A2.1
Bycatch
Main report

Baltic Marine Environment Protection Commission

BLUES

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Activity 2- Biodiversity

2023

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HELCOM BLUES – Activity 2.1 Bycatch

Summary of results

In order to achieve an improved and more complete regional assessment on bycatch (Activity 2.1) as part of the HELCOM BLUES project, two subtasks were conducted; one on the further development of risk area mapping (A2.1.1) and another on exploratory work towards and assessment of food webs (A2.1.2). The summary results, key messages and use of results can be found in this document. The detailed documents, with more information on the work conducted, are available as A2.1 Annex 1 and A2.1 Annex 2.

Subtask 2.1.1 Further development of risk area mapping

Bycatch of marine mammals and waterbirds has been documented in many fisheries worldwide. For many marine mammals and birds, bycatch is regarded as one of the most significant sources of anthropogenic mortality (Lewison et al., 2014; Dias et al., 2019, Zydelis et al., 2009).

In the Baltic Sea (i.e. the HELCOM region), the harbour porpoise *Phocoena phocoena* is the only resident cetacean. Three species of seals are present year-round: the grey seal *Halichoerus grypus,* the harbour seal *Phoca vitulina* and the ringed seal *Pusa hispida*. Another aquatic mammal which also occurs in coastal waters of the Baltic Sea is the Eurasian otter (*Lutra lutra*).

Waterbirds can become entangled in static nets, trapped in trawls, fish traps and fyke nets and get hooked on longlines or get struck by trawl cables (Tasker et al., 2000). According to HELCOM (2018b), the number of waterbird species breeding or wintering in the Baltic Sea is around 80. Žydelis et al. (2009) provided a thorough evaluation of the bycatch of waterbirds in static nets in the Baltic Sea and estimated that most likely between 100,000 and 200,000 waterbirds are bycaught per year in the Baltic and the North Sea.

Mortality due to bycatch can only be determined if bycatch rate related to monitoring effort for all fishing métiers in meaningful metrics and total effort are monitored in a suitable manner (HELCOM 2020). In the absence of quantitative data on bycatch rates, absolute bycatch numbers cannot be assessed. In order to identify marine fishing areas with the greatest bycatch risk of mammal and bird population based upon interaction probabilities, an approach taken is to develop bycatch risk maps which has been applied in several studies (Kindt-Larsen et al., 2016; Goldworthy and Page, 2007), including the HELCOM ACTION project (HELCOM 2021b). Bycatch risk maps can put the estimated mortality, if it is available, into context. Further, areas where monitoring of bycatch needs to be intensified can be pointed out. Mapping the spatio-temporal variability of bycatch risk can thus be a way forward with regard to implementing preventive mitigation measures that reduce bycatch depending on site-specific conditions.

In the BLUES project, application of risk mapping method was performed for 3 seal species and 11 waterbird species in the Baltic Sea, allowing to identify some (species-specific) areas of high bycatch risk. Details on data, methodology, results and discussion can be found in the report A2.1 Annex 1.

Subtask 2.1.2 Evaluating bycatch assessment approach developed in OSPAR-HELCOM by-catch workshop

Evaluations were based on threshold values (TV), with the original threshold proposals outlined in the joint *OSPAR-HELCOM workshop to examine possibilities for developing indicators for incidental by-catch of birds and marine mammals* (September 2019, Copenhagen, OSPAR & HELCOM 2019). Based on the outcome and recommendations of the workshop (built on the expertise of 52 experts representing 20 countries and several organizations) TVs were further developed by the HELCOM BLUES project, taking discussions between HELCOM Contracting Parties and on expert level into account. Limited availability of by-catch and effort data as well as knowledge on species demography parameters was hereby considered. In the development process leading towards HOLAS 3 it was noted that from a policy/management perspective there is a strong wish to have some sort of evaluation in place as this would promote future work.

Marine mammal threshold values:

- PBR = Potential Biological Removal: loss of individuals from bycatch and hunting allowing to maintain a population size reflecting 80% of carrying capacity after 100 years.
- Zero bycatch in critically endangered or vulnerable populations

Waterbird threshold values:

- Population viability not threatened (PVA = Population viability analysis), not applied due to lack of data
- Bycatch number equals 1% of annual adult mortality (red-listed species only)
- Bycatch occurring (red-listed species)

The widespread lack of adequate data on both by-catch rates and fishing effort has hampered a comprehensive evaluation of by-catch in marine mammals and waterbirds. Marine mammals were evaluated on the population level. None of the populations of each of four species of marine mammals (harbour porpoise, ringed seal, harbour seal, grey seal) achieved good status. The harbour seal population of the South-western Baltic and Kattegat could not be assessed. Waterbirds were evaluated on the geographical scale of subdivisions (aggregated sub-basins), with evaluations available for a total of 11 species in four subdivisions. The threshold for good status was not met in any case. The results of this indicator demonstrate that significant mortality from by-catch in fishing gear is widespread across species of marine mammals and waterbirds in the Baltic Sea. In addition to urgent measures to mitigate the problem, monitoring is needed to observe the success of such measures. Information on fishing effort and by-catch of marine mammals and waterbirds is not being recorded and reported in an adequate way allowing the indicator to be fully operationalised.

Overall, the work in this task enabled a bycatch indicator assessments for 6 marine mammal populations and 11 waterbird species, all showing that Good Environmental Status is not achieved.

More information and details on data, methodology, results and discussion can be found in the indicator report on bycatch, available as A2.1 Annex 2.

Key messages

Key messages for **science**

1) Where applicable, bycatch assessments indicated negative impact on marine mammal and waterbird populations.
2) More precise data of fishing effort and mammal/bird bycatch are needed to quantify the impact of bycatch on the population level.
3) High-resolution bycatch assessments are required for development of targeted measures.

Key messages for **policy makers**

1) Bycatch in fishing gear threatens the viability of marine mammal and waterbird populations in many parts of the Baltic Sea.
2) Bycatch monitoring needs to be implemented to allow identification of high-risk areas and population effects as a basis for targeted management measures.
3) Measures against bycatch must be taken to prevent deterioration of marine ecosystems.

Use of results

Overall, the results have contributed towards a more holistic and quantitative assessment of bycatch in the Baltic Sea. More specifically, the outcomes of this task have directly been used in the indicator report on bycatch in HOLAS 3. The work of task A2.1 also directly contributed to the HOLAS 3 Thematic assessment of biodiversity, chapter on bycatch.

By addressing key topics in the thematic assessment of biodiversity, the work connects directly to the BSAP goal of a "Baltic Sea ecosystem ('that') is healthy and resilient", as well as the BSAP management objective "Human induced mortality, including hunting, fishing, and incidental bycatch, does not threaten the viability of marine life". Explicitly, the work on bycatch addresses the BSAP actions B8 and B33 on the need for further development of indicators to allow improved holistic assessments of the state of the Baltic Sea and supporting the conservation of species.

Further, the updated approaches and results for evaluating of bycatch facilitates reporting under the MSFD (D1C1, also links to D4) for HELCOM Contracting Parties that are also EU Member States, as the assessment aimed at following the MSFD Article 8 guidance.

Other relevant international processes/conventions that benefit from the results achieved in this task are the EU Action Plan, ASCOBANS and AEWA.

References

Dias, M. P. et al. (2019) 'Threats to seabirds: A global assessment', Biological Conservation 237: 525–537. doi: 10.1016/j.biocon.2019.06.033.

Goldsworthy, S., and Page, B. 2007. A risk-assessment approach to evaluating the significance of seal bycatch in two Australian fisheries. Biological Conservation, 139: 3–4, pp 269-285

HELCOM (2018b) 'State of the Baltic Sea–Second HELCOM holistic assessment 2011-2016', in Baltic Sea Environment Proceedings, 155 p.

HELCOM 2020. Roadmap on fisheries data in order to assess incidental bycatch and fisheries impact on benthic biotopes in the Baltic Sea. HELCOM Secretariat, Helsinki, Finland, 17 pp. https://helcom.fi/wp-content/uploads/2020/03/HELCOM-Roadmap-on-fisheries-data.pdf

HELCOM (2021b) Bycatch in Baltic Sea commercial fisheries: High-risk areas and evaluation of measures to reduce bycatch. HELCOM ACTION (2021)

Kindt-Larsen, Lotte, et al. "Identification of high-risk areas for harbour porpoise Phocoena phocoena bycatch using remote electronic monitoring and satellite telemetry data." Marine Ecology Progress Series 555 (2016): 261-271.

Lewison, R. L. et al. (2014) 'Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots', Proceedings of the National Academy of Sciences, 111(14), pp. 5271–5276. doi: 10.1073/pnas.1318960111.

OSPAR & HELCOM 2019. Outcome of the OSPAR-HELCOM workshop to examine possibilities for developing indicators for incidental by-catch of birds and marine mammals. https://portal.helcom.fi/meetings/Incidental%20bycatch%20WS%201-2019-647/MeetingDocuments/Outcome%20OSPAR-HELCOM%20incidental%20by-catch%20indicator%20workshop_final.pdf

Tasker, M.L., Camphuysen, C.J., Cooper, J., Garthe, S., Montevecchi, W.A., Blaber, S.J.M., 2000. The impacts of fishing on marine birds. ICES Journal of Marine Science 57, 531–547.

Žydelis, R. et al. (2009) 'Bycatch in gillnet fisheries – An overlooked threat to waterbird populations', Biological C,onservation, 142: 1269–1281. doi: 10/fwdfxp

Baltic Marine Environment
Protection Commission

A2.1 Annex 1
Report on Bycatch risk maps of marine mammals and waterbirds in the Baltic Sea

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Bycatch risk maps of marine mammals and waterbirds in the Baltic Sea

Contents

Introduction

Bycatch of marine mammals and waterbirds has been documented in many fisheries worldwide. For many marine mammals and birds, bycatch is regarded as one of the most significant sources of anthropogenic mortality (Read et al., 2006; Lewison et al., 2014; Dias et al., 2019, Zydelis et al., 2009). Accordingly, HELCOM has formulated in its Baltic Sea Action Plan the management objective that "Human induced mortality, including hunting, fishing, and incidental by-catch, does not threaten the viability of marine life", which is related to the goal of "Baltic Sea ecosystem is healthy and resilient" and the ecological objective "viable populations of all native species" (HELCOM 2021a). In this Action Plan, HELCOM Contracting Parties have agreed the specific actions on bycatch (B8, B21, S43 to S49), which aim at implementing operational conservation measures and promoting effective mitigation measures to achieve the close to zero target for by-catch rates of relevant waterbird and mammal species by 2024, especially the Baltic Proper population of harbour porpoise by 2022 and setting up conservation schemes for key waterbird areas. Further aims are testing, promoting and introducing new technical and operational bycatch mitigation measures (with specific reference to alternative gear) and finally developing and implementing effective data collection for more reliable data on incidentally bycaught birds and mammals and fishing effort for which there has long been a legal obligation (specifically under the EU Birds and Habitats Directive, Common Fisheries Policy and the Data Collection Multiannual Programmes).

In the Baltic Sea (i.e. the HELCOM region), the harbour porpoise *Phocoena phocoena* is the only resident cetacean. Three species of seals are present year round: the grey seal *Halichoerus grypus,* the harbour seal *Phoca vitulina* and the ringed seal *Pusa hispida*. Another aquatic mammal which also occurs in coastal waters of the Baltic Sea is the Eurasian otter (*Lutra lutra*). The Baltic Sea is also a major migratory route for millions of birds and an essential breeding and wintering ground for numerous waterbird species. Bycatch in static nets within Baltic fisheries has been reported for all four species of marine mammals, as well as for >30 species of waterbirds (Žydelis et al., 2009; Degel et al., 2010; Kindt-Larsen et al., 2012; Sonntag et al., 2012; Bellebaum et al., 2013; Žydelis, Small and French, 2013; HELCOM, 2018a, 2018b; Field et al., 2019; ICES, 2020; Glemarec et al., 2020; Marchowski et al., 2020). The harbour porpoise is protected under Annexes II and IV, the seal species under Annex V of the EU Habitats Directive, all waterbird species are protected under the EU Birds Directive.

With respect to marine mammals, in this study we have focused on bycatch risk maps for the seal populations. All seal populations in the Baltic Sea including Kattegat (except for the ringed seal population of the Archipelago Sea, Gulf of Finland and Gulf of Riga) have increased significantly during the past 10 years. In 2021, 42 000 grey seals were counted in aerial surveys in the Baltic Sea. The counted numbers include 60–80% of all individuals (HELCOM 2018c), the overall population size of grey seal in the Baltic Sea in 2021 range between 52,000 up to 69,000 individuals. In the Kattegat and Skagerrak, the most common seal species is the harbour seal (*Phoca vitulina*), and its abundance has also increased considerably to a population size that is larger or equivalent to that in the beginning of the 20th century and comprises more than 15 000 individuals (Hav, 2014). The Baltic population of harbour seals is also increasing and has around 1000 individuals (HELCOM 2018c). Even though we have knowledge on the abundance of seals in the Baltic, there is lack of data on bycatch of seals. There is data on bycatch of seals in ICES subdivision 20 to 25 and in subdivision 27. In area 28 to 32, there are no bycatch rates on seals available. The data on seals in area 20 to 25 are mainly data submitted to the scientific working group on bycatch ICES WGBYC where each ICES Member State participating in the process must submit existing data from their monitored fisheries. These are mainly data collected within the EU data collection framework (DCF). ICES WGBYC has noted that the DCF data sampling is not representative, and bias is introduced from various sources. For example, monitoring of larger vessels and data collection using fisheries observers dominate the dataset. Further, there is no random sampling, therefore calculating the bycatch rates for this area gives biased results. However, pilot studies and research projects are also occasionally submitted. Studies show that bycatch of grey seals most likely occurs in fisheries using static nets and pots and traps but have also been recorded in trawl fisheries (ICES WGBYC 2019; Vanhatalo et al., 2014). In 2012, the bycatch of grey seals was estimated to be between 1240 and 2860 individuals where 88% of the bycatch occurred in the trap-net fisheries (Vanhatalo et al., 2014).

Waterbirds can become entangled in static nets, trapped in trawls, fish traps and fyke nets and get hooked on longlines or get struck by trawl cables (Tasker et al., 2000). According to HELCOM (2018b), the number of waterbird species breeding or wintering in the Baltic Sea is around 80. Žydelis et al. (2009) provided a thorough evaluation of the bycatch of waterbirds in static nets in the Baltic Sea and estimated that most likely between 100,000 and 200,000 waterbirds are bycaught per year in the Baltic and the North Sea. The species most commonly bycaught in the Baltic Sea is the long-tailed duck (*Clangula hyemalis*). Great-crested grebe (*Podiceps cristatus*), great cormorant (*Phalacrocorax carbo*) and greater scaup (*Aythya marila*) are other waterbirds commonly bycaught in the Baltic Sea. In the Baltic Sea, bycatch numbers generally correlate with bird abundance. Species commonly occurring as bycatch are abundant species and least frequent are rare species, such as Slavonian grebe (*Podiceps auritus*) and Steller's eider (*Polysticta stelleri) (*Žydelis et al., 2009). Thereby it can be assumed that mapping the abundance of the species in relation to the fishing effort in the area will give an indication of where the risk of bycatch is high. However, bycatch rates are dependent on the species behaviour, the fishing gear used and also factors related to the fishing operations such as soak time, time of setting/hauling etc.
Even though the bycatch of waterbirds in static nets in the Baltic Sea has been evaluated *(*Žydelis et al., 2009), there is a lack of data on bycatch in other gears such as longlines, trawls or in fyke nets from the Baltic Sea. In a study evaluating bycatch rates in the Baltic Sea, it was concluded that bycatch data published in the literature is scarce (HELCOM, 2021b). There are available data on the bycatch rate estimates for bird species in subdivisions 20 to 26. However, in ICES subdivisions 27 to 32, no data on bycatch are available. The data available from area 25 to 26 are data submitted to

ICES WGBYC and the quality of the data do not account for any assessments of mortality or comparison of bycatch rates. ICES WGBYC (2020) noted that the observed effort, even if multiple years were pooled, was too low to obtain any robust bycatch estimates for seabirds.
Thus, the Baltic Sea hosts a wide range of waterbird species, some of which are threatened in various ways. This report covers eleven species, and the following information for breeding and wintering occurrence is summarised by Keller et al. (2020) and Skov et al. (2011). The velvet scoter (*Melanitta fusca*) breeds and winter in parts of the Baltic Sea. Steller's eider has its main breeding grounds in the Russian Arctic and Alaska. Numerous individuals winter in the Baltic Sea. The Slavonian grebe breeds in fresh waters, but has many winter habitats in marine or brackish waters. The Baltic Sea is one of its most important winter habitats. The red-throated diver (*Gavia stellata*) breeds in Arctic waters, and the Baltic Sea contains some of its wintering habitats. The black-throated diver *(Gavia arctica)* primarily breeds in fresh water lakes in northern Europe and winters along sheltered, ice-free coasts of the Baltic Sea. European populations of the red-necked grebe (*Podiceps grisegena*) breed in temperate wetlands and winters along coasts in the North Sea and the Baltic Sea. European populations of the red-breasted merganser (*Mergus serrator*) typically breed in inland waters, and some of them spend the winter season in the Baltic Sea. The Baltic Sea also hosts common eider (*Somateria mollissima*) both during the breeding season and the winter season. The long-tailed duck breeds in northern Europe and western Siberia and commonly winters in the Baltic Sea. Those greater scaups that breed in the northernmost parts of Europe and western Siberia mainly winter in the North Sea and the Baltic Sea. Common scoters (*Malanitta nigra*), which nest in the Russian taiga, winter in the Baltic Sea and other European waters.

It is only possible to determine the mortality due to bycatch if bycatch rate related to monitoring effort for all fishing métiers in meaningful metrics and total effort are monitored in a suitable manner (HELCOM 2020). In the absence of quantitative data on bycatch rates, absolute bycatch numbers cannot be assessed. In order to identify marine fishing areas with the greatest bycatch risk of mammal and bird population based upon interaction probabilities, an approach taken is developing bycatch risk maps which has been applied in several studies (Kindt-Larsen et al., 2016; Goldworthy and Page, 2007), including the HELCOM ACTION project (HELCOM 2021b). Bycatch risk maps can put the estimated mortality, if it is available, into context. Further, areas where monitoring of bycatch needs to be intensified can be identified. Mapping the spatio-temporal variability of bycatch risk could be a way forward with regard to implementing preventive mitigation measures that reduce bycatch depending on site-specific conditions.
This report aims at identifying the areas of the Baltic Sea which have the highest risk of bycatch of the three seal species in the Baltic Sea as well as the eleven mentioned waterbird species wintering in the Baltic Sea based on available data.

Methods

The risk-mapping approach to identify areas of concern regarding bycatch of protected species requires data on the spatial distribution of marine mammal and waterbird numbers and the spatial distribution of fishing effort, both from the same season and from the same years.

Data sources

Fishing effort data

Following EU regulation, Regulation 1224/2009, commercial fishers must report landings and effort. However, submitted reports differ depending on vessel size. In the Baltic Sea, fishers have to report on a daily basis if they use a fishing vessel above 10 m in overall length (regardless of vessel length if they use a trawl and for some fisheries as cod all vessels above 8 m report effort and catch on a daily basis). Fishermen using vessels smaller than 10 m also report to national authorities, but these reports differ between countries. In some countries, fishers report in monthly journals, in others only

catch from sales notes is used to estimate effort (EU, 2015, 2019). The effort data used for this study were extracted from the ICES regional database (ICES RDB). All member states across the Baltic Sea were requested to allow the use of effort data submitted to ICES RDB for fisheries conducted in the Baltic Sea and Kattegat for the years 2016-2020. Requested data were aggregated by Contracting Party, harbour, métier level 4-6[1], month, vessel size and ICES rectangle.
Since member states estimate and report effort from small vessels (< 10 meters) differently the effort data were analysed and where effort seemed to be considerably higher than for other Contracting Parties, institutions responsible for data entry to ICES RDB were contacted and asked which methods were used to estimate effort and whether the estimated data would differ significantly from other Contracting Parties' estimations. Thereafter data was evaluated to be comparable across countries and years to be able to choose which years of effort data should be included in the bycatch risk maps.

Species abundance data

Waterbirds

The project was granted access to data from a coordinated joint waterbird survey initiated by HELCOM BALSAM and the European Seaduck Working Group which was carried out in the Baltic Sea in 2015 and 2016. The surveys were undertaken by all countries of the Baltic Sea region except for Russia. The surveys were conducted during the winter months from January until February 2016, and both ship-base and aerial surveys were carried out. Relative abundance of bird species per ICES rectangle was obtained by taking the average number of observed birds per positions observed per ICES rectangle. If one position was observed several times, the maximum number of birds observed was taken. The effort of the conducted survey is shown by grey transect lines in Figure 1.

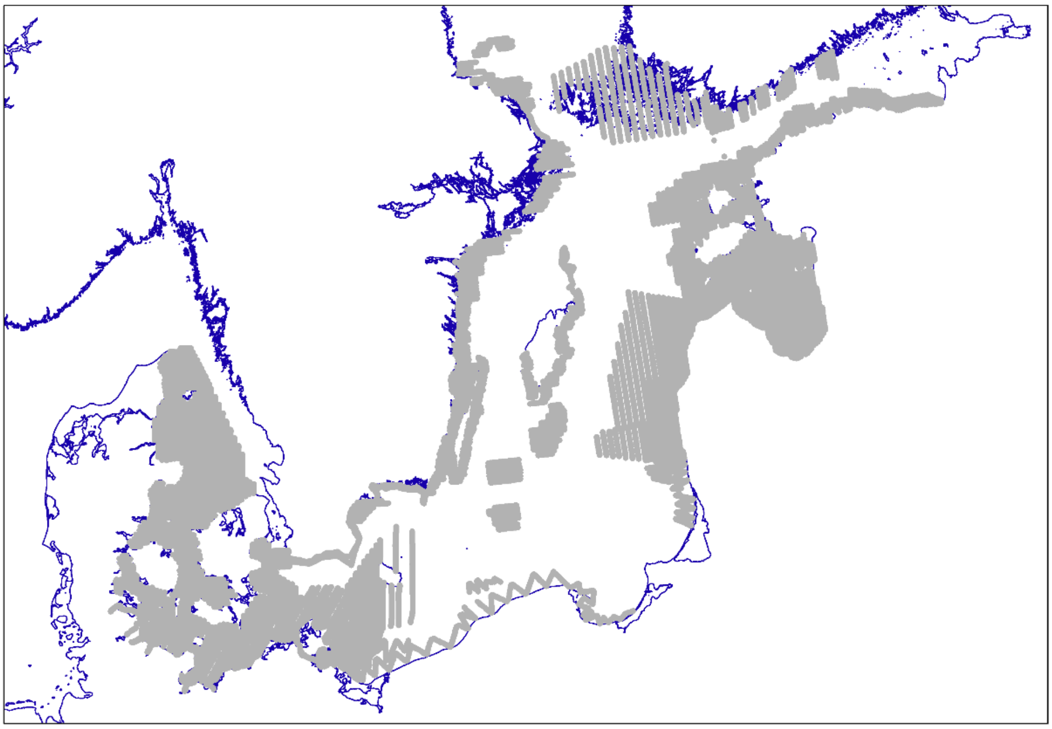


Figure 1. Survey effort of the first coordinated joint winter survey in winter 2015/2016 in the Baltic Sea and southern North Sea (ICES 2020). Grey lines represent the surveyed area.

[1] For explanation see: https://datacollection.jrc.ec.europa.eu/wordef/fishing-activity-metier

Seals

Seals are usually counted at their haul-outs during the moulting or pupping seasons when the animals spend a considerable time hauled-out. Comparable at-sea data representing at-sea abundance is not available. Data on seal abundance in Swedish waters is based on a national monitoring program counting seals on haul outs from 2010 to 2015. To be able to include the seals foraging area a kernel density function was used with a 60 or 40 km range depending on seal species and their typical foraging patterns from haul-outs. Ringed seals have a foraging range of 60 km, harbour seals 40 km and grey seals 60 km. The result is a grid where seal density decreases successively with the distance from the counted seals on the haul out site. Although it is known that seals perform long migrations, this could not be taken into account here. The relative abundance was on a logarithmic scale, with 0 = no seals and 100 = seal colonies with the highest number of seals. This method was developed through the "Symphony" project (HaV, 2018).

Data on grey seal abundance in Finnish waters were provided by the Natural Resources Institute Finland (LUKE). The provided data set contained count data on grey seals per ICES rectangle from 1999 until 2020. However, data from certain areas seem to be lacking and therefore no bycatch risk maps were developed for the Finnish part of the Baltic Sea. Aarhus University in Denmark provided count data on grey seals and harbour seals at seal colonies in Danish waters. Data used in the risk maps were the maximum number of seals counted on haul-outs during 2020 and 2021. Thereafter, the number of seals in seal colonies per ICES rectangle was summarized. The counted number of individuals does not represent the population size as always individuals are submerged and hence not recorded in surveys. The fraction might differ between areas and seasons but the numbers counted at haul-outs is a metric representing a measurement of relative abundance which can then be compared between ICES rectangles. However, since data from certain ICES rectangles in Finnish waters was missing and data collected in Denmark is collected and modified in a different way than in Sweden, we chose to develop bycatch risk maps separately (Denmark and Sweden).

Risk mapping approach

One way of evaluating and determining areas, where there is a risk of bycatch is to plot the product of the fishing effort and the species abundance, both per pre-defined grid cell, in the case of this study per ICES Statistical Rectangle. This assumes that the probability or risk of interaction is proportional to the extent of overlap of species abundance and commercial fishing effort at any location and time. Hence, areas where species abundance is high, but no fishing occurs or vice versa, have a zero probability of interaction. As such, the expected level of interaction will be highest in regions with high species abundance and high fishing effort. This method has been used on porpoises in the Kattegat and Belt Sea (Kindt-Larsen et al., 2016) as well as on seal bycatch in Australian fisheries (Goldsworthy and Page, 2007).

The organization ICES divides the Baltic Sea into ICES rectangles for statistical and other purposes. ICES rectangles are the finest scale for which effort data from small vessels is available and thus is the spatial scale chosen for bycatch risk mapping. The extent of overlap between fishing effort and specified species abundance was calculated as the product of the fishing effort in Days at Sea and the estimated abundance for each ICES rectangle. An ICES rectangle consists of a latitude interval of 30´and a longitude interval of 1° and thereby provides a grid covering a specified area.

Since effort data were provided per ICES rectangle, the minimum level of detail spatially is given per ICES rectangle. For seal bycatch risk maps, fishing effort data from the full year (all months included) were used. It was thus assumed that seals counted during their moult period would be present in the rectangle the whole year. For waterbird bycatch risk maps, only the fishing effort from January to March was used to align with the time of the survey of the wintering waterbirds.

The risk of bycatch differs between fishing gear depending on the species. Since the data on bycatch were limited, we did not have data from the Baltic Sea showing how bycatch risk differs between gears. This does not allow comparison of results between gears. However, ICES WGBYC (2018) evaluated the risk of bycatch of different species for different fishing gears based on expert judgement. The method, called fishPi, was developed to identify areas and gear types where additional monitoring is needed (fishPi, 2014). The fishPi approach combines species group occurrence, bycatch risk, fishing effort and current monitoring levels by area. It is a useful tool to categorize the overall bycatch risk per ICES ecoregion and metier, highlight sampling needs and identify gaps or shortfalls in current monitoring levels. High bycatch risk in fishing gears and fishing grounds was identified in the Baltic Sea ecoregion, considering different protected species taxa, in ICES WGBYC (2018).

Thereby, the evaluated relative risk, between 0 and 3, was based on expert judgement (Table 1) and does no quantify the differences in bycatch risk. With regard to birds, the experts distinguished between bottom feeders and fish feeders. In the terminology used at HELCOM these are benthic feeding and pelagic feeding birds. In fyke nets, the identified bycatch risk was classified as high for pelagic feeding birds (3 instead of 2 as in the fishPi project). A substantial bycatch, especially of cormorants, mergansers, diving ducks and grebes is known in the fyke net fishery in Germany (Erdmann et al., 2005). Also, the bycatch risk in longlines differs between the species groups surface-feeding birds, pelagic-feeding birds and benthic-feeding birds. The bycatch risk for benthic-feeding birds such as diving ducks is low, although some bycatch has been documented (Detloff & Koschinski 2015). Fish feeding birds (of the groups surface-feeding birds and pelagic-feeding birds) may be attracted to the bait resulting in some risk. Surface-feeding birds are especially attracted to bait during the shooting of longlines. Thus, the bycatch risk in longlines is considered to be high in the latter group.

Pelagic-feeding birds dive from the surface and hunt fish in the water column. If feeding on demersal fish, some species such as cormorants may come close to the seafloor. This group has been named “fish feeders diving" by the FishPi project, table 1 is referring to. The following species have been characterized as pelagic-feeding birds: red-breasted merganser, Slavonian grebe, red-throated diver and red-necked grebe. Benthic-feeding birds dive to the seafloor, where they feed on bivalves and other benthic prey. These include: greater scaup, common eider, Steller's eider, long-tailed duck, common scoter and velvet scoter.

Seal bycatch risk maps were produced for the gear types that had a high or medium risk of bycatch (fishPi category 2 and 3). Thereby risk maps per seal species were pooled for fyke nets, uncovered pound nets as well as pots and traps. However, in maps showing bycatch of species in Kattegat, pots and traps were excluded since pot fisheries for Norway lobster (*Nephrops norvegicus*) and European lobster (*Homarus gammarus*), where there is no risk of bycatch, has high fishing effort and thereby gives a misleading result. A summary of data on bycatch of marine mammals from 2008 to 2017 did not show any bycatch of marine mammals in pot fisheries (ICES, 2019). There were also maps produced for all types of nets and longlines. Maps were produced for pooled data of bottom and midwater trawls and pair trawls.

For pelagic-feeding birds, considering the relevant gear, as assessed by WGBYC FishPi risk assessment, it was decided to develop risk maps for static nets (including gillnets and trammel nets), fyke nets, pots and traps, and longlines (including hand and pole lines, drifting longlines and set longlines) fisheries. For the bottom feeding birds, bycatch risk maps were developed for static nets (including gillnets and trammel nets) and fyke nets. Trolling lines has a medium bycatch risk for bottom feeding birds, however no effort on trolling lines are reported in the Baltic. Illustrations of gear types are shown in Annex 1.

Table 1. General assessment of the risk (1: low, 2: medium, 3: high) for a species group to get bycaught in a specific gear type based on by expert judgement. (ICES 2018).

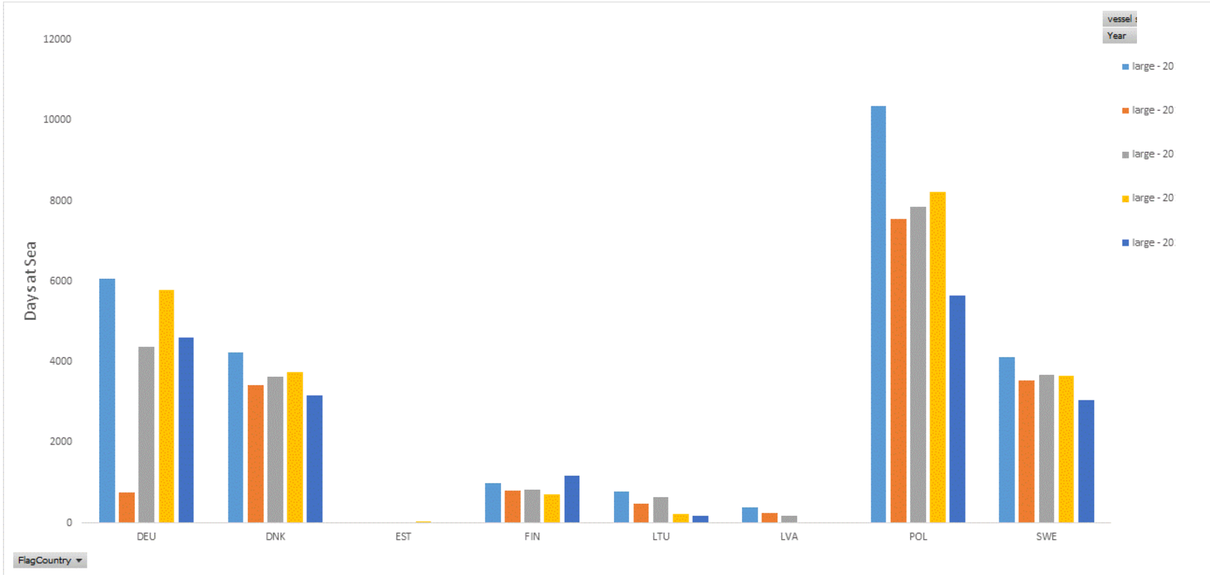
GEAR TYPE	CODE	BIRDS-Pelagic Feeding	BIRDS-Benthic Feeding	BIRDS-Surface Feeding	SEALS
Dredges	DRB	1	1	1	1
Stationary uncovered pound nets	FPN	1	1	1	2
Pots and traps	FPO	2	1	1	2
Fyke nets	FYK	3	2	1	3
Driftnets	GND	3	3	3	3
Set gillnets (including semi-driftnet)	GNS	3	3	3	3
Trammel nets	GTR	3	3	1	3
Hand and Pole lines	LHM	1	1	1	1
Drifting longlines	LLD	2	1	3	2
Set longlines	LLS	2	1	3	2
Trolling lines	LTL	2	2	3	1
Bottom otter trawl	OTB	1	1	1	2
Midwater otter trawl	OTM	1	1	1	2
Multi-rig otter trawl	OTT	1	1	1	1
Purse-seine	PS	1	1	1	1
Bottom pair trawl	PTB	1	1	1	2
Midwater pair trawl	PTM	1	1	1	2
Beach and boat seine	SBV	1	1	1	1
Anchored seine	SDN	1	1	1	1
Fly shooting seine	SSC	1	1	1	1
Beam trawl	TBB	1	1	1	1

Results

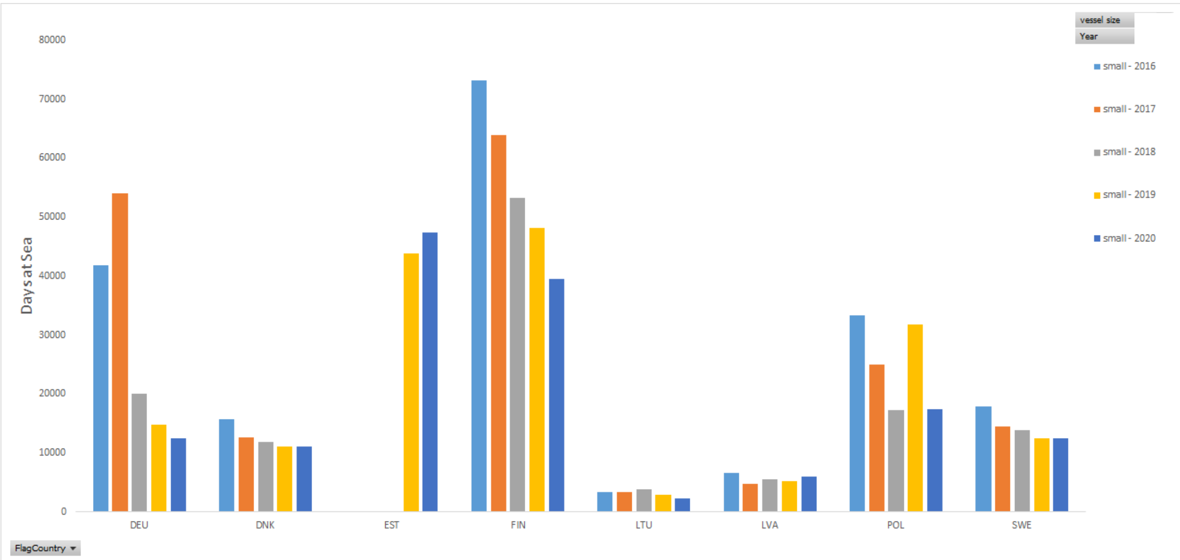
Fishing effort evaluation

Data from Germany, Denmark, Sweden, Estonia, Finland, Lithuania, Latvia and Poland were included in the ICES RDB dataset. Since Contracting Parties estimate effort from small vessels differently (< 10 meter length), fishing effort from large (vessels > 10 meter length) and small vessels fishing with gillnets, trammel nets were analysed to find discrepancies in reported effort among countries. For all member states, the effort in days at sea (DaS) from small vessels considerably exceeded the effort for large vessels, indicating that the fishing fleet with small vessels is dominating for static net fisheries (Figure 2a and b).

