Bycatch in Baltic Sea commercial fisheries:
High-risk areas and evaluation of measures to reduce bycatch

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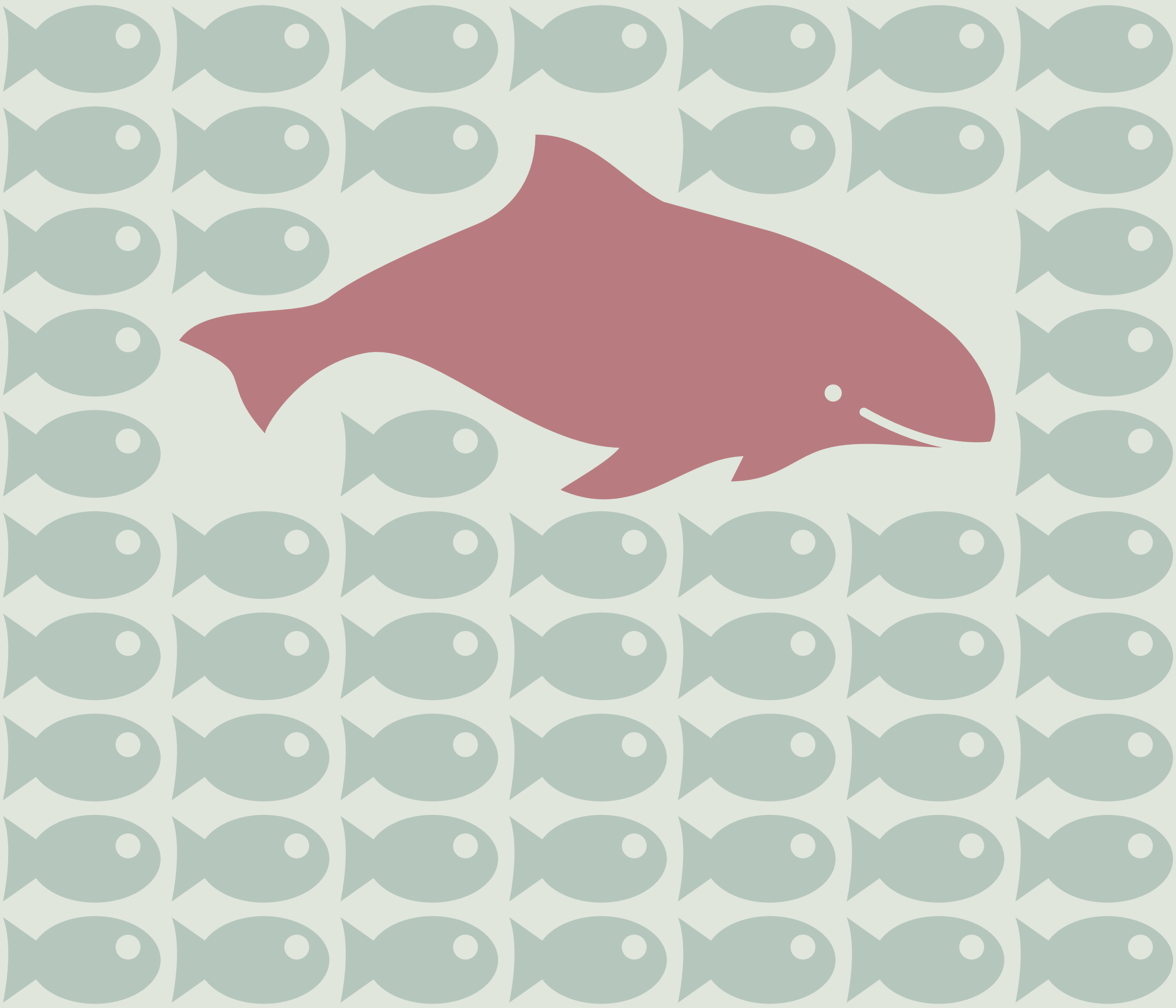

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Bycatch in Baltic Sea commercial fisheries: High-risk areas and evaluation of measures to reduce bycatch.

Contents

1. General introduction and aims

Bycatch of marine mammals and waterbirds in gillnets has been documented in many fisheries worldwide. Moreover, bycatch is regarded as one of the most significant source of premature mortality in a large number of marine mammal and bird species (Read, Drinker and Northridge, 2006; Lewison *et al.*, 2014; Dias *et al.*, 2019). In the Baltic Sea (i.e. the HELCOM region), the harbour porpoise *Phocoena phocoena* is the only resident cetacean, while three species of seals are present year round: the grey seal *Halichoerus grypus*, the harbour seal *Phoca vitulina* and the ringed seal *Pusa hispida*. The Baltic Sea is also a major migratory route for millions of Palearctic birds and an essential breeding and wintering ground for numerous waterbird species. Bycatch in gillnets within Baltic fisheries has been reported for all four species of marine mammals, as well as for dozens of species of seabirds (Vinther, 1999; 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, 2019; Glemarec *et al.*, 2020; Marchowski *et al.*, 2020).

A set of European Union (EU) legislative texts is already in place to ensure the conservation of vulnerable marine mammals and birds in EU waters, among which are the Birds and the Habitat Directives (Directive 2009/147/EC and Directive 92/43/EEC, respectively). These Directives both prohibit the deliberate killing, disturbance or habitat destruction of the species/habitats listed therein. These lists include, among others, the harbour porpoise, the Baltic seal species, and all seabirds (with few exemptions related to hunting for some species). Moreover, the recent EU Regulation on the conservation of fisheries resources and the protection of marine ecosystems through technical measures (Regulation 2019/1241/EU) states that "(t)he catching, retention on board, transhipment or landing of marine mammals (…) referred to in Annexes II and IV to Directive 92/43/EEC and of species of seabirds covered by Directive 2009/147/EC are prohibited".

The possibility to determine the mortality due to bycatch is dependent on whether data on bycatch rates and information on fishing effort are available in the studied areas. Information on population size and distribution is also useful when creating bycatch risk maps, and to put the estimated mortality into context (e.g. potential impact on populations). Thus, there is a need to collate available information on fishing effort, bycatch rates and populations size of the relevant species to support evaluations of bycatch and subsequently the impact on the species or populations of those species. Identification or estimation of high-risk areas for bycatch can be used to evaluate the level of pressure on non-target populations (e.g. porpoise, seals and waterbirds) from fishing activities, and thereby identify areas where monitoring of bycatch needs to be intensified, or where possible preventative measures could be considered.

In this project, various methodologies have been applied to selected species in different sub-regions in the Baltic Sea. While species such as the harbour porpoise have been focussed on, the selection of species and methodology are primarily determined by the data availability and thus by the practicalities in application of the evaluation.

For the harbour porpoise in the Skagerrak Sea, overlaying information on harbour porpoise densities and gillnet fishing effort has previously been used to identify high-risk areas for bycatch, modelling porpoise bycatch risk from these parameters (Kindt-Larsen *et al.*, 2016). In the present report, a similar approach could not be used across the whole region, as either fishing effort data, bycatch data or density data were not available locally, or not available at a suitable temporal and/or spatial resolution. However, in the Western Baltic, including the Kattegat, the Sound and the Kiel Bay, bycatch high-risk maps could be modelled from the combination of known fishing effort and documented porpoise bycatch from the Danish electronic monitoring programme. In the Baltic Proper, risk maps could be produced by overlaying fishing effort and harbour porpoise population densities.

Understanding the spatiotemporal variability of bycatch is important in order to implement adequate mitigation measures that reduce bycatch. There are relatively few mitigation measures available to reduce bycatch of marine mammals, e.g. fisheries closures or the use of alternative “bycatch-free” fishing gears. For echolocating cetacean like the harbour porpoise, a common bycatch reduction method in gillnet fisheries is the use of acoustic deterrent devices (called pingers). Pingers have previously been shown to reduce the bycatch of harbour porpoises while still maintaining catches of target species (Kraus *et al.*, 1997; Dawson *et al.*, 2013; Larsen and Eigaard, 2014). In the Baltic Sea, in order to prevent bycatch of harbour porpoises, the use of pingers is mandatory for vessels with an overall length of 12 m or more if fishing with bottom-set gillnet or entangling net in specified areas (EU, 2019). However, the harbour porpoise population in the Baltic Proper remains listed as critically endangered (CR) both by the IUCN (International Union for the Conservation of Nature) and HELCOM (HELCOM, 2013; IUCN, 2020). Therefore, urgent effective mitigation measures combined with better monitoring of the fishing effort of the gillnet fleet are necessary to better assess the causes and thereby halt further decline of the harbour porpoise in the Baltic Sea, as recommend by ICES (International Council for the Exploration of the Sea) (ICES, 2020a). ICES also recommends the use of pingers in the Baltic Sea during May–October in the sub-region defined by a line drawn between the island of Hanö, Sweden and Jarosławiec (near Słupsk, Poland) and a line drawn between 60.5°N on the Swedish coast and 61°N on the Finnish coast. Similarly, during November–April in EU waters, pingers are also recommended in the area between a line drawn along a longitude of 13°E between the Swedish and German coasts, and a line drawn between 60.5°N on the Swedish coast and 61°N on the Finnish coast. The cost and effectiveness of a full implementation of pingers in Baltic gillnet fisheries has not previously been evaluated. Therefore, the final aim of this study was to evaluate the costs of full pinger implementation in the Southern Baltic Sea, based on an example in the Swedish commercial gillnet fisheries from the southern Baltic.

