in all fishing gears worldwide, with some gear types being more problematic for particular taxa or species (Lewison *et al.,* 2014). In Danish waters, gillnets have been identified as a major source of bycatch mortality for seabirds and marine mammals (Vinther 1999; Vinther and Larsen 2004; Kindt-Larsen *et al.,* 2016; Glemarec *et al.,* 2020). Air-breathing animals entering in contact with nets' threads face the risk of becoming entangled, which generally results in drowning. For some vulnerable species, the additional mortality due to bycatch can have a significant impact on the size of the affected population(s). In Denmark, opportunistic studies have shown that bycatch rates of birds or mammals in gillnets can locally be very high (e.g., Durinck *et al.*, 1993; Degel *et al.*, 2010), while other studies in the Baltic Sea and the North Sea have demonstrated that current bycatch levels may lead to population decrease in the future (Žydelis *et al.,* 2009; Beest *et al.,* 2017; Marchowski *et al.,* 2020).

Under the Data Collection Framework (DCF), on-board observers collect bycatch data routinely in Danish waters, but the sampling effort in the gillnet fleet is limited. Moreover, commercial gillnetters often do not register bycatch events and report their fishing effort at a rough spatiotemporal scale. As a result, the knowledge on the magnitude and distribution of bycatch of vulnerable species has remained scarce in many areas in Denmark until recently. To fill in these gaps, DTU Aqua started a dedicated bycatch data collection programme in 2010, using Electronic Monitoring systems (EM) with videos. These autonomous systems, installed on volunteering fishing vessels, record the position and speed of the vessel, while capturing video footage of the activities on deck and on the side of the vessel where hauling takes place (Figure 1). These EM data allow monitoring of the entire fishing activity of a vessel at a fine spatiotemporal scale for extended periods of time, and thereby capture the occurrence of rare bycatch events.

Figure 1: Footage from the Danish video-based electronic monitoring programme. Up: inside camera showing the bycatch of a seabird (here, a female common eider Somateria mollissima); Down: outside camera showing the bycatch of a harbour porpoise.

1.1 Methods

Data sources

Bycatch data

In this report, data on bycatch of marine mammals and seabirds in gillnet fisheries were collected using EM on board 17 Danish commercial gillnetters between 2010 and 2019 (Figure 2) in ICES areas

IVb (North Sea), IIIan (Skagerrak), IIIas (Kattegat), IIIb23 (the Sound; Øresund in Danish), IIIc22 (Belt Sea); no data were collected in areas IIId24 and IIId25 (Baltic Proper).

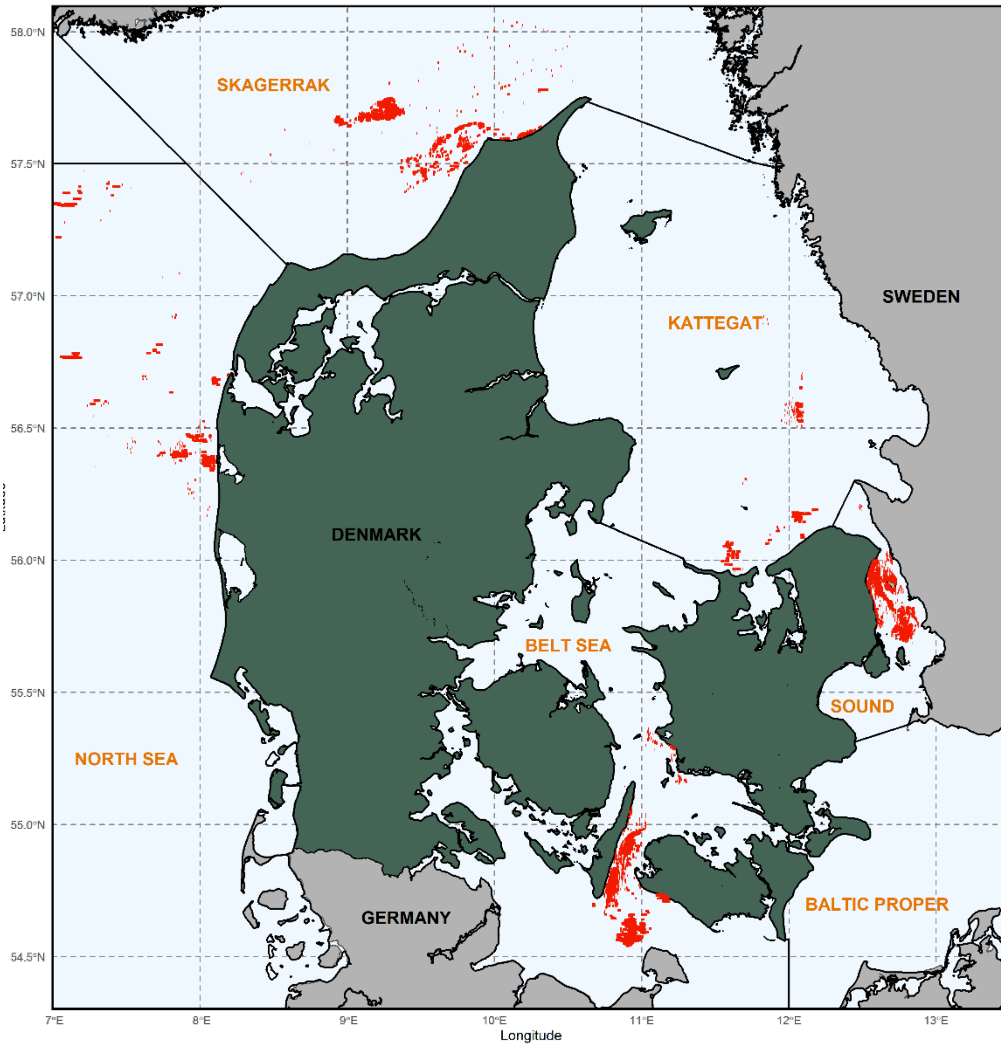

Figure 2: Distribution of the sampling effort (haul positions in red) of the gillnet vessels participating to the EM bycatch data collection programme. Data from 2010-2019. Common name of ICES statistical areas (orange) and separation between ICES statistical areas (black lines) are indicated.

During this period, 5439 vessel-fishing days were recorded and analysed for bycatch, representing an average sampling effort of >2% of the total yearly commercial gillnet fleet effort (Table 1). EM data were also collected for the year 2020, but the Covid-19 crisis slowed down the analysis process considerably. These data were not entirely analysed at the time of writing this report and are therefore not included in the forthcoming analysis.

Table 1: Number of sampled fishing days from 2010-2019 per quarter in the EM bycatch data collection programme. Data from neighbouring ICES areas were grouped together to ensure vessel anonymity, in accordance with EU GDPR rules.

	Q1	Q2	Q3	Q4	Total
North Sea Skagerrak	240	288	316	318	1162
Kattegat Øresund Belt Sea	1023	1319	1020	915	4277
All areas	1263	1607	1336	1233	5439

Two different EM systems were used to monitor the fishing activity and potential bycatch: EM Observe (Archipelago Marine Research Ltd, Canada; http://www.archipelago.ca), replaced with Black Box Video (Anchorlab, Denmark; http://www.anchorlab.dk/) from 2013 and onward. Both EM systems were similar in terms of hardware, consisting of a central processing unit installed in the wheelhouse, integrating data from a position sensor (GPS) and a set of waterproof CCTV (Closed-Circuit TeleVision) cameras recording the activity on deck. Each hardware system was associated with its own specialised EM data analysing software (EM Interpret for Archipelago, and BlackBox Analyzer for Anchorlab - Figure 3), which could both display the recordings alongside information on position and speed of the sampled vessel.

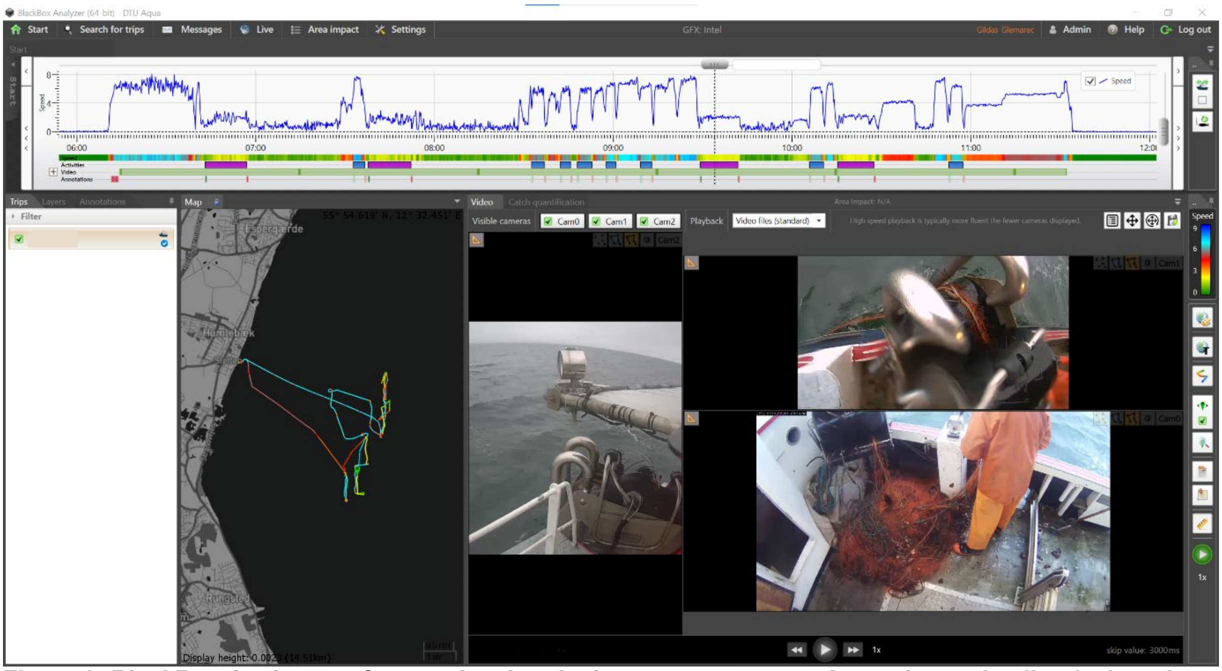

Figure 3: BlackBox Analyzer software, showing the instantaneous vessel speed on a timeline (up), and the map with the position of the vessel and the corresponding video footage from three onboard cameras (down). The details allowing the identification of the vessel were removed.

Data analysts were trained to identify fishing activity (net deployment and retrieval), as well as the bycatch of the species of interest (seabirds, harbour porpoise, and seals). Videos were watched at no more than 3 to 5 times the normal speed, with the possibility to play the sequences frame by frame and rewind. In most cases, angles from multiple cameras and playback functions helped clarifying difficult bycatch items. Nevertheless, weather conditions, luminosity, potential sun flares, or the general cleanliness of the camera lenses could affect image readability; fishers could also sometimes place themselves in the visual field in a way that made the identification process difficult. Generally, degraded image quality could make bycatch identification challenging, yet in most cases the animals observed as bycatch were identified down to species level.

The identification of bycaught animals from the video recordings was generally possible down to species level (95.8%), but some animals could only be identified at genus (0.7%), family (1.1%), or class level (2.4%). There were specific challenges with seal identification as juvenile grey seals can be difficult to distinguish from adult harbour seals in the collected video footage. As a result, seals were identified down to species in only 90.5% of the cases. For categories with rare occurrences in the dataset, grouping was sometimes necessary to allow for statistical analyses. Three main groups were focused on: seals (combining grey seal (*Halichoerus grypus*) and harbour seal (*Phoca vitulina*)), harbour porpoise (*Phocoena phocoena*), and seabirds (categorised as species or group of species, e.g., genus or family). Additionally, some species of seabirds that express sexual or age dimorphism were categorised accordingly, namely the common eider (males and females) and the great cormorant (juveniles and adults). Table 2 shows the number of animals of each species (or group of species) recorded with EM during the study period.

Table 2: Number of bycatches of protected species observed per quarter from 2010-2019 in the EM bycatch data collection programme. Data from neighbouring ICES areas were grouped together to ensure vessel anonymity, in accordance with EU GDPR rules.

	Kattegat Øresund Belt Sea				North Sea Skagerrak			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Birds (all species)	**677**	**91**	**132**	**404**	**26**	**1**	**24**	**55**
Common eider (female + male)	**232**	**64**	**41**	**239**	**0**	**0**	**1**	**0**
Common eider (female)	**43**	**12**	**15**	**55**	**0**	**0**	**0**	**0**
Common eider (male)	**177**	**42**	**17**	**177**	**0**	**0**	**1**	**0**
Great cormorant (juvenile + adult)	**33**	**5**	**75**	**61**	**0**	**0**	**5**	**2**
Great cormorant (juvenile)	**21**	**2**	**44**	**41**	**0**	**0**	**2**	**1**
Great cormorant (adult)	**8**	**0**	**18**	**14**	**0**	**0**	**3**	**0**
Alcidae (all species)	**377**	**14**	**8**	**71**	**20**	**0**	**8**	**48**
Gavidae (all species)	**3**	**1**	**0**	**4**	**0**	**0**	**0**	**0**
Northern fulmar	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**1**
Laridae (all species)	**1**	**1**	**1**	**2**	**1**	**0**	**1**	**0**
Scoter (all species)	**19**	**3**	**3**	**21**	**0**	**0**	**0**	**2**
Grebe (all species)	**4**	**0**	**2**	**2**	**0**	**0**	**0**	**0**
Other bird species	**8**	**3**	**2**	**4**	**5**	**1**	**5**	**2**
Harbour porpoise	**35**	**8**	**8**	**33**	**6**	**1**	**10**	**5**
Harbour seal + grey seal	**38**	**97**	**62**	**35**	**13**	**40**	**92**	**22**

Fishing effort data
Fishing effort data of the vessels which had registered gillnets as their primary or secondary gear for the period 2010-2019 were collated from fisher-reported logbooks for the vessels above 10 metres in overall length (or above 8 metres in the Baltic Sea if the main target species of the vessel is cod (*Gadus morhua*)), monthly declarations (mandatory for vessels between 8 and 10 metres in place of logbooks), and sales notes. In Denmark, these data are reported at the spatial scale of ICES statistical rectangle, a square of 30x30nm and rarely, if ever, mention bycatch of protected species. It can be

noted that the overall effort of the Danish gillnet fishing fleet (measured as the total number of fishing days per year) decreased significantly since 2010 by approx. 25%, with local variation between fishing areas. Figure 4 shows the distribution and intensity of the gillnet effort around Denmark during the study period and illustrates the reduction in overall gillnet effort between the first and the second half of the study period.

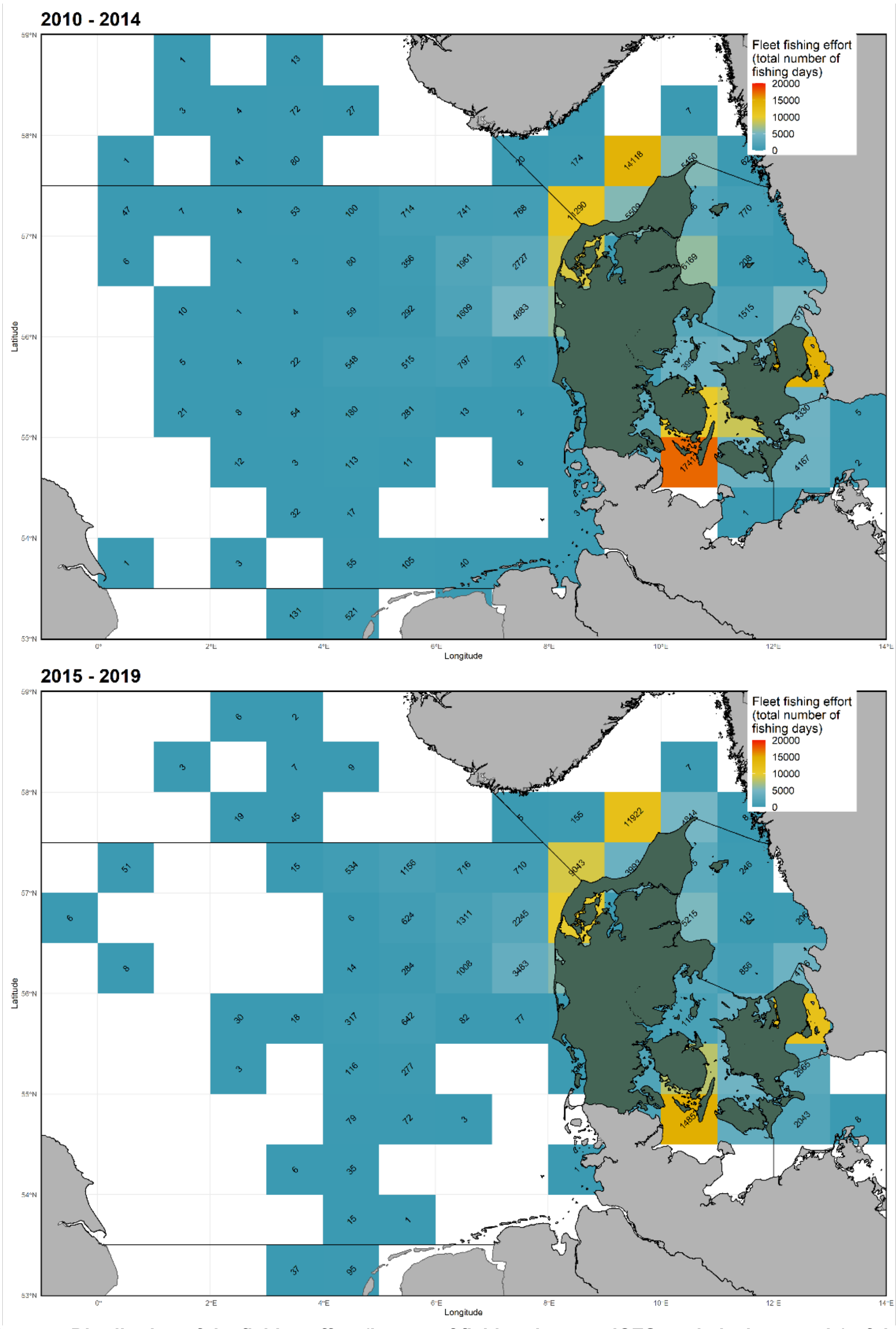

Figure 4: Distribution of the fishing effort (in sum of fishing days per ICES statistical rectangle) of the Danish commercial gillnet fleet for the periods 2010-2014 and 2015-2019. Delimitations between ICES areas are marked as plain grey lines.

Bycatch probability maps

Bycatch model development

Preliminary investigations of the EM dataset showed that species-specific bycatch rates (measured as the number of individuals of a species captured by net length times soak time) were not linearly proportional to the intensity of the fishing effort, but instead varied in time and space. Kindt-Larsen *et al.* (2016) studied such a relationship between net fisheries and harbour porpoise bycatch in the Skagerrak, by fitting a statistical model using a combination of EM and population density data as input. Roughly speaking, this approach consisted of estimating the local probability that a bycatch event occurs given the estimated local porpoise density and the intensity of the fishing effort, while considering the characteristics of the fishery (e.g., average soak time, net length, mesh size, fishing area, season, etc.). In the present report, unlike what was done in Kindt-Larsen *et al.* (2016), data on species densities were incomplete or too coarse for the entire study area, so we developed an alternative model template to explain the observed variations of bycatch rates for each individual species (or group of species species) in the EM dataset based on a combination of operational and ecological parameters.

Concretely, we built a dataset associating bycatch data (number of individuals captured per haul) and information on mesh size, net length, soak time, position of the fishing gear (including ICES area in which fishing was registered, depth at immersion and distance to shore), and temporal dummy variables (year and quarter). This dataset was created from combining the analysed EM data and additional data from official logbooks and sales notes from 2010 to 2019. Our aim was to construct simple and informative maps showing the areas of high-risk of bycatch around Denmark, associated with the uncertainty in the bycatch rate estimates. To achieve this, we created statistical models, assuming that the response variable (the number of bycaught individuals of a species per haul) was related to a combination of fishing effort (measured by soaking duration and total length of the net fleet), and mesh size (which can be used as a proxy for the targeted fish species), while accounting for seasonality and fishing location. Since we knew the position of each haul in the EM dataset, we included additional variables as depth of fishing and distance between the net fleet and the closest point on shore. Moreover, preliminary analyses of the data collected with EM had showed clear signs of spatial autocorrelation, i.e., bycatch events were often clustered in space. To account for this, we also included a spatial autocorrelation parameter to the models using a stationary spatial field with an exponentially decreasing correlation between spatial points.

We wanted to feed a generalised linear model (GLM) with the observed bycatches and fitted a model for each species (or group of species) for each quarter and for the entire year. The response was a count (number of individuals bycaught per haul), so Poisson and negative binomial distributions were initially considered (both using a log link). However, the data were clearly overdispersed with a majority of zeros in the dataset for all species (or group of species). Unlike the Poisson distribution, the negative binomial distribution does not assume equality between mean and variance, allowing more flexibility for the model, often making it a better choice in bycatch estimation studies with lots of zeros (Bærum *et al.,* 2017; Bertram *et al.,* 2021). Therefore, a negative binomial distribution (with a log link) was preferred for this study. Practically, for each species (or group of species), we fitted a full model including all the potential variables of interest in the dataset (Table 3). Then, for each species (or group of species), we also fitted all simpler models containing a subset of the full model's variables and compared all these models using AIC. We selected the best model as the one with the lowest AIC score (Vaida and Blanchard 2005). We built models for harbour porpoise, seals (combining data on harbour and grey seals), and for each species (or group of species) of seabirds for which enough bycatch data were available, i.e., for the common eider (female, male, and total), the great cormorant (juvenile, adult, and total), alcids (combining data on common guillemot and razorbill), and scoters (combining data on velvet and common scoters). For other bird species, including loons (common and black-throated loon), northern fulmar, seagulls (greater black-backed and herring seagull), grebes (red-necked and great crested grebe), and other unidentified seabirds, occurrences of bycatch were rare, and the single-species models generally failed to converge, so these species were grouped together in the category “other birds”.