Submitting DaS to ICES RDB is optional, so therefore DaS are not included all years for all member states. In addition, reporting effort for small vessels is not mandatory for all member states. Thereby fishing effort is estimated by the member states and thereafter reported to the ICES RDB. This estimation can differ among member states. For Germany, the method on how effort is estimated changed from 2017 which also affected the effort, showing a decrease in 2018. Fisheries regulations also considerably affect fishing effort. However, no information was provided on the method to calculate efforts before and after. In July 2019, a Baltic cod fishing ban was implemented (in 24 July 2019, the Commission Regulation (EU) 2019/1248 entered in force, valid until 31 December 2019). The Commission Decision was followed by Council Regulation (EU) 2019/1838, regulating fisheries for the year 2020. These regulations closed static net fisheries for cod in waters deeper than 20 meters in ICES subdivision 24, and in all static net fisheries for cod in subdivisions 25-32. Trawl fisheries targeting cod in the area were also regulated in subdivisions 24 and 25, static net fisheries were mainly targeting cod, and therefore the ban may have resulted in a significant decrease in static net fishing effort in these subdivisions since 24 July 2019. Although a shift in target species to flat fish and relocation of effort into areas shallower than 20 m may partly have obscured this in the data.



a.



b.

Figure 2. The summarized effort in DaS per member state and year for gillnets and trammel nets. A. shows the effort for large vessels (vessels > 10 meter length) and b. the effort for small vessels (vessels < 10 meter length).

Net fisheries are known to be among the fisheries causing high bycatches of protected species. Evaluating the fisheries carried out in the Baltic Sea, the gear type with the highest effort in DaS in the study period was gillnets. Gillnet effort in days at sea amounts to 55.2% of the total fishing effort in 2020 (Table 2.). Fyke nets most likely including some types of trap nets, also had a high number of DaS (18.7%). Overall, there has been a decrease in fishing effort in the Baltic Sea during the investigated period. The gillnet fisheries having the highest effort has decreased. Trammel net fisheries have increased in effort due to fisheries switching in target species from cod to flatfish. However, trammel net fisheries still constitutes only a minor fraction of the set net fisheries (2.7% in

2020). The largest decrease in effort was in set longlines, however, bottom and pelagic pair trawling effort also decreased substantially.

Table 2. Effort in DaS from 2016 until 2020 in the Baltic Sea per gear type. The most commonly used gear types in the Baltic Sea are included.

	Sum of DaysAtSea					
Gear type/Metier	**2016**	**2017**	**2018**	**2019**	**2020**	**% of DaS for 2020**
Stationary uncovered pound nets (FPN)	9242	9561	8957	9003	8879	3,0
Pots and traps (FPO)	18706	18596	15433	20648	11202	3,8
Fyke nets (FYK)	46099	46200	37249	53460	54917	18,7
Set gillnets (GNS)	214986	193631	143533	189071	162031	55,2
Trammel nets (GTR)	3985	1242	3247	3620	4617	1,6
Hand and Pole lines (LHP)	412	319	306	431	513	0,2
Drifting longlines (LLD)	1340	1600	1454	881	839	0,3
Set longlines (LLS)	6870	4902	4642	3456	1294	0,4
Bottom otter trawl (OTB)	34769	27819	29899	25791	19246	6,6
Midwater otter trawl (OTM)	31449	30085	29422	27509	24607	8,4
Multi-rig otter trawl (OTT)	2655	2534	2463	2531	2520	0,9
Bottom pair trawl (PTB)	1517	835	1135	602	713	0,2
Pelagic pair trawl (PTM)	3842	2191	2507	1902	1289	0,4
Total	376389	340547	281001	339786	293389	

It is mainly data from small vessels where the variation in effort among countries and year can indicate that reporting effort is carried out differently among countries. The effort data from small vessels fishing with static nets from Finland, all years, and from Germany in 2016 and 2017 showed significant higher effort than other member states. However, Finland estimates effort similar to other countries and has a large static net fleet. Germany has changed their way of estimating their effort in 2017, which is indicated by the significant reduction in effort in 2018. However, no explanation is given on the changed method. Estonia did not submit effort to RDB until 2018. Thereby the evaluation of the fishing effort submitted by member states resulted in inclusion of data from all member states from 2018 until 2020 in the risk maps. Effort from both large and small vessels was summed in the categories mentioned below for three years in each ICES rectangle. Countries' estimates of fishing effort in absence of a mandatory reporting scheme account for significant uncertainties in the use of estimated effort data in risk mapping. Especially the spatial allocation of fishing effort of small vessels may be problematic if such data is not reported (such as in sales notes) or not recorded in the database.

The spatial distribution of the effort known to cause the highest bycatch of birds and marine mammals are shown in figure 3. Effort was pooled for static net fisheries (gillnets GNS and trammel nets GTR). For trawl fisheries, bottom and pelagic pair trawl were summed with bottom and midwater otter trawl (PTB, PTM, OTB, OTM) and for longlines hand and pole lines, drifting longlines and set longlines (LHP, LLD, LLS) have been pooled. Fyke net and trap-nets are likely defined differently among countries and therefore, fyke nets, pots and traps and stationary uncovered pound nets (FYK, FPO, FPN) were pooled together.
Static net fisheries are carried out all along the Finnish coast and particular intense off Turku. Estonia also has a high coverage of effort, with high fishing effort just north of the Gulf of Riga. Polish static

net fisheries seems aggregated in Puck Bay and western Bay of Gdansk. In the southern Baltic Sea the area where static net effort is the highest is east of Rügen and around the Szczecin lagoon. The areas around Little Belt and the Sound are also indicated as being important areas for static net fisheries. Abovementioned uncertainties with allocation of fishing effort apply to the maps in Figures 3 to 7.

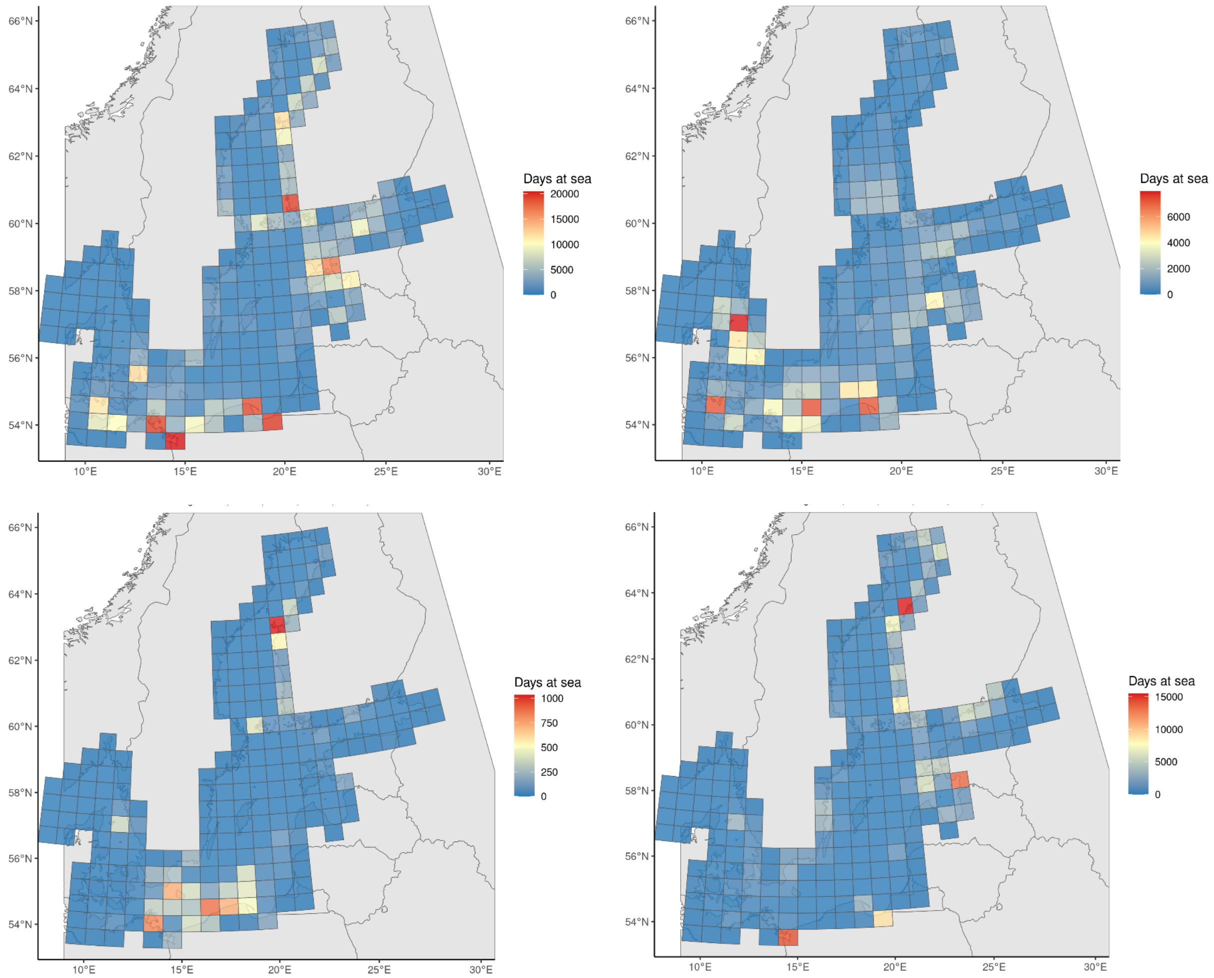


Figure 3. The summarized effort per ices rectangle for 2018 to 2020. a. Static nets (GNS, GTR); b. trawl (PTB, PTM, OTB, OTM) c. longlines (LHP, LLD, LLS) and d. pots, trap-net and fyke net (FYK, FPO, FPN).

Bycatch risk maps

Maps were prepared for the gear types with the highest risk of bycatch according to the fishPi methods. However, some Contracting Parties have not reported fyke net effort and therefore maps on bycatch risk of pelagic feeding birds in fyke nets are only shown in Annex II. Bycatch risk maps for seal are shown for static net fisheries including gillnets and trammel nets (GNS and GTR) as well as fyke nets and stationary uncovered pound net fisheries (FYK and FPN). Since seal data are collected differently in Sweden, Denmark and in Finland, separate maps for the countries have been produced. Bycatch risk maps for métiers with medium bycatch risk such as longline fisheries and trawl fisheries are presented in Annex II.

Relatively high bycatch risk for harbour seals was found in some rectangles in the Belt Sea and the Öresund, but also at Hanö Bight. For grey seals, elevated risk is obvious in waters around Åland, Hanö Bight, Öresund, and at Bornholm. Highest bycatch risk for ringed seals was found in the Northern Bothnian Bay on the Finnish coast (Figure 4).

According to fishPi, fyke nets have an equally high bycatch risk category for seals as static nets. Fyke nets occur in different sizes, gears that are named fyke net in one country can be named trap, trap-net or pound net in another. Therefore, to get a more overall picture of the risk of bycatch in fyke nets and trap nets we have pooled the effort from fyke nets and stationary uncovered pound nets (FYK and FPN) even though stationary uncovered pound nets are evaluated to have a smaller risk of lethal bycatch than fyke nets as seabirds and seals can often escape. Effort from traps and pots (FPO) is excluded, even though they have a medium high bycatch risk category as stationary pound nets for seals and the same for pelagic feeding birds. However, within this metier definition (pots and traps) the fishery targeting European lobster *(Homarus gammarus)* and Norway Lobst*er* using pots is included. The pot fishing effort is high in Kattegat and Skagerrak and there is no pot fishery for Norway lobster or European lobster in the Baltic Sea. Therefore the effort of the pot and trap fishery was excluded to prevent presenting high bycatch risk in areas where risk of bycatch is low since the risk of bycatch of seals is minimal in this fishery. Harbour seals are bycaught in fyke nets mainly in the Belt Sea and east of Hanö Bight. Grey seals are bycaught in Öresund and in the waters north of Öland to south of Stockholm archipelago. The ringed seal are bycaught along the Finnish coast in the most northern part of the Bothnian Bay and north of Wasa (Figure 5.).

Of those eleven species of waterbird studied here, bycatch risk maps were developed for all species bycaught in static net fisheries. For pelagic feeding birds, high risk areas in static net fisheries are scattered along the southern Baltic Sea coast from the island of Rügen (Germany) eastwards to Poland, with some variation in key areas among species (Figures 6). The same holds true for four benthic feeding bird species (common scoter, velvet scoter, long-tailed duck and greater scaup, Figure 7). Deviating from this, highest bycatch risk for common eiders is in the southwestern corner of the Baltic Sea (Belt Sea, Kiel Bay, Bay of Mecklenburg), whereas Steller's eider face highest risk in Estonia.

Bycatch in fyke nets, a gear type which is evaluated to have a high bycatch of benthic feeding birds, could not be evaluated here. Although known to occur in some inside waters, there is no effort reported for fyke nets in the southern Baltic in Denmark, Germany, Lithuania and Poland, therefore presenting maps on bycatch risk based on reported fyke net effort would be misleading.

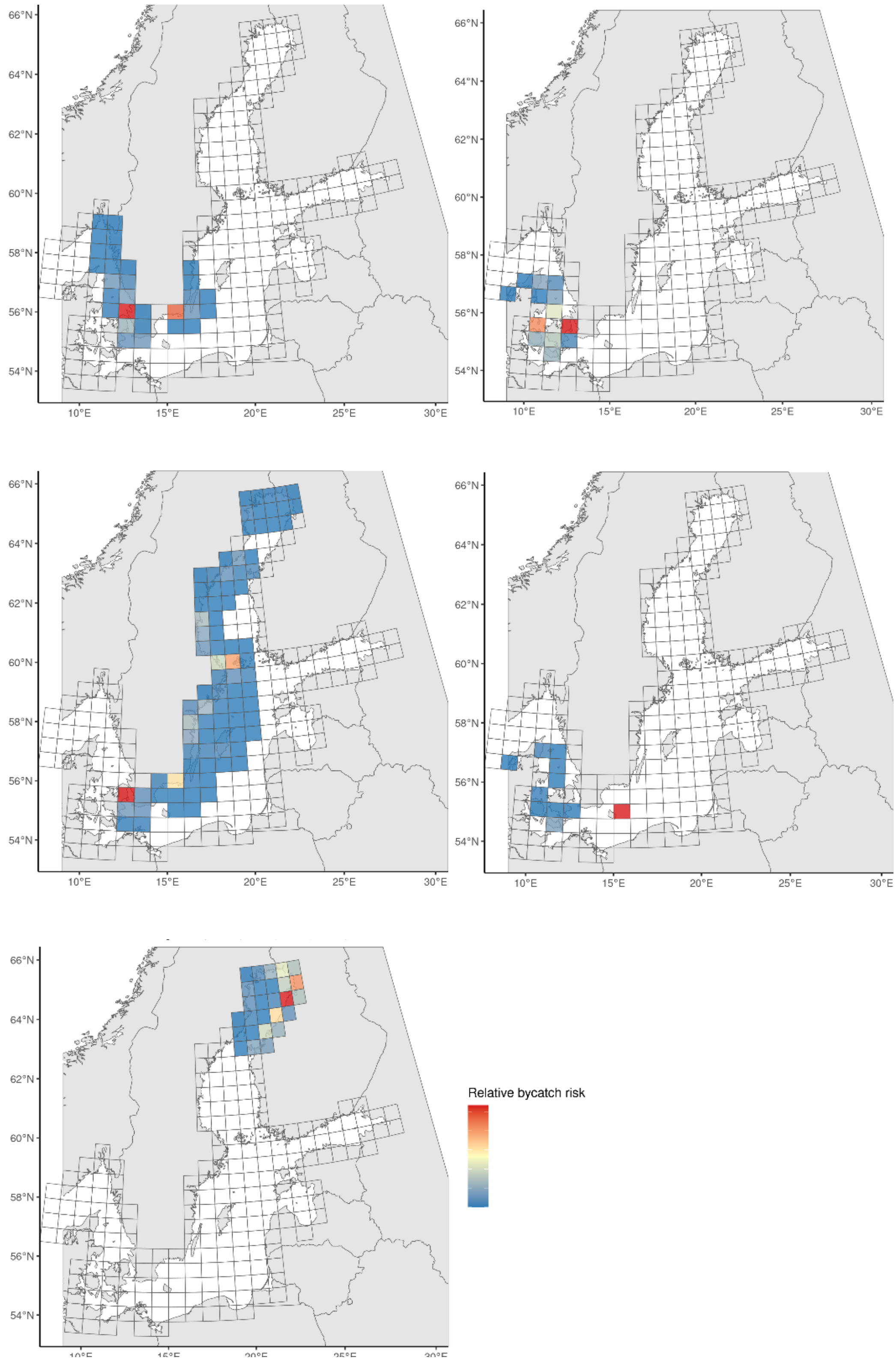


Figure 4 A-F. Bycatch risk of seals per ICES rectangle expressed as the product of the relative seal abundance and the fishing effort for static net fisheries (GNS and GTR, 2018-2020). No unit is presented since it is only relative bycatch and every map needs to be viewed independently. The maps are stand alone and there should not be compared against each other. A. harbour seal, based on seal abundance data from Sweden, B. harbour seal, based on seal abundance data from Denmark, C. grey seal, based on seal abundance data from Sweden, D. grey seal, based on seal abundance data from Denmark, E. ringed seal, based on seal abundance data from Sweden and Finland. White rectangle is when no data is available.

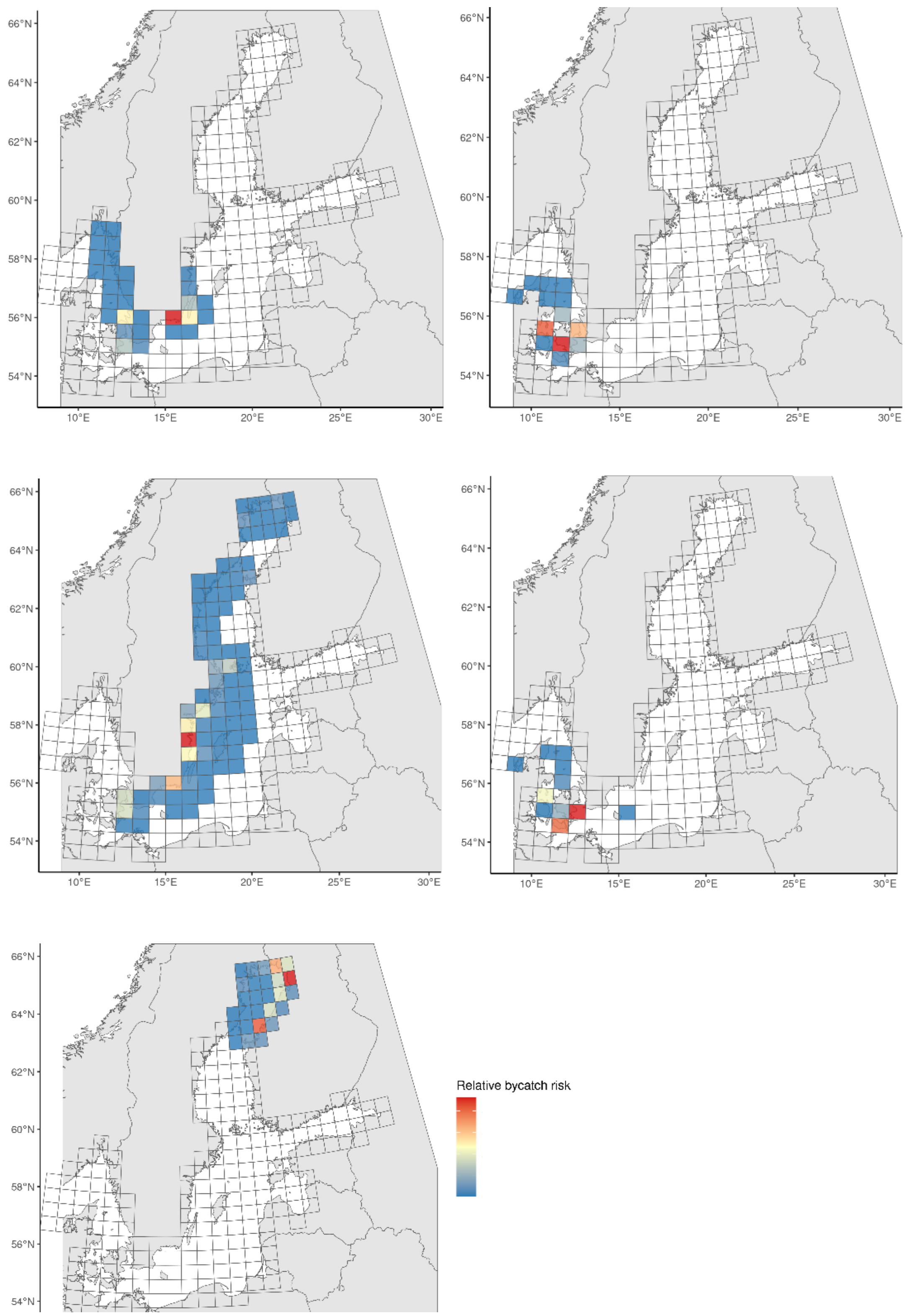


Figure 5 A-E. Bycatch risk of seals per ICES rectangle expressed as the product of the relative seal abundance and the fishing effort for effort for fyke net and stationary uncovered pound net fisheries (FYK and FPN, 2018-2020). No unit is presented since it is only relative bycatch and every map needs to viewed independently. A. harbour seal, based on seal abundance data from Sweden, B. harbour seal, based on seal abundance data from Denmark, C. grey seal, based on seal abundance data from Sweden, D. grey seal, based on seal abundance data from Denmark, E. ringed seal, based on seal abundance data from Sweden and Finland. White rectangle is when no data is available.

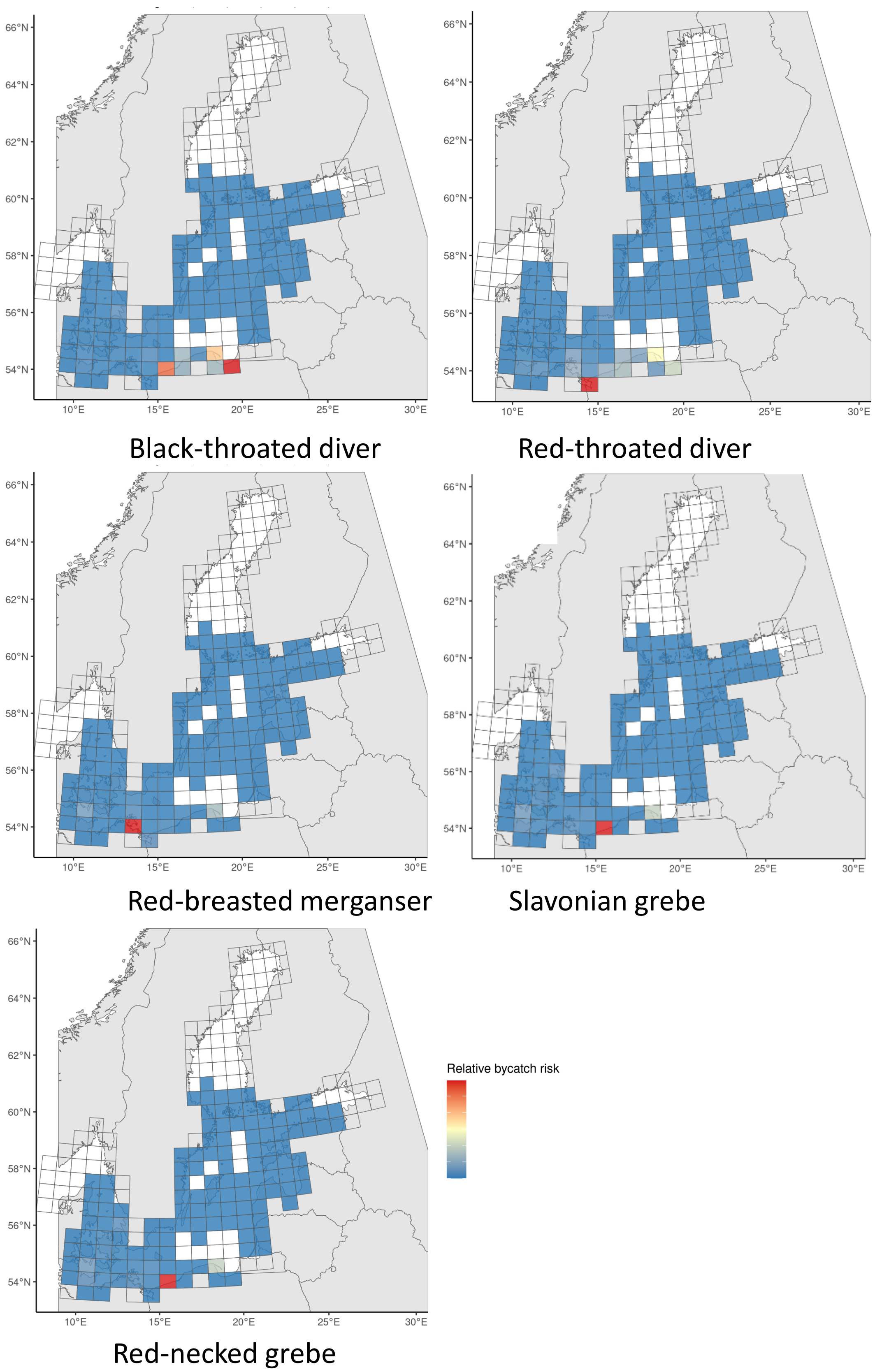


Figure 6. Bycatch risk of pelagic-feeding waterbird species per ICES rectangle expressed as the product of the relative bird abundance (2015-2016) and the fishing effort for static net fisheries (GNS and GTR, 2018-2020). No unit is presented since it is only relative bycatch and every map needs to viewed independently. White rectangle is when no data is available.

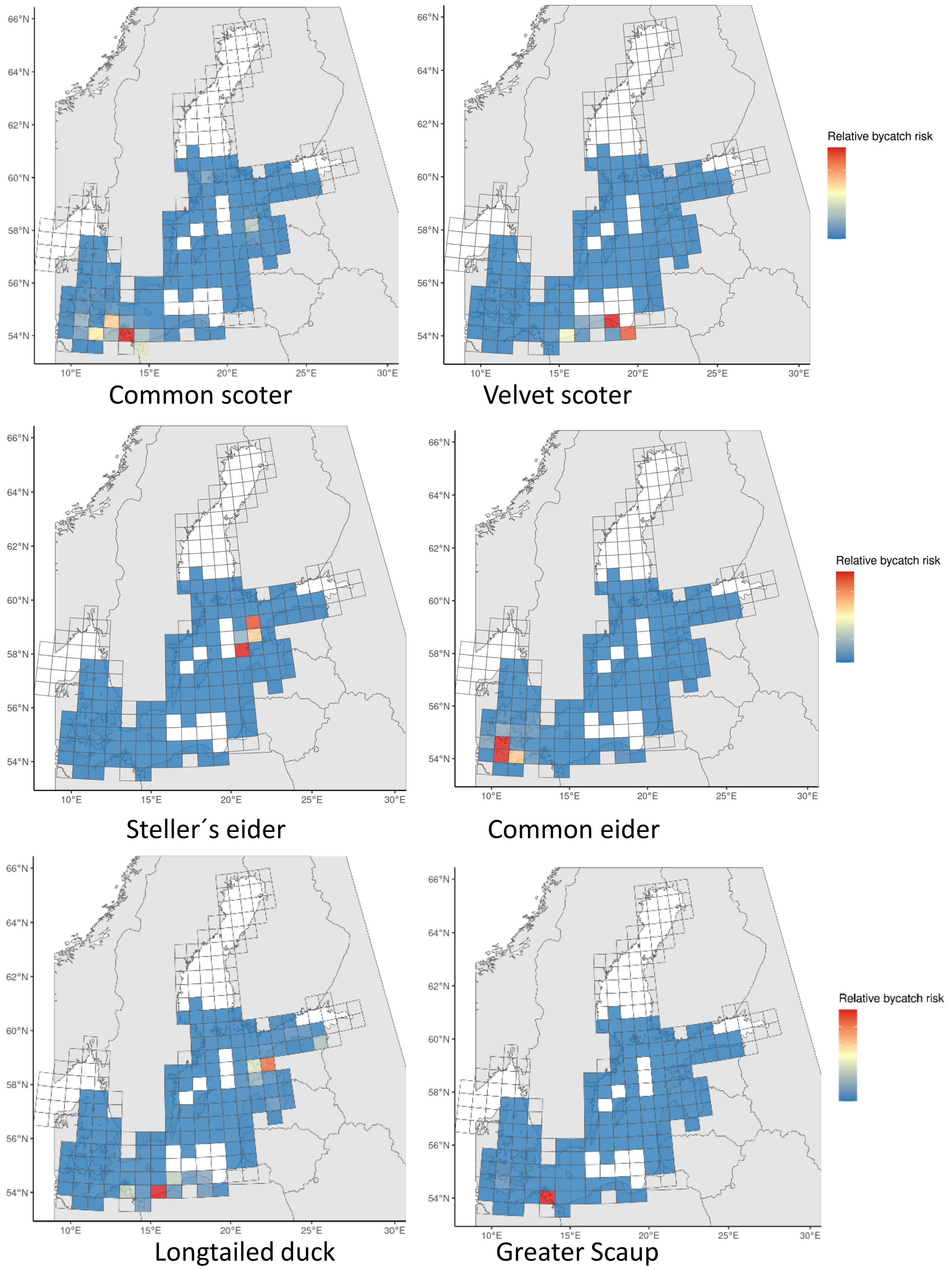


Figure 7. Bycatch risk of benthic-feeding waterbird species per ICES rectangle expressed as the product of the relative bird abundance (2015-2016) and the fishing effort for static net fisheries (GNS and GTR, 2018-2020).). No unit is presented since it is only relative bycatch and every map needs to viewed independently. White rectangle is when no data is available.

Discussion

The spatial variation in risk of bycatch was addressed by producing maps on the product of the abundance of the species and the fishing effort in the same area. Since there is a lack of monitoring data on bycatch in all métiers in the Baltic Sea, which would enable comparison of the risk between gears, bycatch maps can give an indication of areas where the relative risk of bycatch for a given gear is high for the species of concern. However, it is not possible to obtain the total relative risk of bycatch for all métiers since the absence of bycatch data in different métiers from the Baltic Sea does not allow to compare one métier against the other. Further, spatio-temporal variation of fishing effort and species abundance must be taken into account for which data is not available. The same is true for variation between years. Since bycatch is dependent on many factors such as abundance of the species in the area, fisheries effort as well as the behaviour of the species, different gear types have different bycatch rates. To be able to create bycatch risk maps where all gear types are included to get an overview of areas where most bycatch occur, we need to know the bycatch rates in the different gear types. The bycatch maps developed here only give a relative risk of bycatch in each métier. Bycatch risk maps can be used as a management tool to identify areas where monitoring of bycatch needs to be intensified or where implementation of bycatch mitigation measures can be assumed to be most effective. However, there are many types of uncertainty and bias that need to be taken into account when evaluating the results. Thereby the maps produced in this study can only be used to give a general overview of areas of concern in each metier.

The data made available for this study do not permit the development of bycatch risk maps with a detailed spatial and temporal variation. For example, the spatial distribution of effort submitted to ICES does not allow evaluation of effort within or outside MPAs. For waterbirds, it can be assumed that in the case of shallow grounds, targeted by many fisheries and used by diving waterbirds, an overlap cannot be detected when using the resolution of ICES rectangles. In addition, data on abundance do not give a temporal variation which is important with moving or migrating species. Thereby, having risk maps with a broad overview might not always reflect local areas or time periods of concern. Glemarec et al. (2022) identified an elevated risk in Fehmarn Belt in Q1 for common/velvet scoter combined when analyzing data on bycatch in monitored fisheries along with fishing effort and bird abundance. The maps produced in this report do not show a higher bycatch risk for velvet scoter however common scooter do align with the results from Glemarec et al. (2022). To get more precise bycatch risk maps, data quality for fishing effort needs to be improved. Uncertainties can occur due to insufficient reporting, varying and often not meaningful incomparable metrics used, different estimation methods between countries and across fleet segments, and the coarse resolution of spatial distribution of effort. Also, the allocation of a métier for a specific gear might vary between fishers and also between Contracting Parties.
Since the base of the maps is fishing effort and relative abundance, robust estimates of effort would have been ideal. However, the results from the evaluation of fishing effort show that fishing effort in fisheries with high risk of bycatch (static nets, fyke nets and stationary uncovered pound nets) is mainly from small vessels (88% in static net fisheries for vessels less than 10 meters). The reporting of effort from fishermen using small vessels was made differently by different Contracting Parties, some reporting effort as in net length and soak time and others as Days at Sea or fishing trips. Some countries require coastal logbooks whereas others collect sales notes and even other countries get fishermen’s catches reported in monthly journals. Therefore, effort from fisheries using small vessels was estimated differently and therefore can vary substantially between countries. As a consequence, the results of this report cannot be treated as a complete assessment of bycatch risk across the entire Baltic Sea, but nevertheless can highlight some high risk areas. For example, the high risk for waterbirds to be bycaught in static nets known from the Polish waters (Marchowski 2021) and the eastern part of the German Baltic Sea coast (Sonntag et al. 2012) is reflected in the respective maps for benthic feeding waterbirds (Figure 7). In contrast, another bycatch hotspot off the coast of

Lithuania (Morkūnas et al. 2022) is not apparent from the same maps. Inaccuracies in fishing effort data are possibly the reason for this, and a more appropriate recording and reporting of fishing effort (e.g., by using meaningful units such as net length times soak time, numbers of hooks in longlines) is required to get to more comprehensive and reliable risk maps.

Seals

Identifying abundance of species can be difficult due to the movements of individuals. Seals are capable of travelling long distances (Sjöberg et al. 1995, McConnell et al. 1999). However, they also often concentrate their movements in relatively small areas near haul-out sites for long periods (McConnell et al. 1999, Sjöberg & Ball 2000, Austin et al. 2004). Oksanen et al. (2014) estimated the home range of resident grey seals to be 4,443 km^2 which actually is a rather large area. However, the active core areas are at distances of around 10 to 15 km and on average, residents from the Gulf of Finland and the Bothnian Sea used haul-out sites 64 ± 33 km (Oksanen et al., 2014). For harbour seals, Dietz et al. (2013) showed that harbour seals generally remained within a 25 km radius of haul-out sites, and only occasionally travelled around 100 km away from the haul-out sites. However, including the data from Swedish waters, the number of seals at haul-outs thereafter extrapolated from a 60 or 40 km range depending on the species to adjust for the species movement. These seal movement studies however are based on individuals tagged on a haul-out site during a period when seals likely spend much time hauled out. Long-term movements (e.g. dispersal of immature seals from the colonies where they were born) or switching between distant haul-outs could not be accounted for as distribution and density at sea is largely unknown.