2. Review of available data on fishing effort, population abundance and bycatch rates

I. Introduction

Estimating the impact of bycatch at population level requires bycatch-induced mortality to be calculated in the population(s) of concern, in relation to the estimated abundance of the population(s). The most basic information necessary for this in any given areas are: 1) the bycatch rates for the species of concern, 2) the distribution of the fishing effort, and 3) the population estimates for the species(s) of concern. In the Baltic Sea, peer-reviewed studies aiming at estimating bycatch rates in fishing gears of marine mammals and/or seabirds are relatively scarce. However, in some areas (e.g., Kattegat, the Sound and the Belt Seas), long-term studies using electronic monitoring (EM) with videos of commercial gillnet vessels have gathered important information to understand the scale of this issue for mammals and birds (Kindt-Larsen *et al.*, 2012; Glemarec *et al.*, 2020).

Nevertheless, estimating the bycatch rates of each marine mammal or seabird species across the entire Baltic Sea, and for each individual fisheries, is a substantial task and cannot be carried out identically through the region due to sub-regional specificities or data constraints. In this study, we focused on the most problematic fishing gear in terms of incidental catches, i.e. gillnets. In terms of gear type, this corresponds to trammel nets (GTR) or set gillnets (GNS). The species addressed in this report are: grey seal, harbour seal, harbour porpoise, great cormorant *Phalacrocorax carbo*, common eider *Somateria mollissima*, velvet scoter *Melanitta fusca* and common scoter *Melanitta nigra*, as these are species commonly recorded as bycaught in the region. In this section, all the available information on abundance and bycatch rates for the selected species from the Baltic Sea including (ICES subdivisions 20 to 31), from published and unpublished reports as well as peer-reviewed papers, was collated and reviewed.

In addition, fishing effort data from gillnet fisheries were collated when available from the countries operating in the study area (i.e., Poland and Sweden). In the EU, electronic logbooks (elogs) and Vessel Monitoring System (VMS) are mandatory for fishing vessels >12 m, while vessels > 10 m (or > 8 m in the Baltic Sea if these vessels have a quota for cod) need to carry a logbook (EU, 2016). Below this limit, vessels are not required to fill out daily logbooks, but may have to report monthly. For small-scale vessels not using logbooks, which constitute locally a large fraction of the fishing fleet, effort estimates can be derived from these monthly declarations (e.g., Sweden), as well as sales notes (e.g., Denmark). Nonetheless, logbooks and monthly declarations often lack the level of details that would allow understanding the spatiotemporal distribution of gillnet fishing effort. For instance, the number and the location of the nets, their length, the duration the nets were in the water fishing (soak time), with the notable exception of Sweden, where fishers must report detailed information on effort regardless of vessel size. The main outcome of this section of the work was an evaluation of available information on fishing effort in the study area, as well as suitable information on bycatch-vulnerable species (e.g., bycatch rates) that could be combined to estimate bycatch mortality or risk of bycatch.

Based on the summary of these multiple sources, we evaluated the possibilities for an in-depth analysis of the bycatch problem in different areas of the Baltic Sea and identified the current data gaps that may prevent, or weaken the confidence in, any possible assessment. The main objective of this was (1) to identify the areas of high-risk of bycatch for different groups or species (by collecting existing data on fishing effort, bycatch rates and abundance estimates), and (2) to specify the need for additional data to address the problem of bycatch in the identified high-risk areas, using a GAP analysis method.

A map showing the HELCOM Assessment Units (Scale 2, 17 sub-basins) overlaid with the ICES squares used for the collection of much of the project data is provided in Figure 6 (Annex III).

II. Methods

In our analysis, we focused on currently available bycatch rates data in commercial gillnets for marine mammals (harbour porpoise, harbour and grey seals) and seabirds (common eider, velvet scoter, common scoter and great cormorant) per ICES subdivision in the Baltic Sea, with an emphasis on subdivisions 21 to 26. We performed a literature review based on searches through peer-reviewed publications and sourced additional data from ICES, HELCOM, SAMBAH (Static Acoustic Monitoring of the Baltic Sea Harbour Porpoise) reports, as well as unpublished data in the so-called grey literature (Annex 1). We collected data on bycatch rates, individual counts, population densities and fishing effort. The data were summarised from tables and text in reports or peer-reviewed articles, and through personal communication with experts in the field when no published data were available. Annexes 1 and 2 list all the references included in the GAP analysis, together with the findings for the specific species in the area evaluated in this project.

III. Results

i. Fishing effort

In EU waters, commercial fishers typically report catches and fishing effort in logbooks, giving indications on gear type and fishing area, among other details. Generally speaking, logbooks are mandatory for all vessels >10m in overall length or all vessels >8m in overall length targeting cod in the Baltic Sea (EC, 2009; EU, 2016).

However, this can vary between Member States, based on vessel size and/or target species. For example, in Sweden and Poland, fishing effort is reported in logbooks for all vessels independent of size. Logbook data are provided in Days at sea (DaS) or for some countries in more detailed units such as kilometre of nets and soaktime (i.e. length of time nets are deployed). In Denmark and other countries for which a part of the fleet does not fill in logbooks, the overall fishing effort of vessels <10m needs to be derived from landing sales notes.

Fishing effort can also be derived from the STECF (Scientific, Technical and Economic Committee for Fisheries) where EU Member States report their effort in DaS. However, the reliability of these data is unknown. Fishing effort is also registered in the ICES RDB (Regional DataBase), as well as in the ICES WGBYC (Working Group on Bycatch of Protected Species) database, through an ICES data call, and presented in an ICES yearly report. As an example, Table 1 presents the summed annual fishing effort for 2018 in days at sea for the Swedish and Polish gillnet fleets, divided per ICES subdivision.

Table 1: Total gillnet fishing effort in Days at Sea in ICES subdivisions for the year 2018 in the Baltic Sea reported by Sweden and Poland.

ICES subdivision	**Days at sea**	
	Sweden	**Poland**
27.3.a.20	1149	
27.3.a.21	943	
27.3.c.22	1	
27.3.b.23	2467	
27.3.d.24	1323	2314
27.3.d.25	3151	11762
27.3.d.26	4	13684
27.3.d.27	2727	
27.3.d.28	424	
27.3.d.29	1088	
27.3.d.30	3508	
27.3.d.31	1929	

ii. Bycatch rate

Most available data on the bycatch rate of marine birds and mammals linked to a specific ICES subdivision were found in yearly ICES WGBYC reports. The data that go into the yearly WGBYC reports are data from the past year requested by a formal ICES data call. Each Member State participating in the process must also submit existing data from their monitored fisheries. These are mainly data collected within the EU data collection framework (DCF); however, pilot studies and research projects are also regularly submitted. Additionally, some peer-reviewed papers may present data on bycatch per area, yet, numbers on bycatch data published in the literature are scarce (see Annex 1). We found available data on the bycatch rate estimates for all of the selected species in subdivisions 20-25 (Table 2). Bycatch rates of seals and porpoises were missing in subdivision 26, and data on the bycatch rate of porpoises and seabirds were missing in subdivision 27. In subdivisions 28 and 31, we found no available data on the bycatch rate for any of the selected species. We were not able to find any data on bycatch rates of seabirds in subdivision 30. All references on bycatch rates and population estimates included in the GAP analysis are presented in Table 11 (Annex 1).

Table 2: Yearly averaged observed effort (days at sea), total fishing effort (days at sea), total number of species and bycatch rate (individuals bycaught per unit of fishing effort) for harbour porpoise, grey seal, harbour seal, common eider, great cormorant and other seabirds aggregated per ICES subdivision in the Baltic Sea area. Light blue indicates low bycatch rates (<0,1), mid blue indicates intermediate bycatch rate (0,1-0,5) and dark blue indicates high bycatch rates (>0,5). Grey areas indicate missing data. *unit=km-days, **only seals.