Table 3: List of the variables included in the bycatch models. All the models included a spatial autocorrelation component.

Variables	Description
Number of bycatches per haul	Number of individuals of a species (or group of species) taken as bycatch per haul
log(soak)	Soaking duration of the haul (continuous variable in log(hours))
net length	Total length of a haul (continuous variable in metre)
mesh	Size of the stretched mesh in the haul (categorical variable with 3 levels: <120mm, 120-200mm, and >200mm)
d2shore	Distance between the haul and the closest point on shore (continuous variable metre)
depth	Maximal depth of the haul (continuous variable metre)
quarter	Categorical variable with 4 levels
year	Categorical variable with 10 levels
X(*lon*;*lat*)	Spatial correlation variable (decreasing exponentially as a function of the Euclidian distance between spatial points)

The data management and model fitting were dealt with in the R language, using notably the *glmmTMB* package to fit GLMs with a spatial component (Brooks *et al*., 2017; R Core Team 2021). All resulting “winning” models were assessed for goodness-of-fit by a simulation-based approach, similar to a Bayesian p-value or a parametric bootstrap, using the *DHARMa* package (Hartig 2021).

Model predictions and mapping

The selected models were used to estimate the local bycatch risk for each species (or group of species) using the function *predict* in R, returning the predicted values and the associated uncertainty (as standard error). The relative risk of bycatch (no unit) and the uncertainty of the bycatch risk estimates were mapped for the selection of species (or group of species). For each location in the dataset, the uncertainty was estimated using a modified coefficient of variation (CV), such as the modified CV was the standard error of the prediction divided by the predicted value. This statistic can be interpreted as the confidence one can have in the estimate at a given location. It is usually admitted that a CV of 0.3 or less represents a high confidence in the prediction, while above 0.5, the predictions should be taken with a grain of salt. Generally, areas with low confidence (high CV) correspond to those areas where sampling effort was low.

To allow for an easier interpretation of the results, the data points (predictions and uncertainties) on the maps were interpolated. Simply put, this means that we used the information from a limited number of locations (the sampling locations) and applied a mathematical model to provide an educated guess of what the results might look like, if we would have sampled at every possible location. In the bycatch probability maps, we assumed that the points closer in space were more related to one another, and fitted an Inverse Distance Weighting function (IDW) using the R package *gstat* (Pebesma 2004; Gräler, Pebesma, and Heuvelink 2016). For the uncertainty maps, we used the Thin Plate Splines (TPS) regression interpolation method from the *fields* package (Nychka *et al.,* 2021), allowing to map the uncertainty over the entire study area.

Bycatch estimates

Estimating total bycatch of a species at fleet level can be done in a number of ways depending on the bycatch rate and the effort data at-hand (Moore *et al.,* 2021). For instance, Vinther (1999) estimated the total bycatch of harbour porpoises in gillnets using fisheries observers and landings data. While we had access to fine-scale fisheries-dependent data from the EM programme, we could not directly extrapolate bycatch rates at haul level to the entire fleet, as this information is not systematically reported in Denmark for vessels below 12 metres in overall length, which constitute the majority of Danish commercial gillnetters. Therefore, we estimated mean bycatch rates per fishing day for each species (or group of species) and scaled up these estimates from the official logbook and sales notes data from Danish fishers. In summary, the bycatch data collected using EM were combined with fisher-reported data (logbooks and sales notes) to calculate the total bycatch estimate in the Danish setnet fishery for each species (or group of species) per quarter. Fleet-level bycatch mortality was estimated individually for each target group vulnerable to bycatch in gillnets (different species of seabirds, harbour porpoise, and seals). First, using fine-scale EM data from Danish commercial gillnet vessels between 2010 and 2019, mean bycatch rates (bycatch per unit effort or BPUE) were estimated as the number of individuals of each taxon captured per fishing day per quarter per region. Then, data were collated from official fishing logbooks and sales notes for all the vessels which had registered gillnets as their primary or secondary gear for the period 2010-2019 (Figure 4), and mean fishing effort estimates were calculated as the mean total number of fishing days per quarter per region (Table 4). A fishing day was defined as a calendar day during which at least one hauling operation had been registered. Confidence intervals around the mean estimator were obtained using a bootstrapping technique (100 000 repetitions). Finally, the stratified BPUE estimates for each target group and the associated confidence intervals were multiplied with the stratified fishing effort estimates to obtain the corresponding bycatch estimates per quarter per region. Likewise, yearly species-specific bycatch estimates per region were obtained using a similar approach, but they had to be averaged out over the entire study period to ensure vessel anonymity, following the obligations of the European Union General Data Protection Regulation (EU) 2016/679 (GDPR).

Table 4: Number of fishing days per quarter in the Danish commercial gillnet fleet. Data from 2010-2019 compiled by DTU Aqua from official logbooks, sales notes, and monthly declarations.

	Q1	Q2	Q3	Q4	Total
North Sea	1497	2483	1432	854	6266
Skagerrak	1306	2213	1368	1369	6256
Kattegat (incl. Isefjord)	1211	1616	1088	350	4264
Belt Sea	2327	2809	2122	1931	9189
Øresund	726	730	975	1220	3650
All areas	7361	10416	7282	6047	31106

1.2 Results

Bycatch models

Table 5 presents the model structure of all the models used to build the bycatch risk maps. For some species (or group of species) of seabirds with rare occurrences (i.e., with less than 10 occurrences of each species recorded over the course of the monitoring programme), we were not able to build models that would converge, so these were grouped in the category “Other Birds”.

Table 5: Model structure of the models used to build the bycatch risk maps (y = Year; Q = Quarter; log(st) = soak time; nl = net length; m = mesh size; d = depth; d2s = distance to shore; X(lon;lat) = spatial correlation variable).

Response variable	Fixed effects structure
Porpoise per haul	~ y + Q + log(st) + nl + m + d + d2s + X(lon;lat)
Seals per haul	~ Q + log(st) + nl + m + X(lon;lat)
Seabirds per haul (all species)	~ y + Q + log(st) + nl + d + X(lon;lat)
Common eider per haul	~ y + Q + log(st) + d + X(lon;lat)
Common eider per haul (female)	~ Q + log(st) + d + X(lon;lat)
Common eider per haul (male)	~ Q + log(st) + m + d + d2s + X(lon;lat)
Great cormorant per haul	~ y + Q + m + d + d2s + X(lon;lat)
Great cormorant per haul (juvenile)	~ Q + X(lon;lat)
Great cormorant per haul (adult)	~ Q + X(lon;lat)
Alcids per haul (common guillemot and razorbill)	~ y + Q + nl + m + d + d2s + X(lon;lat)
Scoters per haul (common and velvet scoters)	~ Q + log(st) + m + d + d2s + X(lon;lat)
Other seabird species per haul	~ y + Q + log(st) + nl + m + d + d2s + X(lon;lat)

Bycatch probability maps

The maps (Figure 5-Figure 28) presented in this section illustrate the predictions from the bycatch models and show the relative (i.e., no unit) species-specific bycatch risk in the Danish commercial gillnet fisheries with the associated coefficient of variation. These maps could only be created for the species (or group of species) for which enough data were available from the bycatch monitoring programme using EM. Rare species of seabirds were grouped into the category “Other Birds” and a model was created specifically for this subset of the dataset.

Harbour porpoise

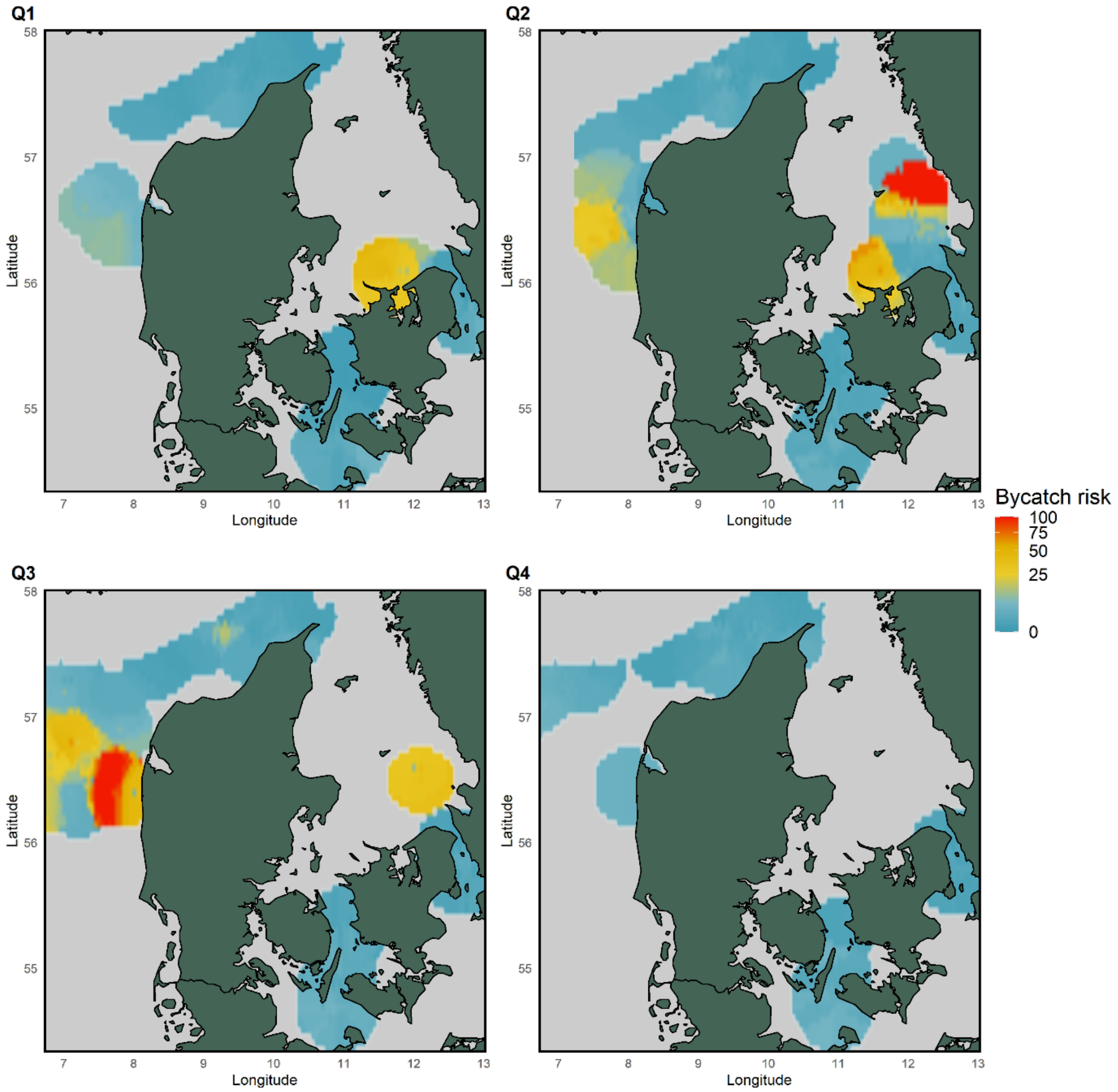

Figure 5: Quarterly bycatch risk (no unit) for harbour porpoise in the Danish commercial gillnet fleet, from model predictions using electronic monitoring data (2010-2019). Regions in light grey correspond to areas where sampling effort was too low to assess bycatch risk (see Figure 2 for comparison).

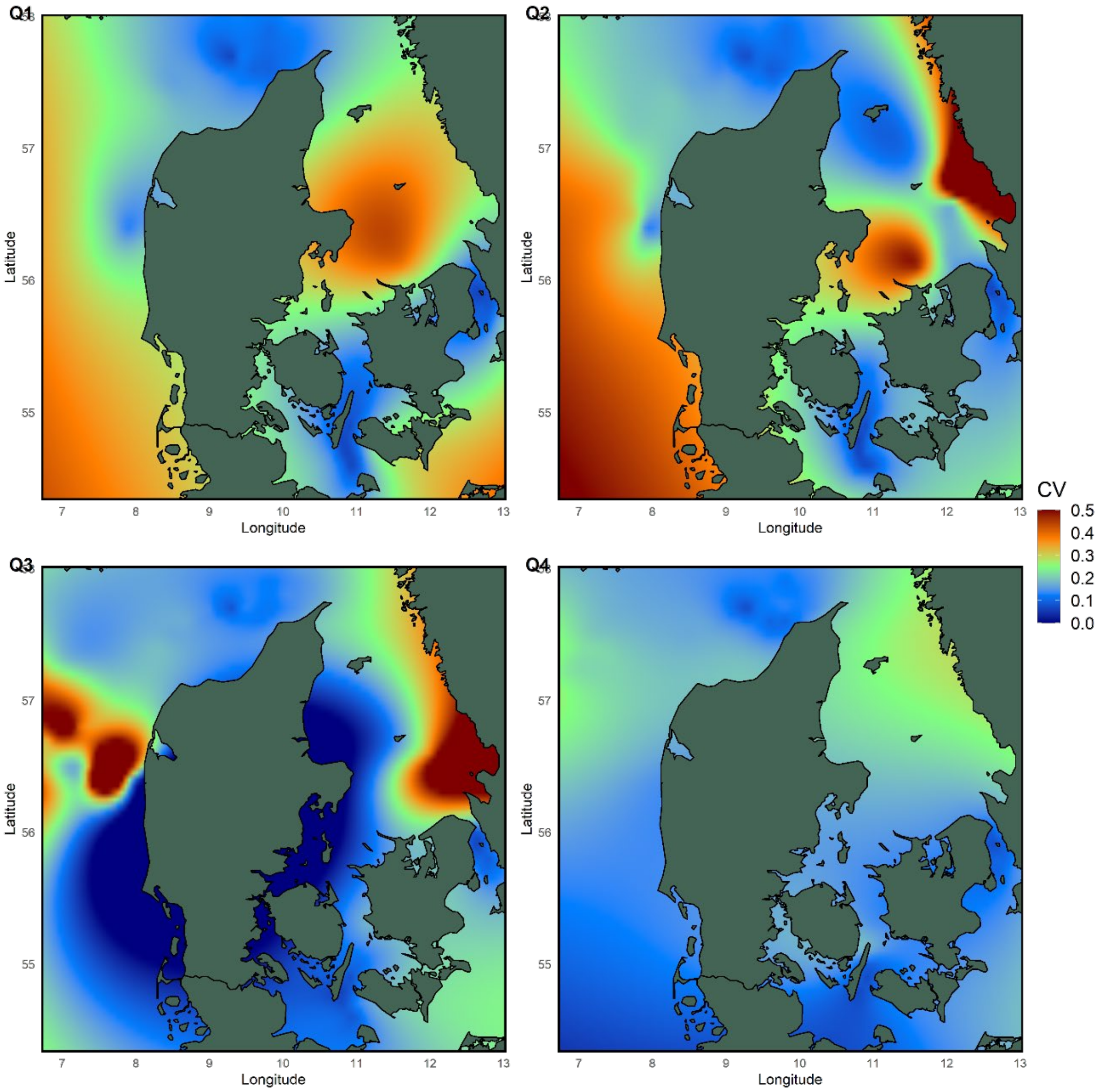

Figure 6: Uncertainty (coefficient of variation) of the quarterly harbour porpoise bycatch risk estimates, using EM data from Danish commercial gillnet vessels (2010-2019). Areas with values below 0.3 represent high confidence in the bycatch risk predictions in the previous figure; variability in the bycatch risk estimates is very high in areas with values equal or above 0.5.

Seals (harbour seal and grey seal)

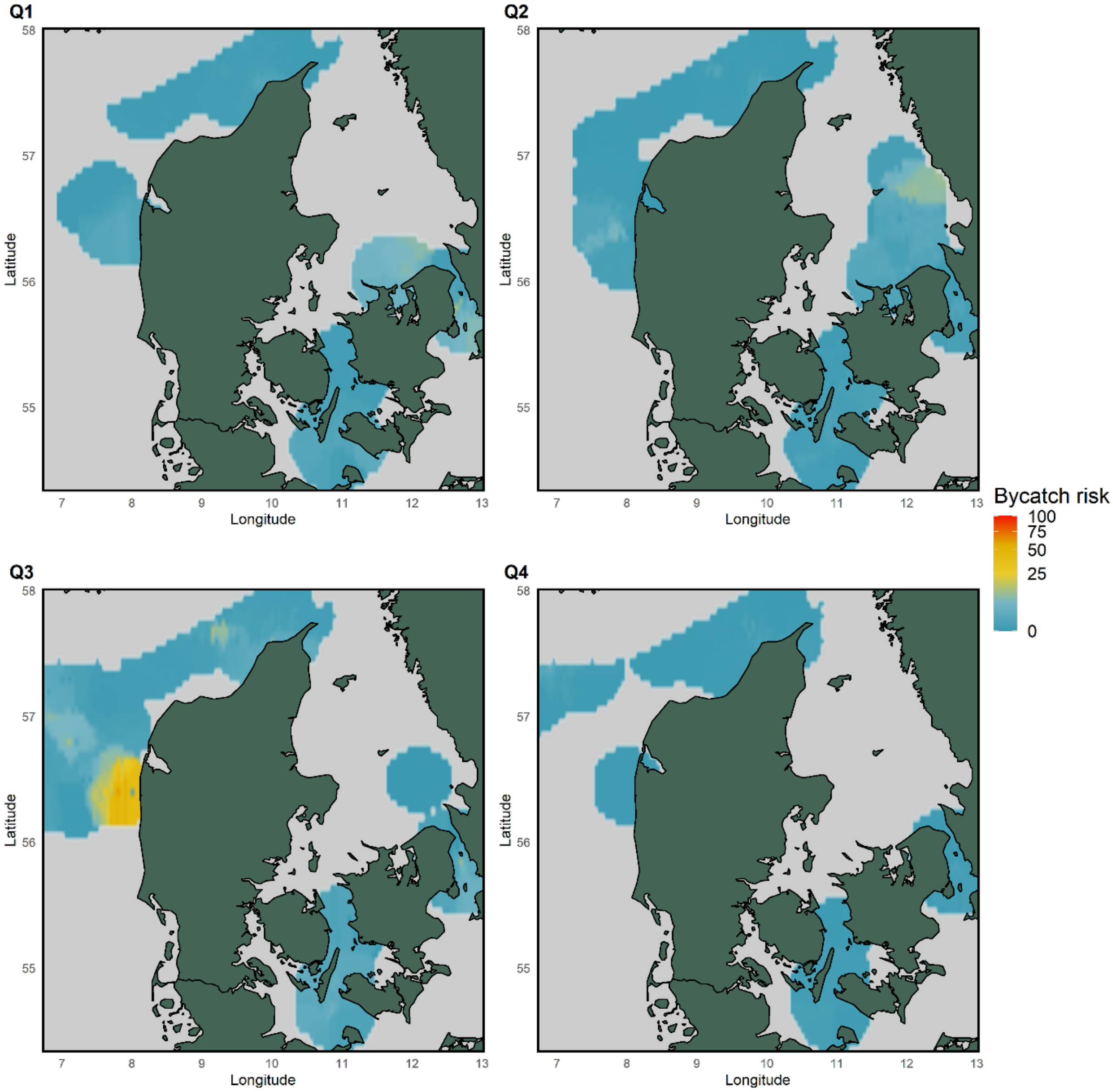

Figure 7: Quarterly bycatch risk (no unit) for seals (harbour seal and grey seal) in the Danish commercial gillnet fleet, from model predictions using electronic monitoring data (2010-2019). Regions in light grey correspond to areas where sampling effort was too low to assess bycatch risk (see Figure 2 for comparison).