Waterbirds

Waterbirds are even more mobile than marine mammals. Outside the breeding season, they often use different areas for post-breeding moult, migratory stop-overs, wintering areas and spring staging areas. Although movements occur even in winter, not least as a response to sea ice conditions, it appears that the main distribution of individuals of a species is recorded accurately by the surveys. Waterbird surveys are currently concentrated during winter months, however significant overlap of fishing effort and bird occurrence may show a different spatial pattern also in other seasons, e.g. during spring staging (Sonntag et al. 2012). Thus, in addition to winter bird data, information about waterbird distribution at sea is also required from other seasons. Since fishers also switch their fishing grounds due to fish movements and operational reasons, a comparison to monthly fishing effort in those seasons needs to be performed to get a full picture. There is considerable variation in waterbird bycatch within and between seasons (Žydelis et al., 2009).

Even if bycatch risk areas of eleven waterbird species could be identified, it is worth noting that there are around 70 other waterbird species in the study area (HELCOM, 2018b), and bycatch risk areas should be assessed for each species that is subject to bycatch. With the exception of greater scaup most of the species that rest very close to the coast (where nets are often concentrated), such as tufted duck, common merganser, common goldeneye and great crested grebe, could not be depicted here. Other very vulnerable groups such as loons, grebes, cormorants and alcids could also not or only partly be included here.

As for seals, waterbird surveys are only carried out once a year or even less frequent. Fisheries effort, on the other side, is available for the full year. Therefore the bycatch risk maps do not give the full picture all year round. Since both birds and seals are highly mobile and seasonal species, the temporal distribution of bycatch risk can vary. In addition, the data for birds only concern the winter months January and February 2016, i.e. in months the seaducks are found in the southernmost part of their annual distributional range. The lack of offshore bird data from many parts of the Baltic Sea in other seasons prevents from producing year-round risk maps. Further, it needs to be taken into account that distributions of wintering birds can shift significantly (e.g., due to climate change, variations in prey availability or even disturbance) which will affect the bycatch risk (Marchowski & Leitner 2019).

Furthermore, several of the investigated and other species require special conservation measures according to the EU Birds Directive (Žydelis et al., 2009). Thus, regardless of the data limitation in this study, prevention and monitoring of waterbird bycatch should still be regarded as an urgent matter. The high-risk areas identified here, are only a minimum for areas where there is a risk of bycatch and where possible mitigation measures can be implemented.
In the risk maps presented here, there appear to be gaps in comparison to known bycatch focus areas such as the Lithuanian coast (Morkunas et al. 2022) or the Swedish offshore banks (Larsson & Tydén 2005). Possible reasons for this could be some of the limitations listed above such as biases in estimating effort, defining fishing gear or abundance of moving animals. It could also be that there is a temporal limitation with the bird maps since bird bycatch risk maps only cover the winter months. Further, recreational fisheries are not included as no effort data is available. However, in some countries, there is an almost uncontrolled use of recreational gillnets and some of these nets also end up as ghost gear.

Uncertainties in the risk map approach presented here, may call for an alternative approach more focused on conservation than on fishery. Another approach could be to use sensitivity maps, drawn on the basis of existing bird abundance and distribution data and susceptibility to bycatch in specific gears by developing a vulnerability index based on weighted bird abundance to account for differences in species' attributes. (cf. Sonntag et al. 2012). However these sensitivity maps also require detailed abundance and distribution data as well as data on fishing effort and therefore can be developed on a more local level.
However, when data is limited, the method used in this study for mapping the bycatch risk of seals and waterbirds gives an overview of areas where risk of bycatch might occur. Still, data on fishing effort and distribution of protected species needs improvement to be able to produce more reliable bycatch risk maps. For seals and waterbirds, coordinated international surveys, more often and on a regular basis, are useful to provide a better basis from the biodiversity side. Improvement of fishing and biodiversity data would allow to meet requirements of EU legislation that Member States take measures prohibiting deliberate killing or capture by any method (Article 5 Birds Directive; Article 12 Habitats Directive).

References

Bellebaum, J. et al. (2018) 'Population dynamics and survival of the Red-necked Grebe *Podiceps grisegena*: results from a long-term study in eastern Poland'. Journal of Ornithology 159:631-641.

Degel, H. et al. (2010) 'Fugle som bifangst i garnfiskeriet'. (Birds as bycatch in gillnet fisheries). DTU Aqua-rapport nr. 227-2010. Charlottenlund: DTU Aqua. Institut for Akvatiske Ressourcer, p. 65.

Available at: https://backend.orbit.dtu.dk/ws/portalfiles/portal/6581125/227-2010_Fugle-som-bifangst-i-garnfiskeriet.pdf (in Danish) (Accessed: 19 February 2020).

Dagys, M. & R. Žydelis (2002) Bird bycatch in fishing nets in Lithuanian coastal waters in wintering season 2001-2002. Acta Zoologica Lituanica 12: 276-282.

Detloff, K.C. & S. Koschinski (2015) Erprobung und Weiterentwicklung alternativer, ökosystemgerechter Fanggeräte zur Vermeidung von Beifängen von Seevögeln und Schweinswalen in der Ostsee. BfN, Bonn-Bad Godesberg.

Dias, M. P. et al. (2019) 'Threats to seabirds: A global assessment', Biological Conservation 237: 525–537. doi: 10.1016/j.biocon.2019.06.033.

Durinck, J., H. Skov, F.P. Jensen & S. Pihl (1994): Important marine areas for wintering birds in the Baltic Sea. Ornis Consult report 1994, Copenhagen.

Erdmann, F., Bellebaum, J., Kube, J., and Schulz, A. 2005. Losses of seabirds and waterfowl by fisheries with special regards to the international important resting, moulting, and wintering areas in the coastal waters of Mecklenburg-Western Pomerania [in German with English summary]. Commissioned by Landesamt für Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern. 129 pp

fishPi project. 2014. Deliverable WP3.1-A regional sampling plan for data collection of PETS (Protected, Endangered, and Threatened Species)

Glemarec, G., M. Vinther, K.B. Håkansson & A. Rindorf (2022): Collection of by-catch data for seabirds and marine mammals and by-catch and population densities for non-commercial fish. DTU Aqua Report no. 408-2022. National Institute of Aquatic Resources, Technical University of Denmark, 53 pp.

Goldsworthy, S., and Page, B. 2007. A risk-assessment approach to evaluating the significance of seal bycatch in two Australian fisheries. Biological Conservation, 139: 3–4, pp 269-285

Hartman, G. et al. (2013). 'Trends and population dynamics of a Velvet Scoter (*Melanitta fusca*) population: influence of density dependence and winter climate'. Journal of Ornithology 154:837-847.

Hav och Vattenmyndigheten. 2014. Sälpopulationernas tillväxt och utbredning samt effekterna av sälskador i fisket. Redovisning av ett regeringsuppdrag. (Growt and distribution of seal populations and the effects on seal damage in fisheries). Havs och vattenmyndighetens rapport 2014-12-30. Havs- och vattenmyndigheten, Göteborg (in Swedish)

HELCOM (2013). HELCOM Red List of Baltic Sea species in danger of becoming extinct. Baltic Sea Environment Proceedings No. 140. https://www.helcom.fi/wp-content/uploads/2019/08/BSEP140-1.pdf

HELCOM (2018a) Number of drowned mammals and waterbirds in fishing gear. HELCOM core indicator report. Online. Available at: https://helcom.fi/wp-content/uploads/2019/08/Number-of-drowned-mammals-and-waterbirds-HELCOM-core-indicator-2018.pdf (Accessed: 3 April 2020).

HELCOM (2018b) 'State of the Baltic Sea–Second HELCOM holistic assessment 2011-2016', in Baltic Sea Environment Proceedings, 155 p.

HELCOM 2018c. Population trends and abundance of seals. HELCOM core indicator report. July 2018

HELCOM 2020. Roadmap on fisheries data in order to assess incidental bycatch and fisheries impact on benthic biotopes in the Baltic Sea. HELCOM Secretariat, Helsinki, Finland, 17 pp. https://helcom.fi/wp-content/uploads/2020/03/HELCOM-Roadmap-on-fisheries-data.pdf

HELCOM (2021a) Baltic Sea Action Plan – 2021 update. HELCOM.

HELCOM (2021b) Bycatch in Baltic Sea commercial fisheries: High-risk areas and evaluation of measures to reduce bycatch. HELCOM ACTION (2021)

ICES WGBYC, 2018. Report of the Working Group on Bycatch of Protected Species (WGBYC). International Council for the Exploration of the Sea, Copenhagen, 128 pp.

ICES WGBYC, 2019. Working Group on Bycatch of Protected Species (WGBYC), ICES Scientific Reports, International Council for the Exploration of the Sea, Copenhagen, Denmark, 163 pp.

ICES WGBYC, 2020. Report of the Working Group on Bycatch of Protected Species (WGBYC). International Council for the Exploration of the Sea, Copenhagen 209 pp.

ICES 2020. Joint OSPAR/HELCOM/ICES Working Group on Seabirds (JWGBIRD; outputs from 2019 meeting). ICES Scientific Reports 2:80. 101 pp. http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/EPDSG/2020/Joint%20OSPAR%20HELCOM%20ICES%20Working%20Group%20on%20Seabirds%20(JWGBIRD;%20outputs%20from%202019%20meeting).pdf

Keller, V., S. Herrando, P. Voříšek, M. Franch, M. Kipson, P. Milanesi, D. Martí, M. Anton, A. Klvaňová, M.V. Kalyakin, H.-G. Bauer & R.P.B. Foppen (2020): European Breeding Bird Atlas 2: Distribution, Abundance and Change. European Bird Census Council & Lynx Edicions, Barcelona.

Lewison, R. L. et al. (2014) 'Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots', Proceedings of the National Academy of Sciences, 111(14), pp. 5271–5276. doi: 10.1073/pnas.1318960111.

Larsson, K. & L. Tydén (2005): Effekter av oleutsläpp på övervintrande alfågel *Clangula hyemalis* vid Hoburgs bank I centrala Östersjön mellan 1996/97 och 2003/04. Ornis Svecica 15: 161-171

Lunneryd, S.G., Königson, S., Sjöberg, N.B., 2004. Bifångst av säl, tumlare och fåglar i det svenska yrkesfisket (By-catch of seals, harbour porpoises and birds in Swedish commercial fisheries), Göteborg/Sweden, 21 pp.

Marchowski, D., and Leitner, M. 2019. Conservation implications of extraordinary Greater Scaup (Aythya marila) concentrations in the OdraEstuary, Poland. Condor 2019, 121

Marchowski, D. (2021) 'Bycatch of seabirds in the Polish part of the Southern Baltic Sea in 1970–2018: a review'. Acta Ornithologica 56: 139-158

McConnell, B.J., Fedak, M.A., Lovell, P. & Hammond, P.S. (1999) Movements and foraging areas of grey seals in the North Sea. Journal of Applied Ecology, 36, 5

Montevecchi, W.A. (2023) 'Interactions between fisheries and seabirds: Prey modification, discards, and bycatch'. In: Young, L., VanderWerf, E. (Eds.) Conservation of Marine Birds. Academic Press, Cambridge, pp. 57-95.

Morkūnas, J., Oppel, S., Bružas, M., Rouxel, Y., Morkūnė, R., Mitchell, D. (2022). 'Seabird bycatch in a Baltic coastal gillnet fishery is orders of magnitude larger than official reports'. Avian Conservation and Ecology 17: 1-31.

Skov, H., S. Heinänen, R. Žydelis, J. Bellebaum, S. Bzoma, M. Dagys, J. Durinck, S. Garthe, G. Grishanov, M. Hario, J.J. Kieckbusch, J. Kube, A. Kuresoo, K. Larsson, L. Luigujoe, W. Meissner, H.W.

Nehls, L. Nilsson, I.K. Petersen, M. Mikkola Roos, S. Pihl, N. Sonntag, A. Stock & A. Stipniece (2011): Waterbird populations and pressures in the Baltic Sea. TemaNord 2011:550. Nordic Council of Ministers, Copenhagen.

Sonntag, N. et al. (2009) ‘A freshwater species wintering in a brackish environment: Habitat selection and diet of Slavonian grebes in the southern Baltic Sea’. Estuarine, Coastal and Shelf Science 84: 186-194.

Sonntag, N., H. Schwemmer, H.O. Fock, J. Bellebaum & S. Garthe (2012): Seabirds, set-nets, and conservation management: assessment of conflict potential and vulnerability of birds to bycatch in gillnets. ICES J. Mar. Sci. 69: 578-589.

Symphony Integrerat planeringsstöd för statlig havsplanering utifrån en ekosystemansats Havs- och vattenmyndighetens rapport 2018:1

Tasker, M.L., Camphuysen, C.J., Cooper, J., Garthe, S., Montevecchi, W.A., Blaber, S.J.M., 2000. The impacts of fishing on marine birds. ICES Journal of Marine Science 57, 531–547.

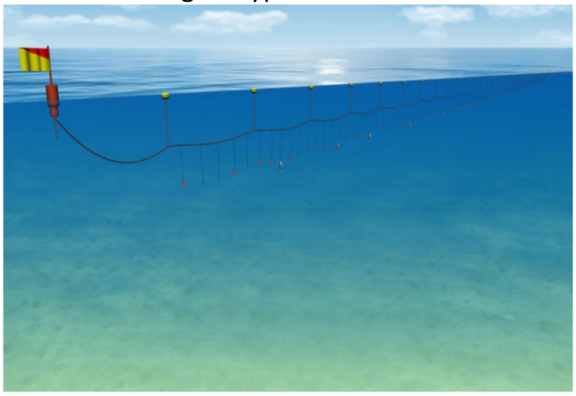
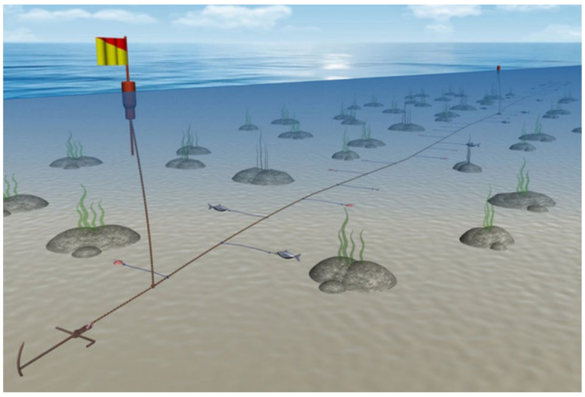
Vanhatalo, Jarno, et al. (2014). "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." PloS one 9.11: e113836.

Žydelis, R. et al. (2009) ‘Bycatch in gillnet fisheries – An overlooked threat to waterbird populations’, Biological C**,**onservation, 142: 1269–1281. doi: 10/fwdfxp.

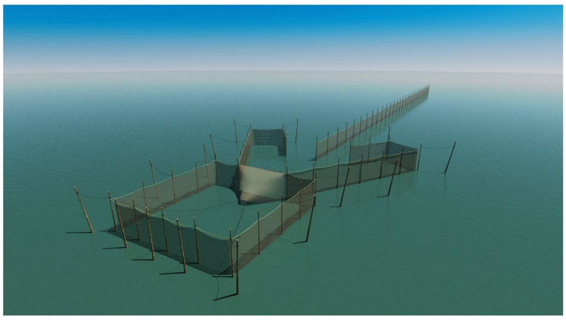
Kindt-Larsen, Lotte, et al. "Identification of high-risk areas for harbour porpoise Phocoena phocoena bycatch using remote electronic monitoring and satellite telemetry data." Marine Ecology Progress Series 555 (2016): 261-271.

Annex 1

Illustrations of gear types used in the Baltic Sea.

A. B.

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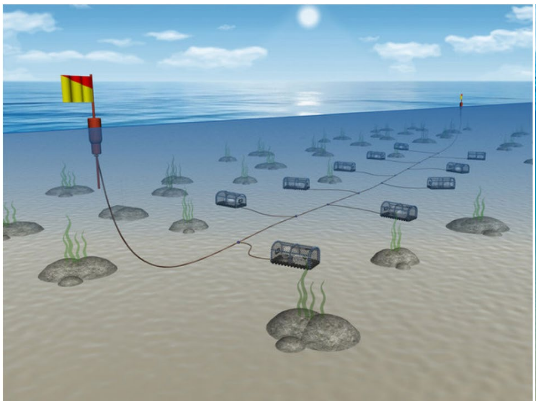
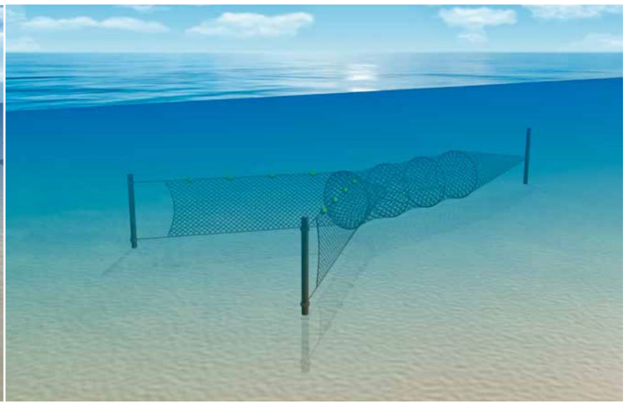

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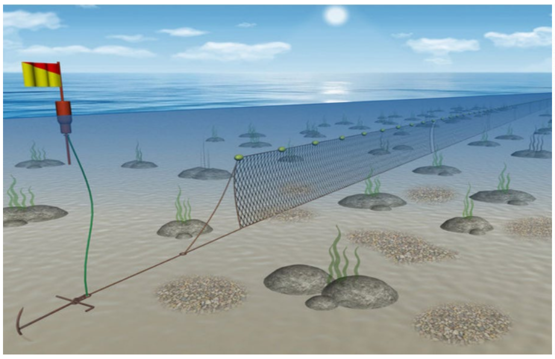
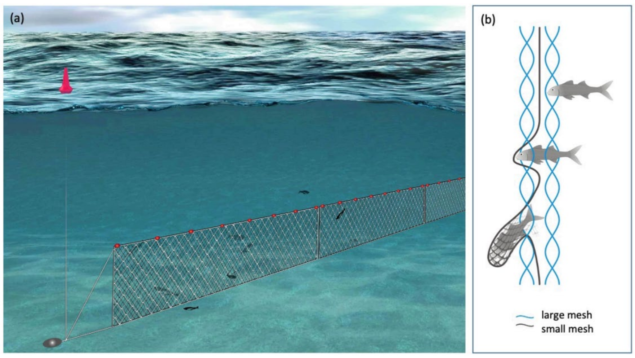

G. H.

Figure A1, 1. A. Drifting longlines (LLD), B. set longlines (LLS), C. hand and pole lines (LHP), D. stationary uncovered pound net (FPN) E. pots and traps (FPO), F. fyke nets (FYK), G. gillnets (GNS), E. trammel nets (GTR), Source: Seafish, 2021 as presented in FAO 2021.

Annex 2

Bycatch risk maps of seals and waterbirds in fisheries evaluated to have a medium risk of bycatch. In addition.

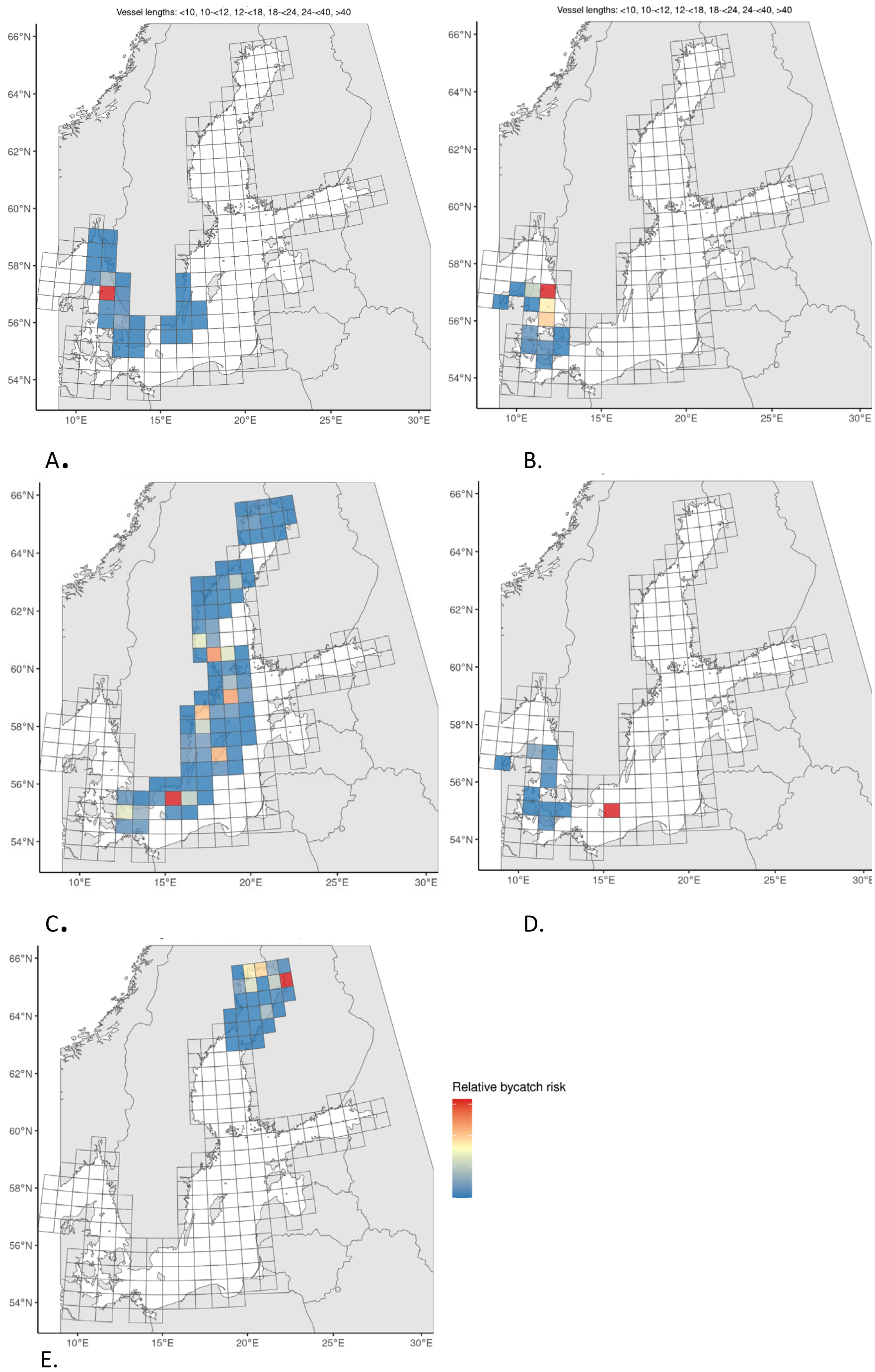

Figure A2, 1 A-E. Bycatch risk of seals per ICES rectangle expressed as the product of the relative seal relative abundance and the fishing effort for bottom, pelagic pair trawl and bottom, midwater otter trawl fisheries (PTB, PTM, OTB and OTM, 2018-2020). No unit is presented since it is only relative bycatch and every map needs to viewed independently. A. harbour seal, based on seal abundance data from Sweden, B. harbour seal, based on seal abundance data from Denmark, C. grey seal, based on seal abundance data from Sweden, D. grey seal, based on seal abundance data from Denmark, E. ringed seal, based on seal abundance data from Sweden and Finland. White rectangle is when no data is available.

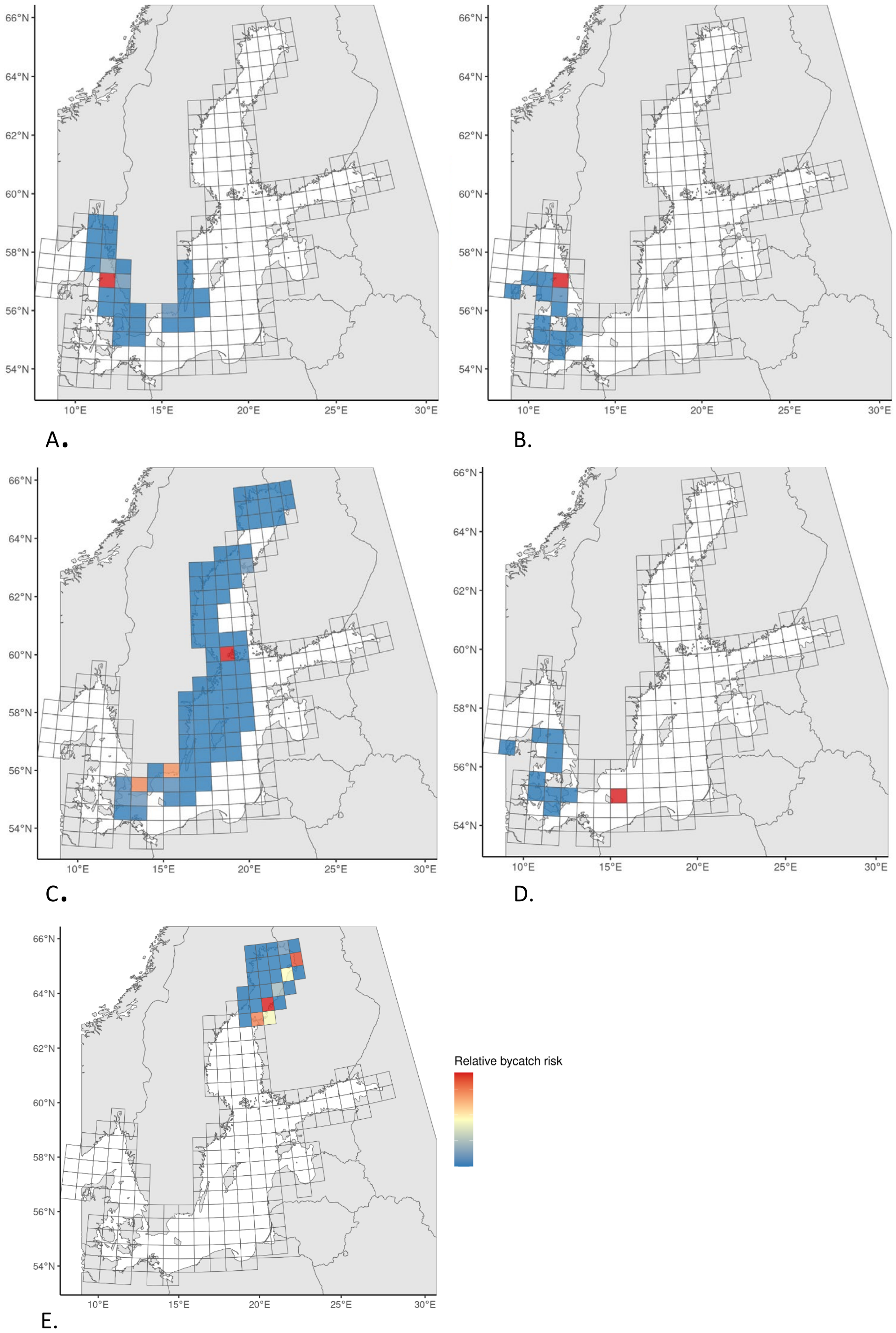

Figure A2, 2 A-E. Bycatch risk of seals per ICES rectangle expressed as the product of the relative seal relative abundance and the fishing effort for drifting longlines (LLD), set longlines (LLS), hand and pole lines (LHP) (2018-2020). No unit is presented since it is only relative bycatch and every map needs to viewed independently. A. harbour seal, based on seal abundance data from Sweden, B. harbour seal, based on seal abundance data from Denmark, C. grey seal, based on seal abundance data from Sweden, D. grey seal, based on seal abundance data from Denmark, E. ringed seal, based on seal abundance data from Sweden and Finland. White rectangle is when no data is available.

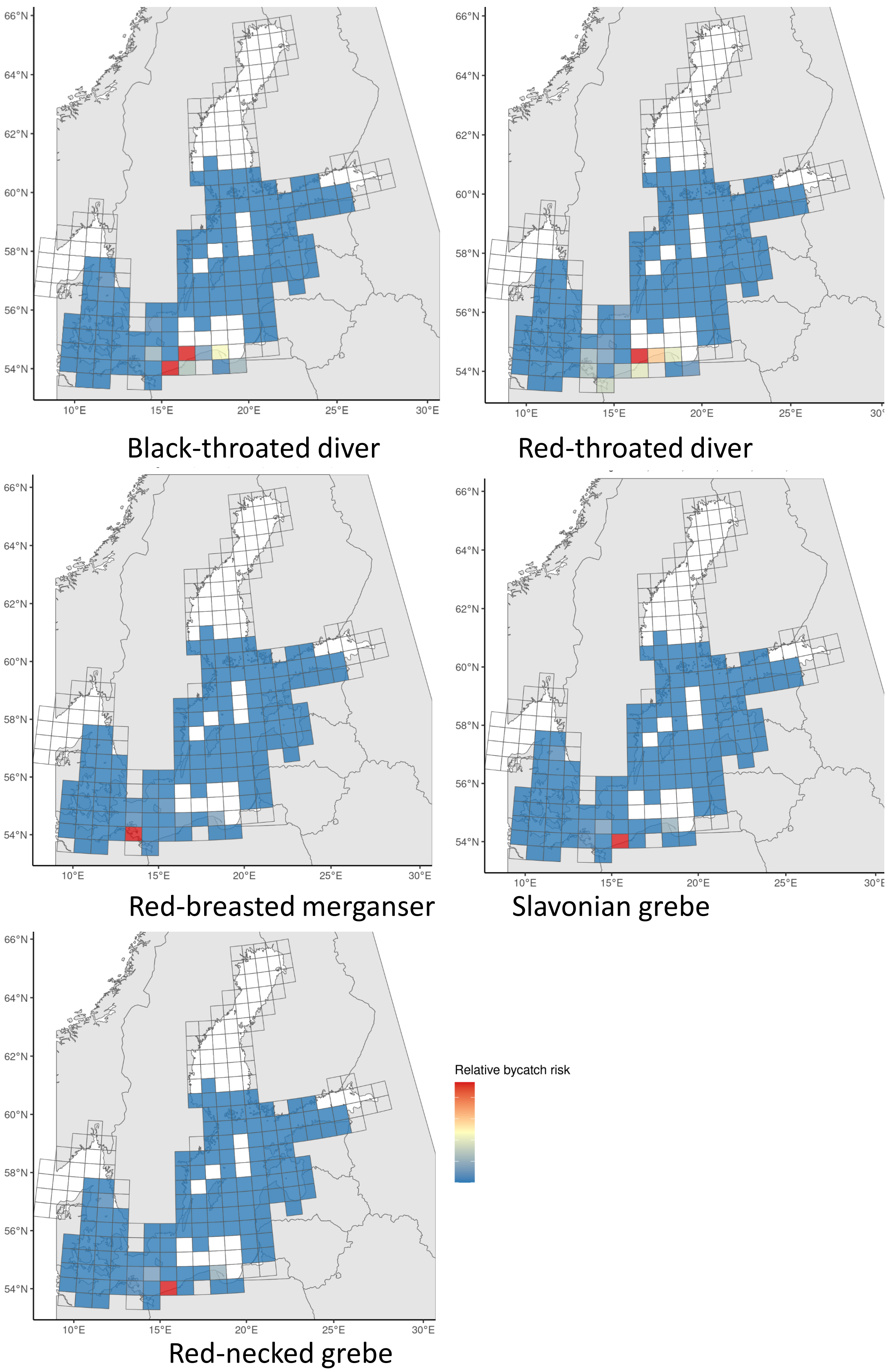

Figure A2, 3. Bycatch risk of pelagic-feeding waterbird species per ICES rectangle expressed as the product of the relative bird abundance (2015-2016) and the fishing effort for drifting longlines (LLD), set longlines (LLS), hand and pole lines (LHP) (2018-2020). No unit is presented since it is only relative bycatch and every map needs to viewed independently. White rectangle is when no data is available.

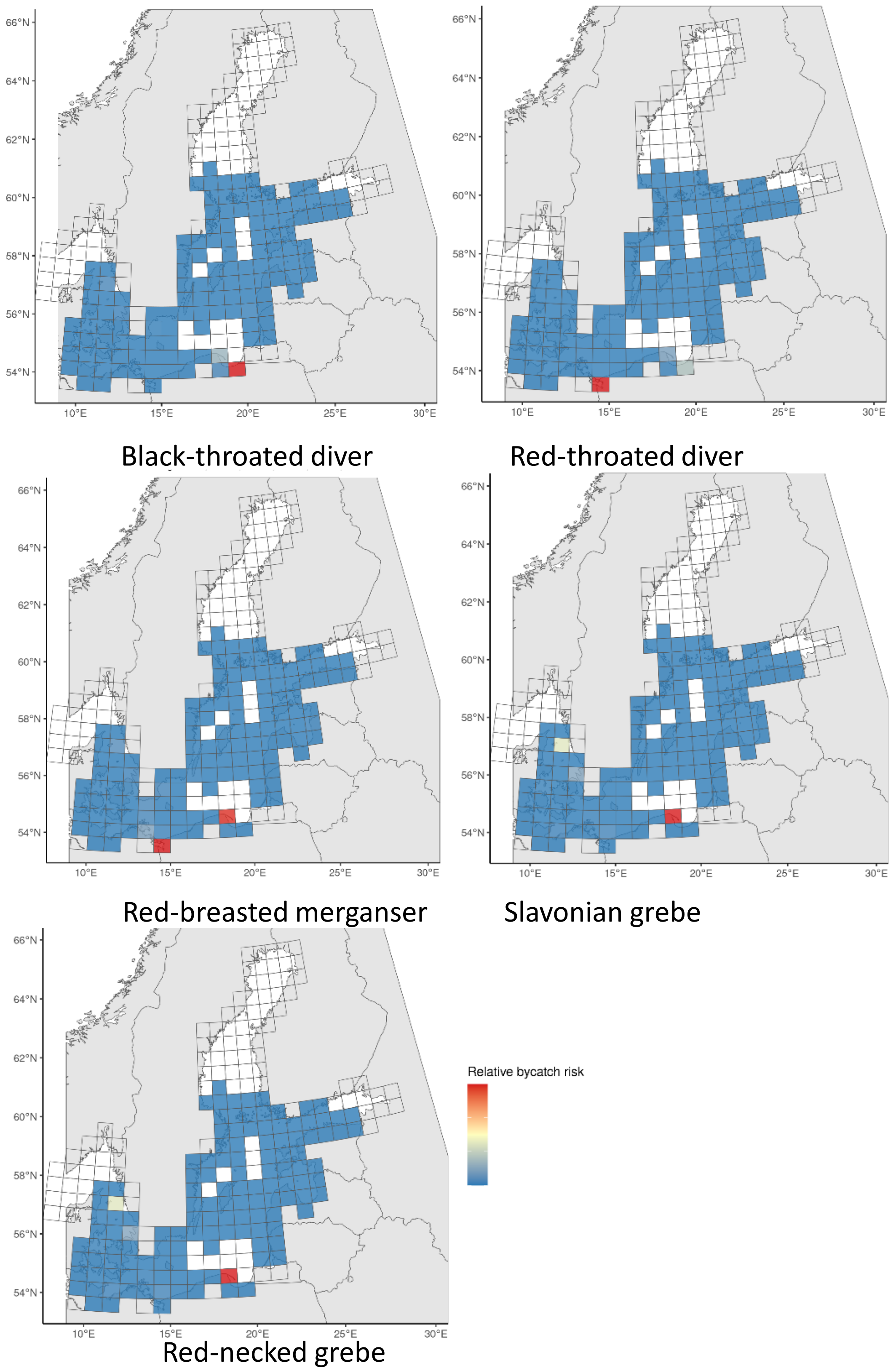

Figure A2, 4. Bycatch risk of Pelagic-feeding waterbird species per ICES rectangle expressed as the product of the relative bird abundance (2015-2016) and the fishing effort for pot and trap fisheries (FPO, 2018-2020). No unit is presented since it is only relative bycatch and every map needs to viewed independently. White rectangle is when no data is available.