				Harbour porpoise		**Grey seal**		**Harbour seal**		**Common eider**		**Great cormorant**		**Other waterbirds**	
ICES subdivision	Year	Observed effort (DaS)	Fishing effort (DaS)	Total number of specimens	BYC rate (specimen/DaS)	Total number of specimens	BYC rate (specimen/DaS)	Total number of specimens	BYC rate (specimen/DaS)	Total number of specimens	BYC rate (specimen/DaS)	Total number of specimens	BYC rate (specimen/DaS)	Total number of specimens	BYC rate (specimen/DaS)
20	2013-2014	123	8515	22	0.18	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
21	2014-2015	40	2049	6	0.15	0	0.00	1	0.03	0	0.00	0	0.00	0	0.00
22	2012, 2014-2017	1251.8	70656, 419	31	0.02	0	0.00	0	0.00	6	0.00	4	0.00	20	0.02
23	2011-2012, 2014, 2017	1452	2281, 446	17	0.01	0	0.00	0	0.00	1	0.00	1	0.00	1	0.00
24	2014-2016	14.9	89938	0	0.00	0	0.00	0	0.00	0	0.00	5	0.34	0	0.00
	2006-2009	125								0	0.00	93	0.74	671	5.34
25	2016	44		0	0.00	1	0.02	0	0.00	0	0.00	0	0.00	0	0.00
27	2012-2013	1402**	7904			20	0.01	0	0.00						
28															
29	2017	23	13302	0	0.00	0	0.00	0	0.00	13	0.52	8	0.32		0.00
30	2012-2013, 2017	25	26017	0	0.00	35	0.02*	0	0.00	7	***	29	***	1	***
31	2008-2013					2	***	0	0.00						
32	2017	8	8861	0	0.00	0	0.00	0	0.00	3	0.38	29	3.63	1	0.13
20-21	2010	925		39	0.04	0	0.00	1	0.00						
25-32	2013	10	31607	0	0.00										

= < 0.1; = 0.1 – 0.5 = > 0.5;

* Unit: km-days; ** only seals; *** different units in observed effort which do not enable calculating bycatch rate

iii. Population abundance

Marine mammals

Four species of marine mammals coexist in the Baltic area (ringed, harbour and grey seals, and the harbour porpoise). Harbour porpoise population abundance estimates are available for subdivision 24 referring to the Baltic proper harbour porpoise population (SAMBAH, 2016). Estimations on the population size of harbour porpoises stretch over multiple subdivisions, due to the mobility of these populations. Estimates of the harbour porpoise population size across subdivisions 21-23 can be found in Hammond *et al.* (2017), population size across subdivisions 21-23 in Viquerat *et al.*, (2014) and across subdivisions 25-32 in SAMBAH (2016) and (Carlén *et al.*, 2018). Like harbour porpoises, seals travel extensively across their distribution range. Therefore, it can be difficult to separate seal populations in the Baltic Sea into single ICES subdivisions. Based on inventories of seals in the Baltic Sea, the Museum of Natural History in Stockholm (NRM) has made rough estimations (pers. com., Marcus Ahola, NRM) on the abundance of grey seals in ICES subdivisions 21-26. The harbour seals of the Baltic are divided into separate populations and, for this species, NRM estimated population abundance separately for ICES subdivisions 21, 22-24 and in subdivision 25 (pers. com., Marcus Ahola, NRM). Additionally, two studies estimated the population size of grey seal in the Baltic area (Vanhatalo *et al.*, 2014; Oksanen *et al.*, 2015) and one study estimated the abundance of ringed seal in subdivision 31 (Oksanen *et al.*, 2015). A summary of population estimates and sighted individuals per ICES subdivision and year of monitoring is provided for marine mammals (Table 3).

Seabirds

The Baltic Sea is an essential area in the life cycle of dozens of bird species, including for breeding, moulting, wintering, or as a resting halt during migration (Mendel *et al.*, 2008; Skov, 2011; Nielsen *et al.*, 2019; Petersen and Sterup, 2019). Some bird species are present year-long, while others are only seasonal. As a result, bird species abundance often needs to be assessed for both the breeding and the wintering populations as a minimum. Besides peer-reviewed articles, a large body of grey literature was analysed to extract the most up-to-date abundance estimates for these species (Table 12 in Annex 1). For each of the selected species, the national population abundance estimates in the HELCOM region, as well as the whole-Baltic population estimates, were obtained from the European Red List of Birds and references within (BirdLife International, 2015), and summed up for the breeding and the wintering populations (Table 13 in Annex 1). A summary of population estimates and sighted individuals per ICES subdivision and year of monitoring is presented for selected waterbirds (Table 4).

Table 3: Marine mammals- summary of population estimates and sighted individuals (per ICES subdivision and year of monitoring) was carried out for.

	Grey seal			**Harbour seal**			**Harbour porpoise**								
ICES SUB-DIVISION	**Sighted individuals (population estimate)**	**Reference**	**Year**	**Sighted individuals (population estimate)**	**Reference**	**Year**	**Population estimate**	**Reference**	**Year**	**Population estimate**	**Reference**	**Year**	**Population estimate**	**Reference**	**Year**
21	2500 (3700)	Data från inventering av säl (Naturhistoriska riksmuseet)	2018	10000 (15000)	Data från inventering av säl (Naturhistoriska riksmuseet)	2018	40,475	ICES WGBYC 2012	2011	42324	Hammond et al. (2017). Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys. Survey report, 40 pp, available from Universt St Andrews	2015	40475	Viquerat, Sacha, et al. "Abundance of harbour porpoises (Phocoena phocoena) in the western Baltic, Belt Seas and Kattegat." *Marine biology* 161.4 (2014): 745-754.	2012
22	2500 (3700)	Data från inventering av säl (Naturhistoriska riksmuseet)	2018	1000 (1500)	Data från inventering av säl (Naturhistoriska riksmuseet)	2018	40,475	ICES WGBYC 2012	2011	42324 21390	Hammond et al. (2017). Estimates of cetacean abundance in European	2015 1-2013	40475	Viquerat, Sacha, et al. "Abundance of harbour porpoises (Phocoena	2012

23											Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys. Survey report, 40 pp, available from Universt St Andrews			phocoena) in the western Baltic, Belt Seas and Kattegat." *Marine biology* 161.4 (2014): 745-754.	
24				1000 (1500) 1500 (2100)	Data från inventering av säl (Naturhistoriska riksmuseet) Data från inventering av säl (Naturhistoriska riksmuseet)	2018 2018					SAMBAH, 2016a. Final report for LIFE+ project SAMBAH LIFE08 NAT/S/000261 covering the project activities from 01/01/2010 to 30/09/2015. Reporting date 29/02/2016, 80pp.				
25															
26															

Table 4: Seabirds - summary of population estimates and sighted individuals for selected species (per ICES subdivision and year of monitoring).

	Common eider			**Cormorant (sighted individuals per area)**			**Scoters (sighted individuals per area)**		
ICES SUBDIVISION	**Sighted individuals per area**	**Reference**	**Year**	**Sighted individuals per area**	**Reference**	**Year**	**Sighted individuals per area**	**Reference**	**Year**
20	1005	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019	214	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019	72	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019
21	1515	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019	591	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019	17212	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019
22									
23	5631	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019	2447	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019	0	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019
24	1	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019	264	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019	32	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019
25	17	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019	2350	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019	808	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019
26									
27	0	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019	1	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019	0	Data from monitioring in January (Svensk Fågeltaxeringen, Lunds universitet)	2019

IV. Discussion

Through our analyses, we gathered estimations of the bycatch rates of seabirds and marine mammals in ICES subdivisions 21-26. In these areas, we collected data on bycatch for the species of concern, as well as gillnet fishing effort for Sweden and Poland. Generally, information on bycatch rates in the Baltic Sea were limited, which prevents in-depth bycatch mortality assessments in many subdivisions for the selected vulnerable species (i.e., harbour porpoise, grey and harbour seals, common eider, common and velvet scoters, and great cormorant). For example, in ICES subdivisions 24-25, 184 days at sea were monitored between 2006 and 2018 in gillnet fisheries (Table 2, Annex 1), where only one bycatch of a grey seal was registered, as well as a large number of seabirds. In areas farther north (ICES area 25-31), there were even fewer observed days at sea, if not including monitored days at sea using interviews as a method (e.g., projects where fishermen from smaller vessels were interviewed on their return to harbour). Therefore, it was not possible to assess bycatch mortality in the Northern Baltic for the different species under scrutiny. Conversely, in ICES subdivisions 21-23, fishing effort and bycatch rates could be estimated for the whole fleet, using a combination of logbooks, sales notes and observed bycatch data. Logbook data offered a census of the fishing effort in Poland and Sweden. In Denmark and Germany, fishing effort from large vessels was available from ICES WGBYC reports, but the majority of the fleet in these countries is composed of small vessels (<10m), which do not report their activity in logbooks. In Denmark, fishing effort could be extrapolated for the fleet by combining sales notes, logbooks and from historical records of Automatic Identification System (AIS) data, an automatic tracking system that uses transponders on ships (including fishing vessels) (Natale *et al.*, 2015; ICES, 2019).