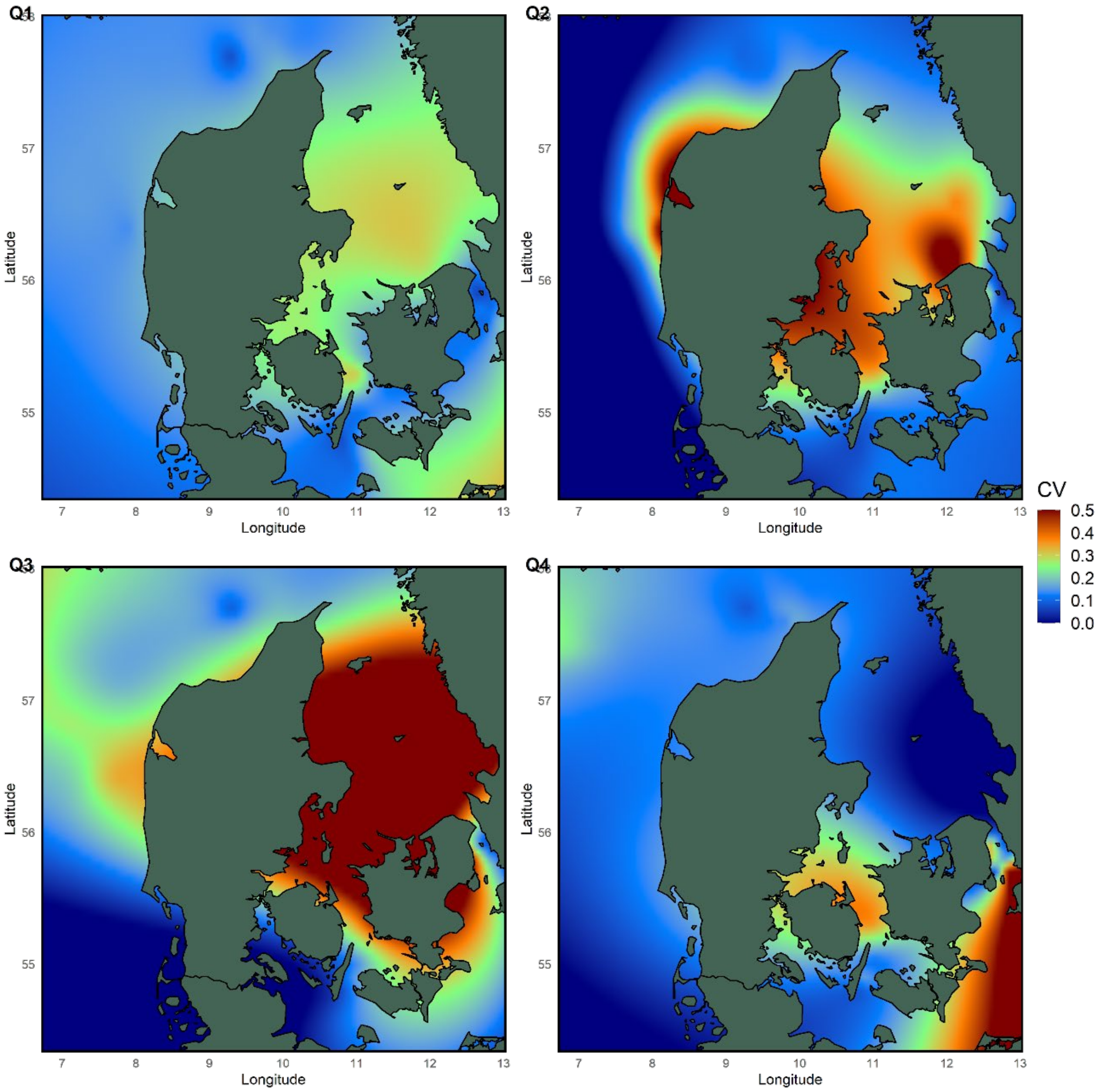

Figure 8: Uncertainty (coefficient of variation) of the quarterly seal bycatch risk estimates (incl. harbour seal and grey seal), using EM data from Danish commercial gillnet vessels (2010-2019). Areas with values below 0.3 represent high confidence in the bycatch risk predictions in the previous figure; variability in the bycatch risk estimates is very high in areas with values equal or above 0.5.

Birds (all species)

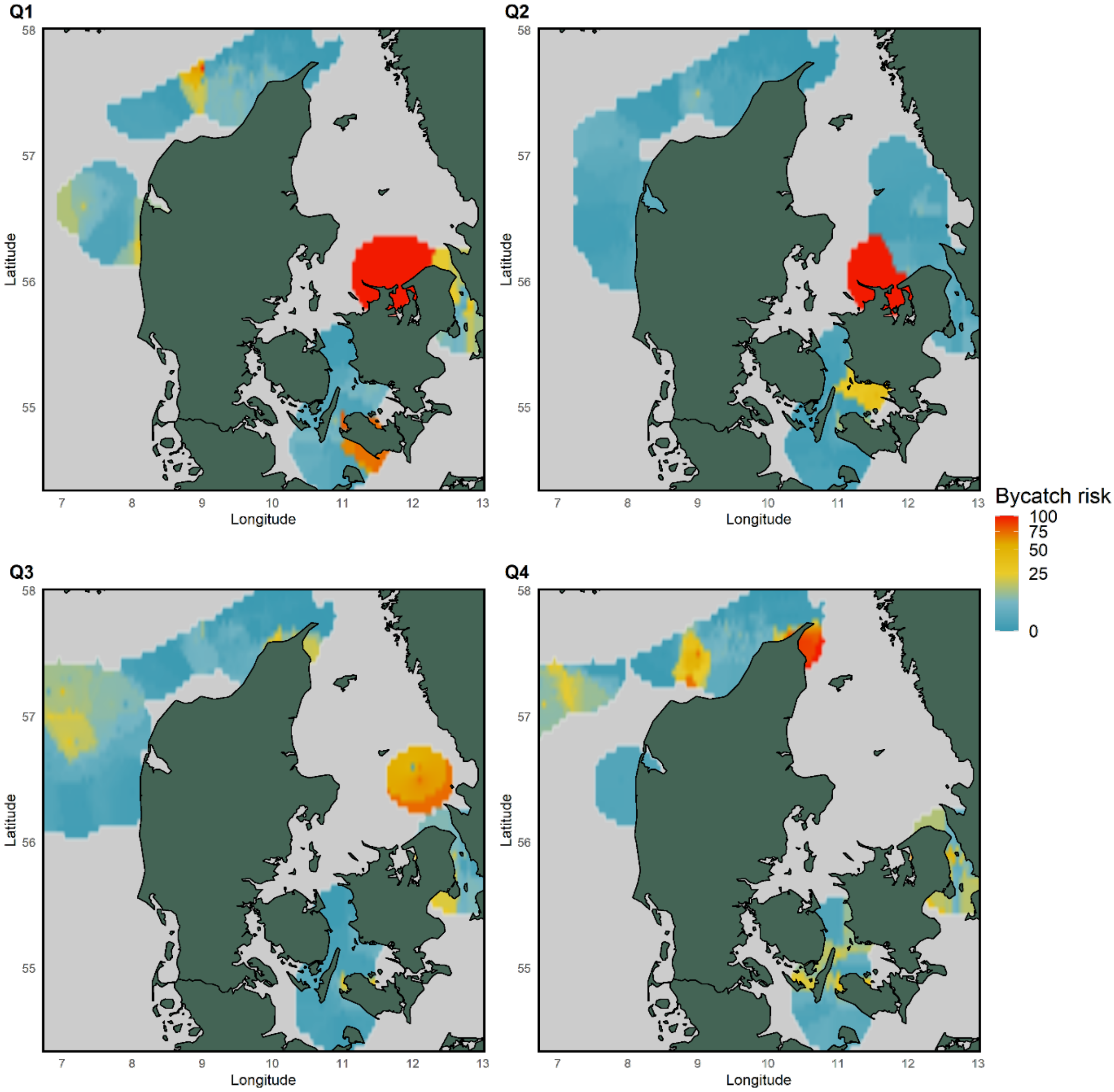

Figure 9: Quarterly bycatch risk (no unit) for seabird (all species) in the Danish commercial gillnet fleet, from model predictions using electronic monitoring data (2010-2019). Regions in light grey correspond to areas where sampling effort was too low to assess bycatch risk (see Figure 2 for comparison).

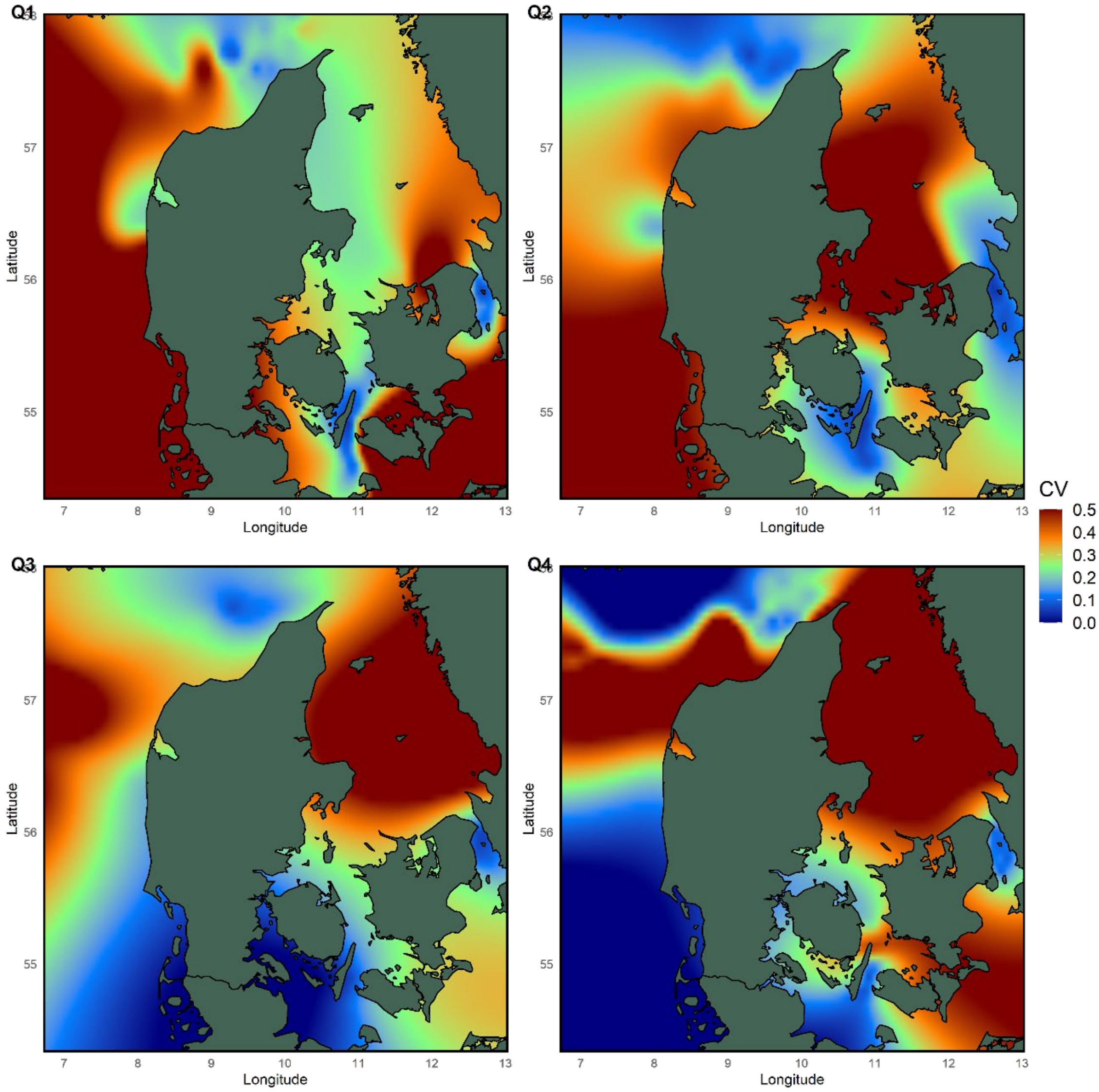

Figure 10: Uncertainty (coefficient of variation) of the quarterly seabird bycatch risk estimates (incl. all seabird species), using EM data from Danish commercial gillnet vessels (2010-2019). Areas with values below 0.3 represent high confidence in the bycatch risk predictions in the previous figure; variability in the bycatch risk estimates is very high in areas with values equal or above 0.5.

Common eider

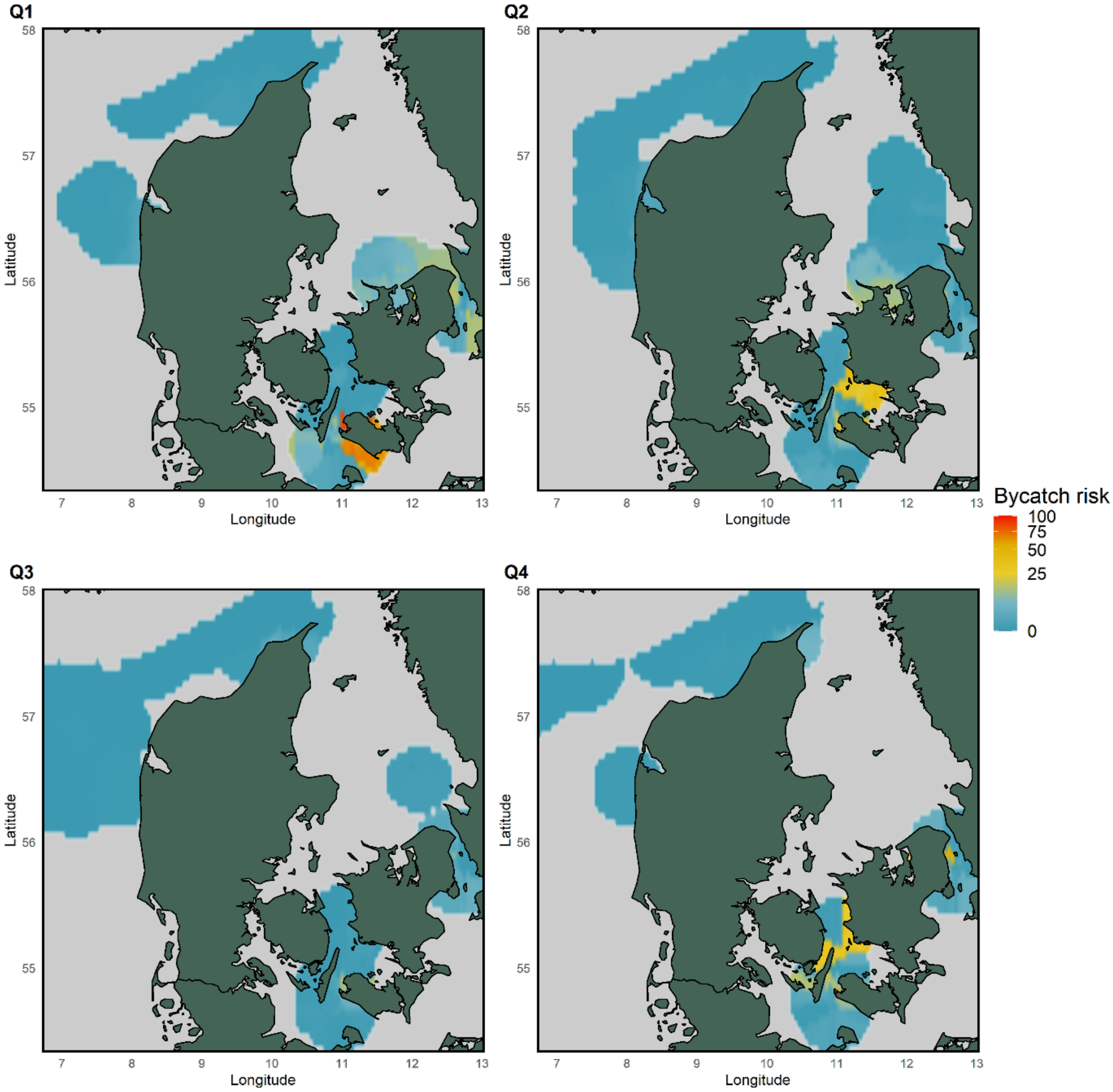

Figure 11: Quarterly bycatch risk (no unit) for common eider in the Danish commercial gillnet fleet, from model predictions using electronic monitoring data (2010-2019). Regions in light grey correspond to areas where sampling effort was too low to assess bycatch risk (see Figure 2 for comparison).

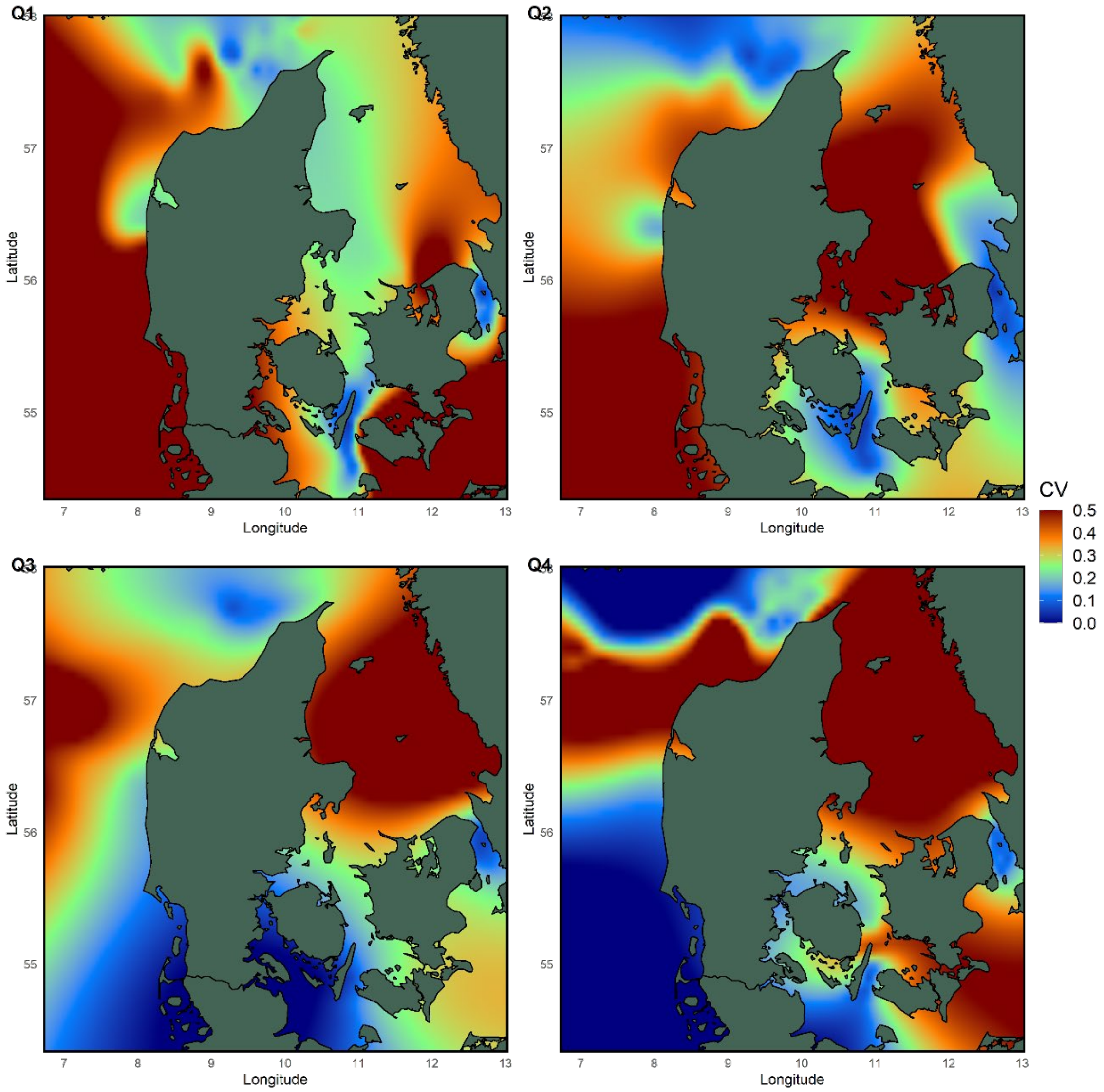

Figure 12: Uncertainty (coefficient of variation) of the quarterly common eider bycatch risk estimates, using EM data from Danish commercial gillnet vessels (2010-2019). Areas with values below 0.3 represent high confidence in the bycatch risk predictions in the previous figure; variability in the bycatch risk estimates is very high in areas with values equal or above 0.5.

Common eider female

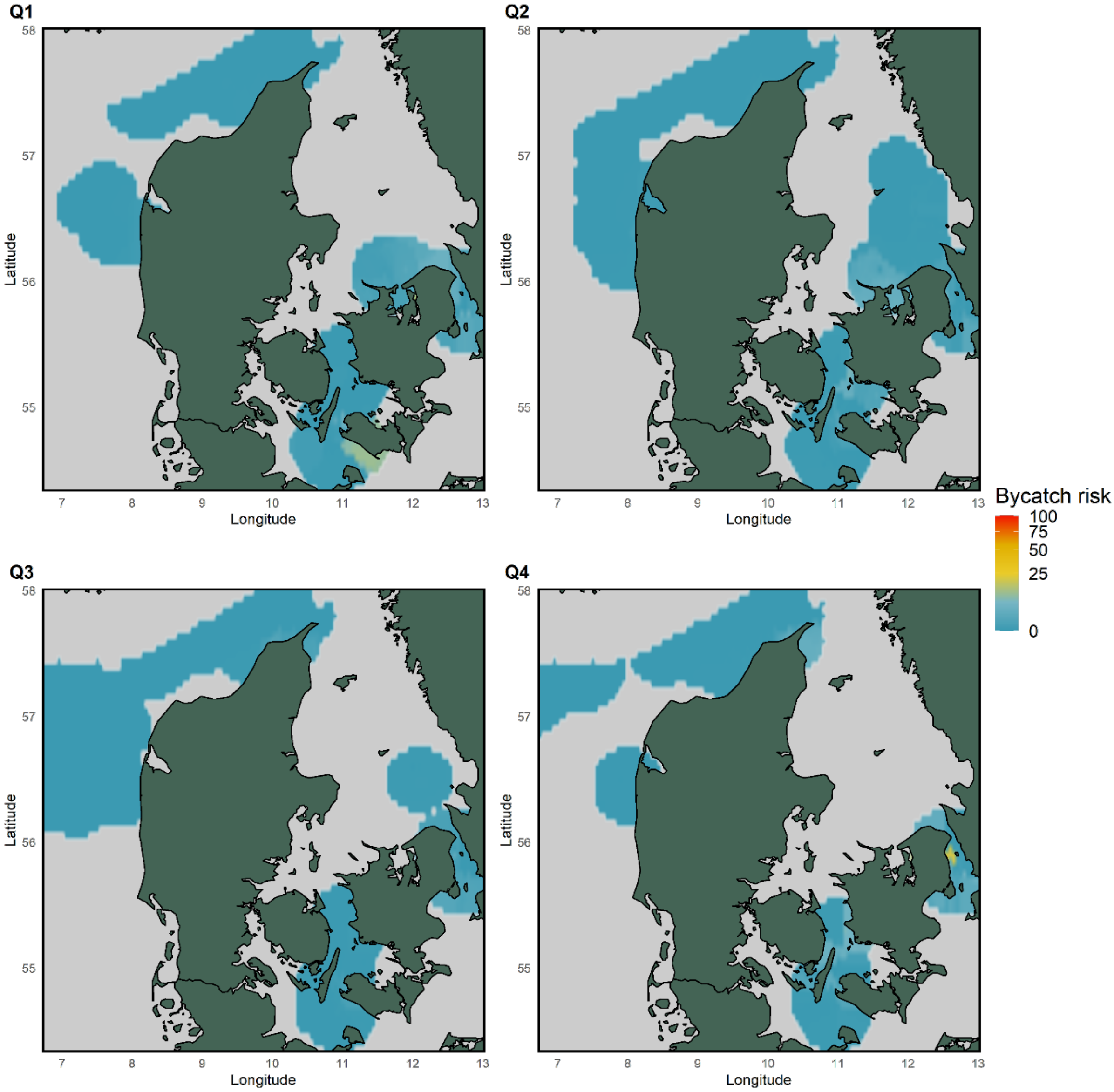

Figure 13: Quarterly bycatch risk (no unit) for female common eider in the Danish commercial gillnet fleet, from model predictions using electronic monitoring data (2010-2019). Regions in light grey correspond to areas where sampling effort was too low to assess bycatch risk (see Figure 2 for comparison).