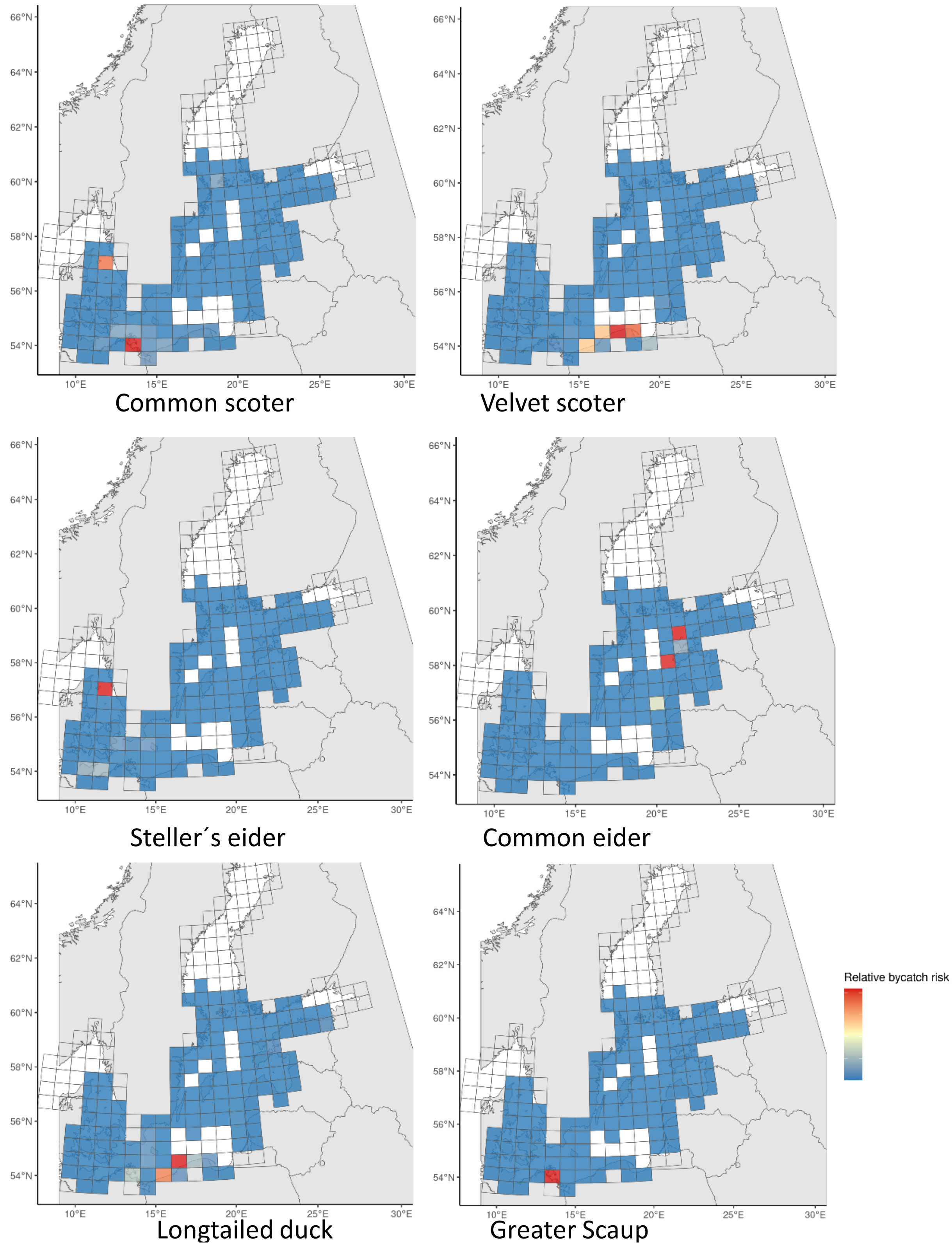

Figure 6. Bycatch risk of benthic-feeding waterbird species per ICES rectangle expressed as the product of the relative bird abundance (2015-2016) and the fishing effort for drifting longlines (LLD), set longlines (LLS), hand and pole lines (LHP) (2018-2020). No unit is presented since it is only relative bycatch and every map needs to viewed independently. White rectangle is when no data is available.

Baltic Marine Environment
Protection Commission

BLUES

Co-funded by the European Union

A2.1 Annex 2

Bycatch indicator report: Number of drowned mammals and waterbirds in fishing gear

For bibliographic purposes this document should be cited as: HELCOM (2023). Number of drowned mammals and waterbirds in fishing gear. HELCOM core indicator report.

2023

HELCOM

Bycatch

INDICATOR TYPE: Pressure
INDICATOR CATEGORY: Core
BSAP SEGMENT: Biodiversity
MSFD CRITERIA: D1C1

Number of drowned mammals and waterbirds in fishing gear

Table of content

1 Key message

The widespread lack of adequate data on both by-catch rates and fishing effort has hampered a comprehensive evaluation of by-catch in marine mammals and waterbirds. Marine mammals were evaluated on the population level. Based on the available data, none of the populations of each of the four species of marine mammals (harbour porpoise, ringed seal, harbour seal, grey seal) achieved good status. The harbour seal population of the South-western Baltic and Kattegat could not be assessed. Furthermore, the quality and number of bycatch data for other seal species is inadequately low in the Baltic Sea region. Thus, the evaluation is primarily based on the number of hunted animals. Waterbirds were evaluated on the geographical scale of subdivisions (aggregated sub-basins), with evaluations available for a total of 11 species in four subdivisions. The threshold for good status was not met in any case (Figure 1). The results of this indicator demonstrate that significant mortality from by-catch in fishing gear is widespread across species of marine mammals and waterbirds in the Baltic Sea. In addition to urgent measures to mitigate the problem, monitoring is needed to observe the success of such measures. Information on fishing effort and by-catch of marine mammals and waterbirds is not being recorded and reported in an adequate way allowing the indicator to be fully operationalised. The underlying data quality issues result in a general low confidence in the evaluation as, for example, even where threshold values may be exceeded it may not represent a full understanding of the overall pressure.

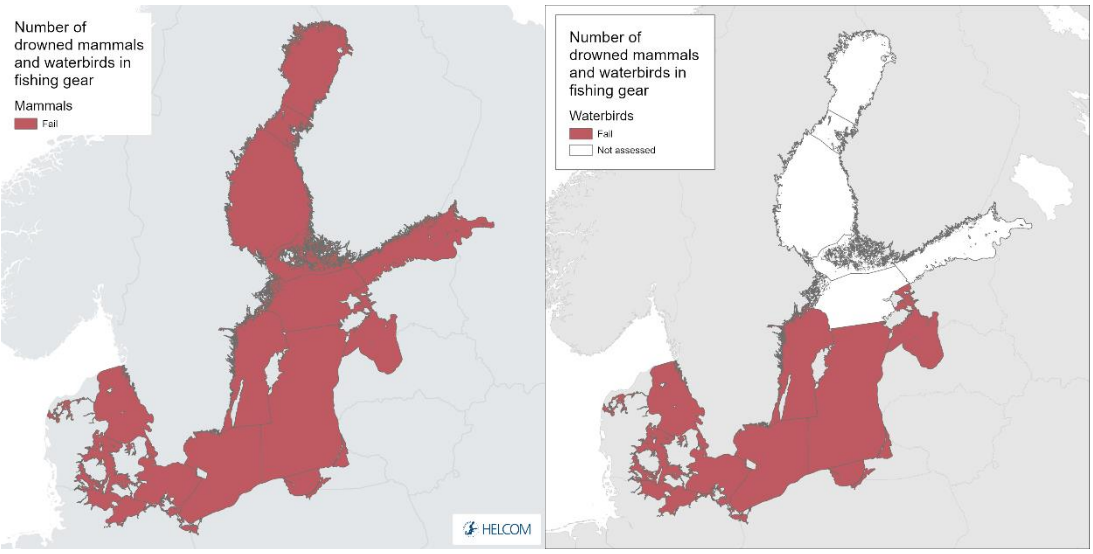

Figure 1. Status evaluation results based on evaluation of the indicator 'Number of drowned mammals and waterbirds in fishing gear': marine mammals (left) and waterbirds (right). The evaluation is carried out using Baltic Sea sub-basins of Scale 2 HELCOM assessment units (defined in the HELCOM Monitoring and Assessment Strategy Annex 4). **See 'data chapter' for interactive maps and data at the HELCOM Map and Data Service.**

1.1 Citation

The data and resulting data products (e.g. tables, figures and maps) available on the indicator web page can be used freely given that it is used appropriately and the source is cited. The indicator should be cited as follows:

HELCOM (2023). Number of drowned mammals and waterbirds in fishing gear. HELCOM core indicator report. Online. [Date Viewed], [Web link].

ISSN 2343-2543.

2 Relevance of the indicator

The indicator is an important tool for detecting additional mortality by incidentally occurring by-catch in key populations of the highly mobile mammal and waterbird species. The populations of marine mammals (cetaceans and seals) and diving waterbirds evaluated in the indicator represent highly mobile animals in the Baltic Sea that are sensitive to additive mortality caused by various métiers of fishing gear due to their characteristic slow reproduction rate.

The distribution and abundance of marine mammal populations is closely linked to abundant fish stocks and is impacted by many human activities. For harbour porpoises, by-catch has been identified as the main known cause of human-related mortality and it is likely to inhibit population recovery towards conservation targets. For seals, by-catch adds to directed takes by hunters, both having a direct effect on the populations. Eurasian otters could not be assessed. They often use coastal areas and are mainly territorial whereas juveniles disperse over wider areas. Due to their coastal distribution otters may be especially vulnerable to specific gear such as static nets, fyke nets and traps, both commercial and recreational, and may need more attention in future evaluations.

Drowning due to by-catch in fishing gear is a significant pressure on waterbirds. It has a strong potential to affect their population trends and demography. In vulnerable species, the numbers of drowned birds may represent a relatively large proportion of the total population size. In some Baltic Sea countries, selected waterbird species are hunted. Also oiling of birds can have an additional substantial impact on waterbird populations. This implies that the loss of individuals due to all human-induced mortality can impact the populations and needs to be taken into account.

2.1 Ecological relevance

Mammals and waterbirds are prone to become entangled in various types of fishing gear and to die by drowning. They belong to species with a high longevity and low reproductive rates. Their populations are therefore vulnerable to the loss, especially of adult individuals, as it takes a relatively long time to compensate for such losses (Bernotat & Dierschke 2021).

For harbour porpoises, by-catch is a significant threat (ASCOBANS 2012, 2016) and may be the main cause of human-related mortality in the Baltic Sea and likely inhibits population recovery towards conservation targets. For seals, by-catch in static nets or traps, especially for those without mitigation devices, is a significant anthropogenic cause of death (Vanhatalo *et al.* 2014, Oksanen *et al.* 2015). For seals, by-catch adds to the number of animals killed by hunters, both having a direct effect on the populations.

Harbour porpoise and seal species are top predators in the Baltic Sea marine food web and thus have an important functional role in the ecosystem. Due to their population dynamics, they are especially vulnerable to additive mortality (Bernotat & Dierschke 2021). Additional anthropogenic mortality that exceeds the potential rate of increase in a population will eventually drive a population to extinction. It is thus necessary to keep the sum of all anthropogenic mortality, including by-catch, below a critical value. From the conservation perspective, immediate management consequences are needed if this threshold is exceeded. In order to set such reference points, the Scientific Committee of the International Whaling Commission recommended that incidental mortality should not exceed half of the potential rate of increase (IWC 1991). Furthermore, incidental mortality greater than one fourth of the potential rate of increase should be considered cause for concern (IWC 1996).

Harbour porpoise

The figure for the potential rate of population increase for harbour porpoises used in simple population models by ASCOBANS and the IWC as well as in the frame of the US Marine Mammal Protection Act (MMPA) is 4% per annum based on their known life history parameters. Advanced technical abilities in computing large amounts of data allow for Management Strategy Evaluation (MSE) frameworks using more sophisticated population models, such as Removal Limit Algorithm (RLA) or modified Potential Biological Removal (mPBR) in which the development of population size can be simulated based on stochasticity of input data and underlying conservation objectives. This has been done for the harbour porpoise populations of the North Sea (RLA) and the Belt Sea (mPBR) (Genu *et al.* 2021, Owen *et al.* 2022).

Given the high levels of environmental contaminants, including heavy metals and PCBs, of harbour porpoises in the Baltic Sea and impaired immune function (e.g. Siebert *et al.* 1999, Beineke *et al.* 2005, 2007a,b, Ciesielski *et al.* 2006) and the correlation between e.g., PCB burdens and reproductive failure (Murphy *et al.* 2015), a precautionary setting of the maximum reproductive rate, an important input value in population models used in the RLA and mPBR methods, is required from a conservation point of view.

The mean longevity of harbour porpoises is severely impacted by anthropogenic activities such as fishing. The average age at death in animals stranded along the German Baltic Sea coast is only 3.67 (±0.30) years, significantly less than in North Sea animals. With a mean age at sexual maturity of 4.95 years, porpoise populations are especially vulnerable to factors that shorten the reproductive lifespan such as additional direct mortality (Kesselring *et al.* 2017) or pollution. For harbour porpoises, the by-catch risk is highest in various types of static nets, including gill nets and semi-driftnets (gear type: GNS) and entangling nets (trammel nets, GTR) (ICES 2016, MASTS 2016). Driftnets are banned in the Baltic Sea, but some hybrid nets such as 'semi-driftnets' which are fixed on one end of the net with the other end drifting around this anchor which are locally used in Poland are of special concern (Skora & Kuklik 2003).

Seals

Seals in general have a higher maximum reproductive rate compared to cetaceans (Wade 1998). In contrast to harbour porpoises, they are still hunted in the Baltic Sea. Thus, there is an additional source of direct takes from the populations which needs to be considered in predictions of a threshold value which still would allow reaching conservation objectives. By-catch numbers of seals in static nets, traps and fyke nets are in the thousands (Vanhatalo *et al.* 2014) although reported numbers are orders of magnitude lower.

Otters

During the 1970s, European otters had disappeared along the coasts of the Baltic Sea. Environmental contaminants such as PCBs, DDT, dieldrin and mercury have shown to be among the leading causes of the decrease in the population. In the 1980s, otters were only found in small scattered areas in Sweden and they were absent from the Baltic coast. Since then the population started to recover and otters also re-established in coastal habitats (Norrgren & Levengood 2012). Eurasian otters are known to be frequently by-caught in static nets and traps (Hauer *et al.* 2020, ICES 2021). However, the otter abundance in the Baltic Sea is not monitored and also by-catch is rarely reported. Hence, no evaluation can be made for HOLAS 3 due to lack of data. In Norway it has been shown that by-catch in local fisheries disrupts the natural re-establishment in otter habitats (Landa & Guidos 2020).

Waterbirds

Waterbirds diving during foraging in order to catch demersal or pelagic fish (divers, grebes, cormorants, mergansers, alcids) and benthic invertebrates (ducks), respectively, are prone to become entangled in various types of static nets and to die by drowning. In addition to hunting (Mooij 2005) and oiling (Larsson & Tydén 2005, Žydelis *et al.* 2006), drowning in fishing gear is a quantitatively important source of mortality for waterbirds living in the Baltic. Scientific studies show that the number of waterbirds by-caught is very high and differs significantly from the much lower numbers reported in official reports (Morkūnas *et al.* 2022). Due to their population dynamics, waterbirds are especially vulnerable to additive mortality (Bernotat & Dierschke 2021). Additional anthropogenic mortality that exceeds the potential rate of increase will eventually drive a population to extinction. It is thus necessary to keep the sum of all anthropogenic mortality, including by-catch, below a critical value.

High longevity is typical for the waterbirds found in the Baltic Sea. The mismatch between the loss of individuals and the effort to replace them is most pronounced in alcids which have a late sexual maturity and only low numbers of offspring, whereas ducks may compensate more easily owing to higher reproductive rates and lower ages of first breeding. However, other factors promoting or impeding population growth rates may override or possibly add to this pattern. For example, fluctuations in population sizes are at least partly caused by favourable supply of prey fish (increase of alcids; Österblom *et al.* 2006), reduced mussel stocks (common eider; Laursen & Møller 2014) or low reproductive success (long-tailed duck; Hario *et al.* 2009).

By-catch of waterbirds is typically occurring also in longline-fishing (Anderson *et al.* 2011) and the risk varying between species groups, but due to the very low overall effort of long-line fisheries in the Baltic Sea, and in the quasi-absence of data for these gears in the region, it is not considered further for HOLAS 3.

Also recreational fisheries using static nets, traps and long-lines contribute to by-catch of mammals and waterbirds. Their effort and spatiotemporal distribution as well as by-catch rates are largely unknown.

2.2 Policy relevance

The core indicator *Number of drowned mammals and waterbirds in fishing gear* addresses the Baltic Sea Action Plan's Biodiversity and nature conservation segment's ecological objectives 'Viable populations of all native species', 'Natural distribution, occurrence and quality of habitats and associated communities' and 'Functional, healthy and resilient food webs' as well as the management objectives 'Human induced mortality, including hunting, fishing, and incidental by-catch, does not threaten the viability of marine life' and 'Reduce or prevent human pressures that lead to imbalance in the food web' (Table 1).

Table 1. Policy relevance of the HELCOM core indicator Number of drowned mammals and waterbirds in fishing gear.

	Baltic Sea Action Plan (BSAP)	**Marine Strategy Framework Directive (MSFD)**
Fundamental link	Segment: Biodiversity Goal: "Baltic Sea ecosystem is healthy and resilient" Ecological objectives: "Viable populations of all native species ", "Natural distribution, occurrence and quality of habitats and associated communities", "Functional, healthy and resilient food webs". Management objective: "Human induced mortality, including hunting, fishing, and incidental by-catch, does not threaten the viability of marine life"; "Minimize disturbance of species, their habitats and migration routes from human activities"; "Effective and coordinated conservation plans and measures for threatened species, habitats, biotopes, and biotope complexes".	Descriptor 1 Species groups of birds, mammals, reptiles, fish and cephalopods Criterion D1C1: The mortality rate per species from incidental by-catch is below levels which threaten the species, such that its long- term viability is ensured. Feature – Species Element of the feature assessed – Waterbirds and mammals.
Complementary link	Segment: Eutrophication Goal: "Baltic Sea unaffected by	Descriptor 1 Species groups of birds, mammals, reptiles, fish and cephalopods

	eutrophication" Ecological objective: "Natural distribution and occurrence of plants and animals". Management objective: "Minimize inputs of nutrients from human activities". Segment: Hazardous substances and litter Goal: "Baltic Sea unaffected by hazardous substances and litter" Ecological objective: "Marine life is healthy", "No harm to marine life from litter". Management objective: "Minimize input and impact of hazardous substances from human activities", "Significantly reduce amounts of litter on shorelines and in the sea". Segment: Sea-based activities Goal: "Environmentally sustainable sea-based activities" Ecological objective: "No or minimal disturbance to biodiversity and the ecosystem", "Activities affecting seabed habitats do not threaten the viability of species' populations and communities". Management objective: "Minimize loss and disturbance to seabed habitats", "Minimize the input of nutrients, hazardous substances and litter from sea-based activities", "Safe maritime traffic without accidental pollution", "Ensure sustainable use of the marine resources".	Criterion D1C2: The population abundance of the species is not adversely affected due to anthropogenic pressures, such that its long-term viability is ensured. Feature – Species groups. Element of the feature assessed – Waterbirds and mammals. Criterion D1C3: The population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity, and survival rates) of the species are indicative of a healthy population which is not adversely affected due to anthropogenic pressures. Feature – Species groups. Element of the feature assessed – Waterbirds and mammals. Criterion D1C4: The species distributional range and, where relevant, pattern is in line with prevailing physiographic, geographic and climatic conditions. Feature – Species groups. Element of the feature assessed – Waterbirds and mammals. Criterion D1C5: The habitat for the species has the necessary extent and condition to support the different stages in the life history of the species. Feature – Species groups. Element of the feature assessed – Waterbird and mammal species. Descriptor 4 Ecosystems, including food webs Criterion D4C1 The diversity (species composition and their relative abundance) of the trophic guild is not adversely affected due to anthropogenic pressures. Feature – Trophic guilds. Element of the feature assessed – Apex predators, sub-apex predators. Criterion D4C4: Productivity of the trophic guild is not adversely affected due to anthropogenic pressures. Feature – Trophic guilds. Element of the feature assessed – Apex predators, sub-apex predators.
Other relevant legislation:	EU Birds Directive (migrating species Article 4 (2); barnacle goose, pied avocet, Mediterranean gull, Caspian tern, sandwich tern, common tern, Arctic tern, little tern listed in Annex I). EU Habitats Directive (harbour porpoise and Eurasian otter listed in Annex IV). Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS).	

	Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA). EU Action Plan for reducing incidental catches of seabirds in fishing gears. UN Sustainable Development Goal 14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development) is most clearly relevant, though SDG 12 (Ensure sustainable consumption and production patterns) and 13 (Take urgent action to combat climate change and its impacts) also have relevance.

HELCOM Contracting Parties have agreed the following specific actions on by-catch: B8, B21, S43 to S49. These actions aim at i.a. implementing operational conservation measures and promoting effective mitigation measures to achieve the close to zero target for by-catch rates of relevant waterbird and mammal species by 2024, especially the Baltic proper population of harbour porpoise by 2022 and setting up conservation schemes for key seabird areas. Further aims are testing, promoting and introducing new technical and operational by-catch mitigation measures (with specific reference to alternative gear) and finally developing and implementing effective data collection for more reliable data on incidentally by-caught birds and mammals and fishing effort for which there has long been a legal obligation (specifically under the EU Birds and Habitats Directive, Common Fisheries Policy and the Data Collection Multiannual Programmes).

For the three seal species occurring in the Baltic Sea, the HELCOM Recommendation (27-28/2) adopted in 2006 relating to seals recommends:

- to take effective measures for all populations in order to prevent illegal killing, and to reduce incidental by-catches to a minimum level and if possible, to a level close to zero;
- to develop and to apply where possible non-lethal mitigation measures for seals to reduce incidental by-catch and damage to fishing gear, as well as to support and coordinate the development of efficient mitigation measures.

For harbour porpoise the HELCOM Recommendation 17/2, adopted in 1996 and updated in 2020, recommends:

- give highest priority to avoiding by-catches of harbour porpoises, particularly following the recommendations of ASCOBANS and the Jastarnia Plan, in order to achieve the ecological objective of the Baltic Sea Action Plan. By-catch of harbour porpoise, shall be significantly reduced with the aim to reach by-catch rates close to zero, recognizing that the Baltic Proper population of harbour porpoise is more threatened than the WBBK population;
- take action for collection and analysis of data on pressures such as by-catch, disturbance, including underwater noise, pollutants, changes in food base and prey quality, habitat deterioration, climate change, and human activities associated with the listed pressures;
- implementing effective and adequate protection measures for the species both inside and outside HELCOM MPAs.

The core indicator also directly or indirectly addresses the following qualitative descriptors of the MSFD for determining Good Environmental Status (European Commission 2008a; see also Table 1):

Descriptor 1: ‘Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions’ and

Descriptor 4: ‘All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity’,

and the following criteria of the Commission Decision 2017/848 (European Commission 2017a):

- Criterion D1C1 (mortality rate from by-catch)
- Criterion D1C2 (population abundance)
- Criterion D1C3 (population demographic characteristics)
- Criterion D1C4 (species distribution)
- Criterion D4C1 (diversity of trophic guild)
- Criterion D4C2 (balance of total abundance between trophic guilds)
- Criterion D4C4 (productivity)

While broad commitments have been made to achieve Good Environmental Status (GES) under the EU Marine Strategy Framework Directive (MSFD), and to Favourable Conservation Status (FCS) under the Habitats Directive, translating these goals into specific targets on by-catch limits under these legislations is as yet unspecified by the EU. However, the EU Regulation 2019/1241 on Technical Measures in Art. 3, 2.(b) formulates the aim to *ensure that incidental catches of sensitive marine species, including those listed under Directives 92/43/EEC and 2009/147/EC, that are a result of fishing, are minimised and where possible eliminated so that they do not represent a threat to the conservation status of these species*. The threshold setting for waterbirds (Evaluation Method 2) uses a legal interpretation of this in which ‘small numbers’ are defined as an approximation of ‘zero by-catch’, which acknowledges that small numbers of seabirds will probably still be caught even when the most effective mitigation measures are in place (see chapter 3).

The EU Habitats Directive lists the harbour porpoise as a strictly protected species (Annex IV) which requires Member States to establish a system of strict protection in their natural range. The harbour porpoise and the three seal species are further listed in Annex II, meaning that they are also to be protected by the means of the Natura 2000 network.

The EU Birds Directive aims to protect, inter alia, habitats of endangered and migratory birds to ensure their conservation in Europe (European Commission 2009). This not only refers to birds needing specific conservation measures (Article 4 (1)) and listed in Annex I (black-throated diver, red-throated diver, Slavonian grebe, Steller’s eider, smew), but also to all migratory species (Article 4 (2)). Therefore, all waterbird species breeding, wintering and staging during migration in the Baltic Sea are covered by this Directive.

EU legislation clearly requires Member States to take measures prohibiting deliberate killing or capture by any method (Article 5 Birds Directive; Article 12 Habitats Directive) which also includes the mere acceptance of the possibility of killing or capture (Case C-221/04 Commission v Spain [2006] ECR I-4515, paragraph 71).

Article 12, paragraph 4 of the Habitats Directive requires that Member States shall establish a system to monitor the incidental capture and killing of the animal species listed in Annex IV (a) (European Commission 1992). In the light of the information gathered, Member States shall take further research or conservation measures as required to ensure that incidental capture and killing does not have a significant negative impact on the species concerned. Member States of the EU are further obliged to develop national programmes for monitoring fisheries, including on board monitoring, under the EU Regulation 2017/1004 (European Commission 2017b). These programmes include detailed data on fleet capacity and fishing effort by metier and fishing area. The Commission Delegated Decision (EU) 2021/1167 (European Commission 2021) requires that by-catch is to be monitored for all marine mammal species protected under Annex II, IV and V of the Habitats Directive. Besides cetacean and seal species this also includes the Eurasian otter. Due to lack of data, a by-catch evaluation for the Eurasian otter needs to be taken forward to HOLAS 4. Further, with reference to the Birds Directive the Delegated Decision requires by-catch monitoring of all waterbird and seabird species, including migratory species. A proposed action in the *Action Plan for reducing incidental by-catches of seabirds in fishing gears* includes the monitoring of seabird incidental by-catch with a minimum coverage of 10% of the fisheries (European Commission 2012) which is far from being reached in relevant gears (ICES 2021).

As a voluntary instrument within the framework of EU and international environmental and fishery legislation and conventions, the EU Commission has adopted an *Action Plan for reducing incidental by-catches of seabirds in fishing gears* (European Commission 2012). It aspires to provide a management framework to minimise incidental by-catch by implementing effective mitigation measures as much as possible in line with the objectives of the EU Common Fisheries Policy (CFP), i.e. to cover all components of the ecosystem.

The Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) aims to achieve and maintain a favourable conservation status of small cetaceans. Six of the nine Baltic Sea countries are Parties to the Convention (Denmark, Germany, Sweden, Poland, Lithuania and Finland).

All waterbird species occurring in the Baltic Sea are subject of the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA), for which Denmark, Germany, Sweden, Lithuania, Latvia, Estonia and Finland are Contracting Parties.

The indicator supports the UN Sustainable Development Goal 14: ‘Conserve and sustainably use the oceans, sea and marine resources for sustainable development.’

2.3 Relevance for other assessments

The level of pressures affecting the status of biodiversity is assessed using several core indicators. Each indicator focuses on one important aspect of a complex issue. This indicator provides an evaluation of the numbers drowned mammals and waterbirds in fishing gear, and this information should be considered together with other biodiversity core indicator evaluations in order to achieve an overall assessment of the status of biodiversity, particularly once further developed.

The results of this indicator can be used for HELCOM integrated assessments (i.e. the BEAT integrated assessment tool).

Further, the results can be used for integrated assessments conducted by EU Member States for their reporting under Article 8 MSFD. According to the relevant guidance for waterbirds (European Commission 2022), the by-catch indicator is weighted equally to the criteria abundance (two indicators for the Baltic Sea) and demography (one indicator). For mammals, the same guidance gives the by-catch criterion the same weight as the other four criteria combined, using the “One-Out All-Out” principle. In this case, the criteria other than by-catch are integrated as in the Habitats Directive, i.e. out of the four parameters population, range, habitat, and future prospects three need to be favourable (and the fourth either unknown or favourable) to achieve favourable conservation status (equalling good status under MSFD).

3 Threshold values

The joint *OSPAR-HELCOM workshop to examine possibilities for developing indicators for incidental by-catch of birds and marine mammals* (September 2019, Copenhagen, OSPAR & HELCOM 2019) proposed the conservation objective '*Minimise and where possible eliminate incidental catches of all marine mammal and bird species such that they do not represent a threat to the conservation status of these species*' to be further considered by HELCOM in work on the Baltic Sea Action Plan. An interim management objective could be '*The mortality rate from incidental catches should be below levels which threaten any protected species, such that their long-term viability is ensured*'. A quite similar wording is provided by the EU Commission Decision 2017/848 which says "*The mortality rate per species from incidental by-catch is below levels which threaten the species, such that its long-term viability is ensured.*"

The threshold proposals outlined here are based on the outcome and recommendations of the workshop, i.e. they are built on the expertise of 52 experts representing 20 countries and several organizations. They have been further developed by the HELCOM BLUES project, taking discussions between HELCOM Contracting Parties and on expert level into account. Limited availability of by-catch and effort data as well as knowledge on species demography parameters was hereby considered. In the development process leading towards HOLAS 3 it was noted that from a policy/management perspective there is a strong wish to have some sort of evaluation in place as this would promote future work.

Available methods for threshold setting are e.g., Removal Limit Algorithm (RLA), modified Potential Biological Removal (mPBR), and Population Viability Analysis (PVA). All three model-based threshold setting procedures require a quantitative objective. This quantitative objective aspires to maintain the assessment units at or above their Maximum Net Productivity Level (MNPL). In marine mammals, early analytical work places MNPL between 50% and 80% of the carrying capacity (K) (Wade 1998). In absence of an agreed conservation objective, for some seal populations, the international widely adopted conservation objective from the US MMPA was used, which assumes MNPL to be at least 50% of K (Wade 1998) and aims to ensure that the bycatch will not deplete the assessment unit and maintain it at or above MNPL after 100 years of exploitation with a probability of 0.95. For the Belt Sea harbour porpoise population, a control rule for deriving the threshold which had been adopted by OSPAR for the North Sea harbour porpoise population was used. The conservation objective used, which aims at restoring, with a probability of 0.8, the population to 80% of carrying capacity after 100 years, the assessment unit is to be maintained well above MNPL. Therefore, for seals we computed thresholds using the PBR approach (Wade 1998) and for harbour porpoise using mPBR (Genu et al. 2021). For waterbirds, the conservation objective is that by-catch mortality shall be below levels which threaten any protected species such that their long-term viability is ensured. Long-term viability is often interpreted to mean that the population size does not decrease more than 30% over three generations (Oliveira 2021, see also Indicator *Breeding success of waterbirds*).

Thresholds represent the upper limit to the sum of anthropogenic mortality beyond which conservation objectives will not be met (Figure 2). The threshold values derived are thus entirely dependent on the conservation objective to be achieved. Where threshold values were calculated, these are given in Tables 2 and 3.

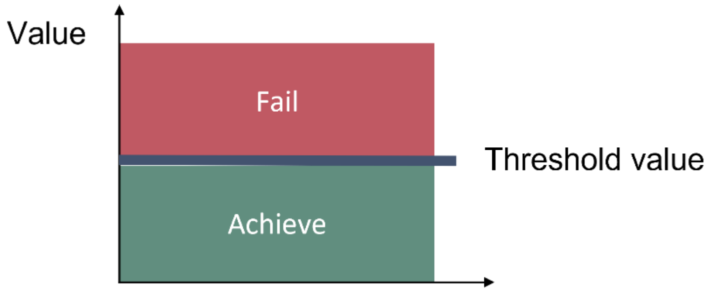

Figure 2. Schematic representation of the threshold values applied in the 'Number of drowned mammals and waterbirds in fishing gear' core indicator (calculated threshold values are presented in Tables 2 and 3).

Table 2. Assessment unit specific threshold values applied to marine mammal populations in this indicator. The indicator is evaluated on the level of populations, which are allocated to scale 2 HELCOM assessment units. Thresholds derived from PBR or mPBR include all anthropogenic mortality such as hunted seals whereas the zero threshold is for by-catch only.

Species	Population	Range (HELCOM sub-basins)	Threshold (animals/year)
Harbour porpoise	Belt Sea	Kattegat, Great Belt, The Sound, Kiel Bay, Bay of Mecklenburg, Arkona Basin	mPBR: 73
	Baltic Proper	Bornholm Basin, Gdansk Basin, Western Gotland Basin, Eastern Gotland Basin, Northern Baltic Proper, Åland Sea	0
Ringed seal	Southwestern Archipelago Sea, Gulf of Finland and Gulf of Riga	Eastern Gotland Basin, Northern Baltic Proper, Åland Sea, Gulf of Finland, Gulf of Riga	0
	Gulf of Bothnia	Bothnian Sea, The Quark, Bothnian Bay	PBR: 443
Harbour seal	Kalmarsund	Western Gotland Basin	0
	South-western Baltic and Kattegat	Kattegat, Great Belt, The Sound, Kiel Bay, Bay of Mecklenburg, Arkona Basin	PBR: 417
Grey seal	Whole Baltic	Kattegat, Great Belt, The Sound, Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin, Gdansk Basin, Western Gotland Basin, Eastern Gotland Basin, Northern Baltic Proper, Åland Sea	PBR: 1330

Table 3. Assessment unit specific threshold values applied to waterbirds in this indicator when Assessment Method 2 is applied. Annual adult mortality according to Bird *et al.* (2020). For data on bird numbers see Chapter 9.2

Species	HELCOM Red List status	Assessment unit	Number of birds in assessment unit	Annual adult mortality	Threshold value
Greater scaup	Vulnerable	Bornholm Group (Poland only)	22,724	0.26	59
		Gotland Group (Poland only)	5,682		15
Long-tailed duck	Endangered	Bornholm Group (Poland only)	347,653	0.25	869
		Gotland Group (Poland only)	52,262		131
Common scoter	Endangered	Bornholm Group (Poland only)	30,761	0.22	68
		Gotland Group (Poland only)	4,303		10
Velvet scoter	Endangered	Bornholm Group (Poland only)	149,158	0.21	313
		Gotland Group (Poland only)	92,177		194

3.1 Setting the threshold value(s)

Threshold values for marine mammals

For the Belt Sea population of harbour porpoises it was agreed that the threshold should be derived using the mPBR method which is modified with respect to the conservation objective to allow recovery to and maintain the population at 80% or more of the carrying capacity in the long-term (100 years), with a probability of 80%. This objective is different from the PBR approach used in the frame of the US MMPA. In an MSE using the mPBR method, a threshold of 29 animals per year was derived (Owen *et al.* 2022). This value is based on the most recent abundance estimate of 17,301 harbour porpoises (95% CI = 11,695-25,688; CV = 0.20) from miniSCANS II in 2020 (Unger *et al.* 2021). Due to subsequent discussions about the input values for the mPBR approach after the threshold value has been proposed, further simulation trials were conducted and three scenarios for the accuracy of the by-catch estimate developed: ‘accurate’, ‘moderate’ (factor 2/3) underestimation and ‘severe’ (factor 2) underestimation. Threshold values for the whole population derived are 117, 73 and 58, respectively (Authier *et al.* 2022). A source of bias of available by-catch data is that an REM dataset is from fishing vessels voluntarily participating in the REM study (Glemarec *et al.* 2022). In the areas not covered by the REM, there is an issue with the quality of data consisting of reported by-catch from logbooks and strandings only (HELCOM EG MAMA 2022). These are orders of magnitude lower and hence can be considered minimum numbers at best. Thus, by-catch estimates can be considered systematically and severely underestimated in those countries which do not have a systematic by-catch monitoring whereas the REM provides more accurate estimates. Based on intersessional discussions contracting parties agreed to use a threshold value of 73 by-caught animals per year, the value for ‘moderate’ underestimation, for HOLAS 3 purposes.