Abundance estimates for the selected species were collated for part of the Baltic. However, since all species of concern are highly mobile and many populations stretch across multiple subdivisions, it was not possible to extract the abundance per specific area. Harbour porpoise abundance estimates, as well as spatial distribution was available. For many of the bird species, sighting data had been collected per ICES subdivision, but fine-scale data on the spatial distribution were often lacking. For seals, abundance estimates were available in some areas, but not the detailed spatial distribution. To produce bycatch high-risk maps, fine-scale information on fishing effort is necessary (e.g., position of the fishing gear, soak time, length of the net fleets). Using the collected data, mapping high-risk bycatch areas was only possible for harbour porpoise in the Western and Southern Baltic Sea. In these areas, spatiotemporal information on harbour porpoise abundance was available together with detailed fishing effort data. However, it was not possible to produce high-risk maps for all the vulnerable species for the entire Baltic Sea, since detailed data on species abundance and/or distribution, as well as fine-scale fishing effort data were not available across the region.

3. Identification of bycatch high risk areas for harbour porpoise

I. Introduction

The harbour porpoise is one of the most iconic marine mammal in the Baltic Sea and the additional mortality from bycatch in gillnets is considered to be a critical factor in the fate of the different sub-populations in the HELCOM region, especially for the Baltic Proper subpopulation, currently listed as critically endangered (HELCOM, 2013). Establishing maps to identify the areas where the risk of bycatch is high is vital to support the implementation of effective mitigation measures that reduce bycatch mortality. However, limited financial resources often lead managers to focus bycatch-monitoring effort on specific fisheries where a high risk of bycatch is suspected (if resources for monitoring are available at all), which in turn can result in biased data and ultimately unreliable bycatch mortality estimates. Combining dedicated bycatch monitoring data where they exist with other data sources provides a valuable resource for fisheries managers and guide precautionary management. It is also important to acknowledge that applying a single common method to identify the areas of high risks of bycatch is not currently feasible at the scale of the entire Baltic Sea, thus different data strands and approaches will need to be combined in various ways to provide management support.

The issue of bycatch is further complicated by factors such as the behaviours or seasonality of the species vulnerable to capture in fishing gears. These issues mean that optimal assessments require data with a high degree of resolution but also often a sufficient frequency to address seasonality. The areas and/or seasons where the risk of entanglement of harbour porpoise is the highest can be identified, e.g. by overlaying temporal harbour porpoise densities and gillnet fishing effort distribution (Kindt-Larsen *et al.*, 2016). Nevertheless, fishing effort and/or porpoise distribution data are missing in large parts of the Baltic Sea. Fisheries monitoring programmes using on-board observers or Electronic Monitoring (EM) with videos, which are often considered the most reliable sources of data on the bycatch of protected species, are expensive and can be challenging to implement (Kindt-Larsen *et al.*, 2012; Plet-Hansen, Bergsson and Ulrich, 2019; Helmond *et al.*, 2020). The objective of this study was to develop bycatch risk maps in areas where enough data was available. Here, we used two methods to establish harbour porpoise bycatch risk maps of in the Western Baltic. In ICES subdivisions IIIa21, IIIb23 and IIIc22, we analysed the long-time series of fine-scale fisheries-dependent data collected using EM with videos on Danish commercial fishing vessels, combined with logbooks and sales notes, to estimate the risk of harbour porpoise bycatch in gillnets, using a modelling approach. In the Baltic Proper, in Swedish and Polish waters, we estimated the relative risk of bycatch by overlapping the porpoise densities, obtained from the SAMBAH project, with the distribution of the gillnet fishing effort in the area.

An overview of the ICES subdivisions used in this report and the HELCOM assessment units (sub-basins) is provided in Annex 3 (Figure 6).

II. Methods

i. Data sources

Gillnet fishing effort data

Since different countries report their catch and effort differently, depending on the vessel size, effort data with different units have been used in the bycatch risk mappings.

Swedish fishing effort data

Following Swedish and EU regulations, fishers must report landings and effort, regardless of vessel size. However, reports differ depending on vessel size. In the Baltic Sea (subdivisions 22 to 31), Swedish fishers have to report on a daily basis if they use a fishing vessel above 8 metres in overall length (and regardless of vessel length if they use a trawl), but must report on monthly basis if the vessel is smaller than 8 metres (EU, 2015, 2019).

In gillnet fisheries, soak time is reported differently between logbooks and monthly journals, respectively in hours and in days. For fishers reporting daily, logbook data include gear type (various gillnet types), mesh size, soaking time (in hours), as well as total net length. Additionally, for each gear type, the average position of the gears is reported to the nearest degree and minute. For fishers reporting on a monthly basis, fishing effort is reported in a monthly journal as soaking (days) times and net length averaged over the past month. Additionally, the fishing effort is categorised by target assemblage:

- DEF – Demersal Fish (typically, cod *Gadus morhua* and various flatfish species),
- FWS – FreshWater Species (typically, European perch *Perca fluviatilis*),
- SPF – Small Pelagic Fish (typically, herring *Clupea harrengus*),
- OTH – Other anadromous species.

For small vessel length classes (<8 metres), fishing effort is reported in monthly journals as 'days at sea' (DaS). Therefore, to avoid overestimating fishing effort, realistic soak durations were calculated from the target species group reported in the journals. For instance, soak times from logbook data averaged 22 hours (i.e. 0.9 days) for *DEF* métiers (fisheries targeting demersal fish), while it approximated 13-14 and 5-7 hours, respectively, for fisheries targeting freshwater (*FWS*) and small pelagic species (*SPF*). In turn, soak times reported in monthly journals were corrected using a gear-specific factor, corresponding to the median soak duration for each target species group (Table 5).

Table 5: Median soak time factor for the fisheries target species groups (in percentage of 24 hours). This factor is used to correct the soak time reported to the monthly journals.

Grouping category	Soak time factor
DEF	0.92
FWS	0.58
SPF	0.21
OTH	0.58

In addition, the *DEF* category was divided into three sub-classes corresponding to the different net mesh sizes (stretched diagonal) used in this fishery (<120 mm; 120-220 mm; >=220 mm). The effort metric (total net length times 24 hours, or meter.day) was stratified temporally (month) and spatially (grid cells of dimension 5000x5000 metres). Data were collected in ICES subdivisions 21 to 29 (i.e. the whole Baltic Sea) for the period 2014-2018.

Polish fishing effort data

In contrast with many HELCOM Contracting Parties that are also EU Member States, in Poland, like Sweden, fishing effort is reported regardless of vessel size. Fishers must report their catch and effort on a monthly and daily basis to the EU logbook. For this study, the national Fisheries Monitoring Centre provided data on fishing effort for Polish fishing operations with static fishing gears (GNS), in 2018. A quality check was carried out to check if reported data was complete. Information on the length of the fishing gears was not available in the monthly reports, therefore, fishing effort was counted in Days at Sea (a unit accepted during the DCF *Workshop on Transversal Variables, Cypr, Nikozja, 2016*[1]). Data were provided in the most accurate available geographical scale (the Baltic sea squares), in size longitude 20' minutes x latitude 10' minutes, coordinates were set for the middle of the square.

Danish fishing effort data

In Denmark, official logbooks are not as precise as, e.g., their Swedish or Polish counterpart. For instance, Danish fishers only report the number of fishing operations or number of hauls per fishing trip per ICES rectangle (a square of 30 nm^2). Lacking fine-scale information on the positions of the gears, the Danish logbook data were augmented with sales notes and, when existing, with a combination of VMS (Vessel Monitoring System) and AIS (Automatic Identification System) data. In addition, information on soak time and net length is also missing from Danish logbooks. Estimates were nonetheless available for the electronic monitoring (EM) with videos of nine commercial gillnetters operating in the region from 2010 to 2018. The mean estimates were stratified per ICES subdivision and mesh size, and these mean values were extrapolated to the whole fleet based on the

[1] https://ec.europa.eu/jrc/en/publication/report-2nd-workshop-transversal-variables-nicosia-cyprus-22-26-february-2016-dcf-ad-hoc-workshop

mesh size registered in the logbooks. However, some target assemblages (métier Level 5) registered in the logbook data were underrepresented in the EM data. Furthermore, gear type is specified in the logbooks, yet, for vessels below 8 metres where no logbook data were available this information had to be inferred from the records in the fleet register combined with the landings data. These data were verified by fisheries observers at the National Institute of Aquatic Resources (DTU Aqua) and/or by looking at pictures of the corresponding small-sized vessels on *fiskerforum.dk*. The target assemblages were extracted from the registered métiers: *DEF*, *FWS* and *SPF* were retained in the dataset as is, and all other target species groups were referred to as *OTH*. A small number of fishing trips registered European eel *Anguilla anguilla* as their main target, but these were likely misclassifications and the corresponding fishing trips were excluded from the dataset.