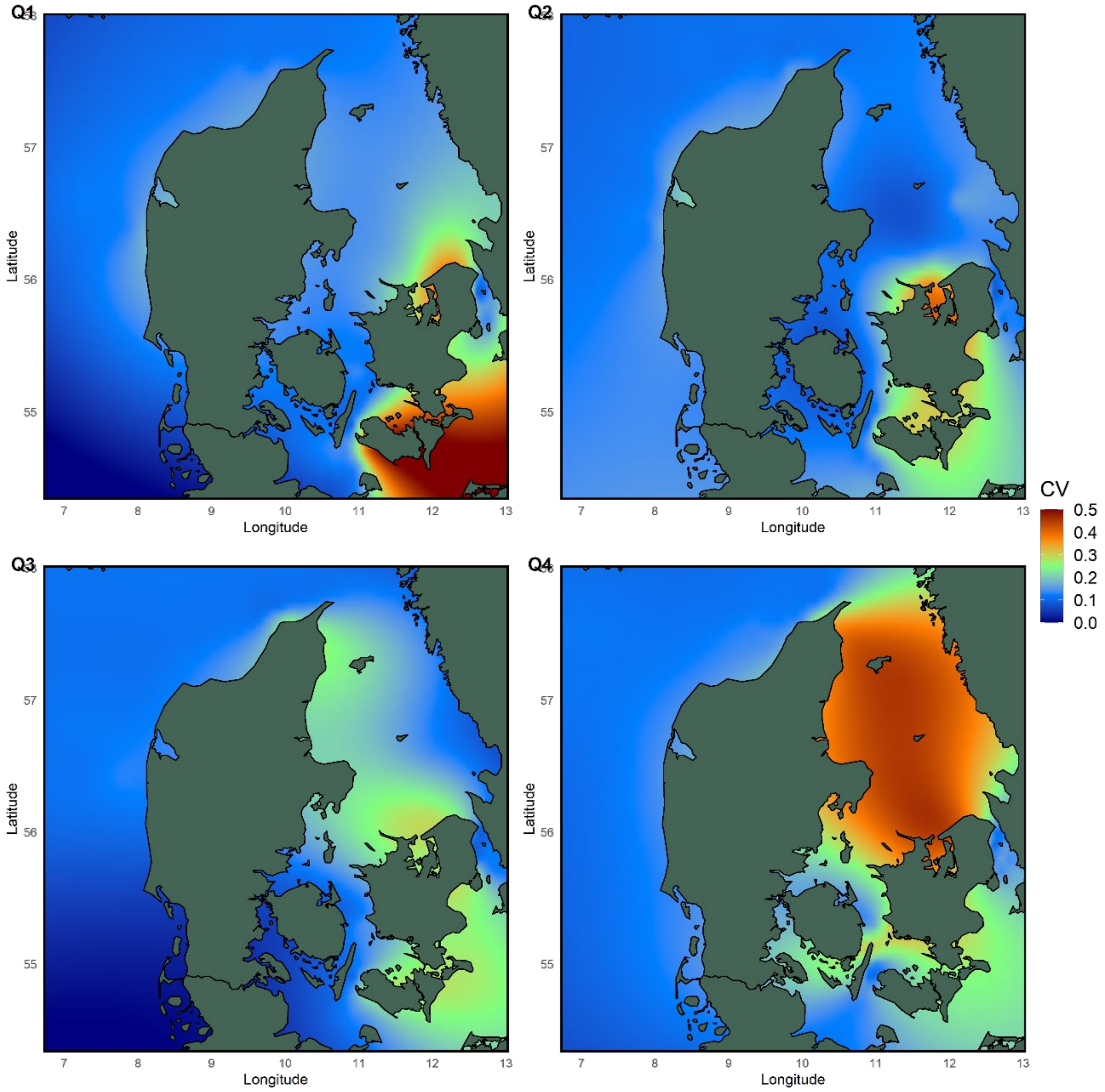

Figure 14: Uncertainty (coefficient of variation) of the quarterly female common eider bycatch risk estimates, using EM data from Danish commercial gillnet vessels (2010-2019). Areas with values below 0.3 represent high confidence in the bycatch risk predictions in the previous figure; variability in the bycatch risk estimates is very high in areas with values equal or above 0.5.

Common eider male

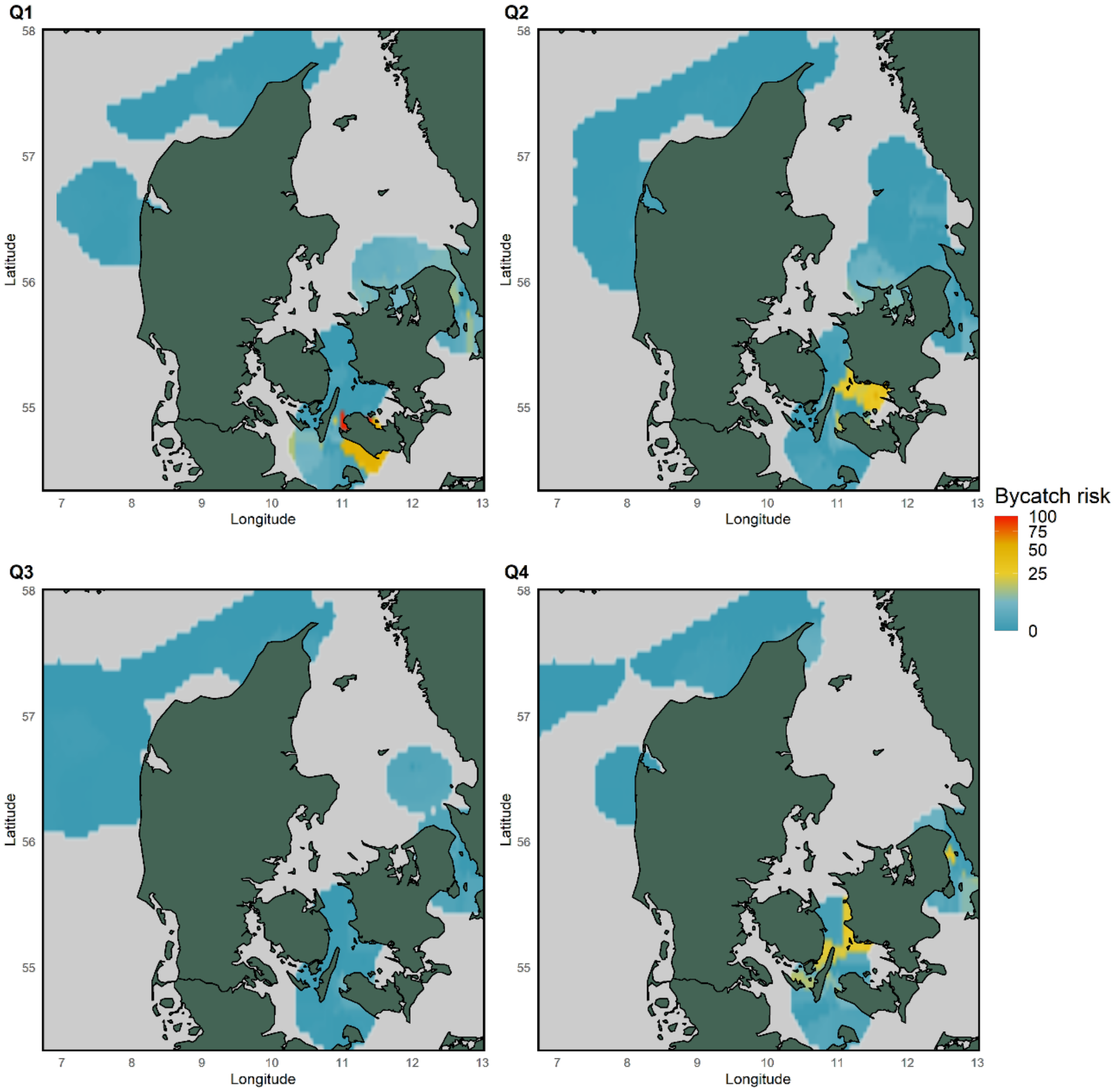

Figure 15: Quarterly bycatch risk (no unit) for male common eider in the Danish commercial gillnet fleet, from model predictions using electronic monitoring data (2010-2019). Regions in light grey correspond to areas where sampling effort was too low to assess bycatch risk (see Figure 2 for comparison).

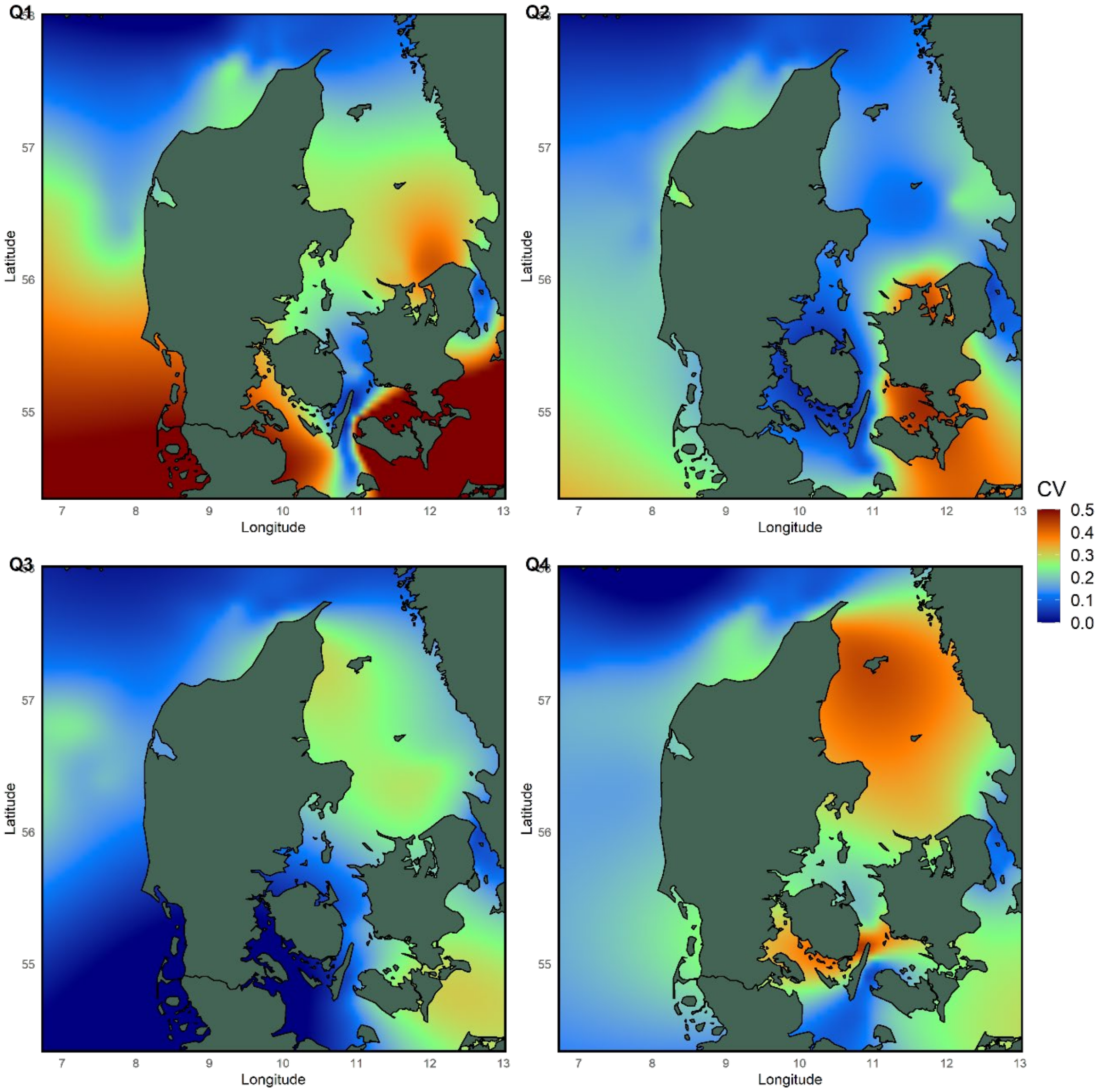

Figure 16: Uncertainty (coefficient of variation) of the quarterly male common eider bycatch risk estimates, using EM data from Danish commercial gillnet vessels (2010-2019). Areas with values below 0.3 represent high confidence in the bycatch risk predictions in the previous figure; variability in the bycatch risk estimates is very high in areas with values equal or above 0.5.

Great cormorant

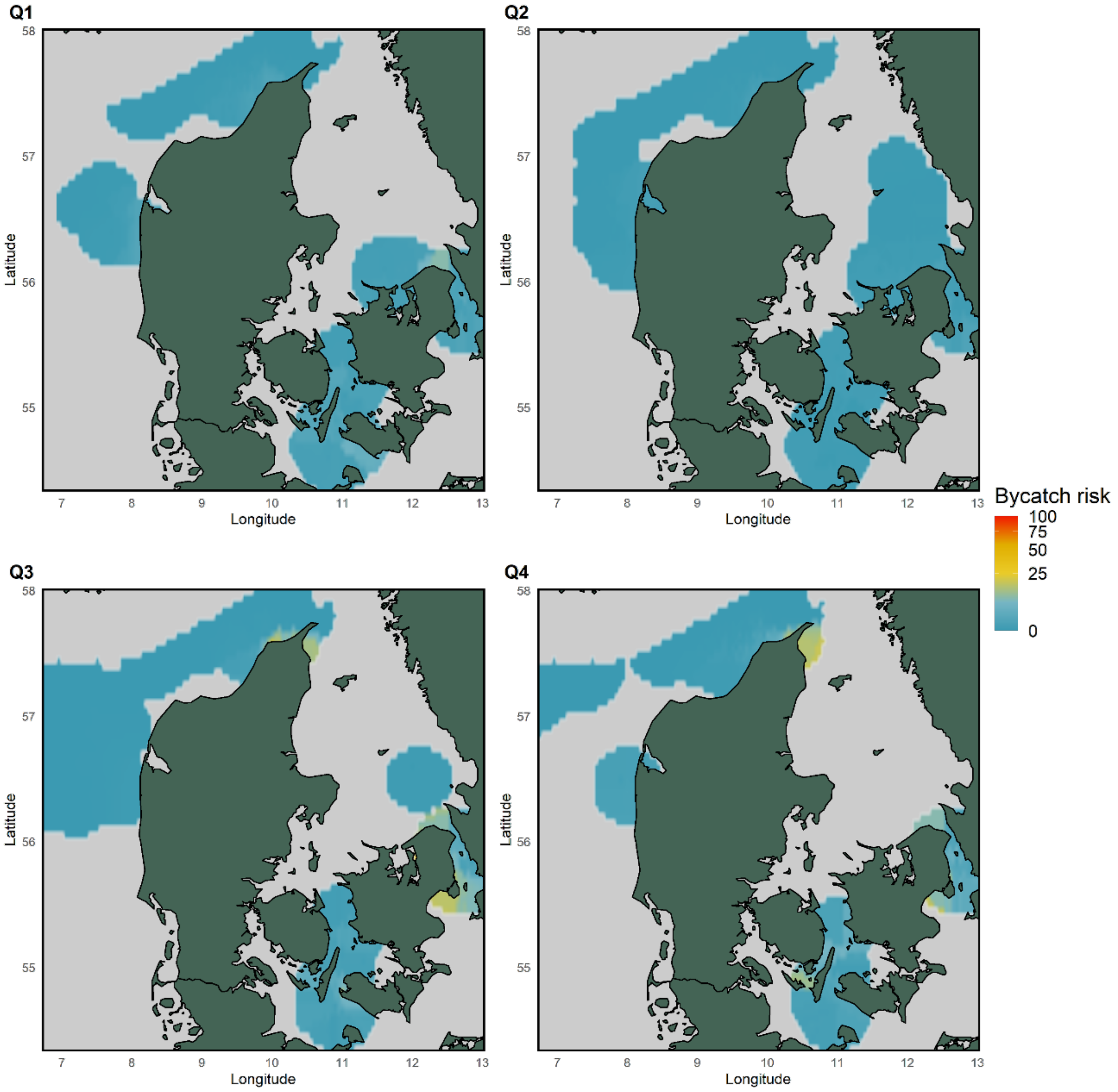

Figure 17: Quarterly bycatch risk (no unit) for great cormorant in the Danish commercial gillnet fleet, from model predictions using electronic monitoring data (2010-2019). Regions in light grey correspond to areas where sampling effort was too low to assess bycatch risk (see Figure 2 for comparison).

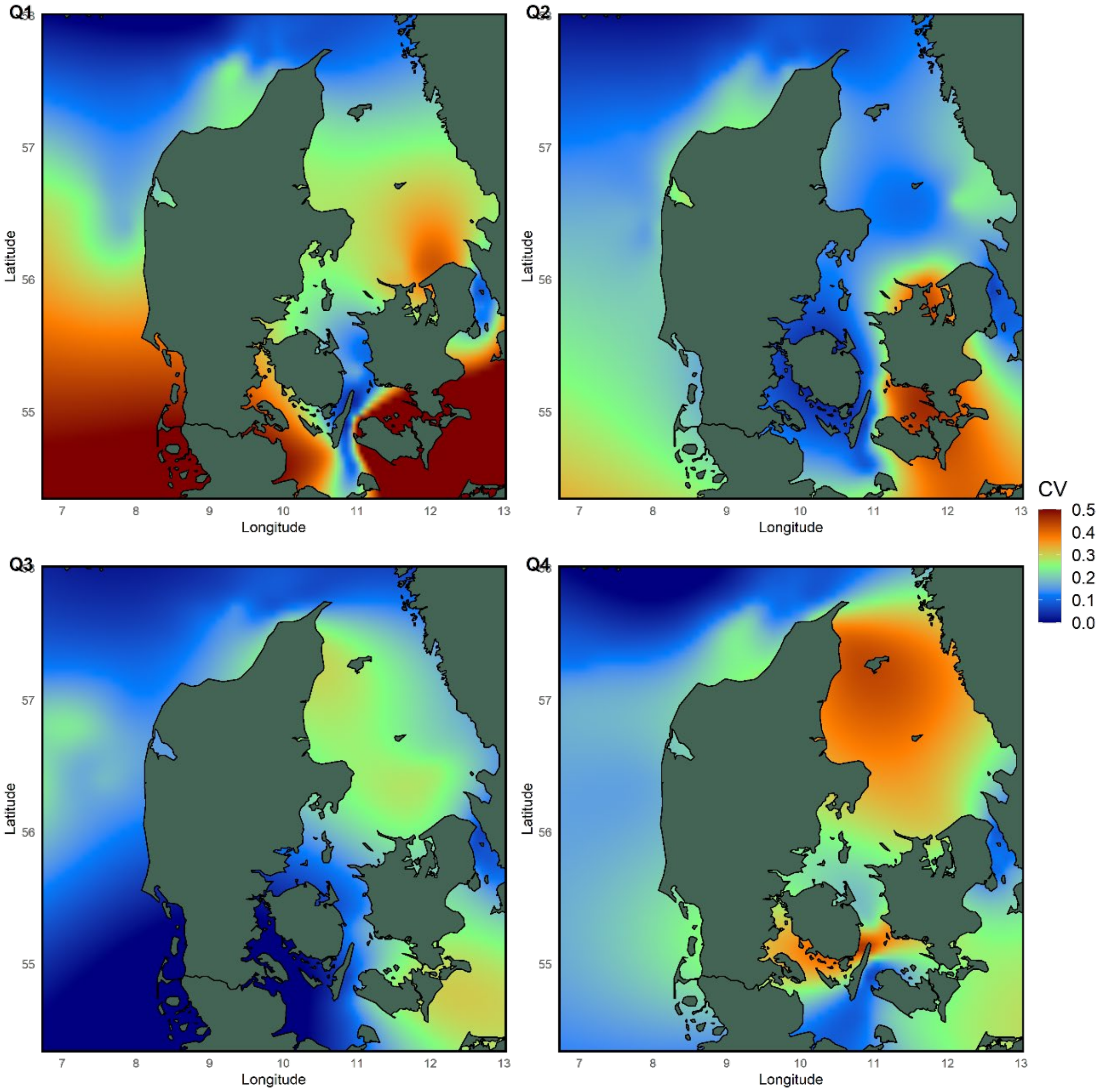

Figure 18: Uncertainty (coefficient of variation) of the quarterly great cormorant bycatch risk estimates, using EM data from Danish commercial gillnet vessels (2010-2019). Areas with values below 0.3 represent high confidence in the bycatch risk predictions in the previous figure; variability in the bycatch risk estimates is very high in areas with values equal or above 0.5.