The threshold for the harbour porpoise population of the Baltic Proper is set to zero by-catch due to the severe depletion of the population and its conservation status as critically endangered. The size of the population is estimated at only 491 individuals (95% CI: 71–1105) (Amundin *et al.* 2022).

The threshold for the ringed seal population of the Southwestern Archipelago Sea, Gulf of Finland and Gulf of Riga is also set to zero by-catch due to its conservation status as vulnerable on species level and the fact that the population is at high risk due to climate change as well as the small population size and range. The population is estimated at 1,800 animals (200 in the Archipelago Sea, 100 in the Gulf of Finland and 1,500 in Western Estonia; M. Ahola, pers.comm.).

For the population of the ringed seal in the Gulf of Bothnia the evaluation is based on the PBR approach adopted from the US MMPA. It must be noted that the US MMPA conservation objective differs from the one suggested during the *OSPAR-HELCOM workshop to examine possibilities for developing indicators for incidental by-catch of birds and marine mammals.* Assumptions were made on maximum reproductive potential of the population (R_{max} =0.10) and recovery factor (F_R =0.5) as well as a conservative measure of abundance for the management unit (N_{min} =17,744). The resulting PBR results in a threshold of 443 animals per year for total anthropogenic removal (i.e., hunting and by-catch).

The threshold for the population of the harbour seal in Kalmarsund is set to zero by-catch. This is due to its conservation status as vulnerable on species level and the small population size and isolated spatial distribution range. The abundance is estimated at 2,900 animals (M. Ahola, pers.comm.).

For the population of the harbour seal in the South-western Baltic and Kattegat the evaluation is based on the PBR approach adopted from the US MMPA. It must be noted that the US MMPA conservation objective differs from the one suggested during the *OSPAR-HELCOM workshop to examine possibilities for developing indicators for incidental by-catch of birds and marine mammals.* Assumptions were made on maximum reproductive potential of the population (R_{max} =0.12) and recovery factor (F_R =0.5) as well as a conservative measure of abundance for the management unit (N_{min} =13,917). The resulting PBR threshold is 417 animals per year for total anthropogenic removal (i.e., hunting and by-catch).

For the grey seal population the evaluation is based on the PBR approach adopted from the US MMPA. It must be noted that the US MMPA conservation objective differs from the one suggested during the *OSPAR-HELCOM workshop to examine possibilities for developing indicators for incidental by-catch of birds and marine mammals.* Assumptions were made on maximum reproductive potential of the population (R_{max} =0.12) and recovery factor (F_R =0.5) as well as a conservative measure of abundance for the management unit (N_{min} =53,232). The resulting PBR threshold is 1,330 animals per year for total anthropogenic removal (i.e., hunting and by-catch).

For all seal populations evaluated under the PBR method, hunted numbers must also be accounted for when assessing the impact of by-catch related takes on the population. Hunted numbers were taken from the HELCOM database (unpublished data). Reliable by-catch data from the assessment period 2016-2021 is not available. Thus, an evaluation using this method can only be made for grey seals for which a by-catch number for the year 2012 is available from interviews with fishers (Vanhatalo *et al.* 2014) and an assumption for the actual by-catch numbers has been made. Whereas the number of legally hunted seals is considered accurate, the by-catch number appears to be severely underestimated. The underestimation factor is likely much larger than 2 (i.e. true mortality twice estimated mortality) which is the maximum factor considered in the PBR approach (Wade 1998). There may be other sources of anthropogenic mortality not considered here.

Threshold values for waterbirds

The joint *OSPAR-HELCOM workshop to examine possibilities for developing indicators for incidental by-catch of birds and marine mammals* proposed a threshold derived from the conservation objective to '*minimise and eliminate by-catch where possible*' (OSPAR & HELCOM 2019). This objective aligns with the prohibition of deliberate killing or capture of birds according to Article 5 of EU Directive 2009/147/EC (Birds Directive). It is also aligned with the conservation target of the EU *Action Plan for reducing incidental catches of seabirds in fishing gears* (COM(2012) 665), which requests Member States to *'minimize and, where possible, eliminate the incidental catches of seabirds'*.

Following BirdLife International (2019), the OSPAR-HELCOM workshop proposed a value of 1% of natural annual adult mortality as an approximation of 'zero by-catch', which acknowledges that small numbers of seabirds will probably still be caught even when the most effective mitigation measures are deployed. The 1% value is derived from legal interpretations in European Court of Justice of 'small numbers'[1] and EU Commission stemming from the EU Birds Directive and EU guide to sustainable hunting (European Commission 2008b). Since for most species it is extremely difficult to identify natural annual adult mortality in the presence of anthropogenic mortality, it is more feasible to use total annual adult mortality as an approximation. Annual adult mortality m was calculated from survival rates s as

$$m = 1 - s$$

The survival values of adult individuals from which the mortality calculated for all bird species can be found in the literature, e.g. Bird *et al.* (2020).

[1] See the following judgements: judgment of 9 December 2004, Commission/Spain, case C-79/03, ECR 2004, p.11619, paragraphs 36 and 41; judgment of 15 December 2005, Commission/Finland, case C-344/03, ECR 2005, p.11033, paragraphs 53-54; judgment of 8 June 2006, WWF Italia and others, case C-60/05, ECR 2006, p.5083, paragraphs 25-27.

Based on this, the indicator evaluates by-catch against the conservation objective *'The mortality rate from incidental catches should be below levels which threaten any protected species, such that their long-term viability is ensured'*. As by-catch mortality for most species is one out of several pressures acting cumulatively and directly decreases the population size, it can have negative impact on the population development especially for threatened species. Therefore, a precautionary approach is applied to species identified as vulnerable, endangered or critically endangered on the HELCOM Red List (HELCOM 2013). The *evaluation* of by-catch mortality includes the following three steps (see also Figure 3):

1. Wherever sufficient data are available population modelling will be used to determine if the fishing-induced mortality threatens the long-term viability of seabird populations (*Evaluation* Method 1 in Figure 3). In accordance with IUCN Red List criteria, 'long-term' is defined as a three-generation timespan (Oliveira 2021). A percentage of maximum acceptable decline for each species/population under scrutiny during this period is yet to be determined. If this threshold value is exceeded for the specific species/population, the indicator is considered failing. This method has not been used here due to lack of sufficient data.

2. If population modelling is not possible in species/populations classified as vulnerable, endangered, or critically endangered on the HELCOM Red List, an alternative threshold will be used, corresponding to a reference value of 1% of the total annual adult mortality of the considered species/population (Evaluation Method 2 in Figure 3). The species-specific threshold value of Evaluation Method 2 (*TV(2))* is estimated from multiplying the point estimate of the number of birds in the evaluation area *N* with the species-specific annual adult mortality rate *m* and 1%:

$$TV(2) = N * m * 0.01$$

where *N* is the estimated population size in the HELCOM subdivision, and *m* is the annual mortality of adults of the species/population. Subdivisions of the Baltic Sea used for waterbird indicator evaluations are described in Chapter 9.1. Threshold values used for Evaluation Method 2 in this indicator are presented in Table 2.

In case by-catch data for a species/population listed on the HELCOM Red List are insufficient to assess against the reference value *TV(2)*, but this species/population is known to be susceptible to by-catch in fisheries <u>and</u> there is a spatio-temporal overlap between species/population occurrence and the respective fishing method(s) causing by-catch, then the considered species/population fails the indicator (Evaluation Method 3 in Figure 3). In this case, by-catch monitoring would have to be intensified to provide evidence that incidental captures for that species/population are below *TV(2)*. This procedure implements the precautionary approach. For data-poor species which are not classified as vulnerable, endangered, or critically endangered on the HELCOM Red List, no status evaluation for by-catch mortality enters the indicator.

If specific model-based threshold values cannot be evaluated due to a shortage in demographic and/or by-catch data, contracting parties must strive to improve by-catch monitoring and by-catch mortality evaluations, and to reduce by-catch rates aiming to reach values close to zero, as committed to in the Baltic Sea Action Plan.

The threshold setting is identical to the OSPAR candidate indicator B5 Marine Bird By-catch. It should be noted that for birds other evaluation methods have either not yet been explored (RLA) or have at most limited applicability (PBR: O'Brien *et al.* 2017, Marchowski *et al.* 2020).

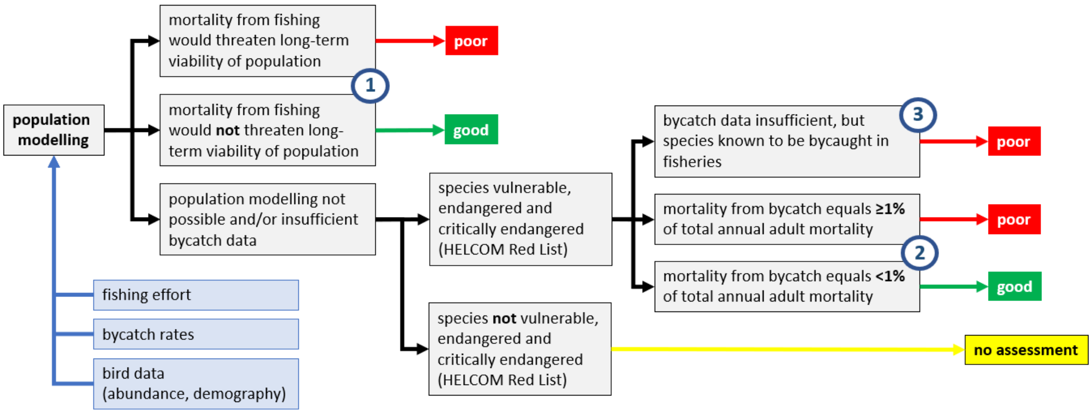

Figure 3. Schematic illustration of the evaluation of waterbird by-catch in fishing gear in the Baltic Sea. Numbers denote the sequence of applicable Evaluation Methods 1, 2 and 3, depending on data availability.

4 Results and discussion

4.1 Status evaluation

With reference to the period 2016-2021 it was possible for the first time to evaluate the number of by-caught marine mammals and waterbirds in the Baltic Sea. Evaluations were possible for at least one population in each of four species of marine mammals (harbour porpoise, ringed seal, harbour seal, grey seal). Waterbirds were evaluated on the geographical scale of subdivisions (aggregated sub-basins), with evaluations available for a total of 11 species in four subdivisions. In all marine mammal populations and those waterbird species considered, the status was sub-GES because the thresholds for good status were exceeded.

Marine mammal by-catch in the Baltic Sea

In cases where scientific by-catch evaluations report an annual by-catch number, this was taken to compare against the threshold. If reported by-catch numbers based on log-books and strandings (HELCOM EG MAMA 2022) were used for the evaluations, these can be assumed underestimating the real by-catch numbers, and thus the highest annual value in the assessment period (2016-2021) was taken. Hunted seal numbers fluctuated during the assessment period and thus the highest annual numbers were taken for a worst case for those evaluations where the sum of by-catch and hunted numbers are compared against a PBR value. Hunted numbers could not be assigned to a population because genetic data are lacking. However, it was assumed that for populations with abundance below the Limit Reference Level no hunting permits were issued by authorities in accordance with HELCOM Recommendation (27-28/2).

For the harbour porpoise population of the Kattegat, Belt Sea and Western Baltic, two available datasets are from fishing vessels voluntarily participating in an REM study in the Danish static net fishery and by-catch reported by fishermen or found during autopsies of stranded animals (as reported to HELCOM EG MAMA). Based on 2010-2019 data the yearly average by-catch in the Danish fishery including ICES areas IIIa21 (Kattegat), IIIb23 (Øresund) and IIIc22 (Belt Sea) is 776 (95% CI: 539-1,044) animals per year. As fishermen were participating voluntarily, the sampling scheme is not random and by-catch numbers may be under- or overestimated (Glemarec *et al.* 2022). Reported numbers of 29 animals were taken from the year 2016 which had the highest reported values. The underestimation factor here is likely much higher as not all harbour porpoise by-catches may be reported. The sum of both was compared against the threshold of 73 (derived using mPBR method). The sum is 805 which means that the status is sub-GES.

NAMMCO & IMR (2019) estimated by-catch numbers for the harbour porpoise population of the Baltic Proper in a precautionary way from the upper limit of the 95% confidence interval of a by-catch rate for the Belt Sea population, adjusted for the lower density in the Baltic Proper, and multiplied with reported static net fishing effort (métiers GNS and GTR) within ICES sub-areas 25-29 during the years 2009-2017. Data on minimum by-catch was also compiled from records of strandings and voluntary by-catch reports for the years from 1984 to 2012. By-caught numbers derived from strandings are most likely an underestimation of the total number. The estimated by-catch number for 2017 is 7 animals, and the minimum by-catch numbers for the years 2000-2012 is on average approximately 3 animals per year. Thus, the status of this population is sub-GES.

For the ringed seal population of the Southwestern Archipelago Sea, Gulf of Finland and Gulf of Riga the reported by-catch number for 2017 was 3 animals which can be considered a minimum estimate only. This exceeds the threshold of zero by-catch. Thus, the status of this population is sub-GES.

For the ringed seal population of the Gulf of Bothnia the number of annually hunted animals in the assessment period is between 176 and 597. The highest reported by-catch number is 8 animals (2017) which can be considered a minimum estimate only. In the years 2019, 2020 and 2021 the hunted numbers alone were higher (538, 597 and 568, respectively) than the PBR threshold of 443 animals. From a worst-case evaluation the status is sub-GES. By-catch data need to be improved for future evaluations.

For the harbour seal population in Kalmarsund the reported by-catch number for the period 2016 to 2020 is 2 or 3 animals each year which is compared against the threshold of zero by-catch. Thus, the status of this population is likely sub-GES. Sweden reports by-catch in terms of West coast and Baltic Proper. However, even Baltic Proper by-catch cannot be assigned to this population with a high degree of certainty as by-caught animals often are juveniles and sometimes by-caught outside the normal range of the population. However, sporadic data from the 1990s suggest that approximately 20 pups were caught annually in fyke nets set for eel, but modified gear and changed structure of the coastal fisheries were suggested to have reduced by-catches (Härkönen & Isakson, 2010). Since then, the number of seals has grown (HELCOM 2018). From this and the by-catches reported to HELCOM EG MAMA it appears realistic that the by-caught number is above zero. Subsequently the status is sub-GES.

For the harbour seal population of the South-western Baltic and Kattegat the number of hunted animals is between 88 and 380 with a maximum in 2018. The reported by-catch number for 2020 is 2 animals. Based on 2010-2019 Remote Electronic Monitoring data the yearly average by-catch in the Danish fishery including ICES areas IIIa21 (Kattegat), IIIb23 (Øresund) and IIIc22 (Belt Sea) is 370 (95% CI: 106-731) seals per year (Glemarec *et al.* 2022). However, REM could not be utilised to its full potential as there were challenges with species identification of juveniles in the video footage and thus it is not distinguished between species. However, due to low confidence in reported seal numbers and missing species identification in REM data the status is not evaluated.

For the grey seal population of the Baltic Sea the annual number of hunted animals is between 465 (2016) and 1,717 (2021), with an average number of 1,065. The highest annual reported by-catch number is 35 animals (2017). However, due to low confidence this data does not allow to assess the true status with any of these options. Thus, an estimation based on earlier and more realistic data was made. Vanhatalo *et al.* (2014) used 2012 data based on interviews with fishermen in Estonia, Finland and Sweden (east coast N of Kalmar) for a more realistic by-catch evaluation. Taking the possible underreporting into account the posterior mean of the total by-catch in that year is between 2,180 and 2,380. The by-catch in the study area was likely to represent at least 90% of the total yearly grey seal by-catch in the Baltic Sea. Reduced fishing effort since

2012 combined with an increased population size suggests a by-catch number in the same order of magnitude for the assessment period. Given the average number of annually hunted grey seals in the assessment period, this is only 265 animals below the PBR threshold. The likely magnitude of by-catch inferred from Vanhatalo *et al.* (2014) is much higher. In the period 2019 to 2021 the hunted numbers alone exceeded the PBR threshold. Thus, the status is sub-GES.

The by-catch evaluations for marine mammal populations are summarised in Table 4. In Table 5 these evaluations are allocated to the HELCOM sub-basins in which the respective populations occur. Using a One-Out All-Out approach all sub-basins are in sub-GES with respect to by-catch of marine mammals.

Table 4. Overview of marine mammal by-catch evaluations per species and population. Note that the PBR-based evaluation method includes annual numbers of seals hunted.

Species	Population	Evaluation method	Threshold value (animals/year)	Observed value bycaught (animals/year)	Observed value hunted (animals/year)	Status
Harbour porpoise	Kattegat, Belt Sea and Western Baltic	mPBR	73	805		sub-GES
Harbour porpoise	Baltic Proper	poor conservation status	0	7		sub-GES
Ringed seal	Southwestern Archipelago Sea, Gulf of Finland and Gulf of Riga	poor conservation status	0	3		sub-GES
Ringed seal	Gulf of Bothnia	PBR	443 (incl. hunting)	reported minimum number 8	176 to 597 Exceeding the threshold in 2019-2021: 538, 597 and 568	sub-GES
Harbour seal	Kalmarsund	poor conservation status	0	2 to 3		sub-GES
Harbour seal	South-western Baltic and Kattegat	PBR	417 (incl. hunting)	REM by-catch data could not be analysed on species level, reported minimum number: 2	88 to 380	not evalu-ated
Grey seal	Baltic Sea	PBR	1330 (incl. hunting)	>2,000	465 to 1,717, average: 1,065	sub-GES

Table 5. Marine mammal by-catch evaluations allocated to sub-basins and integrated assessment per sub-basin.

	Harbour porpoise		**Ringed seal**		**Harbour seal**		**Grey seal**	**Inte-gration**
HELCOM sub-basin	**Kattegat, Belt Sea and Western Baltic**	**Baltic Proper**	**Southwestern Archipelago Sea, Gulf of Finland and Gulf of Riga**	**Gulf of Bothnia**	**Kalmarsund**	**South-western Baltic and Kattegat**	**Baltic Sea**	
Kattegat	sub-GES					n.a.	sub-GES	sub-GES
Great Belt	sub-GES					n.a.	sub-GES	sub-GES
The Sound	sub-GES					n.a.	sub-GES	sub-GES
Kiel Bay	sub-GES					n.a.	sub-GES	sub-GES
Bay of Mecklenburg	sub-GES					n.a.	sub-GES	sub-GES
Arkona Basin	sub-GES					n.a.	sub-GES	sub-GES
Bornholm Basin		sub-GES					sub-GES	sub-GES
Gdansk Basin		sub-GES					sub-GES	sub-GES
Western Gotland Basin		sub-GES			sub-GES		sub-GES	sub-GES
Eastern Gotland Basin		sub-GES	sub-GES				sub-GES	sub-GES
Gulf of Riga			sub-GES					sub-GES
Northern Baltic Proper		sub-GES	sub-GES				sub-GES	sub-GES
Åland Sea		sub-GES	sub-GES				sub-GES	sub-GES
Gulf of Finland			sub-GES					sub-GES
Bothnian Sea				sub-GES				sub-GES
The Quark				sub-GES				sub-GES
Bothnian Bay				sub-GES				sub-GES

Waterbird by-catch in the Baltic Sea

Numbers of waterbirds by-caught in fishing gear during the assessment period 2016-2021 are available from Denmark (Larsen *et al.* 2021, Glemarec *et al.* 2022), Poland (see below) and Lithuania (Morkūnas *et al.* 2022). Nevertheless, it was not possible to apply Evaluation Method 1 because by-catch data were not available across the entire range of the respective bird populations. Using the example of the greater scaup, Marchowski *et al.* (2020) have demonstrated how Evaluation Method 1 including a PVA can be applied to waterbird populations in the Baltic Sea. However, part of the data used in that study are from before the assessment period. Therefore, it was not considered for an evaluation here.

Evaluation Method 2 could also not be used in most cases because no data on the number of birds present in the area with the by-catch data were available. However, where by-catch occurred it was possible to apply Evaluation Method 3 because evidence for by-catch events is in place. Observed waterbirds and static nets during ship-based surveys allow assessing the threshold of overlapping occurrence of waterbirds and fishing gear in German waters. Though these assessments are allocated to Baltic Sea subdivisions it has to be noted that they usually cover only part of the respective subdivision.

Waterbird by-catch in the assessment unit Kattegat

Evaluation Method 3 – Denmark

The risk-mapping approach conducted by Glemarec *et al.* (2022) revealed elevated by-catch risk in static nets in the Kattegat, namely north of the coast of Sjælland (Figure 4). This elevated by-catch risk is based on observed by-catch of common eiders and thus constitutes evidence of spatio-temporal overlap of a fishing method causing by-catch and the occurrence of a HELCOM red-listed species according to Evaluation Method 3. In this indicator the status for common eider is at sub-GES.

The average yearly by-catch estimate for common eider in the westernmost Danish section of the Baltic Sea, including the Kattegat, the Sound, the Belts and part of Bay of Mecklenburg is 2623 birds (95% C.I. 1847-3567 birds) (Glemarec *et al.* 2022).

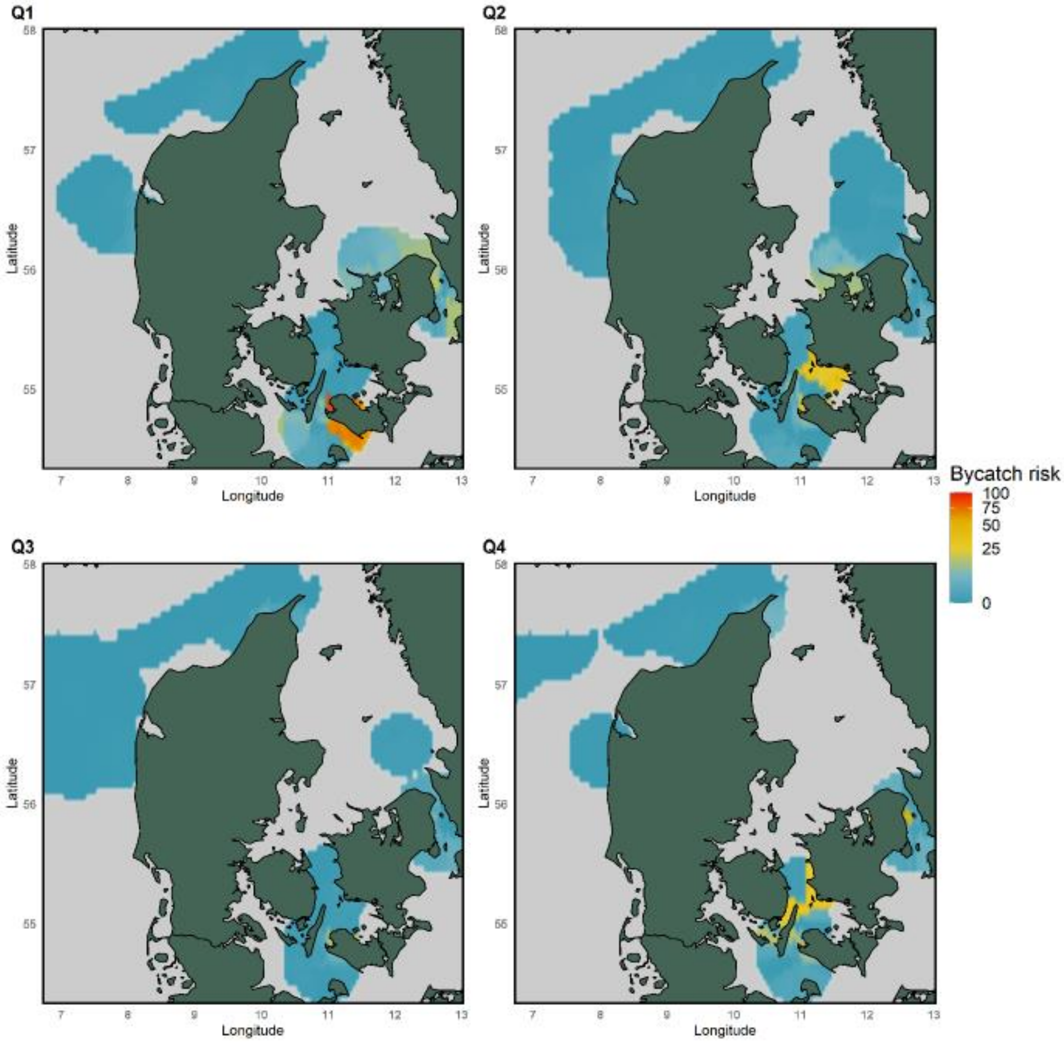

Figure 4: Quarterly by-catch risk (no unit) for common eider in the Danish commercial gillnet fleet, from model predictions using electronic monitoring data (2010-2019). Taken from Glemarec *et al.* (2022).

Waterbird by-catch in the assessment unit Belt Group

Evaluation Method 3 – Denmark

The risk-mapping approach applied by Glemarec *et al.* (2022) revealed elevated by-catch risk in static nets in the Belt Group, namely in the Great Belt (Figure 4). This elevated by-catch risk is based on observed by-catch of common eiders and thus constitutes spatio-temporal overlap of a fishing method causing by-catch and the occurrence of a HELCOM red-listed species according to Evaluation Method 3. In addition, Larsen *et al.* (2021) report by-caught waterbirds from The Sound for the period 2017 to 2019, which include the following red-listed species: common eider, common scoter, velvet scoter and black-throated diver. Again, these by-caught events are treated as evidence for spatio-temporal overlap of a fishing. Thus, the four species are considered to be at sub-GES. Beyond that the two studies cited list species not red-listed and therefore not evaluated by this method (great cormorant, great crested grebe, razorbill and common guillemot as well as undetermined mergansers and gulls).

The average yearly by-catch estimate for common eider in the westernmost Danish section of the Baltic Sea, including the Kattegat, the Sound, the Belts and part of Bay of Mecklenburg is 2623 birds (95% C.I. 1847-3567 birds) (Glemarec *et al.* 2022).

Waterbird by-catch in the assessment unit Bornholm Group

Evaluation Method 3 – Denmark

The risk-mapping approach applied by Glemarec *et al.* (2022) revealed elevated by-catch risk in static nets in the northwestern area of the Bornholm Group, namely south off the coast of Lolland and south of the Sound (Figure 4). This elevated by-catch risk is based on observed by-catch of common eiders and thus constitutes evidence for spatio-temporal overlap of a fishing method causing by-catch and the occurrence of a HELCOM red-listed species according to Evaluation Method 3. In this indicator the status for common eider is at sub-GES.

The average yearly by-catch estimate for common eider in the westernmost Danish section of the Baltic Sea, including the Kattegat, the Sound, the Belts and part of Bay of Mecklenburg is 2623 birds (95% C.I. 1847-3567 birds) (Glemarec *et al.* 2022).

Evaluation Method 3 – Germany

During the wintering season from November to April (2016-2021), the spatial extent of static net fishing overlapped with occurrence of the HELCOM red-listed species red-throated diver, black-throated diver, red-necked grebe, Slavonian grebe, greater scaup, common eider, long-tailed duck, common scoter, velvet scoter, red-breasted merganser and black guillemot in 5x5 km grid squares (Figures 5 to 15). It is well known from earlier studies that these species are by-caught in static nets in the German section of the Baltic Sea (Schirmeister 2003, Erdmann *et al.* 2005, Bellebaum & Schirmeister 2012). Therefore, these species are evaluated as being in sub-GES.

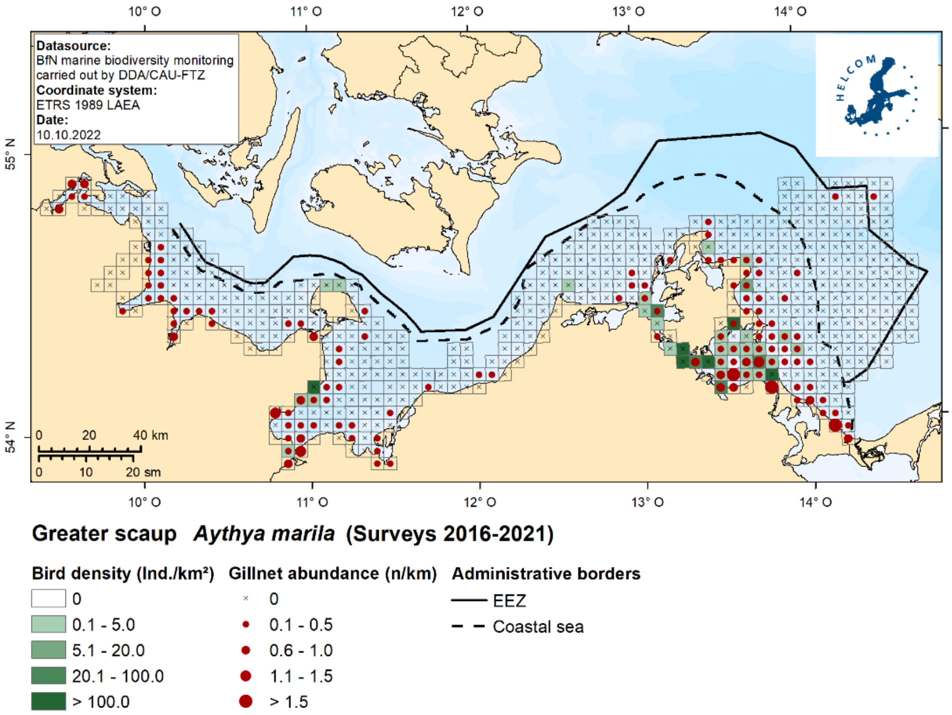

Figure 5: Distribution of static net fishing according to recorded marking flags during bird surveys and distribution of greater scaup, November to April (2016-2021).

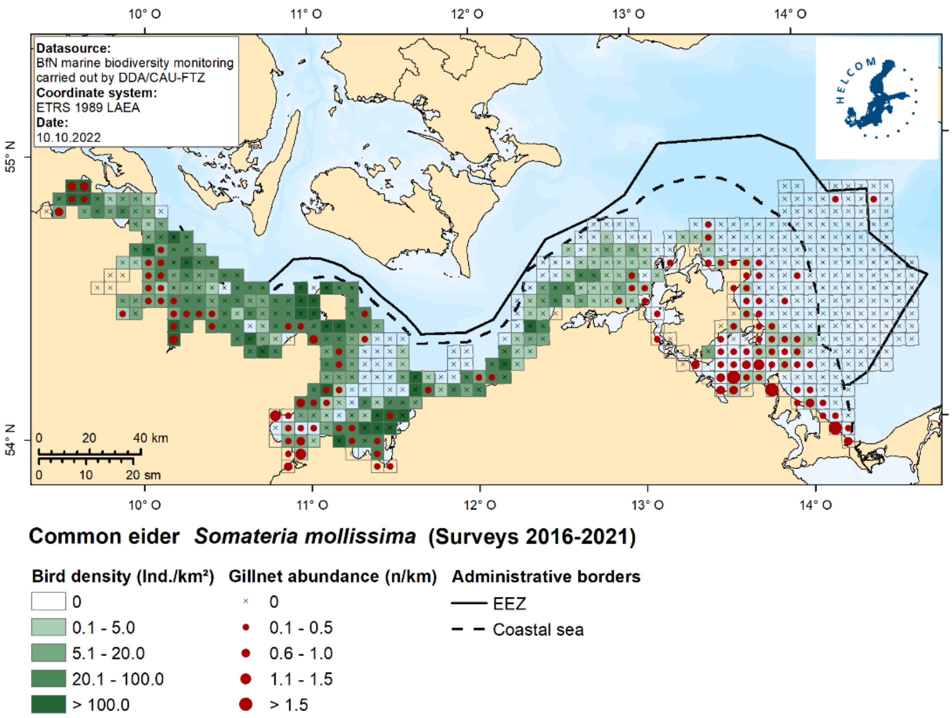

Figure 6: Distribution of static net fishing according to recorded marking flags during bird surveys and distribution of common eider, November to April (2016-2021).

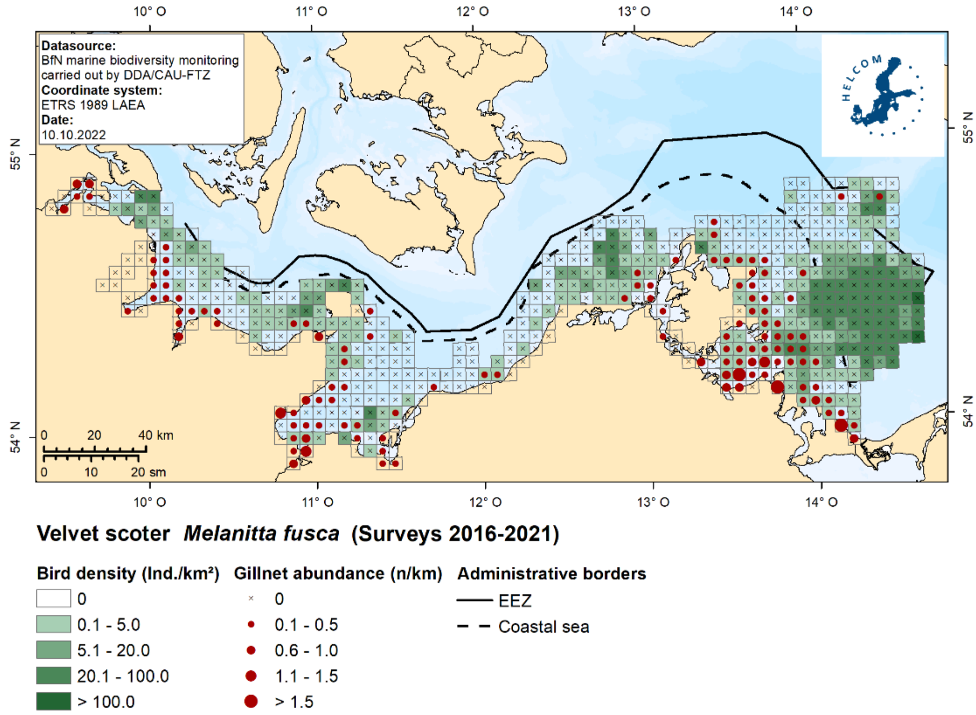

Figure 7: Distribution of static net fishing according to recorded marking flags during bird surveys and distribution of velvet scoter, November to April (2016-2021).