Harbour porpoise distribution data

In the Static Acoustic Monitoring of the Baltic Sea Harbour Porpoise (SAMBAH, www.sambah.org), eight EU Member States around the Baltic Sea (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland and Sweden) joined effort to survey the distribution and abundance of harbour porpoises in the Baltic Sea by using passive acoustics and, thereafter, spatial modelling to describe the harbour porpoise spatial and seasonal distribution (Carlén *et al.*, 2018). The average probability of detection of harbour porpoises in the Baltic Sea from May 2011 to April 2013 over three-month periods was used to follow the harbour porpoise life cycle and seasonal migration pattern.

Harbour porpoise bycatch data

The monitored fishing effort data from the different countries listed above were combined into a single dataset. Across the region, no bycatch of harbour porpoise was documented in gillnets using small mesh sizes. Therefore, the dataset was limited to fisheries with meshes of at least 120 mm, which excluded *de facto* all SPF (small pelagic species) fisheries.

In the resulting dataset, harbour porpoise bycatch was only been registered in the portion of the Danish gillnet fleet carrying EM systems with video. Specifically, the incidental captures of porpoises were systematically recorded in nine Danish commercial gillnet vessels from May 2010 to December 2018, operating in ICES subdivisions IIIa21 (Kattegat), IIIb23 (the Sound) and IIIc22 (the Belts). The EM systems recorded time, position and video footage of all trips (port to port). The video footage of each individual net string was analysed using a dedicated EM analysing software. The start and end of a haul were defined as the moments where the first and the last panel of a net string broke the water surface. Net string length was estimated as the distance between the location of the start and the end of a haul. Soak time was obtained by subtracting the mean time of setting a net string from the mean time of hauling the same net string. Finally, fishing effort was calculated as the product of net string length and soak time (details of the method in Kindt-Larsen *et al.* (2012), updated in Glemarec *et al.* (2020)). The vessels monitored with EM were for the most part targeting demersal species (*DEF*), with very few EM data for the other métiers (i.e., freshwater species *FWS*, small pelagic species *SPF* and other species *OTH*). Since we could not assume that the bycatch rates in these métiers would have been similar to the ones observed in *DEF*, we excluded métiers other than *DEF* from the dataset.

ii. Bycatch risk mapping method based on logbook data and porpoise distribution (Baltic Proper)

The risk of bycatch of harbour porpoise can be spatially plotted by multiplying the harbour porpoise density with the fishing effort giving a spatial relative risk of bycatch in the specific area (Kindt-Larsen *et al.*, 2016). Sweden and Poland are countries where logbook effort is reported in detail to responsible agencies. The probability of detecting a harbour porpoise was derived from the SAMBAH project data. Seasonal maps of the relative risk of bycatch of harbour porpoise in Swedish and Polish waters were produced by multiplying the probability of detection of harbour porpoises from May 2011 to April 2013 (Carlén *et al.*, 2018) with the distribution of static net fishing effort. The Swedish fishing effort data used here were reported to the Swedish Agency for Marine and Water Management for 2019, and includes the fishing activity measured as meters of net and soaked days for all mesh sizes. The Polish fishing effort data, collated from the fishing reports downloaded from the National Fisheries Monitoring Centre database in Poland for 2018, consisted mainly of gillnets recorded as metier (GNS), measured as Days at Sea (DaS). Because of the difference between the registered metrics, the bycatch risk in each country could not be compared directly and the corresponding maps are thus presented separately.

iii. Model description of bycatch risk maps based on a modelling approach (Western Baltic)

We developed a generalised linear model using harbour porpoise bycatch data from the extensive EM programme in the Danish commercial gillnet fisheries, combined with fishing effort from Denmark and Sweden to predict bycatch as a function of effort, spatial coordinates and mesh size in ICES subdivisions 21, 22 and 23. The model was fitted as follow:

$$Log\ E(Y_i) = \mu + Log\ (m_i) + I(mesh_i\ > 120)\alpha + X(lon_i; lat_i) \qquad (1)$$

where Y_i is the number of harbour porpoises observed in the i^{th} haul, μ is the overall mean (on log scale), *m* is the effort in units of meter-days, $I(mesh_i > 120)$ is an indicator function with value 1 if the mesh size is greater than 120 mm and 0 otherwise, α is the corresponding coefficient for the effect of large mesh size compared to small, and *X* is a stationary spatial field with exponentially decreasing correlation as a function of Euclidian distance between to spatial points. The latter implies that the predicted bycatch rates in unsampled spatial regions went towards the overall mean of the data when moving further away from the data points. This rate of decorrelation was estimated as a parameter in the model. The response was assumed to follow either a Poisson or a negative binomial distribution. We restricted ourselves to consider only two mesh size categories, because there are very limited data outside the main category (120-200 mm). However, it is expected that smaller mesh sizes have substantially less porpoise bycatch (Northridge *et al.*, 2017). Proportionality was assumed between the effort m and expected bycatch $E(Y)$ (log(m) was used as a model offset, i.e. the coefficient was assumed to be 1). The model was fitted in the statistical language *R* using the *glmmTMB* package (Brooks *et al.*, 2017; R Core Team, 2020).

The maps of the estimated total harbour porpoise bycatch in the Swedish and Danish *DEF* métier were created by multiplying the bycatch rates calculated from the model with the sum of observed fishing effort in each spatial grid. Figure 1 presents the distribution of the gillnet fishing effort in 2018 for métier *DEF* in ICES subdivisions 21, 22 and 23.

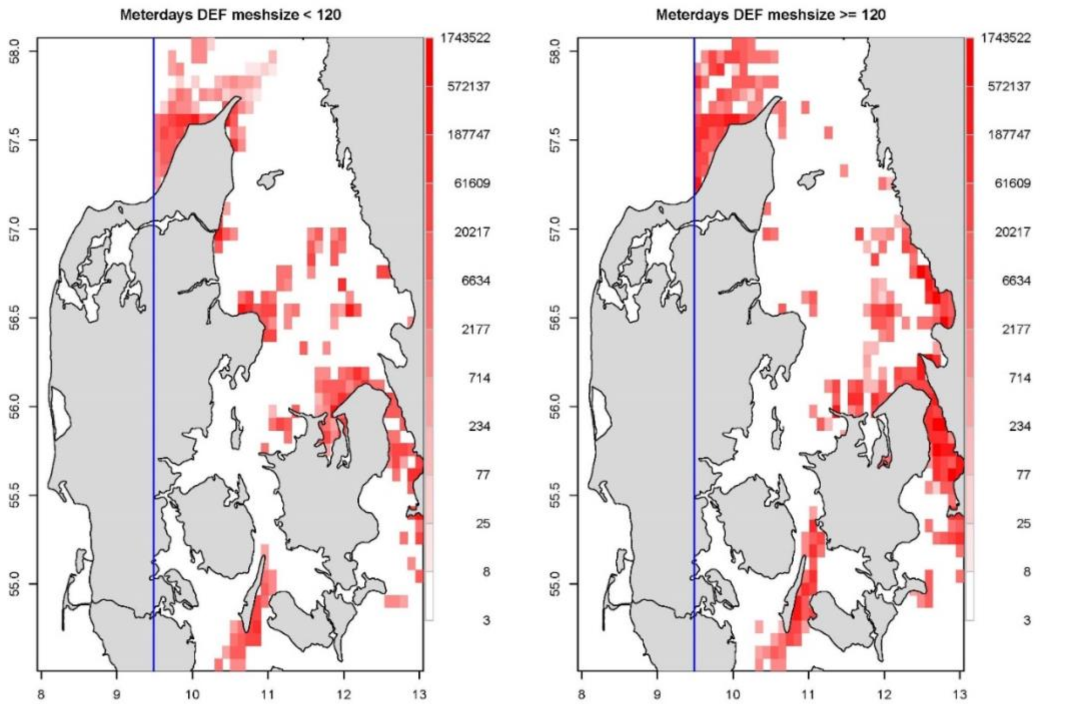

Figure 1: Total effort (metre.days) in 2018 by mesh size - Danish and Swedish "DEF" metiers only. The blue vertical line indicates the western border beyond which no fishing effort data were provided.