Great cormorant juvenile

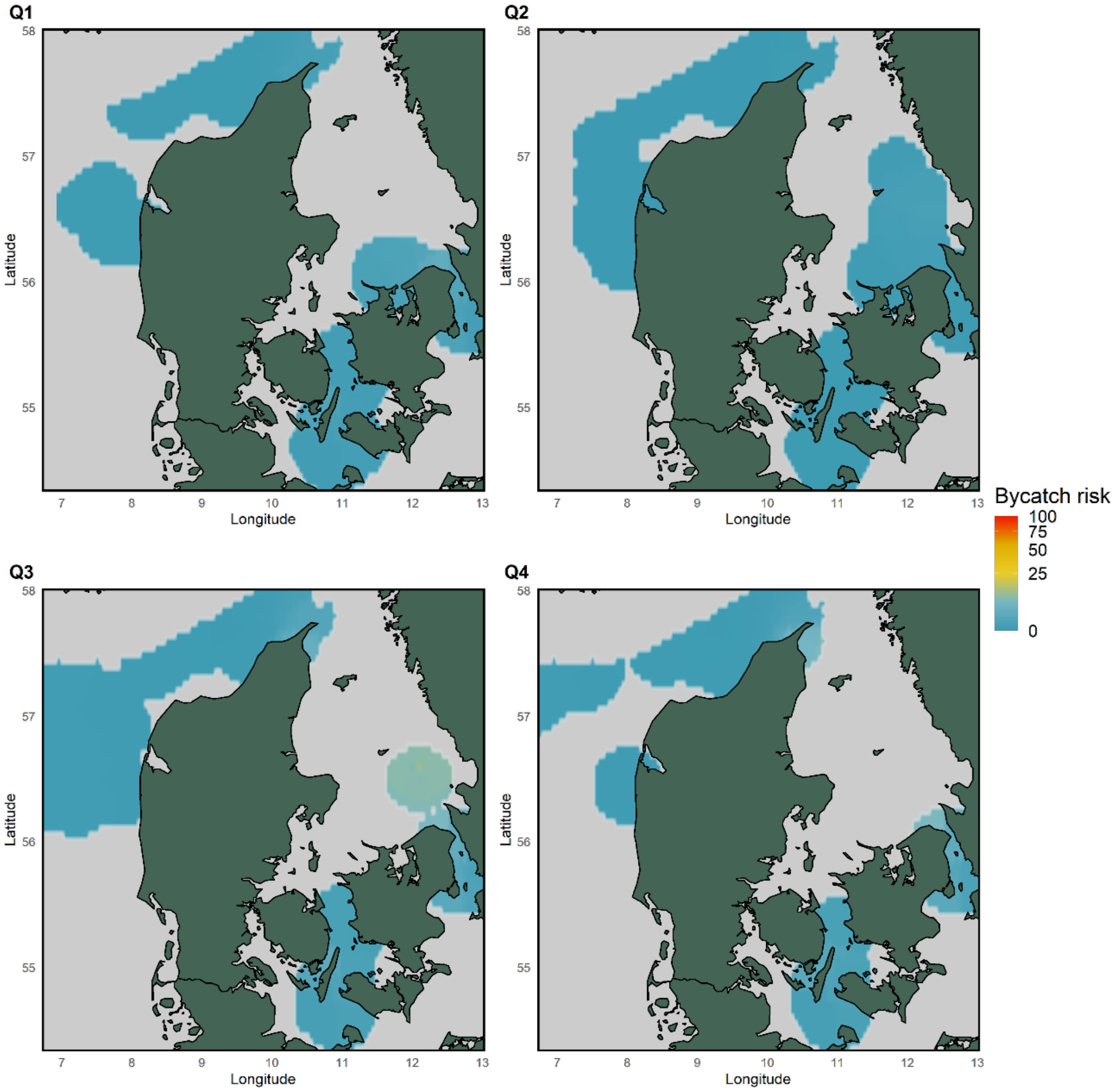

Figure 19: Quarterly bycatch risk (no unit) for juvenile great cormorant in the Danish commercial gillnet fleet, from model predictions using electronic monitoring data (2010-2019). Regions in light grey correspond to areas where sampling effort was too low to assess bycatch risk (see Figure 2 for comparison).

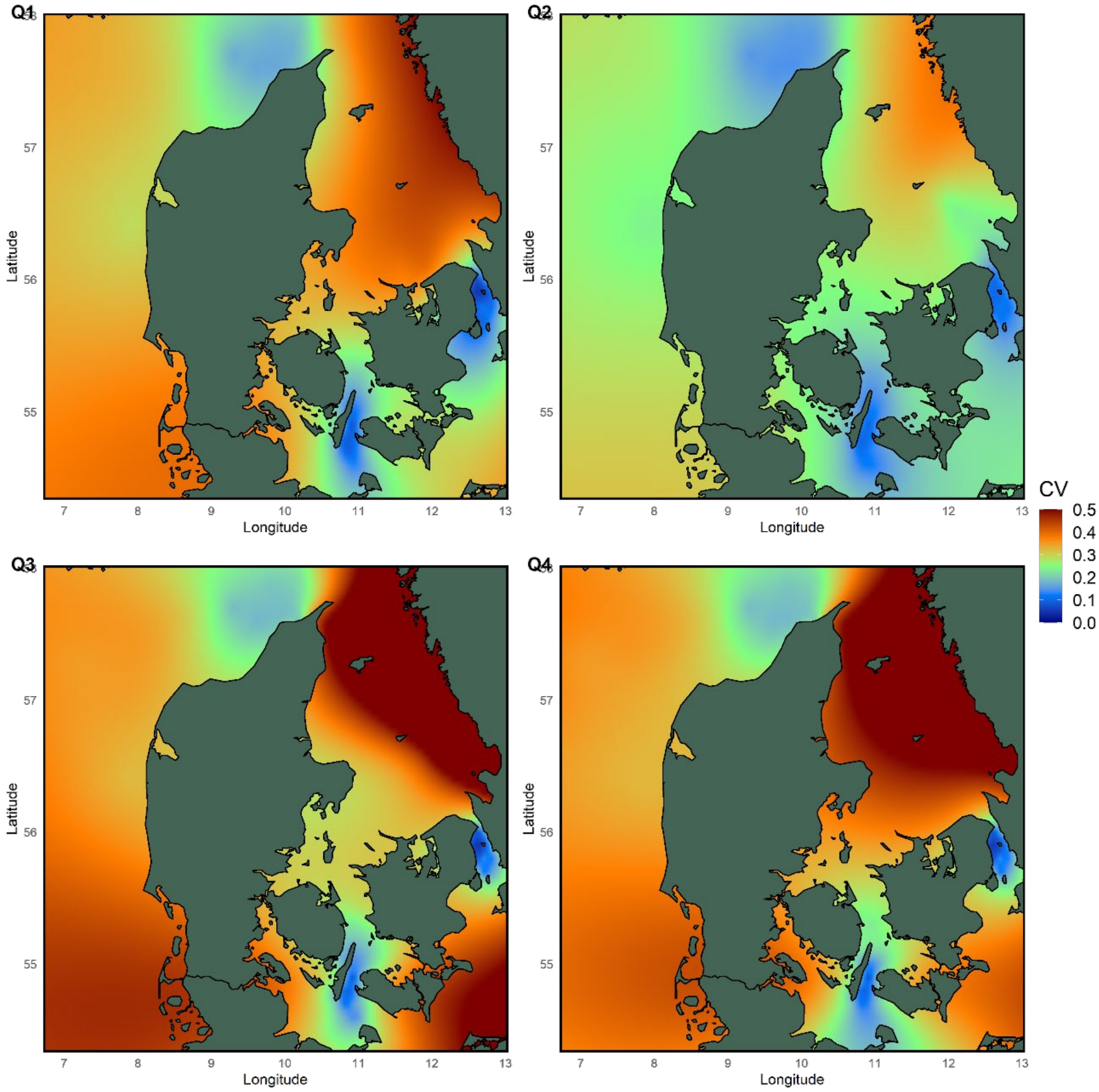

Figure 20: Uncertainty (coefficient of variation) of the quarterly juvenile great cormorant bycatch risk estimates, using EM data from Danish commercial gillnet vessels (2010-2019). Areas with values below 0.3 represent high confidence in the bycatch risk predictions in the previous figure; variability in the bycatch risk estimates is very high in areas with values equal or above 0.5.

Great cormorant adult

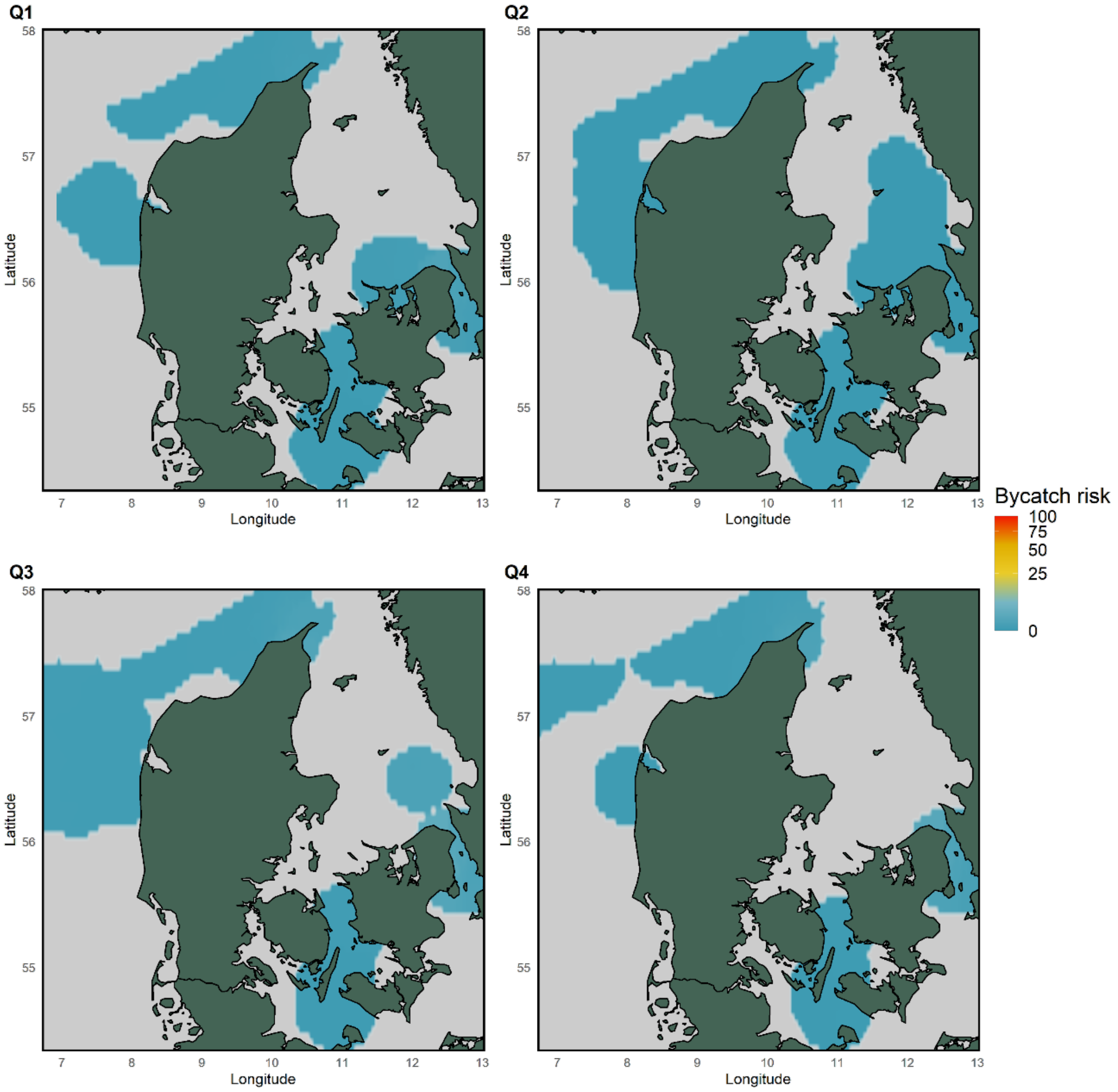

Figure 21: Quarterly bycatch risk (no unit) for adult great cormorant in the Danish commercial gillnet fleet, from model predictions using electronic monitoring data (2010-2019). Regions in light grey correspond to areas where sampling effort was too low to assess bycatch risk (see Figure 2 for comparison).

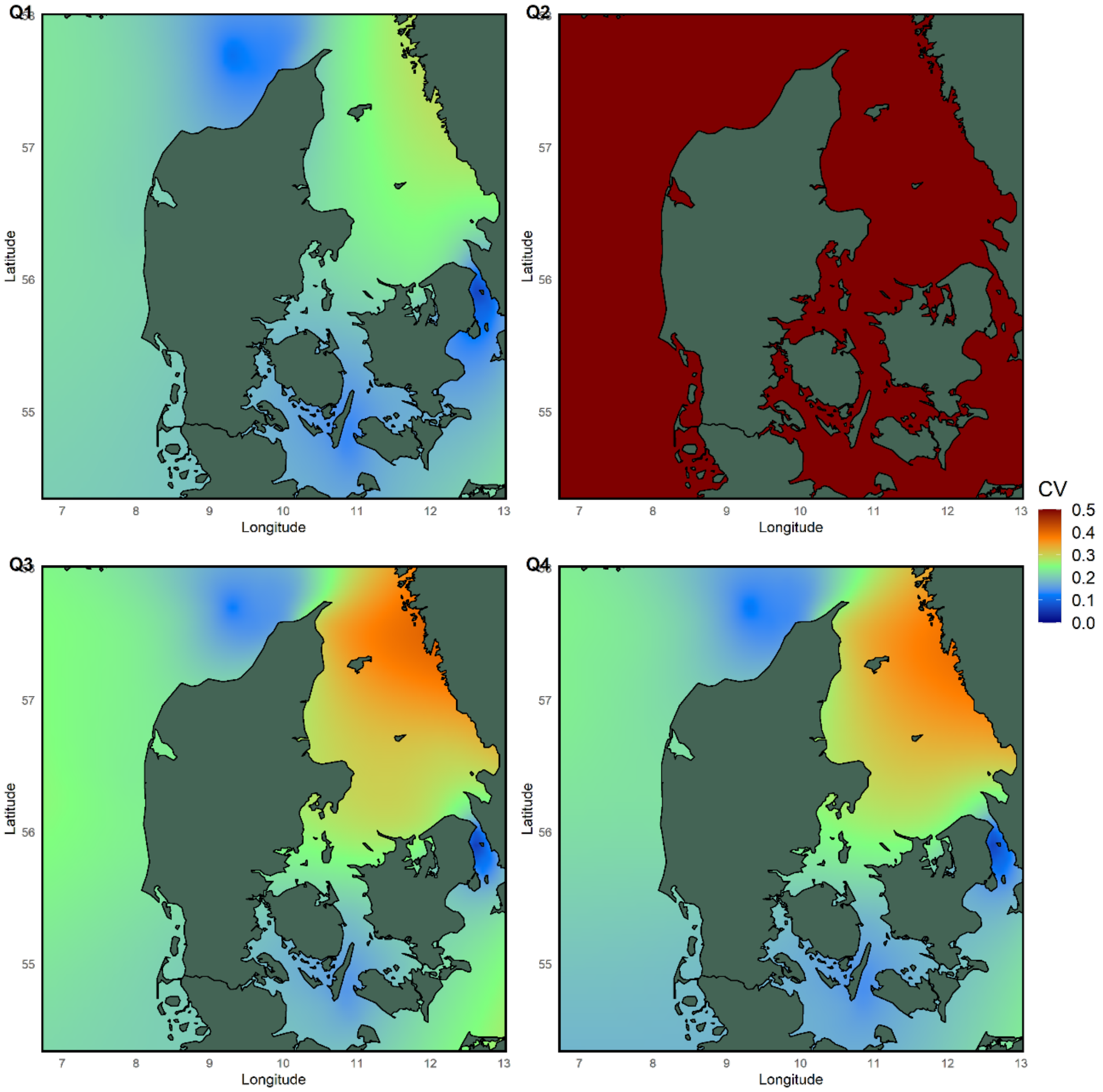

Figure 22: Uncertainty (coefficient of variation) of the quarterly adult great cormorant bycatch risk estimates, using EM data from Danish commercial gillnet vessels (2010-2019). Areas with values below 0.3 represent high confidence in the bycatch risk predictions in the previous figure; variability in the bycatch risk estimates is very high in areas with values equal or above 0.5.

Alcids (common guillemot and razorbill)

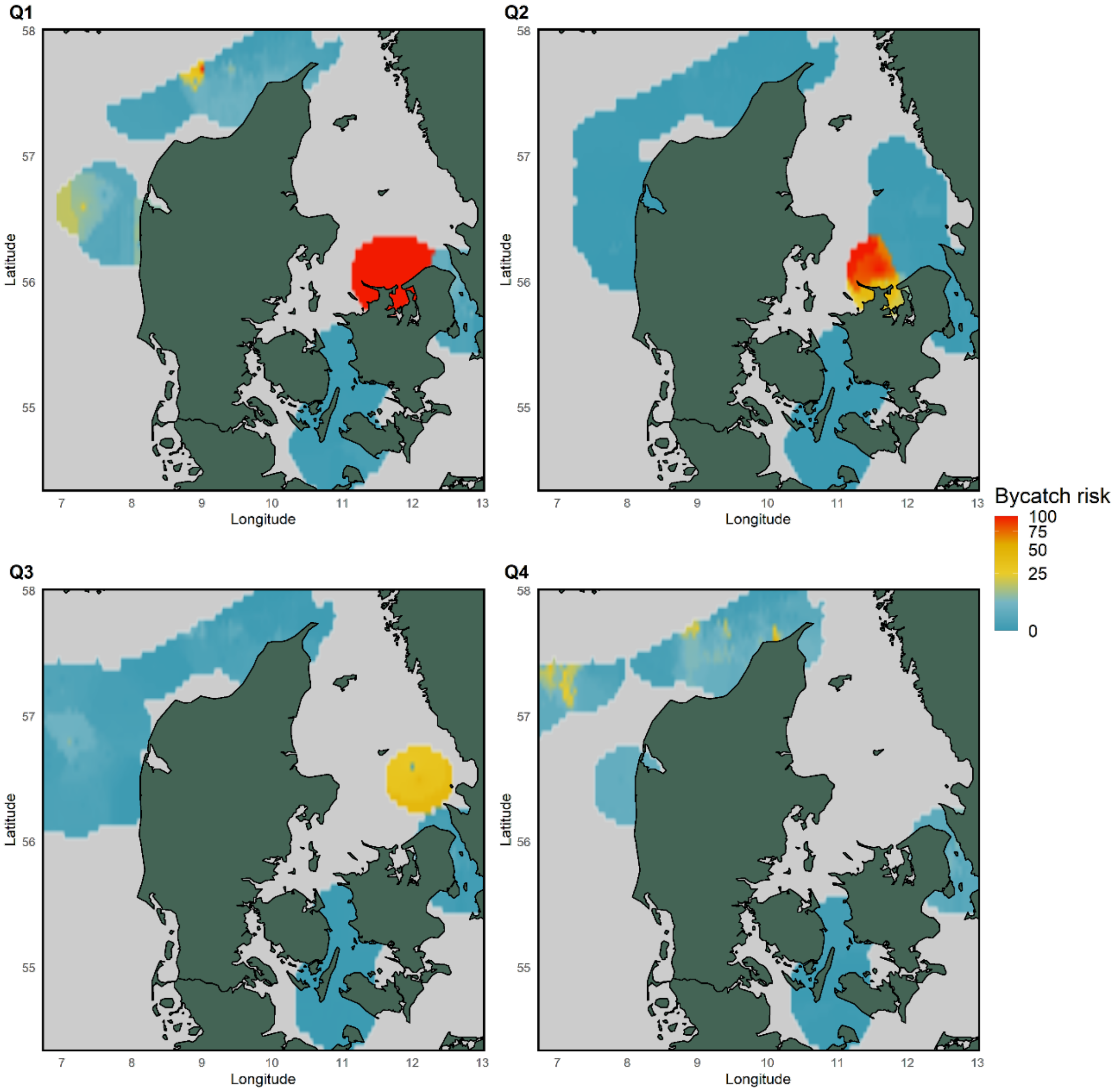

Figure 23: Quarterly bycatch risk (no unit) for alcids in the Danish commercial gillnet fleet (common guillemot and razorbill), from model predictions using electronic monitoring data (2010-2019). Regions in light grey correspond to areas where sampling effort was too low to assess bycatch risk (see Figure 2 for comparison).