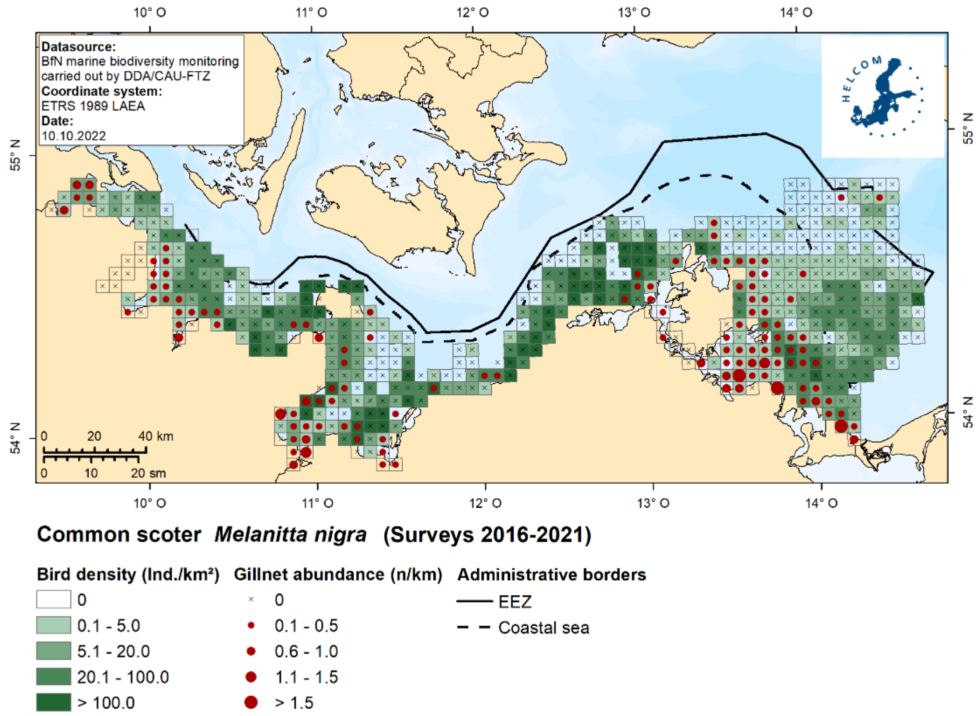

Figure 8: Distribution of static net fishing according to recorded marking flags during bird surveys and distribution of common scoter, November to April (2016-2021).

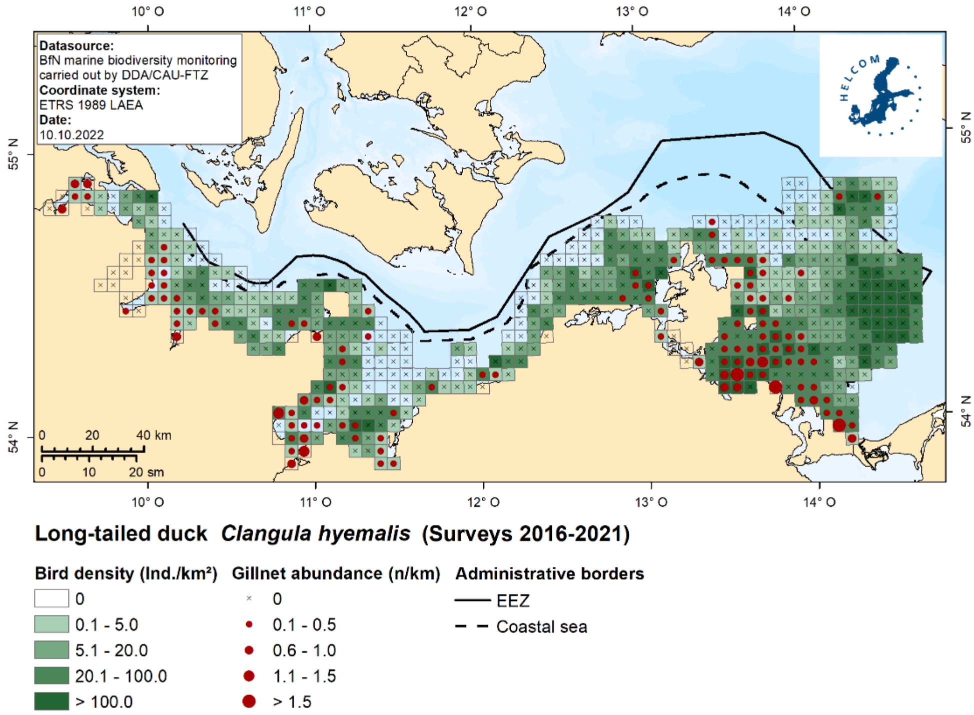

Figure 9: Distribution of static net fishing according to recorded marking flags during bird surveys and distribution of long-tailed duck, November to April (2016-2021).

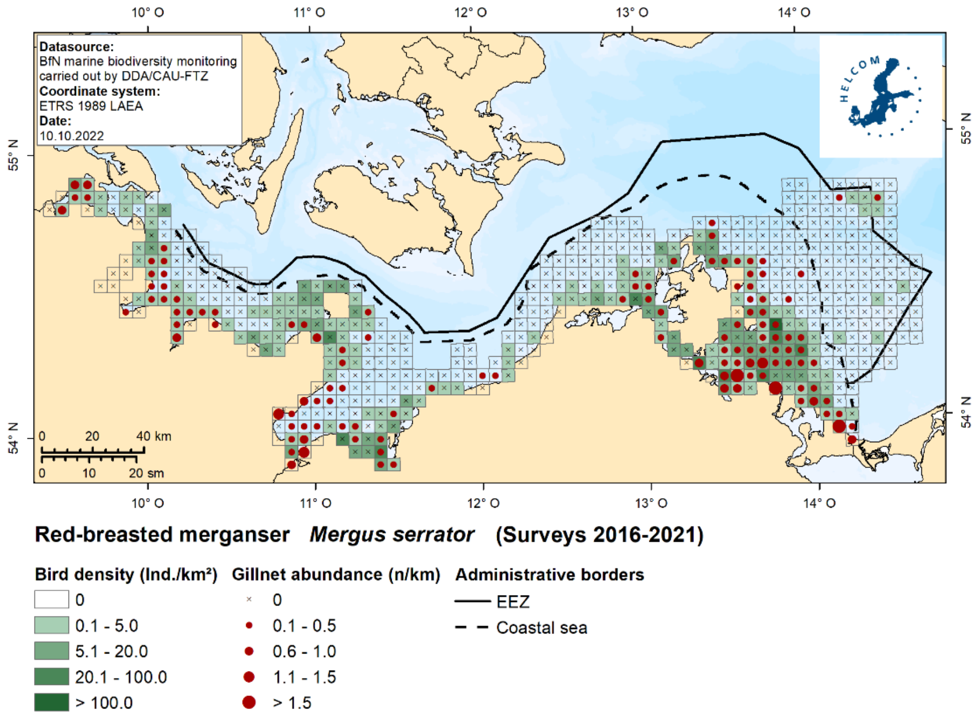

Figure 10: Distribution of static net fishing according to recorded marking flags during bird surveys and distribution of red-breasted merganser, November to April (2016-2021).

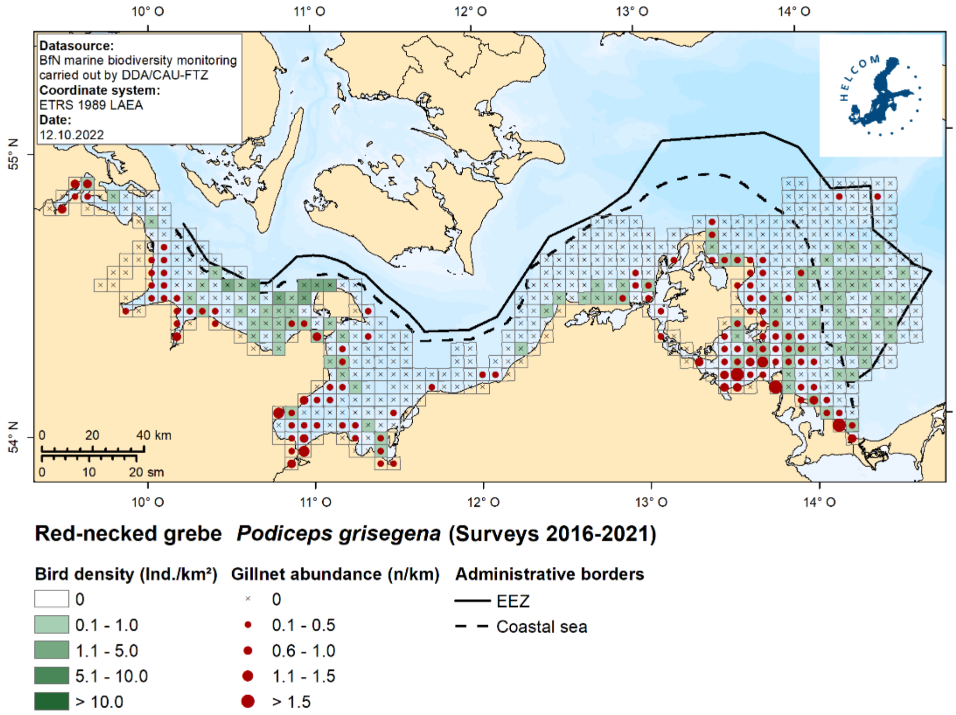

Figure 11: Distribution of static net fishing according to recorded marking flags during bird surveys and distribution of red-necked grebe, November to April (2016-2021).

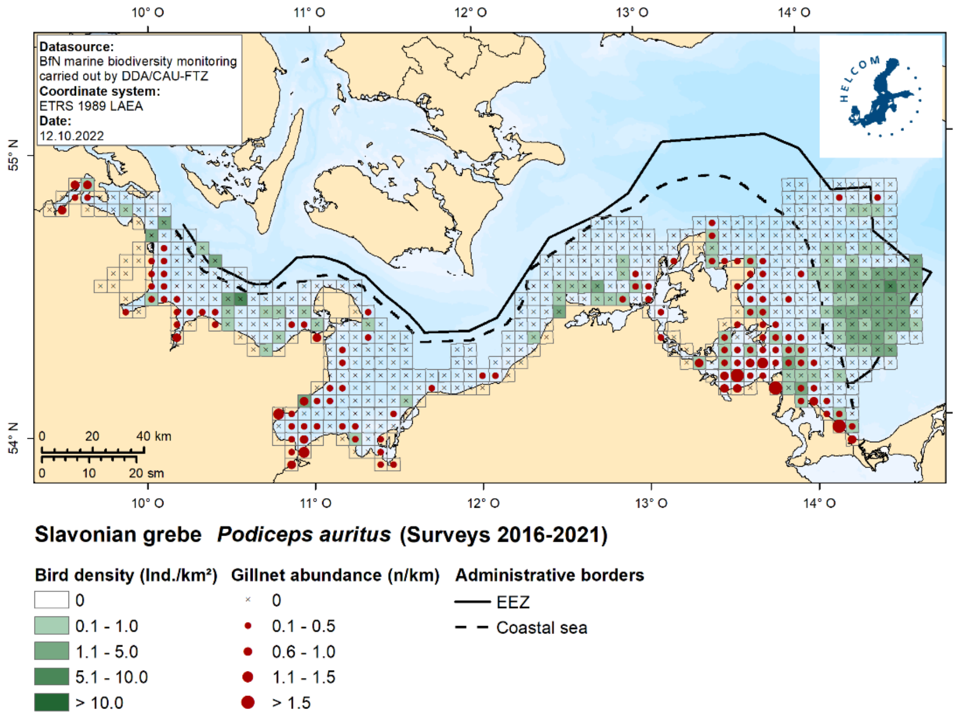

Figure 12: Distribution of static net fishing according to recorded marking flags during bird surveys and distribution of Slavonian grebe, November to April (2016-2021).

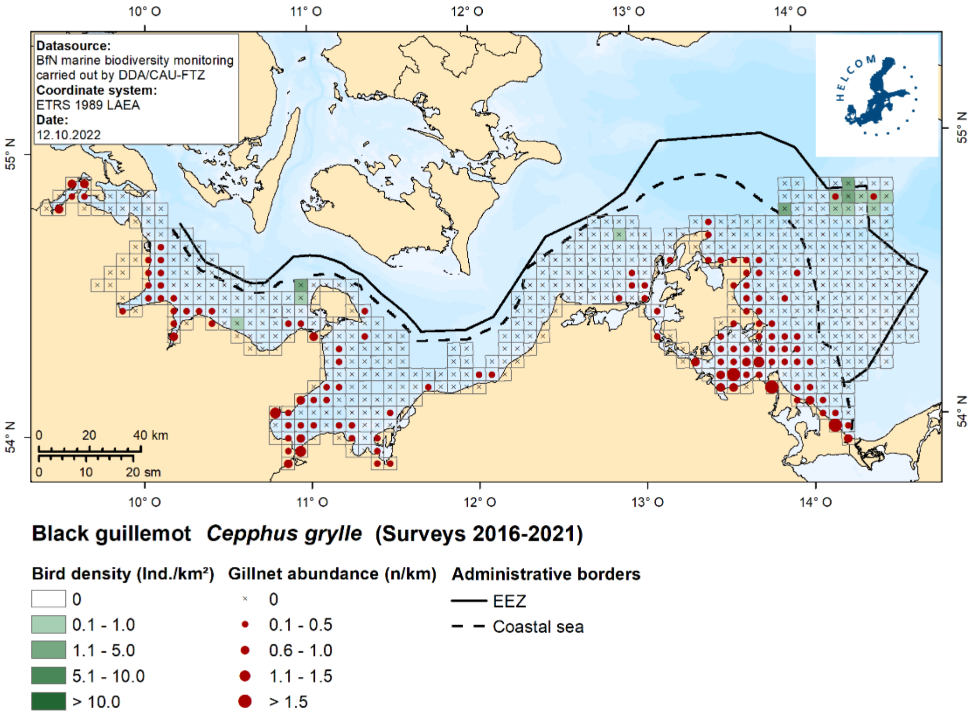

Figure 13: Distribution of static net fishing according to recorded marking flags during bird surveys and distribution of black guillemot, November to April (2016-2021).

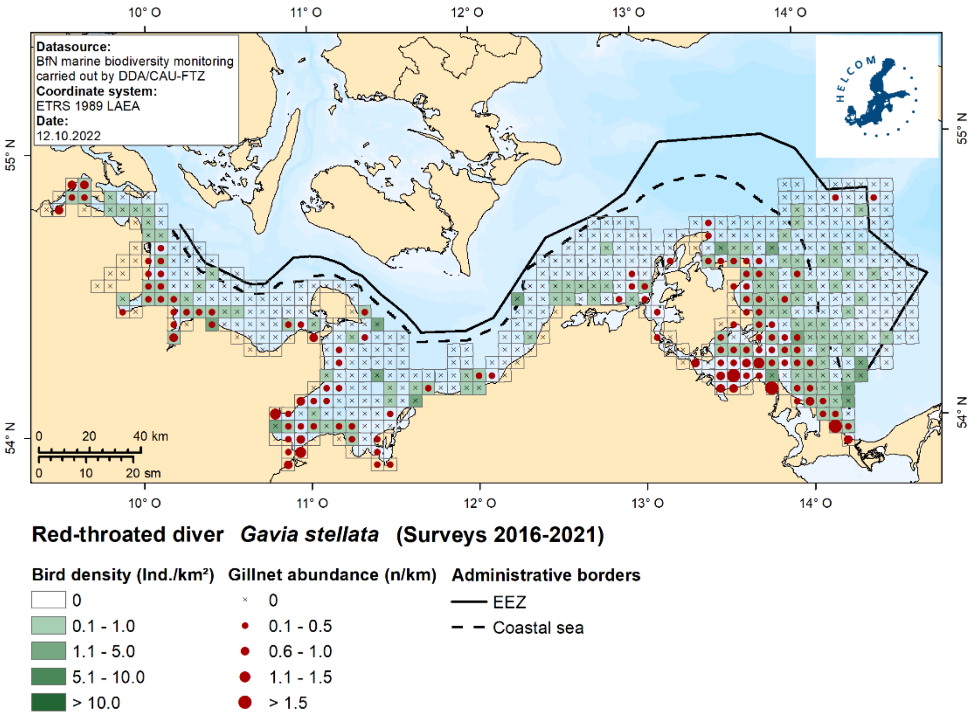

Figure 14: Distribution of static net fishing according to recorded marking flags during bird surveys and distribution of red-throated diver, November to April (2016-2021).

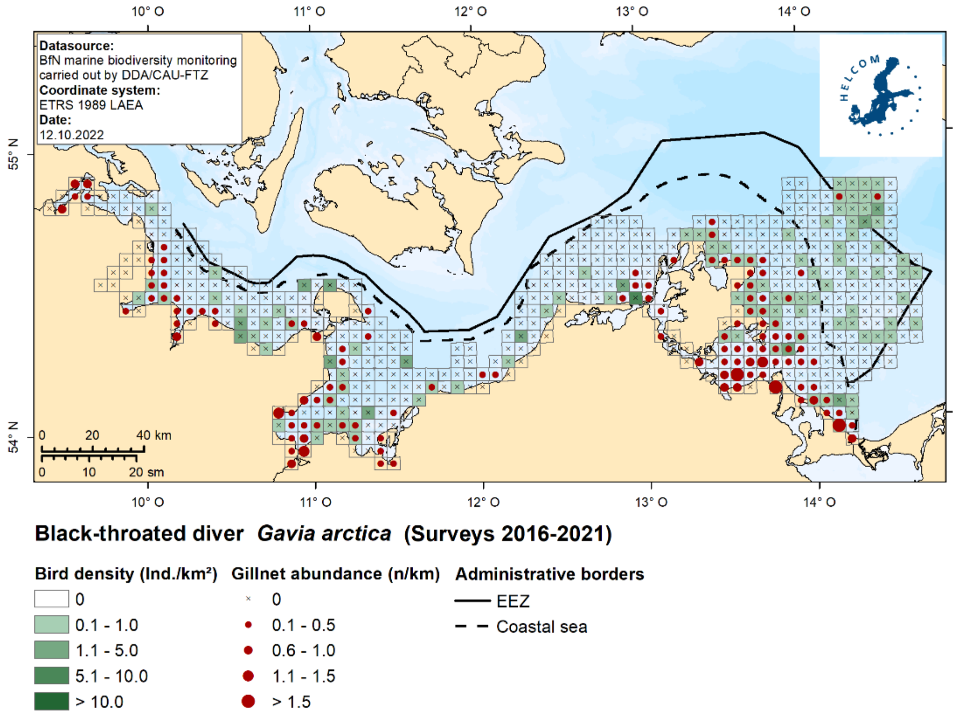

Figure 15: Distribution of static net fishing according to recorded marking flags during bird surveys and distribution of black-throated diver, November to April (2016-2021).

Evaluation Method 2 – Poland

Summing up the average numbers per waterbird species in the five winter seasons 2015/16 – 2019/20, the mean estimated total abundance of all diving waterbirds in the Polish section of the Bornholm Group is 600,845 individuals, of which 94.2% are benthivorous ducks. The mean by-catch estimate for this period is 5,056 birds for October to April. Evaluation Method 2 of the indicator was applied to four benthivorous duck species (greater scaup, long-tailed duck, common scoter, velvet scoter). For each species, the estimated by-catch was higher than the number of birds corresponding to 1% of annual adult mortality. Therefore, these species do not achieve the threshold for good status and represent sub-GES (Table 6).

Table 6. Evaluation of by-catch mortality of waterbirds in the Polish EEZ (Bornholm Group) based on the estimated by-catch (Evaluation Method 2). For the derivation of the threshold value see Table 3.

Species	HELCOM Red List status	Average number of by-caught birds (95% CI; S.E.)	Threshold value (Evaluation Method 2)	Evaluation
Greater scaup	Vulnerable	204 (174 – 227; 14)	59	sub-GES
Long-tailed duck	Endangered	2,915 (2,525 – 3,423; 229)	869	sub-GES
Common scoter	Endangered	260 (225 – 328; 26)	68	sub-GES
Velvet scoter	Endangered	1,213 (1,038 – 3,423; 606)	313	sub-GES

Waterbird by-catch in the assessment unit Gotland Group

Evaluation Method 2 – Poland

The estimated total abundance of all diving waterbirds in the Polish section of the Gotland Group is 207,114 individuals (mean of the five winter seasons 2015/16 to 2019/20, min.: 186,363, max.: 237,536), of which 82.2% are benthivorous ducks. The average by-catch estimate for these seasons is 7,921 birds from October to April. Evaluation Method 2 of the indicator was applied to four benthivorous ducks (greater scaup, long-tailed duck, common scoter, velvet scoter). In all species, the estimated by-catch was exceeding the number of birds corresponding to 1% of annual adult mortality. Therefore, these species failed to achieve the threshold for good status and represent sub-GES (Table 7).

Table 7. Evaluation of by-catch mortality of waterbirds in the Polish EEZ (Gotland Group) based on the estimated by-catch (Evaluation Method 2). For the derivation of the threshold value see Table 3.

Species	HELCOM Red List status	Average number of by-caught birds (95% CI)	Threshold value (Evaluation Method 2)	Evaluation
Greater scaup	Vulnerable	216 (175 – 349); 44	15	sub-GES
Long-tailed duck	Endangered	2,027 (1,639 – 3,294); 422	131	sub-GES
Common scoter	Endangered	173 (139 – 288); 38	10	sub-GES
Velvet scoter	Endangered	3,504 (2,816 – 5,776); 755	194	sub-GES

Evaluation Method 3 – Lithuania

An extensive study of waterbird by-catch in static nets was conducted in Lithuania from October 2015 to May 2020, i.e. nearly completely falling into the HOLAS 3 assessment period (Morkūnas *et al.* 2022). A total of 905 by-caught birds provides evidence of spatio-temporal overlap between waterbird occurrence and static net fishing effort distribution. This includes the HELCOM red-listed species greater scaup, long-tailed duck, common scoter, velvet scoter, red-breasted merganser, red-necked grebe, red-throated diver and black-throated diver, for which this overlap constitutes sub-GES. In addition, some species not red-listed were by-caught (common goldeneye, common merganser, great cormorant, great crested grebe, herring gull, razorbill and common guillemot).

Waterbird by-catch in the assessment units of the Baltic Sea – overview

The results obtained by the help of Evaluation Methods 2 and 3 in four subdivisions of the Baltic Sea are summarised in Table 8. All evaluations are indicating sub-GES for the red-listed waterbird species examined. In all subdivisions evaluated at least one species evaluation is showing sub-GES. Therefore, regarding by-catch GES is not achieved in any subdivision.

Table 8. Overview of waterbird by-catch evaluations per species and subdivision and integrated evaluation per subdivision. AM/C: Evaluation method / country.

Species (HELCOM Red List status*)	Kattegat		Belt Group		Bornholm Group		Gotland Group	
	AM/C	Status	AM/C	Status	AM/C	Status	AM/C	Status
Greater Scaup (VU)					2/PL	sub-GES	2/PL	sub-GES
					3/DE	sub-GES	3/LT	sub-GES
Common eider (EN)	3/DK	sub-GES	3/DK	sub-GES	3/DK	sub-GES		
					3/DE	sub-GES		
Velvet scoter (EN)			3/DK	sub-GES	2/PL	sub-GES	2/PL	sub-GES
					3/DE	sub-GES	3/LT	sub-GES
Common scoter (EN)			3/DK	sub-GES	2/PL	sub-GES	2/PL	sub-GES
					3/DE	sub-GES	3/LT	sub-GES
Long-tailed duck (EN)					2/PL	sub-GES	2/PL	sub-GES
					3/DE	sub-GES	3/LT	sub-GES
Red-breasted merganser (VU)					3/DE	sub-GES	3/LT	sub-GES
Red-necked grebe (EN)					3/DE	sub-GES	3/LT	sub-GES
Slavonian grebe (VU)					3/DE	sub-GES		
Black guillemot (VU)					3/DE	sub-GES		
Red-throated diver (CR)					3/DE	sub-GES	3/LT	sub-GES
Black-throated diver (CR)			3/DK	sub-GES	3/DE	sub-GES	3/LT	sub-GES
Integrated evaluation		**sub-GES**		**sub-GES**		**sub-GES**		**sub-GES**

* Red-list categories: CR critically endangered, EN endangered, VU vulnerable.

4.2 Trends

Due to reduced fishing opportunities of cod and herring since 2018 and the prohibition of all targeted fishing for Western Baltic cod implemented since 2019, there was likely a decreased effort in commercial static net fisheries in parts of the region. The unresolved conflict between certain fisheries and bird and mammal species remains difficult to tackle. Scarcity of by-catch data coupled with incomplete knowledge on fishing effort as well as unavailable conservation objectives call for a consequent application of the precautionary principle. In this evaluation, with respect to by-catch and fishing effort some assumptions had to be made as the current inadequate data collection of by-catches and reporting of effort does not allow nearly precise estimates (see Chapter 5, confidence).

By-catch of harbour porpoises in the Baltic Proper was reportedly high before the 1970's. Ropelewski (1957) reported for the Polish fishery annual by-catches between 16 and 250 porpoises (period 1922-1924) and between 23 and 114 porpoises (period 1928-1932). Lindroth (1962) reported 49 by-catches in Swedish salmon driftnet fisheries during a single year. Current lower by-catch numbers reflect the steep population decline since then (Koschinski 2002). This shows that a trend based by-catch evaluation would not reflect the status well. For the Belt Sea harbour population and the evaluated seal populations no reliable baseline data on by-catch exists.

By-catch of waterbirds in fishing gear, especially in static nets, is well known in the Baltic Region since at least the 1920s, when for example numerous black-throated divers were reported to be caught in salmon drift nets (Schüz 1935).

Trends in the amount of mammal and waterbird by-catch are currently not available because

i) there is no earlier evaluation available which could be used for comparison,
ii) many studies were running only for a short time,
iii) monitoring of waterbird and mammal by-catch is often insufficient, because the métiers responsible for by-catch are not covered adequately,
iv) monitoring using modern techniques (e.g., electronic monitoring with camera) is relatively new and cannot provide long data series yet.

No prior evaluation has been applied for this indicator. Therefore it is not possible to directly compare status between assessment periods. Based on information from literature about the distribution of marine mammals and waterbirds as well as on by-catch in fishing gear it would be expected that no change in status category has occurred between HOLAS 2 (2011-2016) and HOLAS 3 (2016-2021), i.e. both periods would not achieve the threshold values and thus not be in GES.

4.3 Discussion text

Evaluations in this indicator have shown that marine mammals and waterbirds are generally not achieving good environmental status regarding additive mortality from by-catch in fishing gear, given the existing hunting mortality for some assessment units. This in turn applies to all HELCOM sub-basins (mammals) and subdivisions (birds) evaluated. Therefore, by-catch mortality is an ongoing and widespread threat for these populations. Moreover, most of the mammal populations and all bird populations dealt with here are of conservation concern. In these species/populations by-catch is one threat continuing to contribute to further decline and/or inhibiting recovery towards favourable conservation status. PBR- and mPBR-derived thresholds for marine mammals show that already small numbers of by-caught animals are problematic for marine mammal populations, and these low thresholds are exceeded. All waterbird species evaluated are already classified as vulnerable, endangered or even critically endangered by HELCOM (2013), therefore it is possible that the by-catch mortality prevents from improving status or continues to deteriorate the state of the populations.

Unfortunately, a severe lack of data on by-catch and fishing effort prevents undertaking a more exact examination of the true extent and the impact of by-catch on the populations. For waterbirds, Evaluation Method 1 intends to apply population modelling in order to quantify the impact of by-catch mortality on population growth. If sufficient by-catch and fishing effort data are available, such an approach is feasible on the level of bird populations, as has been shown for a benthivorous duck species, the greater scaup (Marchowski *et al.* 2020).

In all thresholds based on population modelling, a conservation objective needs to be defined and all anthropogenic mortality be taken into account. In waterbirds, the main other causes for direct anthropogenic mortality are hunting and oiling (Mooij 2005, Larsson & Tydén 2005, Žydelis *et al.* 2006). In seals, hunting needs to be included in the evaluation, and in all marine mammals direct mortality by impulsive noise e. g., from underwater explosions (Siebert *et al.* 2022). The latter might also be relevant for waterbirds (see Danil & St. Leger 2011), but this has been investigated to a lesser extent than in mammals. Further, compromised fitness (e.g. reduced reproductive potential and survival rate associated with disturbance, habitat alteration, induced for example by overfishing or coastal development, and accumulation of pollutants) can further add to the causes of anthropogenic mortality in waterbirds and marine mammals.

The *HELCOM Roadmap on fisheries data in order to assess incidental by-catch and fisheries impact on benthic biotopes in the Baltic Sea* describes the data needs with respect to by-catch monitoring and reporting of fishing effort, as is also outlined in chapter 8.

5 Confidence

The overall confidence is low. Table 9 presents an evaluation of the confidence in four categories.

1. Accuracy of estimate: A compliance check would allow showing a clear signal whether GES has been achieved or not ('high'), show general GES achievement but with some outliers and variation in the data ('intermediate') or only show GES achievement with only a probability <70% ('low'). This scoring based on expert opinion was used for the HOLAS3 BEAT Tool in case data does not allow calculation of a standard error.
2. Temporal coverage: This is a measure of the temporal coverage of the assessment period. By-catch is subject to year-to-year variation. If monitoring data covers all six years the confidence is 'high', for three or four years of data 'intermediate' is chosen and otherwise 'low'.
3. Spatial representability: This is a measure of the spatial coverage with respect to HELCOM sub-basins. If monitoring data is considered to cover the full spatial variation of the indicator parameter in the assessment area (covering at least 90% of the variation) the confidence is 'high'. For 70 to 89% of the variation 'intermediate' is chosen and otherwise 'low'. The choice was made on the basis of expert knowledge.
4. Methodological confidence: This relates to quality of the monitoring and whether it is according to existing HELCOM or other internationally accepted guidelines ('high'), whether the data is from mixed sources partly quality assured ('intermediate') or data not collected according to guidelines or not quality assured ('low').

Future work will require to address these uncertainties specifically when better data are available.

Table 9. Overview of confidence for the evaluation carried out.

	Accuracy of estimate	**Temporal coverage**	**Spatial representability**	**Methodological confidence**
Harbour porpoise of the Kattegat, Belt Sea and Western Baltic	intermediate	high	low	intermediate
Harbour porpoise population of the Baltic Proper	low	high	low	low
Ringed seal population of the Southwestern Archipelago Sea, Gulf of Finland and Gulf of Riga	low	high	low	low
Ringed seal population of the Gulf of Bothnia	low	high	low	low
Harbour seal population in Kalmarsund	low	high	low	low
Harbour seal population of the South-western Baltic and Kattegat	low	high	low	low
Grey seal population of the Baltic Sea	low	high	low	low
Waterbirds Kattegat (Denmark, Evaluation Method 3)	high	high	low	intermediate
Waterbirds Belt Group (Denmark, Evaluation Method 3)	high	high	low	intermediate
Waterbirds Bornholm Group (Denmark, Evaluation Method 3)	high	high	low	intermediate
Waterbirds Bornholm Group (Germany, Evaluation Method 3)	high	high	low	low
Waterbirds Bornholm Group (Poland, Evaluation Method 2)	intermediate	high	low	intermediate
Waterbirds Gotland Group (Poland, Evaluation Method 2)	intermediate	high	low	intermediate
Waterbirds Gotland Group (Lithuania, Evaluation Method 3)	high	high	low	intermediate

6 Drivers, Activities, and Pressures

In the Baltic Sea, marine mammals and waterbirds are exposed to a number of pressures from various human activities, both directly and indirectly (Table 10). The pressures act variably with regards to seasons, but the effects are cumulative and include carry-over effects from one season to another. The most relevant in this indicator is the “extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities)”, which is directly linked to fishing by static nets and traps, but to a lesser degree also to longline fishing and trawling.

Marine mammal populations suffer from by-catch, most often in combination with threats from other activities. It is difficult to assign which activity adds to what extent to population effects. In particular, many pressures (such as contaminants, disturbance, prey depletion, habitat degradation or habitat loss) are indirect as they affect the viability but do not result in direct mortality. By-catch, hunting of seals or underwater explosions cause direct mortality and the effect on the population is evident in terms of a reduction in the numbers of individuals. Since marine mammals have a late sexual maturity and produce only a low number of offspring (at maximum one per year), they are extremely vulnerable to anthropogenic pressures.

Waterbird populations suffer from the extraction of individuals due to by-catch, but some species are still under pressure from hunting. Loss of individuals can also occur from collisions with offshore wind turbines. At many breeding sites waterbirds suffer from predation by non-indigenous mammalian predators, but also by disturbance from leisure activities. Foraging habitats are downsized due to avoidance of offshore wind farms, but are also physically disturbed by bottom-trawling fishery and aggregate extraction and lost where wind turbines are placed, especially for benthic feeding seaducks. The food supply is influenced by manipulating fish communities by fishing and the input of nutrients. Harmful substances from various sources impair health and body condition of waterbirds, and oil released during shipping leads to plumage contamination, often followed by the death of the affected individuals. It is unknown yet whether impulsive underwater noise as released during the pile driving for offshore wind turbines is threatening the health of diving waterbirds.

Table 10. Brief summary of relevant pressures and activities with relevance to the indicator.

	General	MSFD Annex III, Table 2a
Strong link	The most important human threat to marine mammals and waterbirds under the by-catch criterion is the loss of individuals (additive mortality) from drowning in fishing gear.	Biological pressures: extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities).
Weak link	Marine mammals and waterbirds are additionally influenced by pressures from human activities.	Biological pressures: input or spread of non-indigenous species disturbance of species (e.g. where they breed, rest and feed) due to human presence. extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities). Physical pressures: physical disturbance to seabed (temporary or reversible). physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate). Pressures by substances, litter and energy input of nutrients – diffuse sources, point sources, atmospheric deposition input of organic matter – diffuse sources and point sources. input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides) – diffuse sources, point sources, atmospheric deposition, acute events. input of litter (solid waste matter, including micro-sized litter). input of anthropogenic sound (impulsive, continuous). input of other forms of energy (including electromagnetic fields, light and heat).

7 Climate change and other factors

There are two important aspects of possible impact of climate change related to this indicator. The first involves a likely spatiotemporal shift of fisheries (maybe also combined with the use of other gears) and of mammal or waterbird distribution, both related to availability of fish and/or prey and ice-free water, which would in turn affect the by-catch risk. The other is related to a possible reduced fitness of species/populations due to e.g., reduced availability of prey of a suitable quality and quantity. This in turn would negatively affect the population. Then greater efforts would be needed to preserve the population, also with respect to reducing by-catch.

The ringed seal population of the Southwestern Archipelago Sea, Gulf of Finland and Gulf of Riga is already suffering serious impact of climate change. Availability of suitable breeding ice is known to affect pup survival. Reduced ice cover severely limits the population's growth rate (Sundqvist *et al.* 2012). At the same time reduced ice cover opens new fishing opportunities in winter which may increase the by-catch risk. All anthropogenic pressures will need to be consequently reduced in order to compensate for the reduced or even negative population growth.

Distribution shifts of fish populations (Heath *et al.* 2012) and reduced recruitment of fish species (Polte *et al.* 2021) caused by climate change are already being reported leaving stocks with a lesser resilience to climate-driven changes. Distribution shifts of prey may be partly compensated for by mammals and waterbirds by shifting their distribution range as well which might have implications for the risk of being by-caught. A reduced availability of suitable quantities and quality of important prey species for mammals and waterbirds by climate change and/or overfishing likely will affect their overall fitness. In the North Sea it has been shown that feeding on prey of lesser quality reduces the fitness of harbour porpoises and leaves them starving even with filled stomachs (Leopold *et al.* 2015). Prey energy density has been shown to govern harbour porpoise reproductive success (Ijsseldijk *et al.* 2021).