III. Results

i. Bycatch risk maps based on logbook data and porpoise distribution (Baltic Proper)

Bycatch risk maps, Sweden

The temporal variation in risk of bycatch was addressed by producing maps that followed the life cycle of the harbour porpoise. For Swedish and Polish fisheries, respectively, four maps with data summed for February to April, May to July, August to October and November to January of the year 2019 were produced. The maps produced for Swedish waters represent the fishing period before and after the Baltic cod fishing ban, and thus show the potential risk of bycatch before and after the regulation was put into place (n 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 gillnet fisheries for cod in waters deeper than 20 meters in ICES subdivision 24, and in all gillnet fisheries for cod in subdivisions 25-32. Trawl fisheries targeting cod in the area was also affected. In subdivisions 24 and 25, gillnet fisheries were mainly targeting cod, therefore the ban resulted in a significant decrease in gillnet fishing effort in these subdivisions since 24th July 2019. For Polish waters, the summarized fishing effort in each Baltic sea-square (longitude 20’ minutes x latitude 10’ minutes) was multiplied with the probability of detection of harbour porpoises provided by the SAMBAH project. Evaluating the maps produced for Swedish waters (Figure 2), the highest bycatch risk occurs around the southern tip of Sweden. However, Hanö Bight, the bay area on the south eastern part of Sweden, can also be seen as a high risk area. The Northern and Southern Midsea Banks, situated off-shore south of Gotland and east of Öland do have risk of bycatch, but only temporally and in small, scattered areas. The remaining risk is mainly spread out along the coasts of the Swedish mainland northeast of Hanö Bight, and along the coast of the islands of Öland and east of Gotland. The cod ban came into force at the end of July. The bycatch risk maps from August to October and November to January (January being January 2019 when no cod ban was yet in place) show a decrease in risk of bycatch in Hanö Bay and further away from the shore in waters outside south of Sweden. There is also a decrease in bycatch around northern Öland due to the decrease in gillnet effort in the area. However, the risk of bycatch is still high in areas close to shore most likely because fishing with gillnets is allowed within 20 meter depth in ICES subdivision 24.

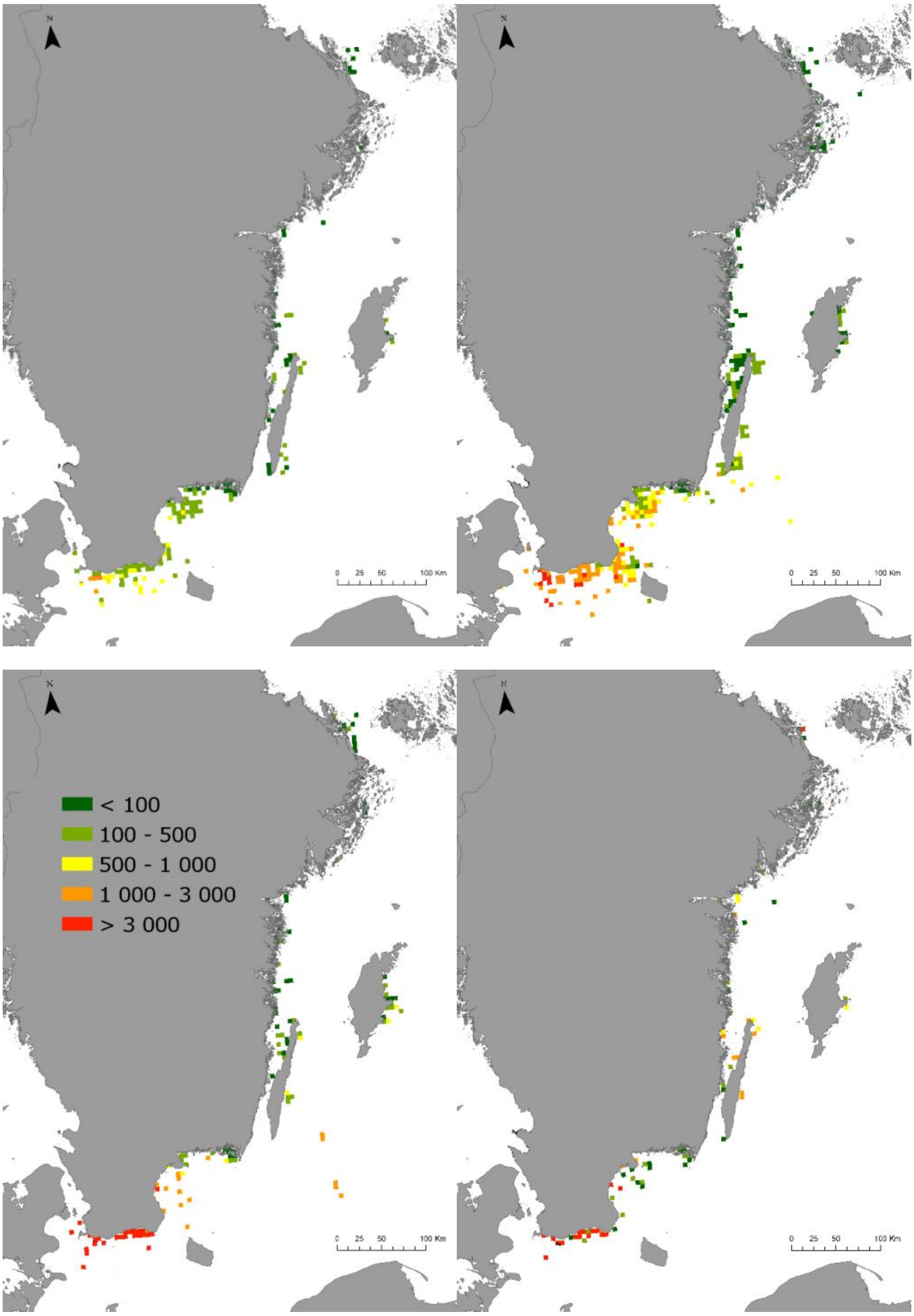

Figure 2: Relative bycatch risk for harbour porpoise, estimated as the probability of harbour porpoise detection during May 2011-April 2013 (data from Carlén et al. *(2018)) multiplied by gillnet fishing effort reported to the Swedish Agency for Marine and Water Management for 2019. Top left: Feb-Apr 2019; top right: May-July 2019; lower left: Aug-Oct 2019 (gillnet effort data after implementation of cod fishing ban); lower right: Jan 2019 (gillnet effort data before the cod fishing ban) and Nov-Dec 2019 (gillnet effort data after the cod fishing ban).*

Bycatch risk maps – Poland

Polish effort data was only reported as Days at Sea. A finer measure of fishing effort, including soaktime and net length, could not be used, so the uncertainty of the resulting risk maps is higher than for the Swedish maps, and the two cannot be compared directly. Moreover, in this area, the detection of harbour porpoises were low compared to areas along the Swedish coast, which resulted in a situation where it is mainly the fishing effort intensity which dictates the output of the maps. It is important that these factors be taken into account when interpreting the maps.

Nevertheless, the risk of bycatch seems to be high in the Western part of Polish waters during all seasons, and highest between August and October. From May to October, the risk of bycatch is low in Eastern Polish waters around the Puck bay, an area where bycatch of harbour porpoise has been reported. Risk of bycatch increases in November until April in that area.