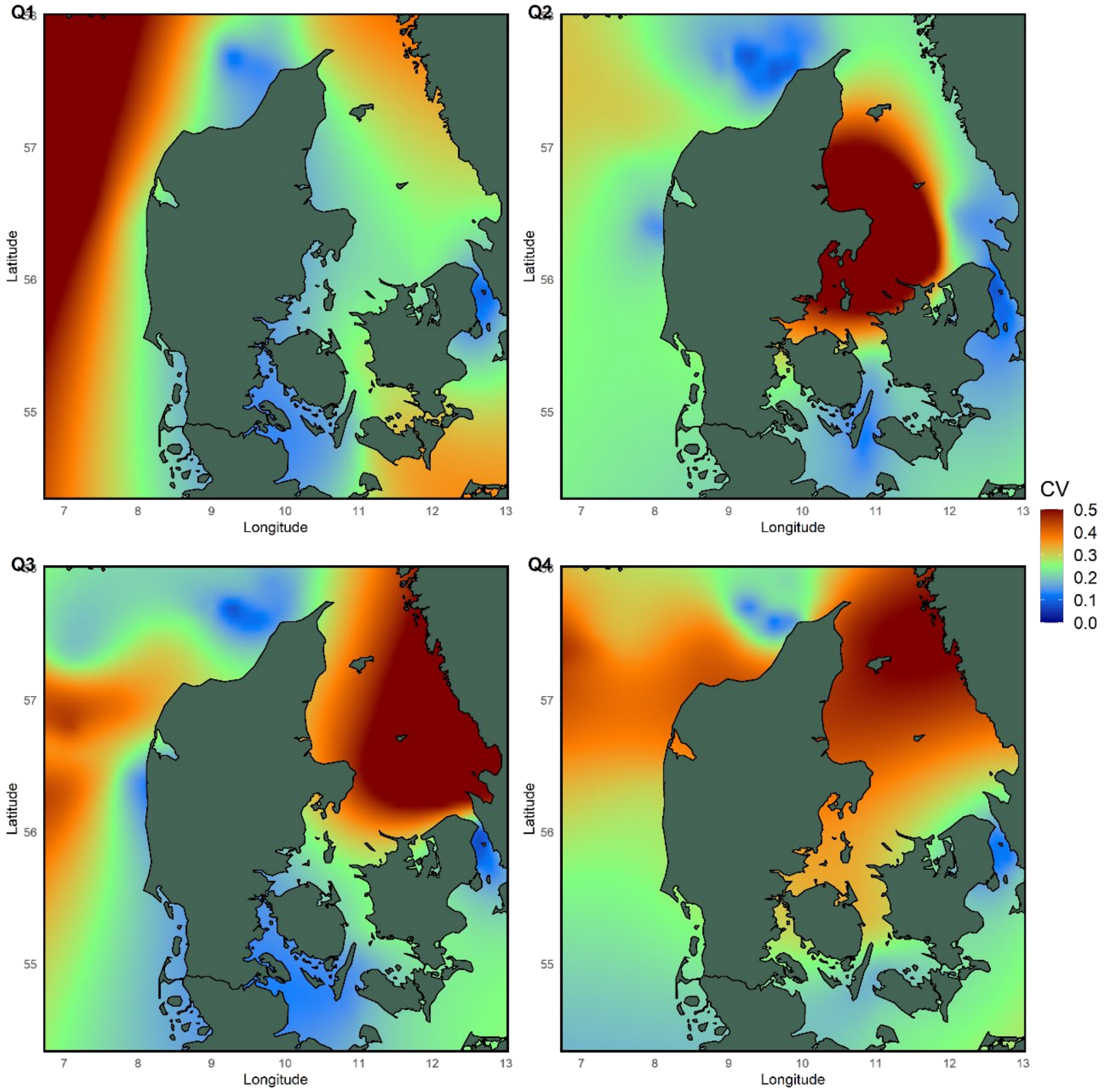

Figure 24: Uncertainty (coefficient of variation) of the quarterly alcids bycatch risk estimates (common guillemot and razorbill), using EM data from Danish commercial gillnet vessels (2010-2019). Areas with values below 0.3 represent high confidence in the bycatch risk predictions in the previous figure; variability in the bycatch risk estimates is very high in areas with values equal or above 0.5.

Scoters (common and velvet scoter)

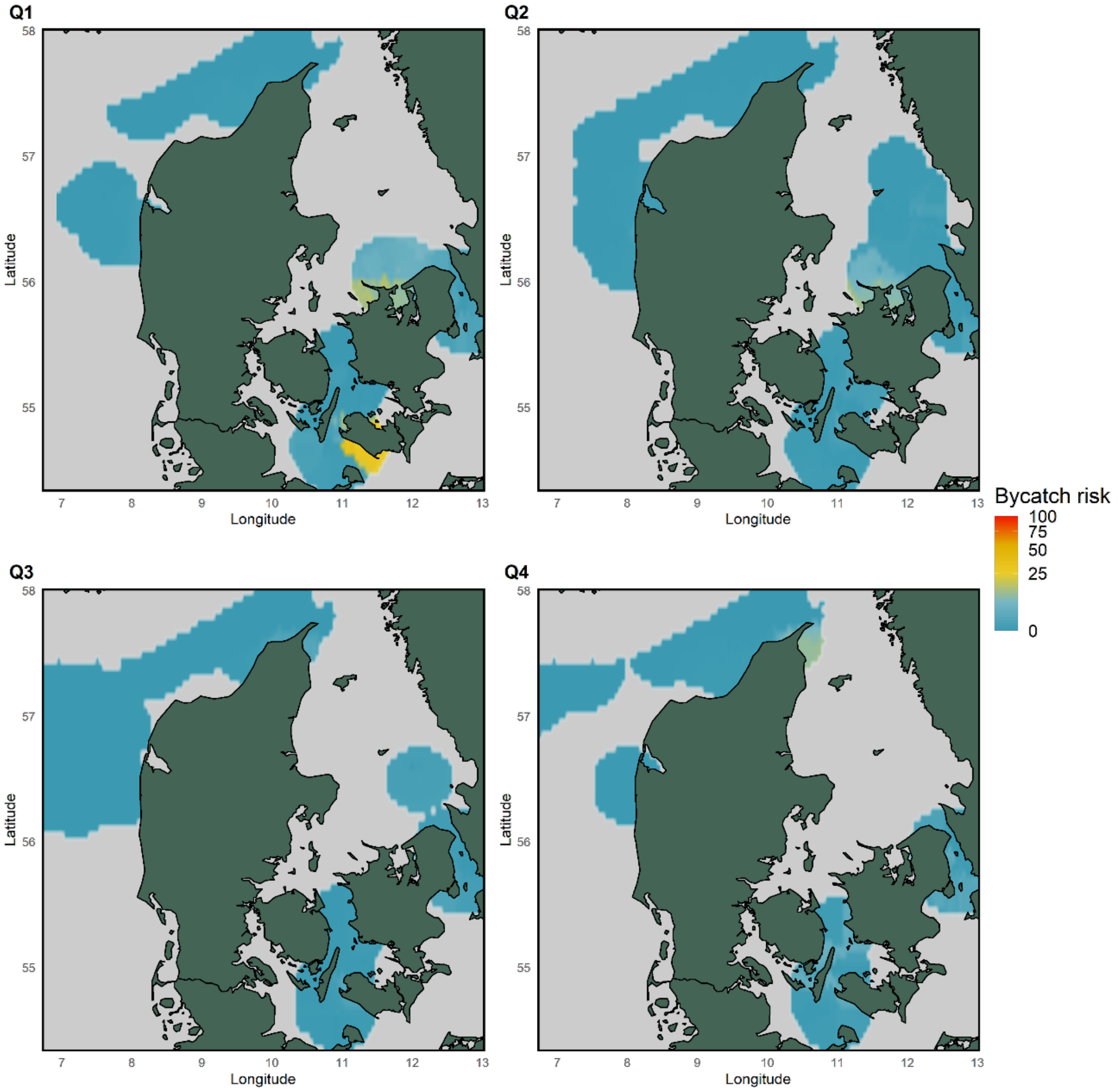

Figure 25: Quarterly bycatch risk (no unit) for scoter in the Danish commercial gillnet fleet (common scoter and velvet scoter), from model predictions using electronic monitoring data (2010-2019). Regions in light grey correspond to areas where sampling effort was too low to assess bycatch risk (see Figure 2 for comparison).

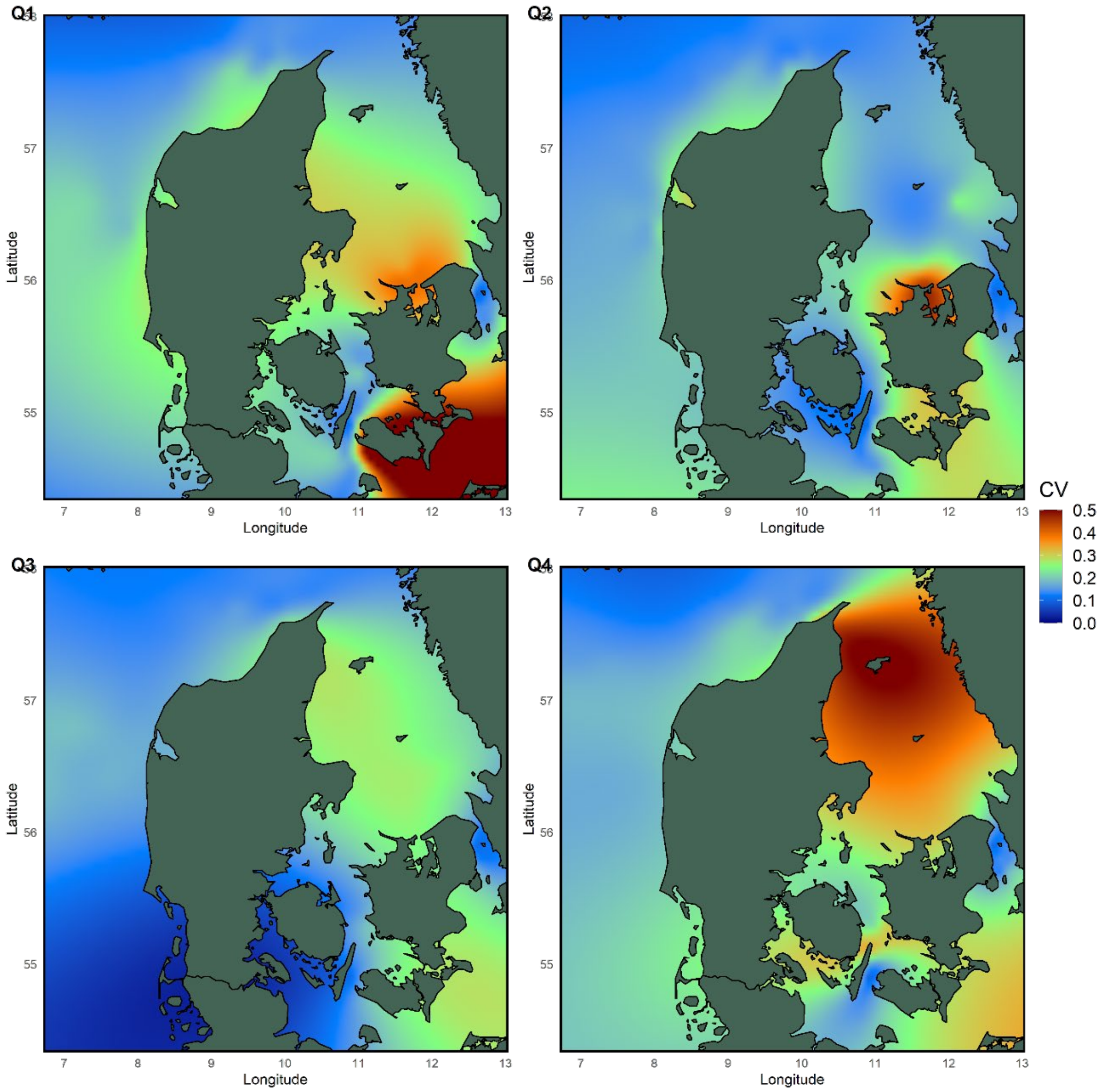

Figure 26: Uncertainty (coefficient of variation) of the quarterly scoter bycatch risk estimates (common and velvet scoter), using EM data from Danish commercial gillnet vessels (2010-2019). Areas with values below 0.3 represent high confidence in the bycatch risk predictions in the previous figure; variability in the bycatch risk estimates is very high in areas with values equal or above 0.5.

Other birds

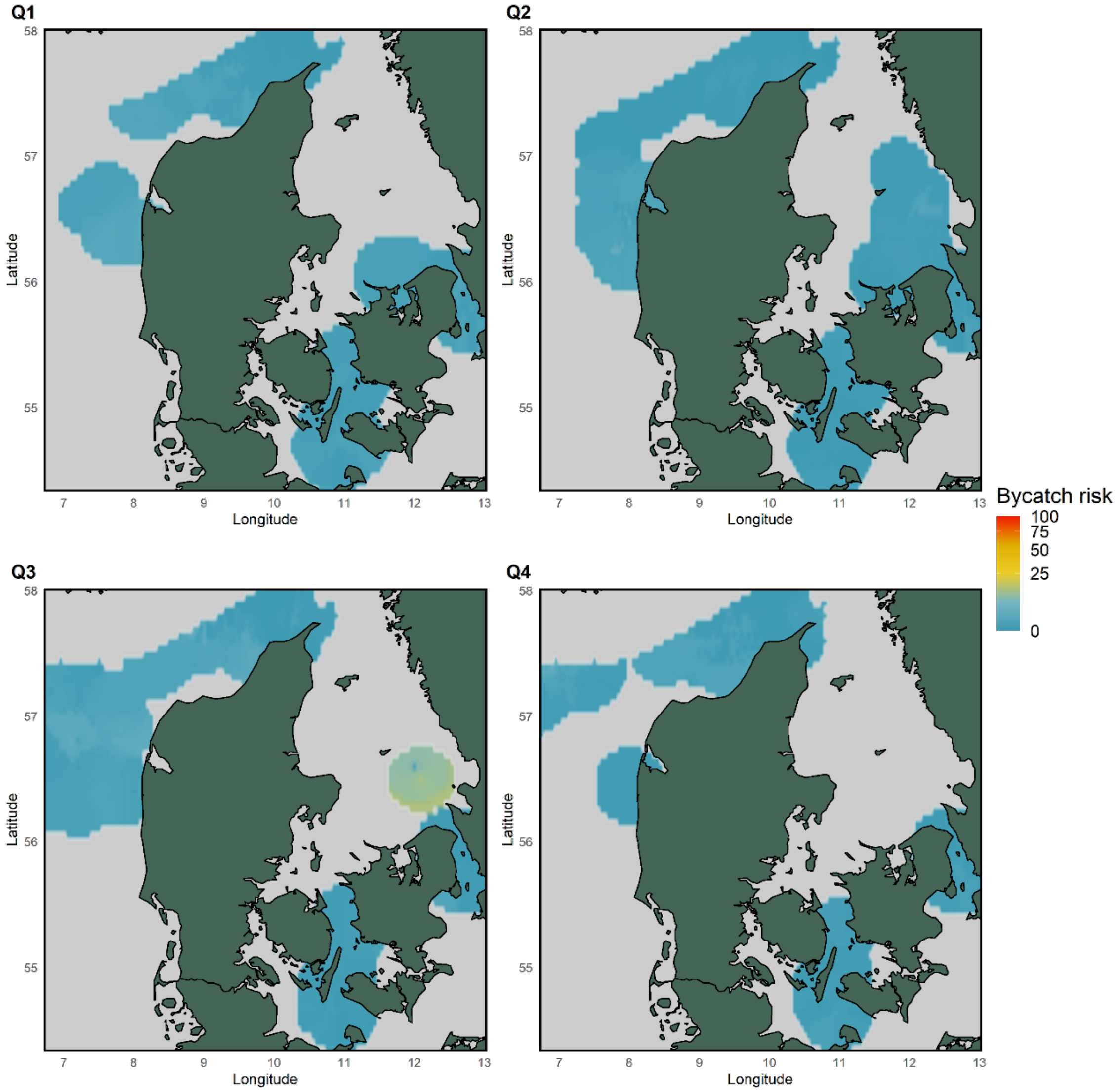

Figure 27: Quarterly bycatch risk (no unit) for other bird species in the Danish commercial gillnet fleet (incl. Northern fulmar, seagulls, grebes, and loons), from model predictions using electronic monitoring data (2010-2019). Regions in light grey correspond to areas where sampling effort was too low to assess bycatch risk (see Figure 2 for comparison).

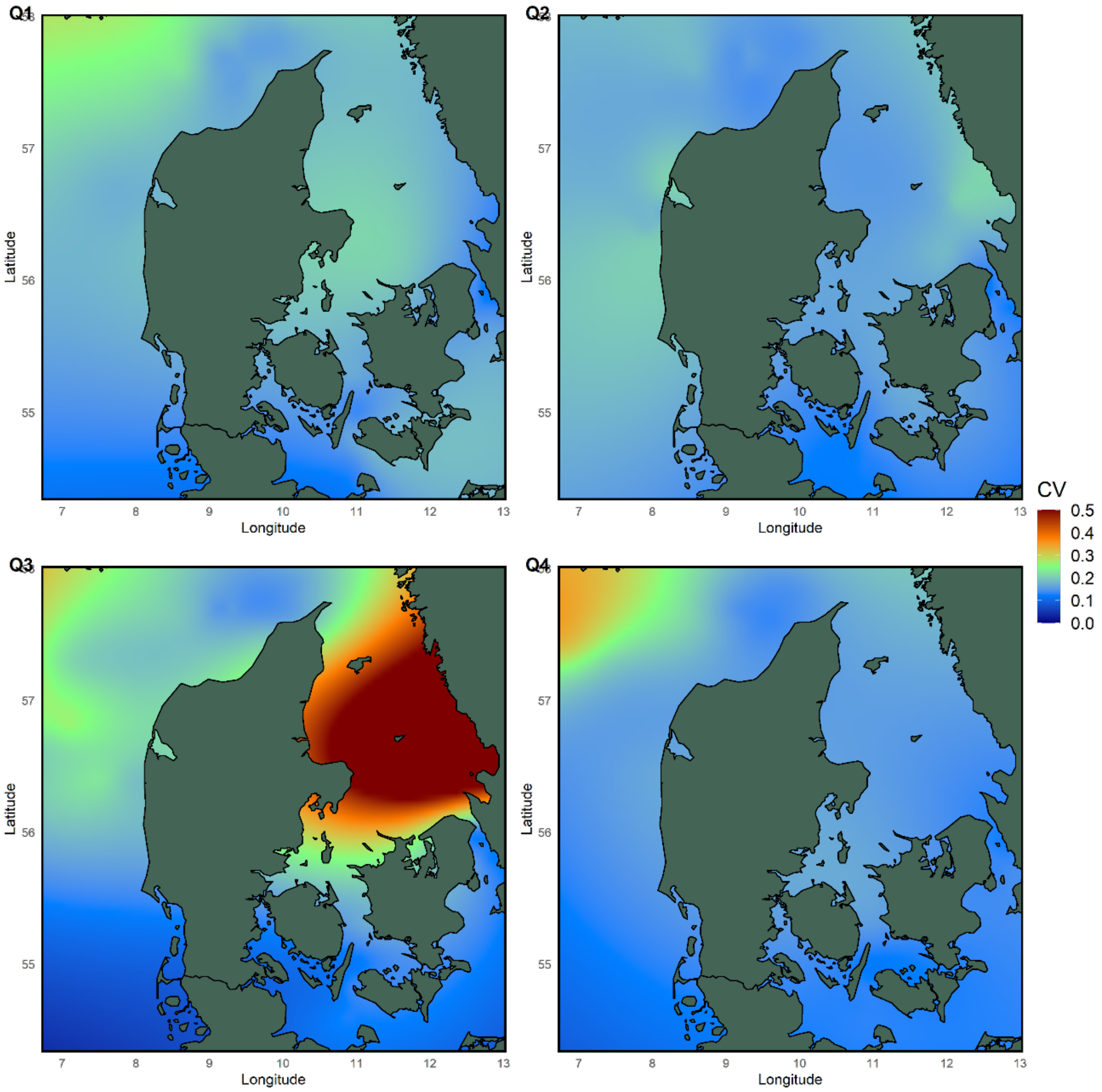

Figure 28: Uncertainty (coefficient of variation) of the quarterly bycatch risk estimates for other bird species (incl. Northern fulmar, seagulls, grebes, and loons), using EM data from Danish commercial gillnet vessels (2010-2019). Areas with values below 0.3 represent high confidence in the bycatch risk predictions in the previous figure; variability in the bycatch risk estimates is very high in areas with values equal or above 0.5.

Bycatch estimates

The European Union General Data Privacy Regulation requires personal data such as the EM data used in this report to be anonymised when made public. In the present case, data had to be aggregated to two regions (North Sea and Baltic Sea). Moreover, in some years, less than 5 vessels per region were monitored, and as such their anonymity could not be ensured. Therefore, the number of casualties imputable to bycatch in Danish commercial gillnets is given here as the yearly average bycatch estimates per region and associated 95% confidences intervals (Table 11 in Annex) and as the quarterly average bycatch estimates per region and associated 95% confidences intervals (Table 12 in Annex).

Mean yearly bycatch was estimated in this report by multiplying the mean annual bycatch rates (measured as bycatch per fishing day) in an area with the mean annual effort (number of fishing days) in the same area, as recommended in e.g., Moore *et al.*, (2021). With a relative paucity in fine-scale effort data on distribution (e.g., GPS location of the fishing gears) and intensity (e.g., net meter day, soaking duration, number fishing fleets deployed) in the Danish commercial gillnet fleet, fishing day was chosen as the metric for fishing effort as this was the most informative metric available at fleet level. Bycatch estimates in Table 11 and 12 are based on this method. The estimates rely on the assumption that the sample of the fleet monitored with EM is representative of the entire fleet in the North Sea and the western Baltic. In 2019, a new vessel was included in the electronic monitoring programme, collecting bycatch data in previously largely unsampled areas of the North Sea. The added vessel supplied less than a year of data and the analysis of the data from this vessel showed that bycatch rates – measured as the number of bycaught animals per fishing day – were substantially larger for some species (e.g., harbour porpoise) than among other vessels in the same grouping area. Compared to the other vessels monitored with EM, the new vessel was larger and used more and longer net fleets for each fishing day, which explains, at least partly, the higher average bycatch rate observed on that vessel. However, the degree to which this vessel is representative of other vessels remains unknown.