Due to higher winter air temperatures and consequently less ice cover of the Baltic Sea in winter (HELCOM & Baltic Earth 2021, Meier *et al.* 2022), many waterbird species have been shifting their winter distribution northeastwards – including also diving species such as common goldeneye, greater scaup and smew (Pavón-Jordán *et al.* 2015, 2019, Marchowski *et al.* 2017). This not only leads to longer presence of a larger number of waterbirds prone to by-catch in the Baltic Sea, but also fisheries are less restricted by sea ice, so that the exposure of waterbirds to mortality is likely to have increased. Further, due to distributional shifts waterbirds overwinter in increasing numbers in unprotected areas (Pavón-Jordán *et al.* 2020). Thus, a mismatch between winter distribution and protected areas may have arisen, with possible consequences for measures to prevent by-catch, which need to be adapted spatially and temporally. A higher variability in winter temperatures and ice covered areas might also lead to a higher variability in the use of wintering areas making it difficult to tailor specific spatiotemporal mitigation measures.

Population-scale impacts of ocean acidification on fish can be assumed for the future which will likely have dramatic effects on the ecosystem and also on fisheries. How this impact will be related to this indicator is, however, even more speculative than the effects highlighted above.

8 Conclusions

This indicator provides evaluations for marine mammals and waterbirds regarding the link between their conservation status and the loss of individuals from populations due to by-catch in fishing gear. In all cases examined, the threshold for good status was not met, meaning that too many individuals are lost. This has implications for efficient measures to be taken in order to achieve a good status of biodiversity in the Baltic Sea.

Poor data has been hampering the evaluation throughout. It has not been possible yet to relate the amount of by-catch to the management objective that by-catch is not threatening the viability of populations directly, because data on both fishing effort and by-catch of mammals and birds was not available due to inadequate recording of fishing effort and insufficient by-catch monitoring. However, in the case of threatened cetacean and seal populations with a very low number of individuals left, a strict threshold value of zero by-catch was exceeded, indicating that intolerable loss of individuals occurred. This situation is certainly also relevant to other (larger) populations of marine mammals and waterbirds, as was shown by the example of the greater scaup (Marchowski *et al.* 2020). Establishing effective monitoring of fishing effort and by-catch is needed in order to allow more precise evaluations as in this example.

With respect to by-catch monitoring there are large differences between countries and the data quality achieved. Dedicated by-catch surveys and Remote Electronic Monitoring using cameras produce a high data quality if they are conducted in a representative manner including all relevant fishing métiers. Onboard observers in the frame of the EU Data Collection Framework (DCF) can also produce high quality data. However, this requires a protocol which takes specific needs of by-catch monitoring guidelines into account as observers normally focus on the commercial fish catch. Monitoring effort in general needs to be increased to allow robust evaluations. ICES (2018b) showed that métiers relevant for waterbird and mammal by-catch are relatively under-sampled whereas other métiers which have less or no by-catch are over-sampled.

In order to assess by-catch numbers from by-catch rates (derived from by-catch monitoring), it is extremely important to have reliable effort data in all relevant métiers, which is currently not the case. Whereas large vessels have VMS and report their fishing effort in their (electronic) logbooks, smaller vessels do not report their effort in a comparable way. In some countries, fishers are only required to keep sales notes, other countries require monthly journals and even others coastal logbooks. Effort might be given in different metrics (days at sea, hours fished, gear dimensions x time, etc.). The European Commission and Member States are aware of this, but improving legislation is difficult and coordinating CPs is also difficult because a solution would require additional resources. More detailed explanations are given in the HELCOM Roadmap on fisheries data.

In some cases however, monitoring would need a full coverage of fisheries because populations are so depleted that even very low by-catch numbers which are hard to detect further threaten the population. In these cases implementing effective mitigation measures such as time-/area closures, gear restrictions or technical measures are a matter of urgency.

8.1 Future work or improvements needed.

Monitoring effort in general needs to be increased to allow robust evaluations. Important aspects are a sufficient and representative coverage of all métiers and all fleet segments at a relevant temporal scale. REM has been shown to be a cost-effective method for by-catch monitoring (Kindt-Larsen *et al.* 2012) which can deliver robust by-catch estimates based on high-quality data (Larsen *et al.* 2021, Glemarec *et al.* 2022). Onboard observers in the frame of the EU Data Collection Framework (DCF) can also produce high quality data. However, this requires a protocol which takes specific needs of by-catch monitoring guidelines into account as observers normally focus on the commercial fish catch. This is a major drawback as fisheries producing highest by-catches in the Baltic Sea are less in the focus of observer programmes. Observer coverage needs to be corrected if observers are engaged with other duties (e.g., measuring fish under deck) (ICES 2018a). Reporting of by-catches in log-books (self-reporting) or port controls are the least reliable method and they do not account for fishing effort, meaning that they do not allow extrapolating results to the effort of the whole fleet. Previously, logbooks did not even have a field to report by-catches of mammals and seabirds. Thus, self-reporting and port controls do not allow indicator evaluations. A detailed analysis of improvements regarding data availability and quality can be found in the *HELCOM Roadmap on fisheries data in order to assess incidental by-catch and fisheries impact on benthic biotopes in the Baltic Sea.*

All uncertainties identified show that sufficient monitoring of by-catch, fishing effort, population size, trend analyses and other sources of anthropogenic mortality are a prerequisite for getting a more reliable evaluation. The European Commission has included by-catch monitoring of protected bird and mammal species in the Commission Delegated Decision (EU) 2021/1167. Further participation of HELCOM Contracting Parties on a regional scale is necessary for the implementation process in order to ensure suitable monitoring methods and sufficient coordinated coverage, as well as effort monitoring, are developed into meaningful parameters (static net fishing effort must be measured in length of nets * soak time, see Monitoring Requirements, Description of optimal monitoring). But also the effort must be given as Days at Sea in order to enable comparisons with earlier years. So far, only fishing effort from logbooks and VMS data can be used for by-catch extrapolations from observer or Remote Electronic Monitoring data (ICES 2021). The additional effort by small commercial vessels for which only monthly journals, landing declarations or sales notes are available without precise information about the spatial distribution of fishing effort and their temporal extent as well as effort by recreational fishermen must be estimated and taken into account. Then the uncertainty in the fishing effort estimates which underlie the by-catch estimate needs to be specified by also adding a 95 % confidence interval.

Nevertheless, in the absence of high-resolution data on effort and bycatch rates, the by-catch figures reported by the scientific community (e.g., ICES WGBYC) are likely underevaluating mortality from bycatch in some cases and, consequently, may not reflect the true extent of the impact of by-catch on populations (Peltier et al. 2016, Morkūnas et al. 2022).

The shortcomings in relation to population estimates, trend analyses and the level of anthropogenic impacts on these populations in common give a low confidence in this indicator. High priority should be given to improvement of these shortcomings.

As specific points to be addressed in future by-catch evaluations, also seal by-catch data based on REM must distinguish between species. A model must be developed to allow estimating what proportion of by-caught seals to assign to each species/population. Further, European otters should also be included in future by-catch evaluations as the coastal distribution of parts of the population overlapping with commercial as well as recreational small scale net and trap fisheries suggests that this population may be of conservation concern.

Description of optimal monitoring

Monitoring of by-caught marine mammals and waterbirds should enable the estimation of annual (seasonal) mortality from all métiers and fleet segments to be compared to the population dynamics of the respective species. Besides fishing effort and by-catch data, data on population size and trend and spatio-temporal delineation of sub-populations (and also fishing effort and by-catches) is also required in order to relate by-catch numbers to the adequate population unit. Monitoring results should not only address the problem of by-catch in general, but should allow to quantify impacts in order to propose management measures such as (temporary) closures of specific fisheries or fishing areas. Optimal monitoring would therefore also provide reliable population size estimates for all species considered from the by-catch perspective.

Except for Evaluation Method 3 in birds, the indicator requires estimates of population sizes for those species suffering from by-catch, either on the level of entire populations (marine mammals, Evaluation Method 1 for birds) or on subdivision level (Evaluation Method 2 for birds). While such estimates are available for a number of marine mammals (especially seals) due to target-oriented surveys, they are quite crude for most waterbird species, especially those wintering in offshore areas. Further, uncertainties in population estimates and incomplete knowledge on spatial and temporal distribution patterns have to be addressed. Thus, internationally coordinated offshore surveys need to be organized and should be established in the respective HELCOM Core Indicator "Abundance of waterbirds in the wintering season".

The species covered by the indicator are highly mobile and fishing methods differ between sub-regions or even on a local level. Due to the resulting variability in by-catch risk, a regionally and fishing method differentiated métier monitoring approach that considers fishing activity per spatial unit (e.g., Statistical Baltic Squares) is recommended. A By-catch Risk Approach (BRA) can be used to identify areas and fisheries that are likely to pose the greatest conservation threat to incidentally caught species, taking into account the uncertainty of their population structure. A BRA was initially developed for cetaceans at an ICES Workshop (ICES 2010). It can also help optimising different methods of monitoring and tailoring mitigation measures. Using REM, Kindt-Larsen *et al.* (2016) were able to identify a number of high-risk areas in the North Sea. The BRA highlights areas where the greatest problems occur and enables educated fisheries management decisions such as proactive mitigation measures before by-catches occur. This is especially important for threatened species/populations such as the critically endangered Baltic Proper harbour porpoise population. Risk-mapping for harbour porpoise conducted in the HELCOM ACTION project provided additional information about spatial distribution of by-catch risk (HELCOM 2021a). Risk-mapping has been extended to seals and waterbirds in the HELCOM BLUES project.

Effort monitoring, as well as by-catch monitoring, has to be carried out on a fine spatial scale in order to relate by-catch to both fishing effort and abundance of mammals and birds. Fishing effort must be monitored in a meaningful parameter (length of nets * soak time instead of simply days at sea). The documentation of net length in the logbook (i.e. for vessels 10 m and longer) used is only optional in EU fisheries (EU Commission Implementing Regulations 404/2011 and 2015/1962). Some national peculiarities apply. E. g. in Sweden, the coastal static net fishermen (vessels <8m in the Baltic marine region and <10m in the Atlantic marine region) are obliged to report their effort in meters*days for each static net type, mesh size and fishing location. Larger vessels are obliged to report number of nets, net length, and time for set and haul for each static net type, mesh size and fishing location. Since not all effort is recorded (small vessels, recreational net fisheries) and thus effort has to be estimated, the uncertainty in the fishing effort estimates which underlie the by-catch estimate needs then to be specified by adding a coefficient of variation or 95 % confidence interval.

Appropriate monitoring is needed, so as not to put more burden than necessary on fisheries from management measures to fulfil legal conservation obligations. Monitoring must be able to cover all métiers and fleet segments. A comprehensive monitoring would include on-board and in-situ off-board observers, REM using onboard CCTV cameras (Kindt-Larsen *et al.* 2012, Glemarec *et al.* 2020), and possibly additional methods such as interviews where the abovementioned are not possible, e.g., in recreational fisheries (ICES 2013a). In exceptional cases, such as in fisheries with small open boats, self-sampling may be a component of the monitoring programme, but data quality must be verified independently.

Human observers are an important component to sample by-catch and collect information on composition and number of by-catch and to deliver specimen to the relevant authorities in order to conduct further examinations regarding age, sex, nutritional state, and injuries. In addition, stomach contents may help to identify in more detail the conflict between marine areas selected by fisheries and habitat demands of mammals and birds. Stranding networks can provide further by-catch information if collected specimen are examined for net marks and previous injury which could have caused by-catch. However, limitations in data quality have to be accounted for (e.g. beached bird surveys may indicate by-catch but never give any information on the type of gear or nationality of the fishing vessel which caused the fatality).

ICES (2013b) has addressed the question of whether it is possible to combine monitoring of protected and endangered species and discard sampling (which will be the main focus of fishery monitoring due to the landing obligation) in the same sampling scheme. If by-caught animals cannot be landed, as a minimum requirement provision must be taken that detailed, meaningful photographs of by-caught mammals and birds can be taken.

The knowledge on by-catch of waterbirds and marine mammals can greatly be improved once a suitable monitoring scheme is implemented on regional and national levels within the DCF, now termed *EU Data Collection Multi-Annual Programme* EU-MAP: The EU-MAP will guide future fishery monitoring and data collection within the EU, covering a broad range of objectives including the landing obligation. It is crucial that in the regional implementation process an adequate sampling coverage plan is developed including mammal and waterbird by-catch in all relevant métiers and fleet segments (also including part-time and recreational fisheries) in the Baltic Sea.

Further actions for optimizing electronic monitoring

Pilot studies using cameras for monitoring harbour porpoise and waterbird by-catch have shown that these have the potential to be a practical and economic tool for obtaining reliable by-catch data (Glemarec *et al.* 2020). Further work is required to demonstrate the potential of the technique to perform consistently with regard to species identification and that all incidents are being detected (ICES 2013a). However, fishermen may reject these systems for personal reasons, hence research and international collaboration is needed on how to create a trustful attitude and to overcome personal reservations against onboard CCTV camera systems.

A main drawback of the onboard camera monitoring of bird and mammal by-catch is that a large footage has to be viewed to verify the data from fishermen's protocols. In order to further reduce costs of a monitoring programme based on video observation, it may be helpful to computerize the work and view only preselected footage. Thus, the development and validation of reliable automated recognition systems for onboard camera systems is desirable.

9.1 Scale of assessment

Marine mammals are evaluated on the basis of populations, and the assessment units reflect the range these populations inhabit (Table 11). With the exception of the Kalmarsund population of the harbour seal, all populations live in more than one Baltic Sea subbasin (HELCOM assessment unit scale 2). Therefore, the outcome of the by-catch evaluation (GES or sub-GES) is applied to all subbasins in which the respective population occurs.

Table 11. Assessments units used for marine mammal populations in terms of inhabited subbasins (HELCOM assessment unit scale 2), which are painted blue for occurrence.

	Harbour porpoise		**Ringed seal**		**Harbour seal**		**Grey seal**	**Integration**
HELCOM sub-basin	**Kattegat, Belt Sea and Western Baltic**	**Baltic Proper**	**Southwestern Archipelago Sea, Gulf of Finland and Gulf of Riga**	**Gulf of Bothnia**	**Kalmarsund**	**South-western Baltic and Kattegat**	**Baltic Sea**	
Kattegat								
Great Belt								
The Sound								
Kiel Bay								
Bay of Mecklenburg								
Arkona Basin								
Bornholm Basin								
Gdansk Basin								
Western Gotland Basin								
Eastern Gotland Basin								
Gulf of Riga								
Northern Baltic Proper								
Åland Sea								
Gulf of Finland								
Bothnian Sea								
The Quark								
Bothnian Bay								

Waterbirds are evaluated in seven subdivisions, which are defined by the merging of up to four of the 17 sub-basins of the Baltic Sea (i.e. HELCOM assessment unit scale 2), the latter following a recommendation by the Joint OSPAR/HELCOM/ICES Working Group on Marine Birds for the waterbird abundance indicators (Figure 16). The seven subdivisions are named as follows:

- A: Kattegat (Kattegat),
- B: Belt Group (Great Belt, The Sound),
- C: Bornholm Group (Kiel Bay, Bay of Mecklenburg, Arkona Basin, Bornholm Basin),
- D: Gotland Group (Gdansk Basin, Eastern Gotland Basin, Western Gotland Basin, Gulf of Riga),
- E: Aland Group (Northern Baltic Proper, Aland Sea),
- F: Gulf of Finland (Gulf of Finland),
- G: Bothnian Group (Bothnian Sea, The Quark, Bothnian Bay).

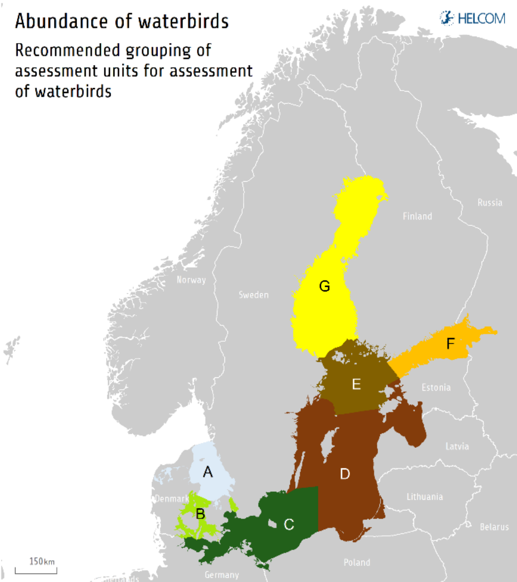

Figure 16. Grouping of 17 sub-basins (HELCOM assessment unit scale 2) to seven subdivisions as spatial units for waterbird indicators as recommended by JWGBIRD (ICES 2018b).

9.2 Methodology applied

Marine mammal by-catch

The evaluation method relies on comparing available by-catch data of various quality against thresholds which are based on population demographics modelling and simulation trials using mPBR (Belt Sea harbour porpoises) or PBR method as developed for the US MMPA. Both methods have different underlying conservation objectives (Wade 1998, Owen *et al.* 2022, Authier *et al.* 2022, see also chapter 3.1).

The models allow population-specific demographic parameters to be utilised to simulate population growth towards carrying capacity (K). In each of the simulations over 100 years, trajectories for the population development are being calculated taking stochasticity of basic input parameters into account. Required parameters are the minimum population estimate (ideally as the 20th percentile of the abundance estimate), maximum net productivity rate (Rmax), and a recovery factor (F_R) between 0.1 and 1.0. Using a recovery factor of less than 1.0 provides a safety factor to account for levels of unknown bias or estimation problems and would also account for co-occurring biases, such as overestimating RMAX while underestimating mortality. For depleted or threatened populations, or where the confidence of the abundance and/or by-catch estimate is low, F_R must be lower than in populations which already have a favourable conservation status and uncertainty is low. Robustness trials with different population scenarios were completed to determine the value for F_R (Genu *et al.* 2021, Owen *et al.* 2022). The scenarios to be further pursued in order to determine the threshold were then selected based on intersessional discussions of HELCOM State and Conservation Working Group.

Waterbird by-catch (Evaluation Method 1)

Evaluation Method 1 is envisaged to be applied to all waterbird species known to be by-caught in fishing gear. Only if the required data is not available, a switch to Evaluation Methods 2 or 3 is foreseen. Evaluation Method 1 focusses on using a population model to quantify the impact on population dynamics by the sum of estimated levels of by-catch mortality and other sources of anthropogenic mortality.

The metric of this approach is the trajectory of the population size over a longer period (three generations time) in relation to elevated levels of mortality due to by-catch. This method needs to be applied on the level of an entire population, and Population Viability Analysis (PVA) appears to be a well-suited method to do this. Age-structure matrix models can be used, they require data for various demographic data such as survival and reproduction of age classes, but also the size of the population.

Using the example of the greater scaup, Marchowski *et al.* (2020) have demonstrated how a PVA can be applied to a by-catch vulnerable species wintering in the Baltic Sea.

Waterbird by-catch (Evaluation Method 2)

For waterbird species listed on the *HELCOM Red List of Baltic Sea species in danger of becoming extinct* (HELCOM 2013), which lack sufficient information about demographic parameters and/or by-catch rates at the population level, Evaluation Method 2 can be used. For each of those species, the minimal data requirements for Evaluation Method 2 include the number of individuals present in a given evaluation area and the number of individuals of that species by-caught in fishing gears (which can be estimated from by-catch rates and total fishing effort).

In this evaluation, Evaluation Method 2 was applied to four species of benthivorous ducks (all of them red-listed by HELCOM 2013) in the Polish Exclusive Economic Zone (PEEZ) including coastal waters and coastal lagoons (c. 30,500 km^2), separated according to the evaluation units (aggregated sub-basins) used in waterbird indicators, here the subdivisions Bornholm Group and the Gotland Group (Figure 17). The analysis lacks data on most of the area of Lake Dąbie and the lower sections of the Odra and Vistula rivers, which are areas of a significant concentration of diving birds (Meissner & Rydzkowski 2007, Marchowski *et al.* 2018), at the same time being exploited for fishing, and thus likely generating bird by-catch. Fishing effort and waterbird data were analysed for the five winter seasons 2015/2016 - 2019/2020. The number of waterbirds was obtained from the annual January counts and was considered constant during the winter period (from October 1 to April 30), while the fishing effort was obtained from fishermen's declarations during this period submitted to the Polish Fisheries Monitoring Centre.

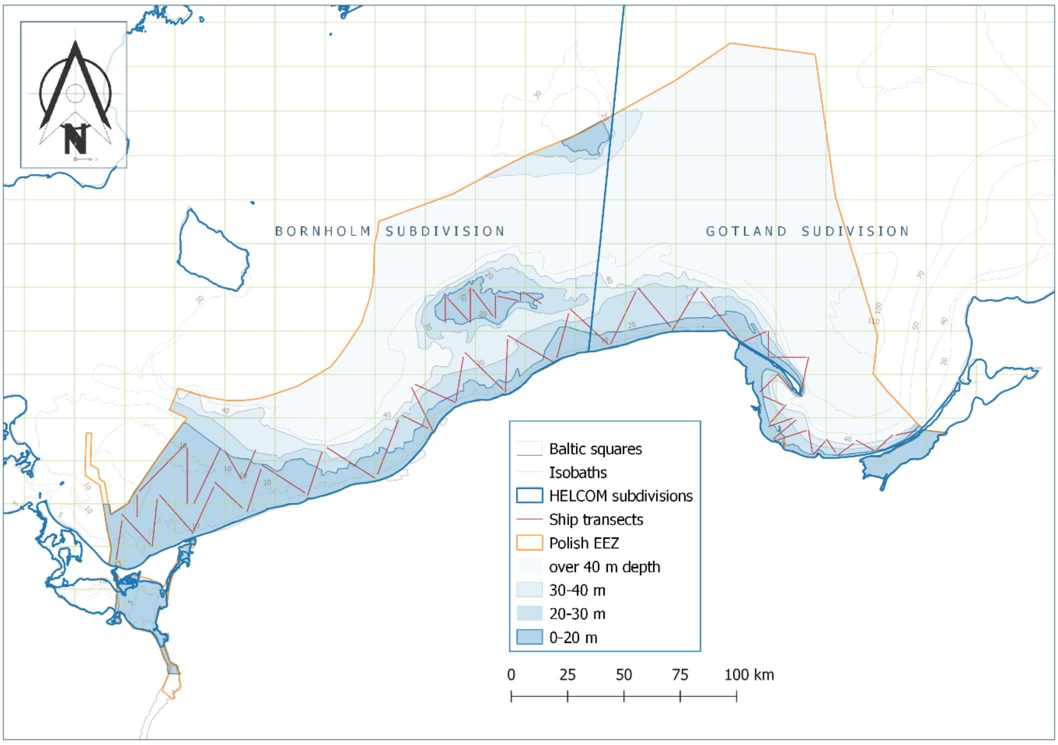

Figure 17. Evaluation area for waterbird by-catch using Evaluation Method 2 in the Polish Exclusive Economic Zone in the southern part of the Baltic Sea, divided into HELCOM subdivisions (Bornholm Group and Gotland Group) and Baltic Squares (20x20 km). Red lines are the transects used for ship-based monitoring of waterbirds offshore.

Waterbird numbers: Ship-based waterbird surveys at sea were carried out along 56 transects ranging from 3.9 km to 28.7 km in length (Chodkiewicz *et al.* 2012) (Figure 17), following a standard study protocol (Komdeur *et al.* 1992; Wetlands International 2010) and a standard distance sampling protocol (Buckland *et al.* 2001), widely used in seabird studies (Ronconi & Burger 2007, Spurr *et al.* 2012). Key parametric functions were evaluated with cosines and simple polynomials for adjustment terms: uniform, half-normal and hazard rate, and the best fitting function was chosen based on the smallest Akaike Information Criterion (AIC) values (Burnham & Anderson 2002). The analyses were performed in the R environment (R Core Team 2021), using the Distance package (Distance Sampling Detection Function and Abundance Estimation, version 1.0.4, Miller *et al.* 2019). Bird numbers obtained from the shore during the standard January waterbirds count and under the International Waterbird Census (Wetlands International 2010) were added to the estimated offshore counts.

Fishing effort: To determine total fishing effort, an analysis of the data obtained from the Fisheries Monitoring Centre (CMR) was performed. Only data from the winter period was used – the time when the most seabirds occur in this part of the Baltic Sea (Skov *et al.* 2011), specifically from 1 October to 30 April. In this analysis, only static nets – the most problematic fishing gear in terms of bird by-catch in this area (Žydelis *et al.* 2009; 2013; Marchowski 2021) – were considered. Other fishing gears susceptible to capturing waterbirds incidentally and considered less problematic than static nets in terms of bird by-catch in the study area (e.g., long-lines and fyke traps) were not taken into account in this analysis, owing to a paucity in fishing effort and/or by-catch data for these gears (Marchowski 2021). Additionally, the impact of Polish vessels operating in non-Polish waters or in areas of Exclusive Economic Zones of other countries, and of non-Polish fleets operating in the Polish Exclusive Economic Zone were not included. For each record, the standard unit of fishing effort in net*metre*days (NMD) (Bellebaum *et al.* 2012; Psuty *et al.* 2017) was calculated. The NMD unit determines how many meters of nets were left in the water for how many days, i.e., the time during which they posed a potential threat to birds.

Waterbird by-catch: Based on the by-catch rates determining the number of caught birds per 1000 NMD in the main static net fisheries operated in Polish sea waters (Table 12), the total number of by-caught birds of all species together was estimated by multiplying these rates with the total fishing effort for each year at the level of Statistical Baltic Squares (SKB), each covering a total area of about 400 km^2 offshore, while the area of the squares adjacent to the coast and extending beyond the borders of the PEEZ is smaller (Figure 17). Subsequently, individual species total by-catch mortality was estimated as the ratio of the entire bird by-catch mortality to the corresponding share in the waterbird population. By-catch rates were calculated based on surveys carried out with the participation of observers on board fishing vessels in the winter season in the 2013/2014 on few water bodies in Polish EEZ, Kamień Lagoon, Szczecin Lagoon, Pomeranian Bay and Puck Bay. The method of fishing for these water bodies is considered representative of the entire Polish fishery, the study sites were selected in such a way that they included areas with high by-catch, medium by-catch, and areas with no by-catch (Psuty *et al.* 2017).

Table 12. By-catch rates based on studies carried out in the Polish waters of the Baltic Sea in the winter seasons of 2013/2014 and 2014/2015 (according to Psuty *et al.* 2017). By-caught birds/1000 NMD: number of by-caught birds per 1000 nets * metres * days.

Type of static nets	By-caught birds/1000 NMD (95% CI)
Cod, flounder, and turbot gillnets/trammel nets	0.221 (0.218 – 0.225)
Herring, perch, roach, garfish and spart gillnets	0.227 (0.217 – 0.238)
Zander and bream gillnets	0.651 (0.447 – 1.386)
Trout, salmon, pike and whitefish gillnets and one-side anchored nets (i.e. semi-driftnets)	0.279 (0.250 – 0.309)

Setting the threshold values: Species-specific threshold setting for Evaluation Method 2 using bird numbers from the assessment area and annual adult mortality from literature data (Bird *et al.* 2020) is explained in section 3.1.

Waterbird by-catch (Evaluation Method 3)

Evaluation Method 3 compares spatial distributions of waterbirds and the exercise of fishing methods by-catching those waterbirds for the same part of the year, but shall be applied only to red-listed species (HELCOM 2013) if Evaluation Methods 1 and 2 are not possible due to lacking by-catch or bird population data. Evaluation Method 3 was used for waterbirds in Germany and Denmark.

Germany: Waterbird distribution in German waters (falling into the subdivision Bornholm Group) was recorded during standardised ship-based surveys (HELCOM 2021b) during the wintering season from November to April and entirely falling into the assessment period 2016-2021. Survey data were aggregated to species maps showing mean densities (birds per km^2) in a 5x5 km grid across the six years. During the ship-based bird surveys also marking flags of static nets were recorded and aggregated in a 5x5 km grid map (flags per km travelled).

Bird density maps and static net effort maps were combined in order to check for existing of spatio-temporal overlap. Bird occurrence was defined as being relevant for densities above 1 bird/km^2 in less numerous species and for densities above 5 birds/km^2 in abundant species in order to avoid overvaluation of insignificant occurrences. Since the fishing effort was only recorded during the bird surveys, published maps of static net fishing (von Dorrien 2019) were checked in order to identify any undetected fishing effort in areas with relevant bird occurrence (which actually was not the case).

Denmark: For three subdivisions (Kattegat, Belt Group, Bornholm Group) covering Danish waters in the Baltic Sea, a risk assessment for common eiders could be used for this by-catch evaluation. Using data from electronic by-catch monitoring, Glemarec *et al.* (2022) produced risk maps and modelled total annual and quarterly by-catch totals for common eiders among other species and species groups. Recorded by-catch events give evidence for the spatio-temporal overlap of fishing and bird occurrence and thus can feed into Evaluation Method 3 as long as a spatial allocation is possible.

Lithuania: Species-specific by-catch data from an extensive study in Lithuania from October 2015 to May 2020 (Morkūnas *et al.* 2022) gave evidence for by-catch and thus could be used for Evaluation Method 3.

9.3 Monitoring and reporting requirements

Monitoring methodology

Monitoring relevant to the indicator is described on a general level in the HELCOM Monitoring Manual in the sub-programme: Fisheries by-catch.

Current monitoring

Commission Delegated Decision (EU) 2021/1167 (European Commission 2021) requires by-catch monitoring of protected mammal and waterbird species. Current national discard/by-catch monitoring programmes carried out under the EU data collection framework (DCF) only to very limited extent target marine mammal and bird by-catches. Monitoring of by-catch of cetaceans under Annex XIII of the EU regulation 2019/1241 lays measures concerning by-catches of cetaceans in fisheries using onboard observers but is limited to vessels >15 m and hence results in the lowest observer coverage of fisheries posing greatest threat to porpoises in the Baltic Sea (ICES 2013b).

Thus, monitoring activities relevant to the indicator are only partially carried out by HELCOM Contracting Parties (see HELCOM Monitoring Manual). These consist generally of DCF at-sea monitoring with a low on-board observer coverage in métiers and fleet segments relevant to marine mammal and waterbird by-catch, with the exception of Denmark and since recently Sweden, for which electronic monitoring in static net fisheries can provide data with a level of high confidence. In other areas, self-reported data from logbooks are being reported which are likely incomplete and do not allow extrapolations on fleet effort. These can at best be considered as absolute minimum estimates.

Sub-programme: Fisheries by-catch

Monitoring Concept Table

All HELCOM Contracting Parties which are also EU Member States are obliged to carry out monitoring to provide estimates of population sizes in accordance with the requirements of the Habitats Directive and the Birds Directive.

Contracting Parties currently do not comply with Article 12 Habitats Directive as there is no monitoring in place that gives information that serves the target that incidental capture and killing does not have a significant negative impact on the species. Even more, current monitoring practice led to the unsatisfactory situation that the extent of the by-catch problem is still not known precisely and as a consequence only limited conservation measures regarding by-catch (such as defined in the EU Regulation 2019/1241) are implemented. Some countries like Denmark have been engaged in developing monitoring based on on-board video cameras recently. In Denmark, this programme is now fully integrated to the regular national monitoring programme of Danish fisheries (i.e., DCF or EU-MAP), and a similar programme is on tracks in Sweden.

Monitoring programmes are carried out under the EU Data Collection Framework (DCF). However, DCF monitoring effort has focused primarily on the problem of discard. Available resources have thus been allocated to large vessels operating active gears for which bycatch of protected, endangered and threatened species is a minor issue, rather than on the more problematic small vessels using static nets which are responsible for most of the by-catch in the Baltic Sea. Thus by-catch of marine mammals and waterbirds is not adequately addressed but rather recorded opportunistically at best not providing the needed data to enhance the confidence of the indicator.

EU Regulation 2019/1241 obliges Member States to monitor cetacean by-catch in static nets. Further, monitoring under Regulation 2019/1241 is not suited to the data needs for this indicator because only vessels >15 m are covered by the observer programme and the majority of Baltic static net fisheries is carried out by small vessels which use the same gear. Under Annex VIII of EU Regulation 2019/1241 vessels are allowed to set 9 km (vessel length <12 m) or even 21 km (vessel length >12 m) of static net, respectively, illustrating the high risk of by-catch even by small vessels (European Commission 2019).

Only very limited data are collected for protected waterbird taxa under DCF, and it is not possible to estimate effort or coverage. Besides national differences there are large differences in coverage between fishing métiers favouring larger vessels and mainly trawlers. As a result, from these programmes there are no robust estimates of by-caught waterbirds and marine mammals for various types of fishing gear (mainly gillnets and entangling nets) in the Baltic Sea, because so far no adequate observer coverage has been achieved with existing monitoring programmes such as DCF and EU Regulation 2019/1241. On the other hand, the results of pilot studies such as interviews are frequently questioned by fishermen and fisheries authorities. Especially in métiers which have been identified by pilot studies as fisheries with a high risk for mammal or bird by-catch, monitoring is inadequate and a revision of existing monitoring programmes is urgently needed.

10 Data

By-catch estimates harbour porpoises from Kattegat, Belt Sea and the Sound were taken from Larsen *et al.* (2021) and Glemarec *et al.* (2022) as results from a Danish REM study. Further marine mammal by-catch data was added from a compilation of reported by-catches and strandings data compiled by HELCOM EG MAMA, from NAMMCO & IMR (2019) and Vanhatalo *et al.* (2014).

By-catch data for waterbird Evaluation Method 2 in Polish waters were supplied by Dominik Marchowski (unpublished data based on Polish bird surveys, by-catch rates published by Psuty *et al.* (2017) and effort data from fishermen's declarations submitted to the Polish Fisheries Monitoring Centre). Estimates of annual adult mortality used for Evaluation Method 2 were taken from Bird *et al.* (2020)

By-catch data for waterbird Evaluation Method 3 in Danish waters was taken from Larsen *et al.* (2021) and Glemarec *et al.* (2022). Data for waterbird Evaluation Method 3 in Lithuanian waters was taken from Morkūnas *et al.* (2022). Data for waterbird Evaluation Method 3 in German waters was taken from German seabird surveys from November to April (2016-2021) which also record the distribution of static net flags, and further from scientific case studies in German waters (Schirmeister 2003, Erdmann *et al.* 2005, Bellebaum & Schirmeister 2012).

11 Contributors

The indicator “Abundance of waterbirds in the breeding season” is led by Germany (responsible experts: Sven Koschinski, Volker Dierschke and Axel Kreutle) and co-led by Poland (responsible expert: Katarzyna Kaminska).

For the waterbird evaluations, analyses were supplied by Poland (Dominik Marchowksi) and Germany (Kai Borkenhagen, Volker Dierschke, Jana Kotzerka, Nele Markones, Henriette Schwemmer) based on the waterbird monitoring in the respective countries and Polish fishing effort data (Fisheries Monitoring Centre). Literature data were used for additional evaluations in Denmark and Lithuania.

The indicator was developed following recommendations from 50 experts at the *OSPAR-HELCOM workshop to examine possibilities for developing indicators for incidental by-catch of birds and marine mammals*. Regarding waterbirds, the indicator concept was evaluated by experts of the OSPAR/HELCOM/ICES Joint Working Group on Marine Birds (JWGBIRD): Gildas Glemarec, Dominik Marchowski.