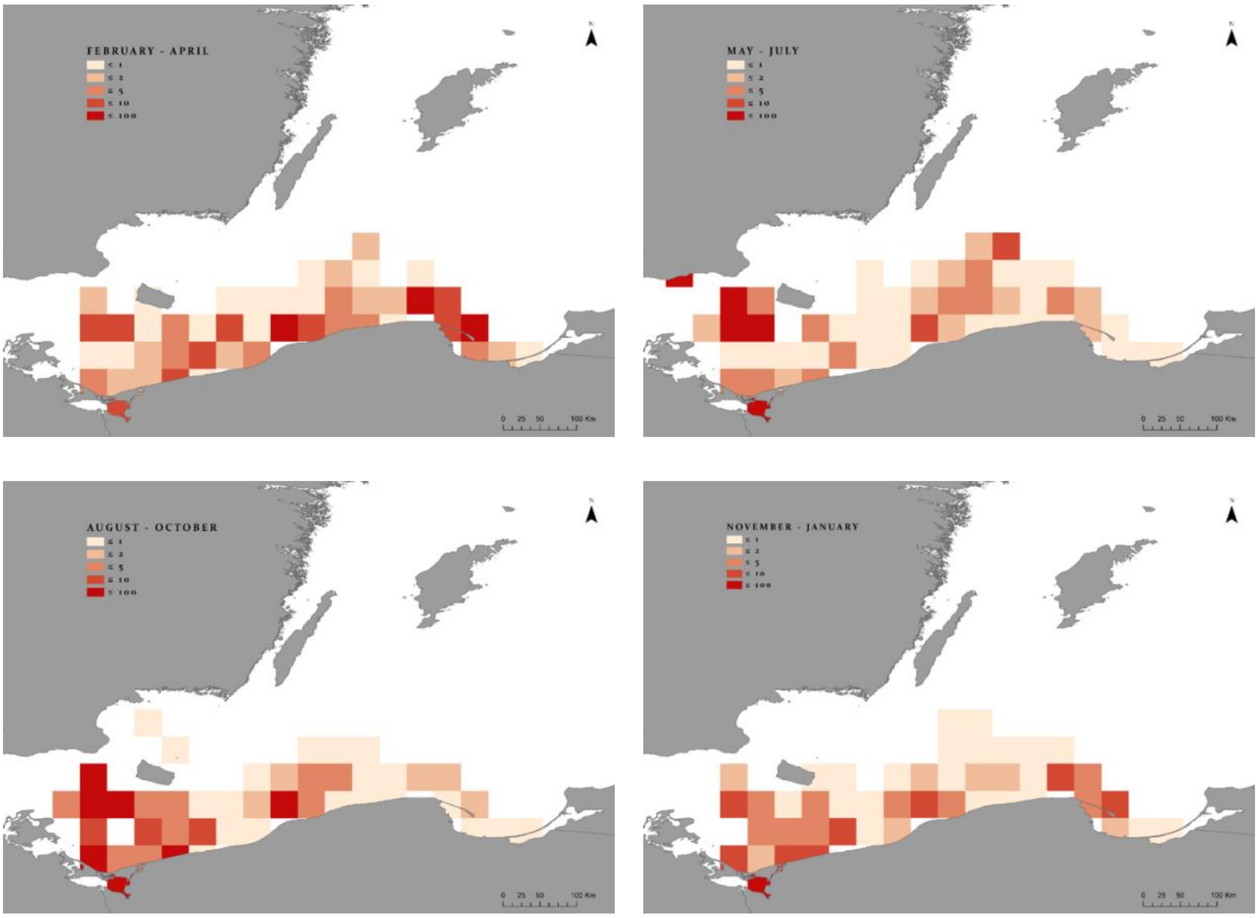

Figure 3: Relative bycatch risk for harbour porpoise, estimated as the probability of harbour porpoise detection during May 2011-April 2013 (data from Carlén et al. *(2018)) multiplied by gillnet fishing effort reported by the National Fisheries Monitoring Centre database in Poland; top left: Feb-Apr 2018; top right: May-July 2018; lower left: Aug-Oct 2018 ; lower right: Jan 2018 and Nov-Dec 2018.*

ii. Bycatch risk maps based on a modelling approach (Western Baltic)

The Poisson assumption was rejected in favour of the negative binomial (ΔAIC = 35.8). The parameter α, the effect of large mesh sizes compared to small, was estimated to be 0.2723, indicating that large mesh sizes have exp(0.2723) ⍰ 1.3 times higher bycatch rate. However, the standard error of this estimate was 0.61, which implies that its effect is not statistically significant. We chose not to remove it from the model, since the effect aligned with our prior expectation that larger mesh sizes have higher bycatch rates. Figure 4 presents a map of the estimated bycatch rates in the study area and its associated uncertainty.

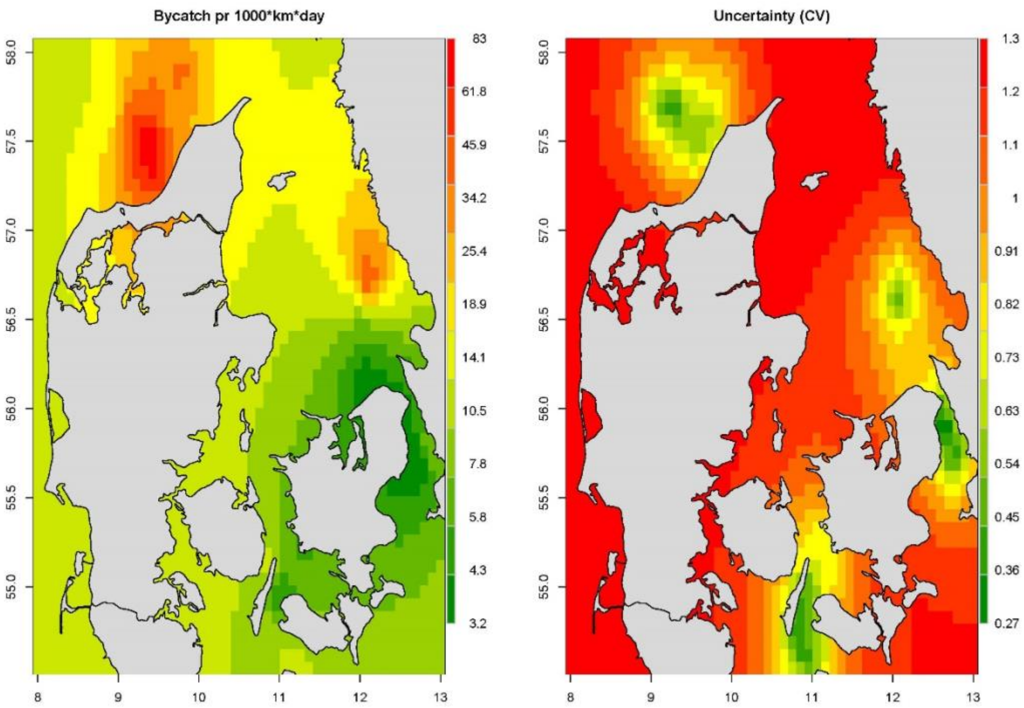

*Figure 4: **Left**: Estimated bycatch per unit effort (number of porpoise per 1000 km.day). **Right**: Uncertainty of the estimates on left map (coefficient of variation). The green/yellow regions in the uncertainly map (right) indicate where data are present, whereas red areas are unsampled and thus quite uncertain.*

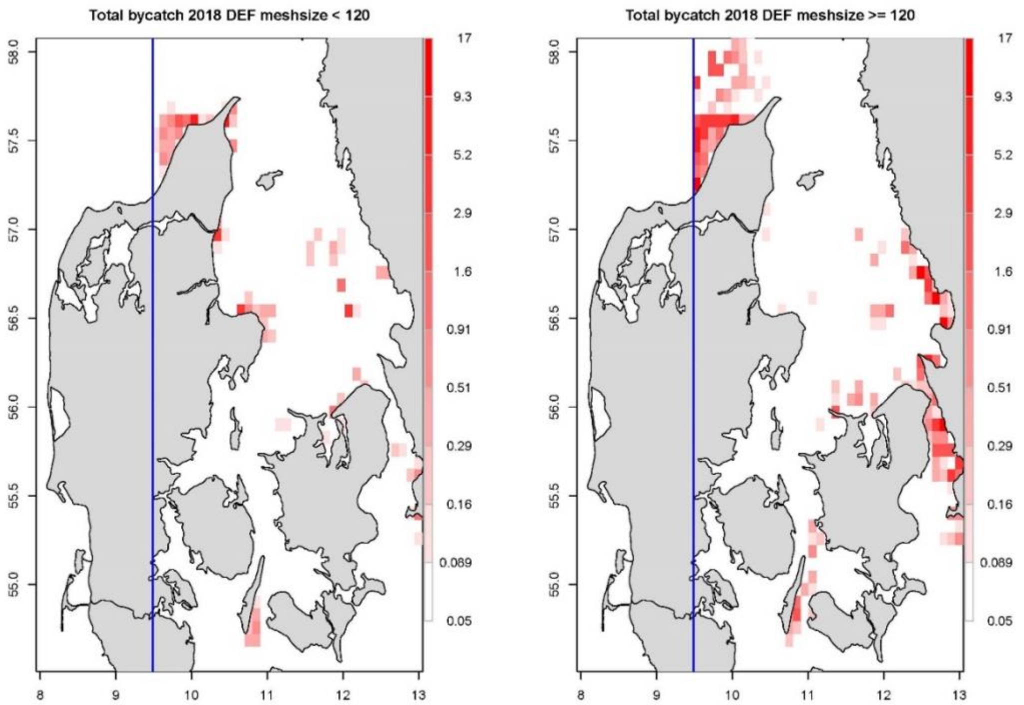

Figure 5: Estimated porpoise bycatch for the year 2018. Left: total porpoise bycatch in gillnets using mesh sizes <120 mm; Right: total porpoise bycatch in gillnets using mesh sizes ≥120 mm. These estimates were obtained by multiplying the estimated fishing effort (Figure 1) and the estimated mean porpoise bycatch rates (Figure 4 - Left). The blue vertical line indicates the western border beyond which there was no effort data provided. Only Danish and Swedish effort data were available, so these estimates do not take into account additional bycatch from the German gillnet fleet, notably in the most southern end of the maps.