This raises the question of the representativity of the sampled fleet and, particularly, of the representativity of the additional vessel in 2019. In the mapping of areas of high-risk of bycatch for the different affected species, the sampling units was haul (see Table 3: List of the variables included in the bycatch models) and no rescaling of the results was performed. In this analysis, the spatial distribution of bycatch risk is therefore expected to be largely unbiased. However, in the estimated fleet-wide bycatch levels, fishing day was used as the sampling unit. This introduces a potential source of bias as applying the same bycatch rates to the entire fleet in the same area, it is assumed that the probability of bycatch per fishing day was equivalent regardless of vessel size. In turn, the bycatch estimates for the North Sea grouping area presented in Table 11 and 12 are substantially larger for some species (e.g., harbour porpoise) than what was previously estimated with a similar method using data from an earlier period (Larsen *et al*., 2021). The large influence of one vessel on bycatch rates estimates suggests that the bycatch levels reported here in the North Sea may be overestimated for some species, and possibly underestimated for others. The large confidence intervals around the mean estimates for the North Sea area also indicate that these results are not to be considered without accounting for their uncertainty. Readers should carefully consider these points if they intend to use these estimates in other contexts.

The present report identified areas where bycatch of protected species in gillnets is likely problematic in Danish waters. More work is needed to determine differences in bycatch probability between e.g., vessels of different length classes, gear types, mesh sizes, or target species, and obtain a more accurate assessment of the number of marine mammals and seabirds that drown in Danish gillnet fisheries.

2. Non-commercially exploited fish

The joint ICES/OSPAR effort to identify sensitive species and indices of their abundance (ICES WKABSENS 2021) reviewed suggested lists of sensitive species from previous ICES and OSPAR groups together with listings by the IUCN, Habitat Directive and national legislation and produced an agreed list of 140 sensitive species or species groups in the Northeast Atlantic (including the Baltic Sea). Among these, 37 species or species groups had sufficient data to provide abundance indices and have occurred at least once in survey data from Danish waters (Table 6). Four of these (*Leucoraja circularis*, *Leucoraja naevus*, *Lophius budegassa* and *Raja brachyura*) were at the edge of their distribution, leaving 33 species or species groups in Danish waters, 14 of which were sharks, skates, or rays. The study also identified the two major commercial species cod and hake as sensitive, but as these are commercial fish, they are not included here.

Table 6: Species or species groups identified as sensitive and occurring in Danish waters. Species with * had questionable sensitivity. ** Recorded in commercial landings from Danish waters * borders of distribution in Danish waters.**

Population	Danish name	English name
*Alosa spp**	Stamsild og majsild	Shads
Amblyraja radiata	Tærbe	Starry ray
Anarhichas lupus	Havkat	Wolffish
Anguilla Anguilla	Ål	European eel
Brosme brosme	Brosme	Tusk
*Chelidonichthys lucerna**	Rød knurhane	Tub gurnard
Chimaera monstrosa	Havmus	Rabbitfish
*Cyclopterus lumpus**	Stenbider/kvabso	Lumpsucker
Dipturus spp	Skader	Common skate complex
Etmopterus spinax	Sorthaj	Velvet belly
*Galeorhinus galeus***	Gråhaj	Tope shark
*Galeus spp***	Ringhaj	Blackmouth catshark
Helicolenus dactylopterus	Blåkæft	Blackbelly rosefish
*Hippocampus hippocampus**	Kortsnudet søhest	Shortsnouted seahorse
Hippoglossus hippoglossus	Helleflynder	Halibut
*Lampetra fluviatilis**	Flodlampret	River lamprey
*Leucoraja circularis****	Sandrokke	Sandy ray
*Leucoraja naevus****	Pletrokke	Cuckoo ray
*Lophius budegassa****	Sort havtaske	Balckbellied anglerfish
Lophius piscatorius	Havtaske	Anglerfish
Molva molva	Lange	Ling
Mustelus spp	Stjernehaj og glathaj	Starry smoothound and smoothhound
*Petromyzon marinus**	Havlampret	Sea lamprey
Phycis blennoides	Skælbrosme	Greater forkbeard
Pollachius pollachius	Lubbe/lyssej	Pollock
*Raja brachyura****	Blond rokke	Blonde ray
Raja clavata	Sømrokke	Thornback ray
Raja microocellata	Småøjet rokke	Smalleyed ray
Raja montagui	Storplettet rokke	Spottedray
Raja undulata	Broget rokke	Undulate ray
Scophthalmus maximus	Pighvar	Turbot

Scophthalmus rhombus	Slethvar	Brill
Scyliorhinus canicula	Småplettet rødhaj	Lesser spotted dogfish
Scyliorhinus stellaris	Storplettet rødhaj	Nursehound
*Sebastes viviparous**	Lille rødfisk	Norway redfish
Squalus spp	Pighaj	Spurdog
*Zoarces viviparous**	Ålekvabbe	Eelpout

2.1 Survey abundance and distribution sensitive fish species

Under the EMFF project 'DNA baseret monitering af hajer og rokker, samt risikobaseret analyse af bifangst i forskellige fiskerier', distribution and abundance of the sharks, skates and rays was investigated further. The approach developed in that project was presented to WKABSENS (ICES 2021) and subsequently used by this group to calculate official ICES abundance estimates and associated uncertainties from survey data, for all fish on the list. In brief, the approach analysed survey catch rates using Generalized additive models (GAMs, Hastie and Tibshirani 1990) to estimate abundance indices while correcting for confounding factors such as spatial position of the haul, depth, time of day, or swept area. Two models were fitted, one accounting for differences in vessels and gear types beyond those caused by difference in swept area of the hauls, GAM+, and another assuming all gear to be equal except for differences caused by differences in swept area, GAM. The final model was selected by AIC and hence differs between species. The results are available at **https://datras.ices.dk/Data_products/Download/Download_Data_public.aspx** (choose sensitivespeciesabundanceindices in the dropdown menu).

The spatial distribution of the species can be seen in Figure 29 and the temporal development in abundance of the species in Figure 30.

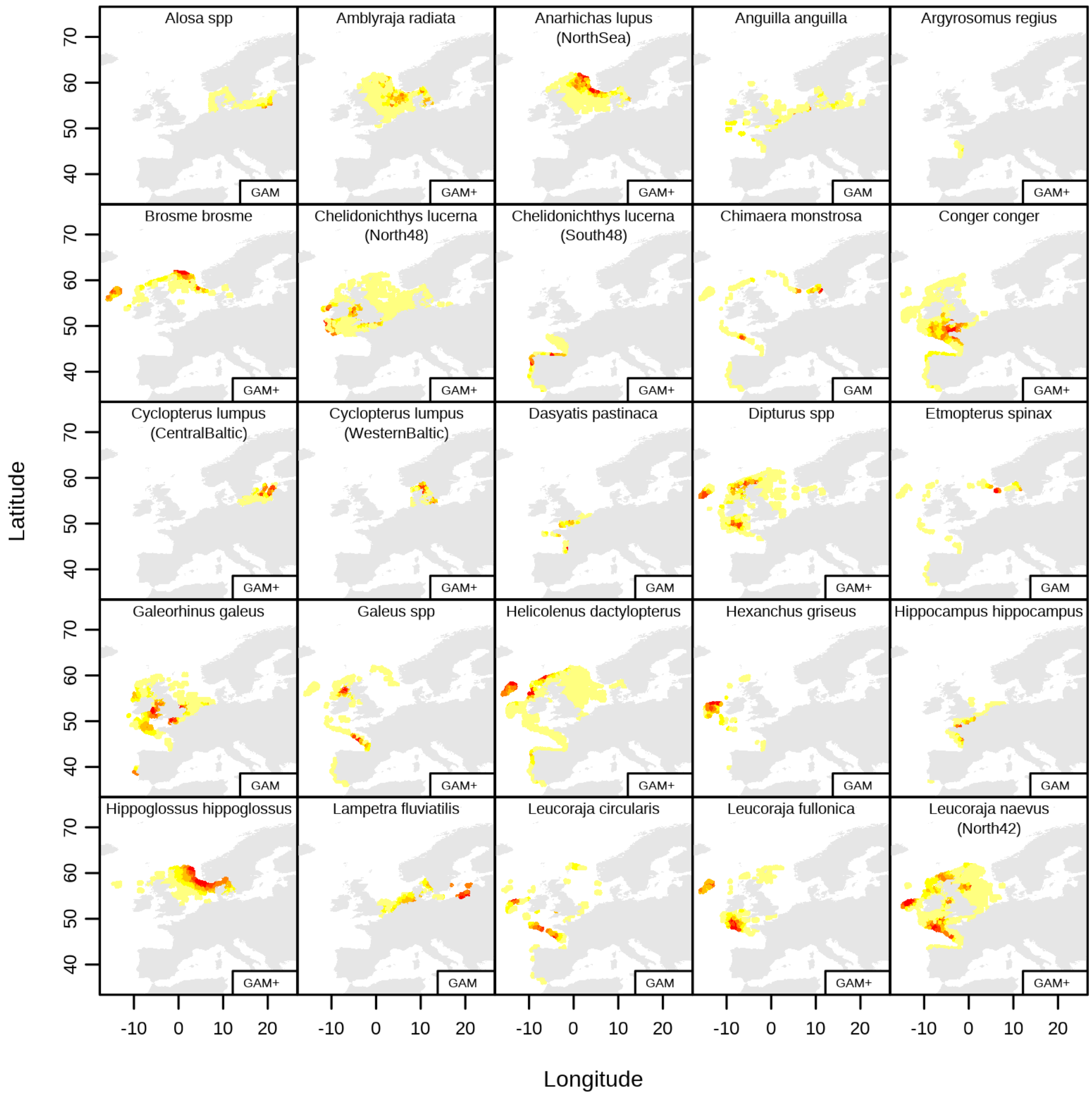

Figure 29: Spatial patterns of abundance for the first 25 out of 50 species. Colour scale indicates high (red) to low abundance (yellow) and is population-specific. Note that maps are only representative of realised habitat (statistical rectangles with at least one occurrence over whole time period). From ICES WKABSENS 2021.

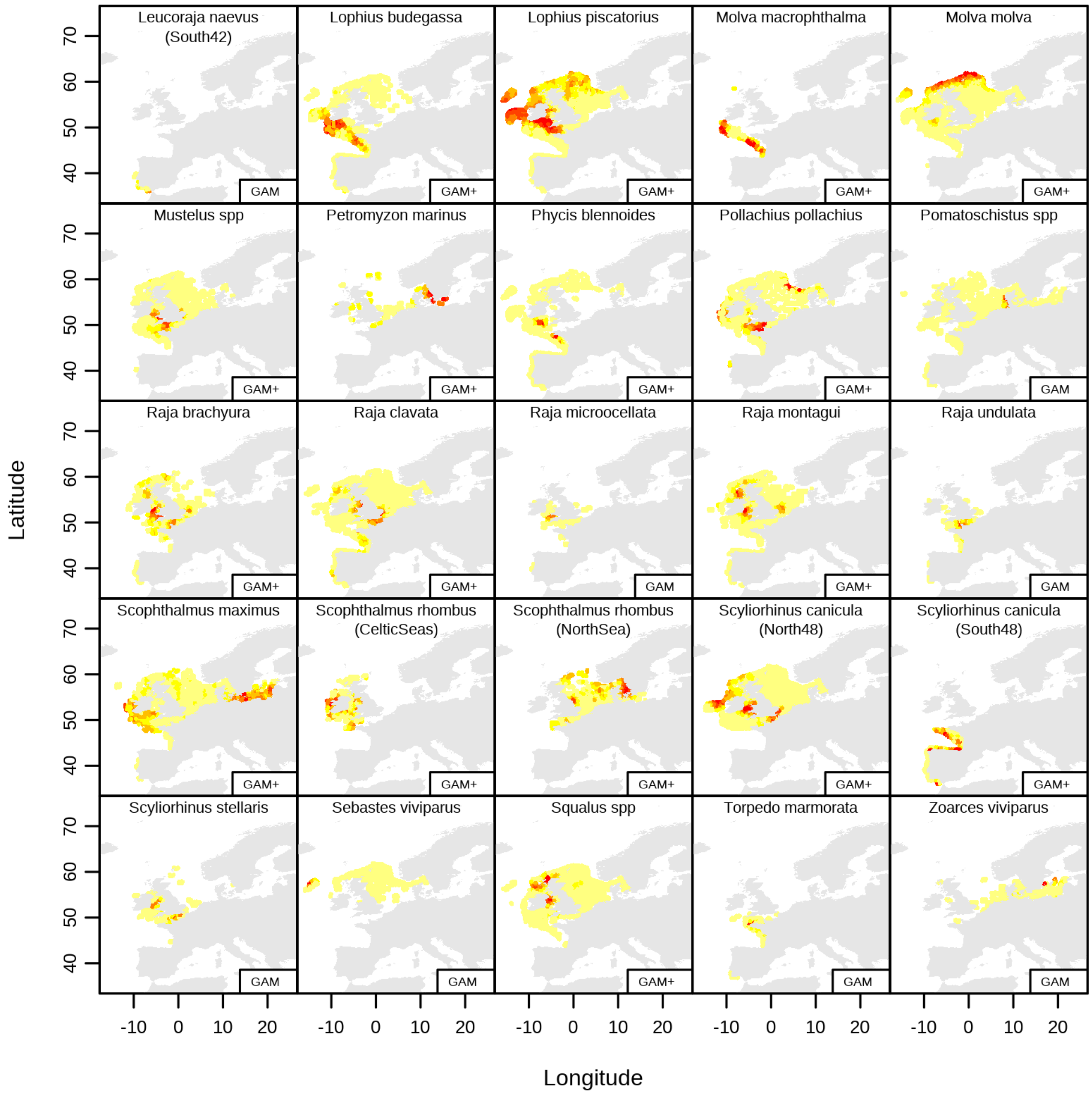

Figure 29 continued: Spatial patterns of abundance for the second 25 out of 50 species. Colour scale indicates high (red) to low abundance (yellow) and is population-specific. Note that maps are only representative of realised habitat (statistical rectangles with at least one occurrence over whole time period). From ICES WKABSENS 2021.

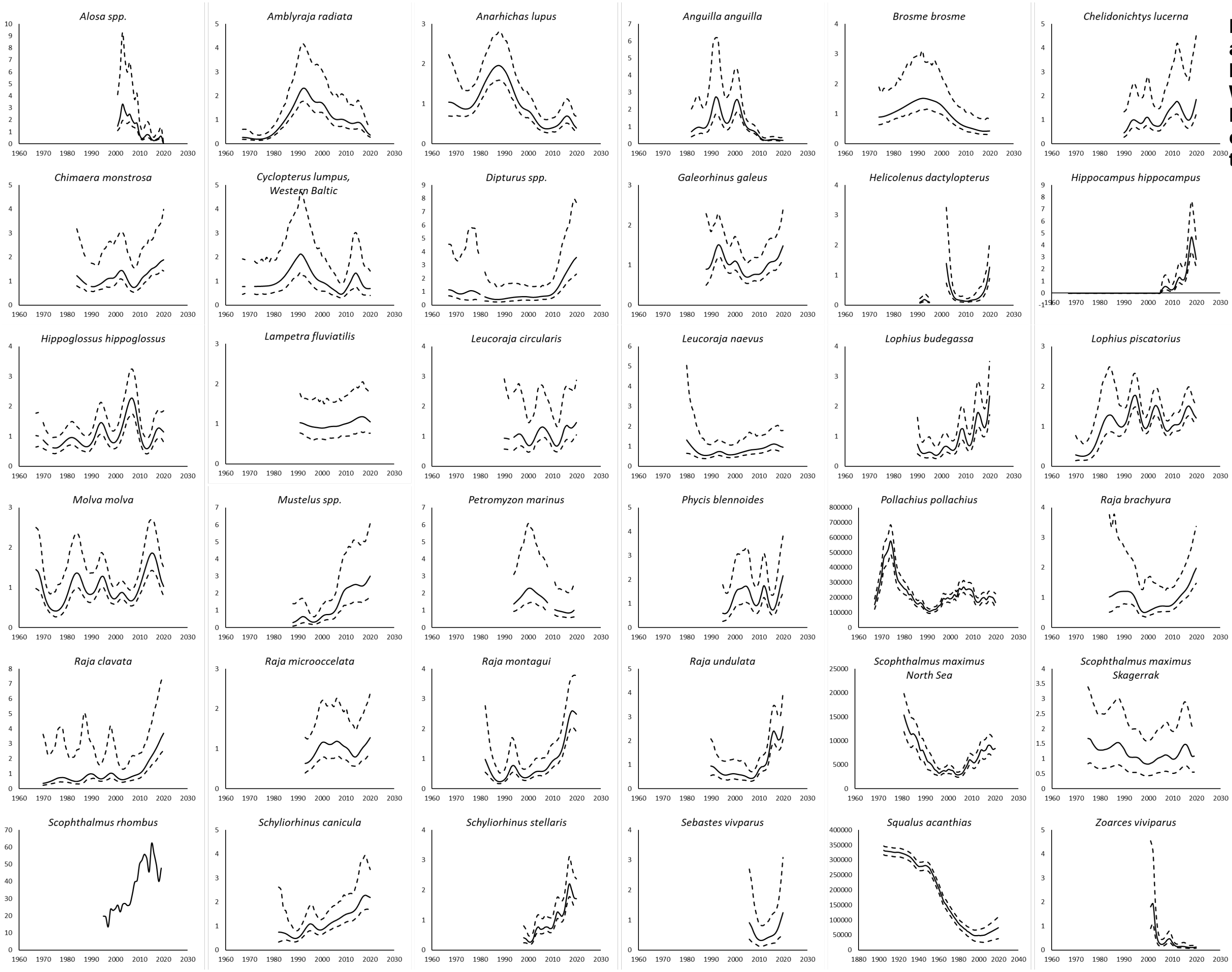

Figure 30: Standardised abundance indices based on data from ICES WKABSENS 2021. Hatches lines are 95% confidence intervals of the predicted value.

2.2 Estimates of annual bycatch of sensitive fish species

Landings given in the tables below are derived from the official sale slips from Danish vessels. The aggregated amount covers all areas and gears, but the majority of the landings are from Skagerrak and the North Sea (area 27.3 and 27.4, respectively).

Discards are estimated from data collected by DTU Aqua's observer program at-sea. The program main covers seiners and bottom trawlers targeting demersal fish and crustanceans and beam trawlers targeting crustaceans in Skagerrak and the North Sea. Minor effort has in some years been dedicated to gillnet fishery. Fisheries for reduction have never been sampled in this program.

Discards are estimated by area, fishery and quarter or year, the latter dependent on number of samples. Within a domain a discard ratio is in general calculated as

$$Discard\ ratio = \frac{\sum observed\ discards\ of\ species\ (kg)}{\sum observed\ andings\ of\ all\ species\ \ (kg)}$$

The ratio is applied to the total landings amount of official landings to derive the total discard within a domain.

Estimates for areas and fisheries not sampled within a year is not provided.

The resulting landings and discards by year are given in Table 7 and Table 8, and the total landings and discards from 2002-2020 are given in Table 9.

Table 7: Annual Danish landings by species in kg as registered in the sale slips. All areas and gears included, but the majority of the landings are from Skagerrak and the North Sea.

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Alosa spp.	2	0	5	220	340	180	104	168	367	488
Amblyraja radiata	0	0	0	0	0	0	0	0	0	0
Anarhichas spp.	249626	177579	165465	131582	112279	129257	141432	181324	236636	159276
Anguilla anguilla	582872	627393	535372	530792	586267	533388	460889	466805	425525	371257
Brosme brosme	221742	223182	156558	134306	160398	96799	58241	50602	37649	54914
Chelidonichthys lucerna	63232	37335	47165	75881	59287	80317	74412	39502	38983	37320
Chimaera monstrosa	82	42	1287	10804	956	580	118	1299	954	1883
Cyclopterus lumpus	756422	1170078	429844	186573	182662	253929	192549	92017	232685	287128
Dipturus batis	143	379	209	49	0	32	215	2521	1410	1515
Etmopterus spinax	0	0	0	0	0	0	0	0	0	0
Galeorhinus galeus	4513	4986	4555	7992	5708	3456	4214	3135	1900	3822
Galeus melastomus	0	0	0	0	0	0	0	0	0	0
Helicolenus dactylopterus	0	0	0	0	0	0	0	0	0	0
Hippoglossus hippoglossus	81893	113136	120535	146851	140055	118629	129957	110510	77085	49171
Lampetra fluviatilis	0	0	0	0	0	0	0	0	0	0
Lophius piscatorius	2036658	2017024	2197709	1953463	1865442	1427777	1640973	1772283	1654186	1423193
Molva molva	829445	958653	776009	860460	786347	529849	548043	643471	549807	686079
Mustelus spp.	0	0	0	0	0	0	0	0	0	0
Petromyzon marinus	0	0	0	0	0	0	0	0	0	0
Phycis blennoides	0	0	0	0	0	0	0	0	0	2
Pollachius pollachius	467376	370856	304623	335481	256295	367826	319234	330885	477835	301215
Raja clavata	0	0	0	0	0	0	118	257	1152	952
Raja montagui	0	0	0	0	0	0	324	218	0	0
Scophthalmus maximus	1005968	731938	759992	665326	535232	556863	721262	840370	737517	790129
Scophthalmus rhombus	148650	198980	244876	249210	236564	234475	319054	274869	280856	295250
Scyliorhinus canicula	0	0	0	0	136	62	0	0	0	0
Scyliorhinus stellaris	0	0	0	0	0	0	0	0	0	0
Sebastes	0	0	0	0	0	0	0	0	0	0
Sebastes mentella	41663	69941	43323	30407	47430	17022	2851	16469	2716	3991
Sebastes norvegicus	572	2205	375	3083	2039	10321	597	18818	3283	7997
Sebastes viviparus	0	0	0	0	0	0	0	0	0	0
Squalus acanthias	255925	233234	219517	150835	121805	76569	78585	82849	15926	25738
Zoarces viviparus	0	0	0	0	1	0	0	0	201	16

Table 7 continued: Annual Danish landings by species in kg as registered in the sale slips. All areas and gears included, but the majority of the landings are from Skagerrak and the North Sea.