For the marine mammal evaluation, Markus Ahola, Mathieu Authier, Julia Carlström, Anita Gilles, David Lusseau, Kylie Owen contributed to the development and testing of threshold setting methods and evaluation scenarios.

HELCOM Secretariat: Jannica Haldin, Owen Rowe, Jana Wolf

12 Archive

This version of the HELCOM core indicator report was published in April 2023:

The current version of this indicator (including as a PDF) can be found on the HELCOM indicator web page.

Earlier versions of this indicator can be found below:

Number of drowned mammals and waterbirds in fishing gear – 2018 (HOLAS 2) (pdf)

Number of drowned mammals and waterbirds in fishing gear – 2013 (Korpinen & Bräger)

13 References

Amundin, M., Carlström, J., Thomas, L., Carlén, I., Teilmann, J., Tougaard, J., Loisa, O., Kyhn, L.A., Sveegaard, S., Burt, M.L., Pawliczka, I., Koza, R., Arciszewski, B., Galatius, A., Laaksonlaita, J., MacAuley, J., Wright, A.J., Gallus, A., Dähne, M., Acevedo-Gutiérrez, A., Benke, H., Koblitz, J., Tregenza, N., Wennerberg, D., Brundiers, K., Kosecka, M., Ljungqvist, C.T., Jussi, I., Jabbusch, M., Lyytinen, S., Šaškov, A., Blankett, P., 2022. Estimating the abundance of the critically endangered Baltic Proper harbour porpoise (*Phocoena phocoena*) population using passive acoustic monitoring. Ecology and Evolution 12: e8554. https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.8554

Anderson, O.R.J., Small, C.J., Croxall, J.P., Dunn, E.K., Sullivan, B.J., Yates, O., & Black, A. 2011. Global seabird bycatch in longline fisheries. Endangered Species Research 14: 91-106. https://www.int-res.com/articles/esr_oa/n014p091.pdf

ASCOBANS 2012. ASCOBANS conservation plan for the harbour porpoise population in the Western Baltic, the Belt Sea and the Kattegat, 7th Meeting of the Parties to ASCOBANS, Brighton, United Kingdom, 22-24 October 2012, Bonn, Germany, 40 pp. https://www.ascobans.org/sites/default/files/document/HarbourPorpoise_ConservationPlan_WesternBaltic_MOP7_2012.pdf

ASCOBANS 2016. Resolution No. 3: Revision of the Recovery Plan for Baltic Harbour Porpoises (Jastarnia Plan), 8th Meeting of the Parties to ASCOBANS, Helsinki, Finland, 30 August - 1 September 2016, Bonn, 94 pp. https://www.ascobans.org/sites/default/files/document/MOP8_2016-3_JastarniaPlan_inclAnnex.pdf

Authier, M., Carlström, J., Genu,M., Gilles, A., Kindt-Larsen, L., Larsen, F., Lusseau, D., Owen, K., Sköld,M., Sveegaard, S. 2022. Personal communication with experts on further scenarios to increase the robustness of mPBR. August 2022

Beineke, A., Siebert, U., McLachlan, M., Bruhn, R., Thron, K., Failing, K., Müller, G. & Baumgärtner, W. (2005) Investigations of the potential influence of environmental contaminants on the thymus and spleen of harbor porpoises (*Phocoena phocoena*). Environmental Science & Technology 39: 3933–3938. https://pubs.acs.org/doi/abs/10.1021/es048709j

Beineke, A., Siebert, U., Müller, G. & Baumgärtner, W. (2007a) Increased blood interleukin-10 mRNA levels in diseased free-ranging harbor porpoises (*Phocoena phocoena*). Veterinary immunology and immunopathology 115: 100–106. https://www.sciencedirect.com/science/article/abs/pii/S0165242706002686

Beineke, A., Siebert, U., Stott, J., Müller, G. & Baumgärtner, W. (2007b) Phenotypical characterization of changes in thymus and spleen associated with lymphoid depletion in free-ranging harbor porpoises (*Phocoena phocoena*). Veterinary immunology and immunopathology 117: 254–265. https://www.sciencedirect.com/science/article/abs/pii/S0165242707001018

Bellebaum J., Schirmeister B. 2012. Verluste von Seevögeln durch die Küstenfischerei in Mecklenburg-Vorpommern. Onithol. Rundbr. Mecklenburg-Vorpommern 47, Sonderheft: 97-102.

Bellebaum J., Schirmeister B., Sonntag N., Garthe S. 2012. Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast. Aquat. Conserv. Mar. Freshwater Ecosys. 23: 210–221. https://onlinelibrary.wiley.com/doi/abs/10.1002/aqc.2285

Bernotat, D., & Dierschke, V. (2021): Übergeordnete Kriterien zur Bewertung der Mortalität wildlebender Tiere im Rahmen von Projekten und Eingriffen Teil I: Rechtliche und methodische

Grundlagen 4. Fassung, Stand 31.08.2021. https://www.researchgate.net/publication/356290132_Ubergeordnete_Kriterien_zur_Bewertung_der_Mortalitat_wildlebender_Tiere_im_Rahmen_von_Projekten_und_Eingriffen_Teil_I_Rechtliche_und_methodische_Grundlagen_4_Fassung_Stand_31082021

Bird J.P., Martin R., Akçakaya H.R., Gilroy J., Burfield I.J., Garnett S.T., Symes A., Taylor J., Şekercioğlu Ç.H. & Butchart, S.H.M. 2020. Generation lengths of the world's birds and their implications for extinction risk. Conservation Biology, 34: 1252-1261. https://doi.org/10.1111/cobi.13486

BirdLife International 2019. BirdLife position on Good Environmental Status threshold criteria for Descriptor 1: seabird bycatch and population abundance. https://portal.helcom.fi/meetings/Incidental%20bycatch%20WS%201-2019-647/MeetingDocuments/BirdLife%20position%20D1criteria_02092019_FINAL.pdf.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L., Thomas. L. 2001. Introduction to distance sampling - Estimating abundance of biological populations. Oxford University Press, Oxford, UK.

Burnham, K. P., Anderson D. R. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach, 2nd ed. Springer-Verlag, New York, USA.

Chodkiewicz T., Neubauer G., Meissner W., Sikora A., Chylarecki P., Woźniak B., Bzoma S., Brewka B., Rubacha S., Kus K., Rohde Z., Cenian Z., Wieloch M., Zielińska M., Zieliński P., Kajtoch Ł., Szałański P., Betleja J. 2012. Monitoring of Polish birds in 2010–2012. Biuletyn Monitoringu Przyrody 9: 1–44.

Ciesielski, T., Szefer, P., Bertenyi, Z., Kuklik, I., Skóra, K., Namieśnik, J. & Fodor, P. (2006). Interspecific distribution and co-associations of chemical elements in the liver tissue of marine mammals from the Polish Economical Exclusive Zone, Baltic Sea. Environment International 32: 524 –532. https://www.sciencedirect.com/science/article/pii/S0160412005002473

Danil, K., & St. Leger, J.A., 2011. Seabird and dolphin mortality associated with underwater detonation exercises. Marine Technology Science Journal 45: 89-95. https://www.ingentaconnect.com/content/mts/mtsj/2011/00000045/00000006/art00012?crawler=true&mimetype=application/pdf

Erdmann F., Bellebaum J., Kube J., Schulz A. 2005. Verluste von See- und Wasservögeln durch die Fischerei unter besonderer Berücksichtigung der international bedeutsamen Rast-, Mauser- und Überwinterungsgebiete in den Küstengewässern Mecklenburg-Vorpommerns. ILN Greifswald, IfAÖ Neu Broderstorf. https://www.lung.mv-regierung.de/dateien/lung_seevoegel_u_fischerei_2005.pdf

European Commission 1992. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Habitats Directive). Off. J. Eur. Union L 206: 7–50. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A31992L0043

European Commission 2008a. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32008L0056&from=EN

European Commission 2008b. Guidance document on hunting under Council Directive 79/409/EEC on the conservation of wild birds "The Birds Directive". Available at: https://ec.europa.eu/environment/nature/conservation/wildbirds/hunting/docs/hunting_guide_en.pdf

European Commission 2009. Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds. Off. J. Eur. Union L 20. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009L0147

European Commission 2012. Action Plan for reducing incidental catches of seabirds in fishing gears. COM(2012) 665. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012DC0665&from=EN

European Commission 2017a. Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32017D0848

European Commission 2017b. Regulation (EU) 2017/1004 of the European Parliament and of the Council of 17 May 2017 on the establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy and repealing Council Regulation (EC) No 199/2008 (recast). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32017R1004

European Commission 2019. Regulation (EU) 2019/1241 of the European Parliament and of the Council of 20 June 2019on the conservation of fisheries resources and the protection of marine ecosystems through technical measures, amending Council Regulations (EC) No 1967/2006, (EC) No 1224/2009 and Regulations (EU) No 1380/2013, (EU) 2016/1139, (EU) 2018/973, (EU) 2019/472 and (EU) 2019/1022 of the European Parliament and of the Council, and repealing Council Regulations (EC) No 894/97, (EC) No 850/98, (EC) No 2549/2000, (EC) No 254/2002, (EC) No 812/2004 and (EC) No 2187/2005. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1241&from=EN

European Commission 2021. Commission Delegated Decision (EU) 2021/1167 of 27 April 2021 establishing the multiannual Union programme for the collection and management of biological, environmental, technical and socioeconomic data in the fisheries and aquaculture sectors from 2022. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021D1167

European Commission 2022. MSFD CIS Guidance Document No. 19, Article 8 MSFD, May 2022. https://circabc.europa.eu/d/d/workspace/SpacesStore/d2292fb4-ec39-4123-9a02-2e39a9be37e7/GD19%20-%20MSFDguidance_2022_Art.8Assessment(1).pdf

Genu, M., Gilles, A., Hammond, P.S., Macleod, K., Paillé, J., Paradinas, I., Smout, S., Winship, A.J., & Authier, M., 2021. Evaluating strategies for managing anthropogenic mortality on marine mammals: An R implementation with the Package RLA. Frontiers in Marine Science 8: 795953. https://www.frontiersin.org/articles/10.3389/fmars.2021.795953/full?&utm_source=Email_to_authors_&utm_medium=Email&utm_content=T1_11.5e1_author&utm_campaign=Email_publication&field=&journalName=Frontiers_in_Marine_Science&id=795953

Glemarec, G., Kindt-Larsen, L., Lundgaard, L.S. & Larsen, F. 2020. Assessing seabird bycatch in gillnet fisheries using electronic monitoring. Biological Conservation 243: 108461. https://www.sciencedirect.com/science/article/abs/pii/S0006320719313916

Glemarec G., Vinther M., Håkansson K.B., Rindorf A. 2022. Collection of by-catch data for seabirds and marine mammals and by-catch and population densities for non-commercial fish. DTU Aqua Report no. 408-2022. National Institute of Aquatic Resources, Technical University of Denmark, 53 pp.

https://backend.orbit.dtu.dk/ws/portalfiles/portal/282860680/408_2022_Collection_of_bycatch_data_for_seabirds_and_marine_mammals.pdf

Hario, M., Rintala, J., & Nordenswan, G. 2009. Dynamics of wintering long-tailed ducks in the Baltic Sea – the connection with lemming cycles, oil disasters, and hunting. Suomen Riista 55: 83-96.

Härkönen, T., Isakson, E., 2010. Status of harbour seals (*Phoca vitulina*) in the Baltic proper, in: Desportes, G., Bjørge, A., Rosing-Asvid, A., Waring, G. (Eds.), Harbour Seals in the North Atlantic and the Baltic, The North Atlantic Marine Mammal Commission, Tromsø pp. 71-77.

Hauer, S., Ansorge, H., & Zinke, O. 2002. Mortality patterns of otters (*Lutra lutra*) from eastern Germany. Journal of Zoology 256: 361–368. https://doi.org/10.1017/S0952836902000390

Heath, M.R., Neat, F.C., Pinnegar, J.K., Reid, D.G., Sims, D.W., Wright, P.J., 2012. Review of climate change impacts on marine fish and shellfish around the UK and Ireland. Aquat.Conserv. 22, 337-367

HELCOM 2013. HELCOM Red List of Baltic Sea species in danger of becoming extinct. Baltic Sea Environment Proceedings No. 140. https://www.helcom.fi/wp-content/uploads/2019/08/BSEP140-1.pdf

HELCOM 2018. Population trends and abundance of seals HELCOM core indicator 2018. HELCOM Secretariat, Helsinki, Finland. 34 pp.

HELCOM 2021a. Bycatch in Baltic Sea commercial fisheries: High-risk areas and evaluation of measures to reduce bycatch. HELCOM ACTION, https://helcom.fi/wp-content/uploads/2021/11/Bycatch-in-Baltic-Sea-commercial-fisheries.pdf

HELCOM 2021b. Guidelines for monitoring seabirds at sea. https://helcom.fi/wp-content/uploads/2021/11/HELCOM-Monitoring-guidelines-for-seabirds-at-sea-monitoring.pdf

HELCOM & Baltic Earth 2021. Climate Change in the Baltic Sea. 2021 Fact Sheet. Baltic Sea Environment Proceedings 180. https://helcom.fi/baltic-sea-climate-change-fact-sheet-new-publication-shows-latest-scientific-knowledge-on-climate-change-in-the-baltic-sea/

HELCOM EG MAMA 2022 By-catches 2016-2021. Template containing strandings and by-catches of marine mammals reported by CPs to HELCOM EG MAMA.

ICES 2010. Report of the Workshop to Evaluate Aspects of EC Regulation 812/2004 (WKREV812). ICES ADVISORY COMMITTEE, 28-30 September 2010, ICES CM 2010/ACOM:66, International Council for the Exploration of the Sea, Copenhagen, Denmark. 64 pp. https://www.ascobans.org/sites/default/files/document/ICES_WKREV812_final-updated_2011.pdf

ICES 2013a. Report of the Workshop to Review and Advise on Seabird Bycatch (WKBYCS). ICES CM 2013/ACOM:77.
International Council for the Exploration of the Sea, Copenhagen, Denmark. 77 pp.

ICES 2013b. Report of the Workshop on Bycatch of Cetaceans and other Protected Species (WKBYC). ICES CM 2013/ACOM:36. International Council for the Exploration of the Sea, Copenhagen, Denmark. 53 pp.

ICES 2016. Working Group on Bycatch of Protected Species (WKBYC), 1–5 February 2016 Copenhagen, Denmark, 77 pp.

ICES 2018a. Report from the Working Group on Bycatch of Protected Species (WGBYC). 1–4 May 2018. Reykjavik, Iceland. 128 pp.

ICES 2018b. Report of the Joint OSPAR/HELCOM/ICES Working Group on Seabirds (JWGBIRD), 6–10 November 2017, Riga, Latvia. ICES CM 2017/ACOM:49. 97 pp. Available at: http://ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2017/JWGBIRD/01%20JWGBIRD%20Report.pdf

ICES 2018c. WKPETSAMP REPORT 2018. Joint WGBYC-WGCATCH Workshop on sampling of bycatch and PET species (WKPETSAMP) 24–26 April 2018 SLU Aqua, Lysekil, Sweden

ICES 2021. Working Group on Bycatch of Protected Species (WGBYC). ICES Scientific Reports 3, 168.

IJsseldijk, L.L., Hessing, S., Mairo, A., ten Doeschate, M.T.I., Treep, J., van den Broek, J., Keijl, G.O., Siebert, U., Heesterbeek, H., Gröne, A., Leopold, M.F., 2021. Nutritional status and prey energy density govern reproductive success in a small cetacean. Scientific Reports 11: 19201. https://www.nature.com/articles/s41598-021-98629-x

IWC (International Whaling Commission) 1991. Report of the scientific committee: small cetaceans. Reports of the International Whaling Commission 42: 75-81.

IWC (International Whaling Commission) 1996. Report of the Sub-Committee on Small Cetaceans. Reports of the International Whaling Commission 46: 160-179.

Kesselring, T., Viquerat, S., Brehm, R., & Siebert, U., 2017. Coming of age: - Do female harbour porpoises (*Phocoena phocoena*) from the North Sea and Baltic Sea have sufficient time to reproduce in a human influenced environment? PLOS ONE 13(6): e0199633. https://doi.org/10.1371/journal.pone.0199633

Kindt-Larsen, L., Dalskov, J., Stage, B., Larsen, F., 2012. Observing incidental harbour porpoise *Phocoena phocoena* bycatch by remote electronic monitoring. Endang. Species Res 19: 75-83. https://www.int-res.com/abstracts/esr/v19/n1/p75-83/

Kindt-Larsen, L., Berg, C.W., Tougaard, J., Sørensen, T.K., Geitner, K., Northridge, S., Sveegaard, S., Larsen, F., 2016. Identification of high-risk areas for harbour porpoise *Phocoena phocoena* bycatch using remote electronic monitoring and satellite telemetry data. Mar. Ecol. Prog. Ser 555: 261-271. https://www.int-res.com/abstracts/meps/v555/p261-271

Komdeur J., Bertelsen J., Cracnell G. 1992. Manual for Aeroplane and Ship Surveys of waterfowl and Seabirds. IWRB Special Publication No. 19, Slimbridge.

Koschinski, S., 2002. Current knowledge on harbour porpoises (*Phocoena phocoena*) in the Baltic Sea. Ophelia 55, 167-198

Landa, A., & Guidos, S. 2020. Bycatch in local fishery disrupts natural reestablishment of Eurasian otter in western Norway. Conservation Science and Practice 2020;2: e208. https://doi.org/10.1111/csp2.208

Larsen, F., L. Kindt-Larsen, T.K. Sørensen & G. Glemarec 2021. Bycatch of marine mammals and seabirds. Occurrence and mitigation. DTU Aqua Report no. 389-2021. https://backend.orbit.dtu.dk/ws/portalfiles/portal/261340293/389_2021_Bycatch_of_marine_mammals_and_seabirds.pdf

Larsson, K., & Tydén, L. 2005. Effects of oil spills on wintering Long-tailed Ducks *Clangula hyemalis* at Hoburgs bank in central Baltic Sea between 1996/97 and 2003/04. Ornis Svecica 15: 161-171

Laursen. K., & Møller, A.P. 2014. Long-term changes in nutrients and mussel stocks are related to numbers of breeding Eiders *Somateria mollissima* at a large Baltic colony. PLoS ONE 9(4): e95851. https://doi.org/10.1371/journal.pone.0095851

Leopold, M.F., Heße, E., Ijsseldijk, L.L., Begeman, L., Mielke, L., Schelling, T., van der Steeg, L., Meesters, E., Kejil, G.O., Jauniaux, T., Hiemstra, S., Gröne, A., van der Meer, J., 2015. Are starving harbour porpoises (*Phocoena phocoena*) are sentenced to eat junk food? In: Leopold, M.F. (ed.): Eat or be eaten: porpoise diet studies, pp. 59-87, Wageningen University, Wageningen.

Lindroth, A., 1962. Baltic salmon fluctuations 2: porpoise and salmon. Rep. Inst. Freshwat. Drottingholm 44, 105-112

Marchowski, D., Jankowiak, Ł., Wysocki, D., Ławicki, Ł., & Girjatowicz, J., 2017. Ducks change wintering patterns due to changing climate in the important wintering waters of the Odra River Estuary. PeerJ 5:e3604. https://peerj.com/articles/3604/

Marchowski, D., Ławicki, Ł., Guentzel, S., Kaliciuk, J., & Kajzer, Z. 2018. Long-term changes in the number of waterbirds at an important European wintering site. Acta Biologica 25: 111-122. file:///C:/Users/volke/Downloads/09_marchowski.d-lawicki.l-guentzel.s.pdf

Marchowski, D., Jankowiak, Ł., Ławicki, Ł., Wysocki, D. & Chylarecki, P. 2020. Fishery bycatch is among the most important threats to the European population of Greater Scaup *Aythya marila*. Bird Conservation International 30: 176-193. https://www.cambridge.org/core/journals/bird-conservation-international/article/abs/fishery-bycatch-is-among-the-most-important-threats-to-the-european-population-of-greater-scaup-aythya-marila/45C625AD34CEC637D9D7496EBD12BE0C

Marchowski, D. 2021. Bycatch of Seabirds in the Polish Part of the Southern Baltic Sea in 1970–2018: A Review. Acta Ornithologica 56: 139-158. https://bioone.org/journals/acta-ornithologica/volume-56/issue-2/00016454AO2021.56.2.001/Bycatch-of-Seabirds-in-the-Polish-Part-of-the-Southern/10.3161/00016454AO2021.56.2.001.short

MASTS 2016. Strengthening regional cooperation in fisheries data collection; the FishPi project report. Report to the European Commission in Fulfilment of Grant Award: EU MARE/2014/19., MASTS, University of St. Andrews, St. Andrews, Scotland, 617 pp. https://www.masts.ac.uk/media/36266/fishpi-final-report.pdf

Meier, H.E.M., Kniebusch, M., Dieterich, C., Gröger, M., Zorita, E., Elmgren, R., Myrberg, K., Ahola, M.P., Bartosova, A., Bonsdorff, E., Börgel, F., Capell, R., Carlén, I., Carlund, T., Carstensen, J., Christensen, O.B., Dierschke, V., Frauen, C., Frederiksen, M., Gaget, E., Galatius, A., Haapala, J.J., Halkka, A., Hugelius, G., Hünicke, B., Jaagus, J., Jüssi, M., Käyhkö, J., Kirchner, N., Kjellström, E., Kulinski, K., Lehmann, A., Lindström, G., May, W., Miller, P.A., Mohrholz, V., Müller-Karulis, B., Pavón-Jordán, D., Quante, M., Reckermann, M., Rutgersson, A., Savchuk, O.P., Stendel, M., Tuomi, L., Viitasalo, M., Weisse R., & Zhang, W. 2022. Climate change in the Baltic Sea region: a summary. Earth System Dynamics 13: 457-593. https://esd.copernicus.org/articles/13/457/2022/

Meissner W., Rydzkowski P. 2007. Wintering of waterfowl in the Bay of Gdańsk in the season 2005/2006. Not. Orn. 48: 143–147.

Miller D.L., Rexstad E., Thomas L., Marshall L., Laake J.L. 2019. Distance Sampling in R. Journal of Statistical Software, 89:1-28. https://doi.org/10.1101/063891

Mooij, J.H. 2005. Protection and use of waterbirds in the European Union. Beitr. Jagd- Wildforsch. 30: 49-76.

Morkūnas, J., Oppel, S., Bružas, M., Rouxel, Y., Morkūnė, R., & Mitchell, D. 2022. Seabird bycatch in a Baltic coastal gillnet fishery is orders of magnitude larger than official reports. Avian Conservation and Ecology 17(1): 31. https://ace-eco.org/vol17/iss1/art31/

Murphy, S., Barber, J.L., Learmonth, J.A., Read, F.L., Deaville, R., Perkins, M.W., Brownlow, A., Davison, N., Penrose, R., Pierce, G.J., Law, R.J. & Jepson, P.D. 2015. Reproductive failure in UK harbour porpoises *Phocoena phocoena*: Legacy of pollutant exposure? PLoS ONE 10, e0131085. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0131085

NAMMCO & IMR, 2019. Report of the Status of Harbour Porpoise in the North Atlantic Workshop, Tromsö, North Atlantic Marine Mammal Commission, Tromsö, Norwegian Institute for Marine Research, Bergen, p. 186. https://nammco.no/wp-content/uploads/2020/03/final-report_hpws_2018_rev2020.pdf

Norrgren, L. & Levengood, J.M. 2012. Ecology and Animal Health, Ecosystem Health and Sustainable Agriculture, Vol. 2. The Baltic University Programme, Uppsala, 382 pp.

O'Brien, S.H., Cook, A.S.C.P., & Robinson, R.A., 2017. Implicit assumptions underlying simple harvest models of marine bird populations can mislead environmental management decisions. Journal of Environmental Management 201: 163-171. https://www.sciencedirect.com/science/article/pii/S0301479717306187

Oksanen, S.M., Ahola, M.P., Oikarinen, J., Kunnasranta, M. 2015. A novel tool to mitigate by-catch mortality of Baltic seals in coastal fyke net fishery. PLoS ONE 10(5): e0127510. https://doi.org/10.1371/journal.pone.0127510

Oliveira, N. 2021. Preparatory work to assist in the delivery of a pilot OSPAR indicator: B5 Marine Bird Bycatch. JNCC Report No., JNCC, Peterborough, ISSN 0963-9091 (in press).

OSPAR & HELCOM 2019. Outcome of the OSPAR-HELCOM workshop to examine possibilities for developing indicators for incidental by-catch of birds and marine mammals. https://portal.helcom.fi/meetings/Incidental%20bycatch%20WS%201-2019-647/MeetingDocuments/Outcome%20OSPAR-HELCOM%20incidental%20by-catch%20indicator%20workshop_final.pdf

Österblom, H., Casini, M., Olsson, O., & Bignert, A. 2006. Fish, seabirds and trophic cascades in the Baltic Sea. Marine Ecology Progress Series 323: 233-238. https://www.int-res.com/articles/meps_oa/m323p233.pdf

Owen, K., Authier, M., Genu, M., Sköld, M., & Carlström, J., 2022. Estimating a mortality threshold for the Belt Sea population of harbour porpoises, Naturhistoriska riksmuseet, Stockholm, p. 16. https://www.diva-portal.org/smash/get/diva2:1645775/FULLTEXT01.pdf

Pavón-Jordán, D., Fox, A.D., Clausen, P., Dagys, M., Deceuninck, B., Devos, K., Hearn, R.D., Holt, C.A., Hornman, M., Keller, V., Langendoen, T., Ławicki, Ł., Lorentsen, S.H., Luigujõe, L., Meissner, W., Musil, P., Nilsson, L., Paquet, J.-Y., Stipniece, A., Stroud, D. A., Wahl, J., Zenatello, M., & Lehikoinen, A., 2015. Climate-driven changes in winter abundance of a migratory waterbird in relation to EU protected areas, Diversity and Distributions 21: 571-582. https://doi.org/10.1111/ddi.12300

Pavón-Jordán, D., Clausen, P., Dagys, M., Devos, K., Encarnaçao, V., Fox, A.D., Frost, T., Gaudard, C., Hornman, M., Keller, V., Langendoen, T., Ławicki, Ł., Lewis, L. J., Lorentsen, S.-H., Luigujoe, L., Meissner, W., Molina, B., Musil, P., Musilova, Z., Nilsson, L., Paquet, J.-Y., Ridzon, J., Stipniece, A., Teufelbauer, N., Wahl, J., Zenatello, M., & Lehikoinen, A., 2019. Habitat- and species-mediated short- and long-term distributional changes in waterbird abundance linked to variation in

European winter weather, Diversity and Distributions 25: 225-239. https://doi.org/10.1111/ddi.12855

Pavón-Jordán, D., Abdou, W., Azafzaf, H., Balaž, M., Bino, T., Borg, J.J., Božič, L., Butchart, S.H.M., Clausen, P., Sniauksta, L., Dakki, M., Devos, K., Domsa, C., Encarnaçao, V., Etayeb, K., Faragó, S., Fox, A.D., Frost, T., Gaudard, C., Georgiev, V., Goratze, I., Hornman, M., Keller, V., Kostiushyn, V., Langendoen, T., Ławicki, Ł., Ieronymidou, C., Lewis, L.J., Lorentsen, S.-H., Luigujoe, L., Meissner, W., Mikuska, T., Molinaa, B., Musil, P., Musilova, Z., Nagy, S., Natykanets, V., Nilsson, L., Paquet, J.-Y., Portolou, D., Ridzon, J., Santangeli,A., Sayoud, S., Šćiban, M., Stipniece, A., Teufelbauer, N., Topić, G., Uzunova, D., Vizi, A., Wahl, J., Yavuz, K.E., Zenatello, M., & Lehikoinen A., 2020. Positive impacts of important bird and biodiversity areas on wintering waterbirds under changing temperatures throughout Europe and North Africa. Biological Conservation 246: 108549. https://www.sciencedirect.com/science/article/pii/S000632071931170X

Peltier, H., Authier M., Deaville R., Dabin W., Jepson PD., van Canneyt O., Daniel P., & Ridoux V. 2016. Small cetacean bycatch as estimated from stranding schemes: The common dolphin case in the Northeast Atlantic. Env. Sci. Pol. 63: 7–18. https://discovery.ucl.ac.uk/id/eprint/1502337/1/jepson_Peltier%20et%20al.%20_envt%20science%20and%20policy_def.pdf

Polte, P., Gröhsler, T., Kotterba, P., von Nordheim, L., Moll, D., Santos, J., Rodriguez-Tress, P., Zablotski, Y., Zimmermann, C., 2021. Reduced Reproductive Success of Western Baltic Herring (*Clupea harengus*) as a Response to Warming Winters. Front. Mar. Sci. 8:589242. https://www.frontiersin.org/articles/10.3389/fmars.2021.589242/full?&utm_source=Email_to_authors_&utm_medium=Email&utm_content=T1_11.5e1_author&utm_campaign=Email_publication&field=&journalName=Frontiers_in_Marine_Science&id=589242

Psuty I., Szymanek L., Całkiewicz J., Dziemian Ł., Ameryk A., Ramutkowski M., Spich K., Wodzinowski T., Woźniczka A., Zaporowski R. 2017. Developing the Basis for Rational Monitoring of By-catch of Birds for Sustainable Management of Coastal Fishing in the Marine Areas of NATURA 2000. Morski Instytut Rybacki - Państwowy Instytut Badawczy, Gdynia. https://mir.gdynia.pl/wp-content/uploads/2016/04/Psuty-i-in-2017.pdf

R Core Team 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Ronconi R.A., & Burger A.E. 2009. Estimating seabird densities from vessel transects: distance sampling and implications for strip transects. Aquatic Biology 4: 297–309. https://www.int-res.com/articles/ab2008/4/b004p297.pdf

Ropelewski, A., 1957. The common porpoise (*Phocaena phocaena L.*) as a by-catch in Polish Baltic fisheries. Prace. Morskiego. Instytutu. Rybackiego. 9:427. 437

Schirmeister, B. 2003. Verluste von Wasservögeln in Stellnetzen der Küstenfischerei - das Beispiel der Insel Usedom. Meer und Museum 17: 160-166.

Schüz E. 1935. Vom Zug des Polar-Seetauchers (*Colymbus a. arcticus*). Vogelzug 6: 113-118.

Siebert, U., Joiris, C., Holsbeek, L., Benke, H., Failing, K., Frese, K. & Petzinger, E. 1999. Potential relation between mercury concentrations and necropsy findings in cetaceans from German waters of the North and Baltic Seas. Marine Pollution Bulletin 38: 285–295

Siebert, U., Stürznickel, J., Schaffeld, T., Oheim, R., Rolvien, T., Prenger-Berninghoff, E., Wohlsein, P., Lakemeyer, J., Rohner, S., Schick, L.A., Gross, S., Nachtsheim, D., Ewers, C., Becher, P., Amling, M., Morell, M., 2022. Blast injury on harbour porpoises (*Phocoena phocoena*) from the Baltic Sea after explosions of deposits of World War II ammunition. Environment International 159: 107014. https://www.sciencedirect.com/science/article/pii/S0160412021006395

Skov, H., Heinänen, S., Žydelis, R., Bellebaum, J., Bzoma, S., Dagys, M., Durinck, J., Garthe, S., Grishanov, G., Hario, N., Kieckbusch, J.J., Kube, J., Kuresoo, A., Larsson, K., Luigujoe, L., Meissner, W., Nehls, H.W., Nilsson, L., Petersen, I.K., Mikkola Roos, M., Pihl, S., Sonntag, N., Stock, A., Stipniece, A., 2011. Waterbird populations and pressures in the Baltic Sea. TemaNord 2011:550. Nordic Council of Ministers, Copenhagen. http://norden.diva-portal.org/smash/get/diva2:701707/FULLTEXT01.pdf

Skora, K.E., & Kuklik, I., 2003. Bycatch as a potential threat to harbour porpoises (*Phocoena phocoena*) in Polish Baltic waters. NAMMCO Scientific Publications 5: 303–315. https://septentrio.uit.no/index.php/NAMMCOSP/article/view/2831

Spurr E.B., Borkin K.M., Drew K.W. 2012. Line-transect distance sampling compared with fixed-width strip-transect counts for assessing tomtit (*Petroica macrocephala*) population trends. New Zealand Journal of Ecology 36: 365–370. https://newzealandecology.org/system/files/articles/NZJEcol36_3_365.pdf

Sundqvist, L., Harkonen, T., Svensson, C.J., Harding, K.C., 2012. Linking Climate Trends to Population Dynamics in the Baltic Ringed Seal: Impacts of Historical and Future Winter Temperatures. Ambio 41: 865-872. https://link.springer.com/article/10.1007/s13280-012-0334-x

Unger, B., Nachtsheim, D., Ramírez Martínez, N., Siebert, U., Sveegaard, S., Kyhn, L., Balle, J.D., Teilmann, J., Carlström, J., Owen, K., Gilles, A., 2021. MiniSCANS-II: Aerial survey for harbour porpoises in the western Baltic Sea, Belt Sea, the Sound and Kattegat in 2020. Joint survey by Denmark, Germany and Sweden. Final report to Danish Environmental Protection Agency, German Federal Agency for Nature Conservation and Swedish Agency for Marine and Water Management. 28 pp. https://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Eksterne_udgivelser/20210913_Report_MiniSCANSII_2020_revised.pdf

Vanhatalo, J., Vetemaa, M., Herrero, A., Aho, T., & Tiilikainen, R., 2014. By-catch of Grey Seals (*Halichoerus grypus*) in Baltic fisheries - a Bayesian analysis of interview survey. PLoS ONE 9(11): e113836. https://doi.org/10.1371/journal.pone.0113836

von Dorrien C. 2019. International fishing activities (2013-2018) in German waters of the Baltic Sea in relation to the designated Natura 2000 areas and proposed management measures for mobile bottom contacting gears. 3rd version 27.11.2019. Johann Heinrich von Thünen-Institute, Rostock.

Wade, P., 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Marine Mammal Science 14: 1-37. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1748-7692.1998.tb00688.x

Wetlands International. 2010. Guidance on waterbird monitoring methodology: Field protocol for waterbird counting. Wetlands International, Wageningen. https://www.wetlands.org/publications/iwc-guidance-field-protocol-for-waterbird-counting/

Žydelis, R., Dagys, M., Vaitkus, G. 2006. Beached bird surveys in Lithuania reflect marine oil pollution and bird mortality in fishing nets. Marine Ornithology 34: 161-166. http://www.marineornithology.org/PDF/34_2/34_2_161-166.pdf

Žydelis, R., Bellebaum, J., Österblom, H., Vetemaa, M., Schirmeister, B., Stipniece, A., Dagys, M., van Eerden, M., Garthe, S. 2009. Bycatch in gillnet fisheries – an overlooked threat to waterbird populations. Biological Conservation 142: 1269-1281. https://oceanrep.geomar.de/id/eprint/9872/1/1-s2.0-S0006320709001001-main.pdf

Żydelis, R., Small C., French G. 2013. The incidental catch of seabirds in gillnet fisheries: A global review. Biol. Conserv. 162: 76–88. https://www.bmis-bycatch.org/system/files/zotero_attachments/library_1/R7E25Q8P%20-%20%C5%BDydelis%20et%20al.%20-%202013%20-%20The%20incidental%20catch%20of%20seabirds%20in%20gillnet%20fisher.pdf

14 Other relevant resources

Population Parameters necessary for developing indicators for incidental by-catch of birds and marine mammals (Evans in prep.).