Species	2012	2013	2014	2015	2016	2017	2018	2019	2020
Alosa spp.	82	59	4	1	5	189	63	123	691
Amblyraja radiata	0	0	0	0	0	16	1112	2563	0
Anarhichas spp.	219697	170571	285671	311189	466485	420326	445609	516509	356566
Anguilla anguilla	318748	331217	332015	263088	266389	259540	183731	186317	182957
Brosme brosme	30460	45447	24251	27981	34371	38772	40438	47086	48743
Chelidonichthys lucerna	57187	68075	198634	115886	76825	86194	22179	30957	34653
Chimaera monstrosa	16	271	131	506	2634	162	121	742	684
Cyclopterus lumpus	96617	129264	418251	573387	199969	110477	380495	175437	259808
Dipturus batis	115	0	47	742	2033	15710	25331	14785	8696
Etmopterus spinax	0	0	0	0	0	0	0	0	0
Galeorhinus galeus	1012	986	3438	1410	931	2202	1836	1171	1633
Galeus melastomus	0	0	0	0	0	0	0	0	0
Helicolenus dactylopterus	0	0	0	0	0	0	0	0	0
Hippoglossus hippoglossus	35345	56633	47673	58412	119576	169700	183230	167257	139692
Lampetra fluviatilis	0	0	0	0	0	0	0	0	0
Lophius piscatorius	1466619	1386094	1491240	1705692	2533216	3145896	2870103	2969343	2057985
Molva molva	552148	674783	519988	546348	864764	1190017	1167299	1164863	837920
Mustelus spp.	0	0	0	0	6	4	559	92	29
Petromyzon marinus	0	0	0	0	0	0	0	0	586
Phycis blennoides	0	503	8938	16299	3753	4921	37039	65360	70447
Pollachius pollachius	328593	340750	312512	372881	278816	372544	365800	379812	403938
Raja clavata	295	2073	8651	3652	2687	1087	1755	112	3710
Raja montagui	0	110	1389	58	0	0	0	134	728
Scophthalmus maximus	755286	731737	656468	643564	759206	748483	599886	472376	471235
Scophthalmus rhombus	249621	227767	180526	262161	291268	288743	233075	224623	263537
Scyliorhinus canicula	0	4	24	11	18	35	27	113	30
Scyliorhinus stellaris	0	0	0	0	0	0	0	0	0
Sebastes	0	0	0	0	0	2	158	1200	1582
Sebastes mentella	637	914	237	574	187	755	4486	3404	4356
Sebastes norvegicus	9762	7589	329	1707	10010	1885	5965	2951	4644
Sebastes viviparus	0	0	0	0	0	0	0	0	0
Squalus acanthias	31211	20159	11108	26614	23884	36710	19453	21130	32463
Zoarces viviparus	30	483	503	285	169	290	319	387	540

Table 8: Annual estimated discards/below minimum landing size by species in kg. All areas and gears are grouped, but DTU Aqua's observer program covers Skagerrak and the North Sea and mainly active gears.

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Alosa spp.	1866	1280	462	44	0	133	347	38	711	1464
Amblyraja radiata	4454629	5633811	4622008	2354765	4296672	2283071	1631505	963944	3148364	2643831
Anarhichas spp.	1106	1419	2731	192	1891	87	632	147	996	71
Anguilla anguilla	0	0	0	0	0	0	0	0	0	0
Brosme brosme	6267	4261	1286	13696	0	838	591	0	0	38
Chelidonichthys lucerna	6715	29832	32633	4619	15906	22411	6224	9400	1806	10425
Chimaera monstrosa	791046	1045109	92991	713515	268308	30791	176361	190390	233778	894103
Cyclopterus lumpus	12900	178179	69222	66939	52286	28308	14051	55826	292486	16826
Dipturus batis	570823	110148	0	0	28506	4352	3262	2805	4161	10838
Etmopterus spinax	2533677	239383	80209	227706	46275	5832	111836	18387	52763	20054
Galeorhinus galeus	0	0	0	0	0	0	0	0	0	0
Galeus melastomus	0	0	21525	50714	0	1732	32036	18679	22129	6445
Helicolenus dactylopterus	108402	3839	4911	0	947	0	24	0	329	0
Hippoglossus hippoglossus	687	255	394	795	2628	6819	114	0	0	0
Lampetra fluviatilis	0	0	0	0	0	0	0	0	3	0
Lophius piscatorius	176095	212137	54212	377015	26468	28592	4388	1251	5312	1005
Molva molva	7129	25782	609	11812	2557	67388	26090	43074	51106	4099
Mustelus spp.	3484	0	1659	6046	0	0	0	7	51	16
Petromyzon marinus	0	0	0	0	0	0	0	0	0	0
Phycis blennoides	647925	65480	18570	42590	0	7885	55472	45953	46626	175890
Pollachius pollachius	0	0	217	921	677	0	323	2230	1342	12401
Raja clavata	180	2361	0	0	0	160777	105428	0	0	2316
Raja montagui	0	0	0	0	0	0	0	0	0	0
Scophthalmus maximus	59455	29837	35559	62687	33784	43431	46497	7050	27436	72098
Scophthalmus rhombus	33432	13217	30006	18970	33098	92436	25332	19724	74762	73115
Scyliorhinus canicula	2331	35218	9761	9402	7350	7550	21319	711	4606	14573
Scyliorhinus stellaris	0	0	0	0	0	0	0	0	200	0
Sebastes	0	0	0	0	0	0	0	0	0	0
Sebastes mentella	0	0	0	0	0	0	0	0	0	0
Sebastes norvegicus	286753	108414	22421	48240	853	1826	58741	4631	22013	6250
Sebastes viviparus	3649	826	92	0	848	505	6701	250	250	0
Squalus acanthias	12391	31360	5066	2034	1425	0	2128	6593	10946	55486
Zoarces viviparus	0	0	0	0	0	0	0	5470	34208	388

Table 8 continued: Annual estimated discards/below minimum landing size by species in kg. All areas and gears are grouped, but DTU Aqua's observer program covers Skagerrak and the North Sea and mainly active gears.

Species	2012	2013	2014	2015	2016	2017	2018	2019	2020
Alosa spp.	31	2346	1900	75	751	285	0	302	430
Amblyraja radiata	1276891	800593	1373574	1329366	816958	1660283	329296	379266	422084
Anarhichas spp.	3440	812	214	1788	378	419	1126	1448	220
Anguilla anguilla	0	0	0	0	0	0	0	0	0
Brosme brosme	28	1628	171	658	0	5023	165	35	98
Chelidonichthys lucerna	9913	1725	12552	3057	8495	6652	4112	14727	3095
Chimaera monstrosa	24501	132449	9651	14229	4046	50306	24961	19995	71927
Cyclopterus lumpus	45473	62235	13878	21081	9850	12788	207899	45077	110299
Dipturus batis	38591	15958	1830	7757	10871	3866	13378	8477	7559
Etmopterus spinax	12378	31361	9818	32005	6172	17518	27022	51836	13023
Galeorhinus galeus	0	0	0	106	0	0	61	91	1304
Galeus melastomus	8717	4981	858	499	223	14251	6746	16674	12489
Helicolenus dactylopterus	0	0	0	0	0	92	17	988	842
Hippoglossus hippoglossus	0	71	103	0	97	130	218	550	0
Lampetra fluviatilis	0	0	0	0	0	0	0	0	0
Lophius piscatorius	8321	22030	8375	11485	28699	26777	29897	43076	37120
Molva molva	3760	841	3713	864	2661	3713	4696	4321	4223
Mustelus spp.	0	17	531	247	39609	323	2360	5700	2426
Petromyzon marinus	0	0	0	308	0	0	0	0	0
Phycis blennoides	48967	336832	14594	39701	10398	194951	48761	16907	14980
Pollachius pollachius	408	27201	763	3337	930	1305	2538	1197	597
Raja clavata	2697	2627	2864	10515	12631	11429	10499	7376	42798
Raja montagui	0	0	0	0	0	0	993	1338	582
Scophthalmus maximus	54346	26092	47903	24132	62978	37557	34425	30309	148081
Scophthalmus rhombus	29003	24261	61140	67492	21723	45074	85225	36005	79229
Scyliorhinus canicula	23733	22030	5011	6180	8788	10983	37532	17584	9721
Scyliorhinus stellaris	3188	0	2628	5227	0	1604	0	470	149
Sebastes	0	0	0	0	0	0	0	122	0
Sebastes mentella	0	0	0	0	0	0	0	0	0
Sebastes norvegicus	406	13106	81	81	104	182	38	2106	71
Sebastes viviparus	0	41	0	6	0	497	1341	548	959
Squalus acanthias	7134	233267	34087	33056	717950	41385	43694	40707	234432
Zoarces viviparus	14716	3669	4038	2222	2205	2016	6155	2355	289

Table 9: Total landings, discards/ below minimum landing size and catches by species in kg and landed proportion.

Species	Total landing	Total discard	Total catch	Landing in proportion of catch
Alosa spp.	3091	12466	15557	0.20
Amblyraja radiata	3691	40420912	40424603	0.00
Anarhichas spp.	4877079	19118	4896197	1.00
Anguilla anguilla	7444562	0	7444562	1.00
Brosme brosme	1531940	34782	1566722	0.98
Chelidonichthys lucerna	1244024	204298	1448322	0.86
Chimaera monstrosa	23272	4788456	4811728	0.00
Cyclopterus lumpus	6127592	1315603	7443195	0.82
Dipturus batis	73932	843182	917114	0.08
Etmopterus spinax	0	3537254	3537254	0.00
Galeorhinus galeus	58900	1562	60462	0.97
Galeus melastomus	0	218699	218699	0.00
Helicolenus dactylopterus	0	120390	120390	0.00
Hippoglossus hippoglossus	2065340	12860	2078200	0.99
Lampetra fluviatilis	0	3	3	0.00
Lophius piscatorius	37614894	1102255	38717150	0.97
Molva molva	14686294	268438	14954732	0.98
Mustelus spp.	690	62475	63165	0.01
Petromyzon marinus	586	308	894	0.66
Phycis blennoides	207262	1832481	2039743	0.10
Pollachius pollachius	6687272	56390	6743662	0.99
Raja clavata	26501	374498	400999	0.07
Raja montagui	2961	2913	5874	0.50
Scophthalmus maximus	13182838	883656	14066494	0.94
Scophthalmus rhombus	4704105	863241	5567346	0.84
Scyliorhinus canicula	460	254383	254843	0.00
Scyliorhinus stellaris	0	13466	13466	0.00
Sebastes	2942	122	3064	0.96
Sebastes mentella	291363	0	291363	1.00
Sebastes norvegicus	94132	576318	670450	0.14
Sebastes viviparus	0	16512	16512	0.00
Squalus acanthias	1483715	1513141	2996856	0.50
Zoarces viviparus	3224	77732	80956	0.04

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Annex

Table 10: Yearly average bycatch estimates per region in Danish commercial gillnets +- 95% confidence intervals (data from 2010 to 2019). Baltic includes ICES areas IIIa21 (Kattegat), IIIb23 (Øresund) and IIIc22 (Belt Sea); NS includes ICES areas IVb (North Sea) and IIIa20 (Skagerrak).

Region	Species	Bycatch Estimates	Lower 95% CI	Lower 95% CI
Baltic	Harbour porpoise	760	636	889
NS	Harbour porpoise	4273	3075	5742
Baltic	Seals	366	276	463
NS	Seals	1433	1011	1910
Baltic	All seabirds	4532	3625	5515
NS	All seabirds	7800	3436	13994
Baltic	Auks (Alcidae)	739	569	929
NS	Auks (Alcidae)	7076	2713	13226
Baltic	Common Eider	2623	1847	3567
NS	Common Eider	55	0	129
Baltic	Common Eider female	569	370	802
NS	Common Eider female	18	0	55
Baltic	Common Eider male	1888	1275	2642
NS	Common Eider male	37	0	92
Baltic	Northern Fulmar	0	0	0
NS	Northern Fulmar	73	0	184
Baltic	Loons (Gaviidae)	32	9	60
NS	Loons (Gaviidae)	18	0	55
Baltic	Great Cormorant	793	650	939
NS	Great Cormorant	147	55	276
Baltic	Great Cormorant adult	183	119	253
NS	Great Cormorant adult	55	0	129
Baltic	Great Cormorant juvenile	490	390	600
NS	Great Cormorant juvenile	73	18	147
Baltic	Grebes (Podicipedidae)	37	14	64
NS	Grebes (Podicipedidae)	0	0	0
Baltic	Gulls (Laridae)	23	5	46
NS	Gulls (Laridae)	37	0	92
Baltic	Scoters (*Melanitta spp*)	192	115	280
NS	Scoters (*Melanitta spp*)	110	18	220
Baltic	Unidentified Birds	363	256	476
NS	Unidentified Birds	495	276	735

Table 11: Quarterly average bycatch estimates per region in Danish commercial gillnets +- 95% confidence intervals (data from 2010 to 2019). Baltic includes ICES areas IIIa21 (Kattegat), IIIb23 (Øresund) and IIIc22 (Belt Sea); NS includes ICES areas IVb (North Sea) and IIIa20 (Skagerrak).

Region	Quarter	Species	Bycatch Estimates	Lower 95% CI	Lower 95% CI
Baltic	Q1	Harbour porpoise	114	73	162
Baltic	Q2	Harbour porpoise	191	135	252
Baltic	Q3	Harbour porpoise	310	225	405
Baltic	Q4	Harbour porpoise	161	106	225
NS	Q1	Harbour porpoise	540	282	843
NS	Q2	Harbour porpoise	2280	1112	3960
NS	Q3	Harbour porpoise	1475	963	2102
NS	Q4	Harbour porpoise	244	133	376
Baltic	Q1	Seals	102	25	207
Baltic	Q2	Seals	27	0	71
Baltic	Q3	Seals	241	81	453
Baltic	Q4	Seals	0	0	0
NS	Q1	Seals	88	0	256
NS	Q2	Seals	155	0	439
NS	Q3	Seals	570	175	1092
NS	Q4	Seals	28	0	80
Baltic	Q1	Seabirds	1417	637	2538
Baltic	Q2	Seabirds	410	92	872
Baltic	Q3	Seabirds	657	253	1176
Baltic	Q4	Seabirds	1575	765	2544
NS	Q1	Seabirds	5614	1304	11605
NS	Q2	Seabirds	323	0	899
NS	Q3	Seabirds	372	86	707
NS	Q4	Seabirds	569	92	1258
Baltic	Q1	Auks (Alcidae)	350	138	642
Baltic	Q2	Auks (Alcidae)	0	0	0
Baltic	Q3	Auks (Alcidae)	44	0	105
Baltic	Q4	Auks (Alcidae)	498	238	809
NS	Q1	Auks (Alcidae)	5429	1216	11350
NS	Q2	Auks (Alcidae)	258	0	775
NS	Q3	Auks (Alcidae)	137	35	309
NS	Q4	Auks (Alcidae)	508	67	1209
Baltic	Q1	Common Eider	834	224	1763
Baltic	Q2	Common Eider	337	62	757
Baltic	Q3	Common Eider	170	33	380
Baltic	Q4	Common Eider	695	206	1347
NS	Q1	Common Eider	35	0	88
NS	Q2	Common Eider	0	0	0
NS	Q3	Common Eider	5	0	16
NS	Q4	Common Eider	0	0	0
Baltic	Q1	Common Eider female	166	25	402
Baltic	Q2	Common Eider female	58	0	153

Region	Quarter	Species	Bycatch Esti-mates	Lower 95% CI	Lower 95% CI
Baltic	Q3	Common Eider female	50	9	114
Baltic	Q4	Common Eider female	166	25	369
NS	Q1	Common Eider female	17	0	52
NS	Q2	Common Eider female	0	0	0
NS	Q3	Common Eider female	0	0	0
NS	Q4	Common Eider female	0	0	0
Baltic	Q1	Common Eider male	610	170	1261
Baltic	Q2	Common Eider male	201	43	437
Baltic	Q3	Common Eider male	65	8	156
Baltic	Q4	Common Eider male	488	129	974
NS	Q1	Common Eider male	17	0	52
NS	Q2	Common Eider male	0	0	0
NS	Q3	Common Eider male	5	0	16
NS	Q4	Common Eider male	0	0	0
Baltic	Q1	Northern Fulmar	0	0	0
Baltic	Q2	Northern Fulmar	0	0	0
Baltic	Q3	Northern Fulmar	0	0	0
Baltic	Q4	Northern Fulmar	0	0	0
NS	Q1	Northern Fulmar	0	0	0
NS	Q2	Northern Fulmar	0	0	0
NS	Q3	Northern Fulmar	67	0	200
NS	Q4	Northern Fulmar	21	0	62
Baltic	Q1	Loons (Gavidae)	11	0	28
Baltic	Q2	Loons (Gavidae)	0	0	0
Baltic	Q3	Loons (Gavidae)	0	0	0
Baltic	Q4	Loons (Gavidae)	15	0	40
NS	Q1	Loons (Gavidae)	0	0	0
NS	Q2	Loons (Gavidae)	18	0	55
NS	Q3	Loons (Gavidae)	0	0	0
NS	Q4	Loons (Gavidae)	0	0	0
Baltic	Q1	Great Cormorant	120	17	260
Baltic	Q2	Great Cormorant	40	0	96
Baltic	Q3	Great Cormorant	411	102	781
Baltic	Q4	Great Cormorant	274	83	526
NS	Q1	Great Cormorant	0	0	0
NS	Q2	Great Cormorant	18	0	55
NS	Q3	Great Cormorant	46	0	107
NS	Q4	Great Cormorant	8	0	19
Baltic	Q1	Great Cormorant adult	30	0	78
Baltic	Q2	Great Cormorant adult	0	0	0
Baltic	Q3	Great Cormorant adult	74	17	146
Baltic	Q4	Great Cormorant adult	63	0	160
NS	Q1	Great Cormorant adult	0	0	0
NS	Q2	Great Cormorant adult	0	0	0

Region	Quarter	Species	Bycatch Esti-mates	Lower 95% CI	Lower 95% CI
NS	Q3	Great Cormorant adult	26	0	67
NS	Q4	Great Cormorant adult	0	0	0
Baltic	Q1	Great Cormorant juvenile	66	9	144
Baltic	Q2	Great Cormorant juvenile	5	0	14
Baltic	Q3	Great Cormorant juvenile	212	60	412
Baltic	Q4	Great Cormorant juvenile	170	47	332
NS	Q1	Great Cormorant juvenile	0	0	0
NS	Q2	Great Cormorant juvenile	18	0	55
NS	Q3	Great Cormorant juvenile	20	0	51
NS	Q4	Great Cormorant juvenile	4	0	11
Baltic	Q1	Grebes (Podicipedidae)	15	0	40
Baltic	Q2	Grebes (Podicipedidae)	0	0	0
Baltic	Q3	Grebes (Podicipedidae)	9	0	27
Baltic	Q4	Grebes (Podicipedidae)	9	0	22
NS	Q1	Grebes (Podicipedidae)	0	0	0
NS	Q2	Grebes (Podicipedidae)	0	0	0
NS	Q3	Grebes (Podicipedidae)	0	0	0
NS	Q4	Grebes (Podicipedidae)	0	0	0
Baltic	Q1	Gulls (Laridae)	3	0	10
Baltic	Q2	Gulls (Laridae)	12	0	35
Baltic	Q3	Gulls (Laridae)	4	0	13
Baltic	Q4	Gulls (Laridae)	12	0	35
NS	Q1	Gulls (Laridae)	13	0	39
NS	Q2	Gulls (Laridae)	0	0	0
NS	Q3	Gulls (Laridae)	25	0	74
NS	Q4	Gulls (Laridae)	0	0	0
Baltic	Q1	Scoters (*Melanitta spp*)	51	2	128
Baltic	Q2	Scoters (*Melanitta spp*)	7	0	21
Baltic	Q3	Scoters (*Melanitta spp*)	12	0	36
Baltic	Q4	Scoters (*Melanitta spp*)	54	14	114
NS	Q1	Scoters (*Melanitta spp*)	52	0	105
NS	Q2	Scoters (*Melanitta spp*)	18	0	55
NS	Q3	Scoters (*Melanitta spp*)	0	0	0
NS	Q4	Scoters (*Melanitta spp*)	8	0	23
Baltic	Q1	Unidentified Birds	114	21	248
Baltic	Q2	Unidentified Birds	33	0	99
Baltic	Q3	Unidentified Birds	32	0	84
Baltic	Q4	Unidentified Birds	110	22	236
NS	Q1	Unidentified Birds	151	0	365
NS	Q2	Unidentified Birds	47	0	141
NS	Q3	Unidentified Birds	183	17	421
NS	Q4	Unidentified Birds	55	0	133

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