IV. Discussion

In this section, we developed methods to identify the areas of the Baltic Sea where the risk of bycatch of harbour porpoises in commercial gillnets is highest. Using detailed logbook data and predicted spatiotemporal porpoise distribution, we established the relative bycatch risk along the Swedish (Figure 2) and Polish coasts (Figure 3). In the Kattegat and in Inner Danish waters, previous satellite-tracking of harbour porpoises showed some clear seasonal distribution shifts between the different populations in this area (Sveegaard *et al.*, 2011), highlighting potential conflicting areas between the cetaceans and gillnet fishers. In addition, Kindt-Larsen *et al.* (2016) demonstrated that, for the Skagerrak population, harbour porpoise captures were proportional to the intensity of the fishing effort in areas where there is a known overlap between porpoise densities and gillnet fishing activities. Therefore, our approach in the Western Baltic was to estimate bycatch mortality from observed captures and a census of the gillnet effort in the area in the year 2018. We estimated bycatch risks in ICES subdivisions III21, III22c and III23b using long time-series of porpoise bycatch registrations from electronic monitoring of Danish commercial gillnetters (Figure 4 Left), combined with the predicted distribution of the Swedish and Danish gillnet fishing effort in the area (Figure 1). With this, we could model and estimate porpoise bycatch at fleet level (Equation (1) and Figure 5).

Moreover, the associated uncertainty of the bycatch estimates (Figure 4 Right) allowed assessing the confidence of these estimates.

The bycatch risk maps in Swedish waters (Figure 2) show that the highest bycatch risk is in the southern Baltic waters. This area is primarily used by the Belt Sea harbour porpoise population during May-October, while both this and the Baltic Proper populations occur here during November-April (Carlén *et al.*, 2018). The second highest bycatch risk is in Hanö Bight. During May-October, the north-eastern side of Hanö Bight is primarily used by the Baltic Proper harbour porpoise population, and the south-western side by the Belt Sea population (Carlén *et al.*, 2018). There is also a minor risk of bycatch spread out along the coasts of the Swedish mainland northeast of Hanö Bight, and along the coast of the islands of Öland and east of Gotland. These areas are within the distribution range of the Baltic Proper population year-round. Since the risk of bycatch is dependent on the spatial distribution of fishing effort, and the maps have used data from 2019, the bycatch risk has been affected by the implemented cod fishing ban. Because of the cod fishing ban, the gillnet effort decreased significantly from July 2019 when the Commission Regulation (EU) 2019/1248 entered in force. Thereby, the risk of bycatch of harbour porpoise along the Swedish coast decreased considerably due to the decreased effort caused by the cod fishing ban (Figure 2) upper figures compared to lower figures). However, in August 2019 when the cod ban was implemented, the risk of bycatch along the Southern coast appeared to be concentrated near shore, in waters below 20 meters where gillnet fisheries for cod was still allowed. However, the risk of bycatch further off shore and in Hanö Bay, the east bay area, decreased and the risk of bycatch around Öland and Gotland, the islands in the Baltic Proper, almost disappeared. This is mainly due to the introduction of the new Regulation (EU) 2019/1248, followed by (EU) 2019/1838, since the main target species for gillnet vessels in the South and Central Baltic is cod.

The bycatch risk maps in Polish waters (Figure 3) are based on Polish fishing effort reported in Days at Sea. Lacking detailed information, we assumed that the length of nets were similar in all Polish gillnet fisheries. As a result, the relative bycatch risk should only be compared within Polish waters and is not directly comparable with the relative bycatch risk from Swedish waters (Figure 2). In Figure 3, the bycatch risk seems to be higher in eastern part of polish waters during August to October. The porpoise distribution according to Carlén *et al*. (2018) seems to indicate that the cetacean are concentrated in the Baltic proper (Midsea bank) in August, with high concentrations in areas south of Sweden (ICES subdivision 24). However, harbour porpoise from both populations forage in these areas, especially between November and April. In addition, there seems to be a higher detection of porpoises in January and February in Western Polish waters (Carlén *et al.*, 2018). The bycatch risk in this area is high related to other areas and time periods from August to January. From February to April, the bycatch risk in the western end of Polish waters is also relatively high, while in the eastern part, the relative risk of bycatch is higher from November to April.

Methods combining fishing effort distribution and harbour porpoise densities are useful to identify the areas where conflicts are likely occurring using relative bycatch risk. This information can be utilised to guide management decisions aiming at protecting vulnerable porpoise populations. However, in a management perspective, quantifying total bycatch at fleet level is also important. Generally, this requires to combine a full census of the fishing effort intensity and distribution in the study area (e.g., using a combination of official logbooks, sales notes, monthly reports and AIS data) with a representative sample of the fishing activity of the fleet (e.g., using electronic monitoring or exhaustive fishers reported bycatch records where they exist) over long periods. In this study, we collected fishing effort data from all Danish and Swedish gillnet vessels operating in the Western Baltic. German gillnet fishing effort, despite being substantial in the region, notably in the Southern part of ICES IIIc22, could not be included in this study since most of the German gillnet fleet is composed of numerous small vessels for which logbook registration is not mandatory. Therefore, the fishing effort distribution of the German gillnet fleet in the Western Baltic remains largely unknown.

Additionally, self-reported logbook data may not be entirely accurate as highlighted in previous studies (Kindt-Larsen, Kirkegaard and Dalskov, 2011; Mangi *et al.*, 2015), which cast some uncertainty on the fishing effort distribution estimates. Furthermore, small vessels below 10 metres in overall length are normally not required to fill in logbooks, but only sales notes (the limit is down to 8 m for vessels targeting cods in the Baltic Sea). This reduces even more the precision of the fishing distribution estimates.

Mean bycatch rate estimates in the Western Baltic were calculated using bycatch registrations from the Danish electronic monitoring (EM) programme. We assumed that the bycatch rates on the Danish and Swedish vessels were comparable, and that the bycatch rates in the Danish fleet could be applied to the Swedish fleet. However, the Danish vessels sampled with EM represented only a small fraction of all the gillnetters operating in the area, so a possible lack of representativity cannot be excluded. Nevertheless, because the fishers participating in the bycatch data collection were volunteers and were aware of the constant monitoring of their fishing activity, they may have paid more attention to bycatch of vulnerable species than fishers not monitored with EM, e.g. by avoiding fishing in areas (and at times) where (and when) they believed large bycatch events would occur. Therefore, and despite a possible lack of representativity, the bycatch rates estimated here are likely below what a perfectly designed sampling programme would come up with. These estimates thus ought to be considered as minimum bycatch rates, which constitutes an important step forward for management and a baseline a baseline for future assessments.

In addition, for the vessels fishing in the Kattegat, only 27 valid fishing trips could be used to estimate bycatch rates. Local large bycatch events, with up to 24 harbour porpoises captured in one trip may have influenced the mean bycatch rate estimates. This is reflected in Figure 4 (right panel), where the map shows the coefficient of variation (i.e. the uncertainty) of the bycatch rate estimates. In the Northern and Western part of the Kattegat, as well as in the Northern part of the Belt Seas, the uncertainty was also very high. There were substantially higher bycatch rates in the Northern parts of the study area (in the Kattegat) compared to the two southern effort clusters, i.e., the Sound and around the island of Langeland (Figure 4 Left). However, due to the high amount of fishing effort in these clusters, in particular in the Sound, the estimated total bycatch is still substantial (Figure 5).

Despite the limitations of the datasets stated above, we could estimate harbour porpoise bycatch mortality in the year 2018 in commercial gillnets in the Western Baltic. However, because the fishing activity of a large number of vessels (German fleet) was not included in our dataset, these estimates are likely underestimating the total number of porpoises captured in gillnets, especially in the area where German fishing vessels are operating. Thus, this estimation should be considered as the minimum number of casualties. Moreover, large coefficients of variation in some areas highlight the need for better monitoring of the bycatch of harbour porpoise using e.g., on-board and/or electronic monitoring to reduce this uncertainty.

In this study, we have used different data sources and methodologies (adapted to data needs) to try to estimate the risk of bycatch of harbour porpoise in gillnets. The model used in Kattegat, the Belt Seas and the Sound uses actual bycatch observations from electronic monitoring of Danish commercial gillnetters, but since the monitored days at sea was limited, the reliability of the results vary spatially. As shown, there are large areas where there is a high uncertainty due to low monitoring coverage. It should be stressed that reducing this uncertainty will require longer time-series of continuous fine-scale spatial and temporal monitoring, including exhaustive records of both catches of target species and bycatches. Such monitoring data would greatly increase our capacity to assess bycatch at fleet level and increase the confidence in these assessments.

As for the other applied method, using harbour porpoise distribution effort and gillnet effort, there are also important caveats. Porpoise distribution has only been measured once in the Baltic and we know from other large-scale studies that there are shifts in distribution and that porpoises tend to travel extensively accross their distribution range (Hammond *et al.*, 2017). Clearly, the risk of bycatch is dependent on the distribution of fishing effort and, as shown in this study, regulation among other factors such as target species abundance and market demand affects fisheries and where fishing effort is allocated. Consequently, relying solely on bycatch risk maps when implementing mitigation measures is not advisable and could result in undesirable outcomes, such as no decrease of total bycatch mortality.

4. Bycatch estimates of harbour porpoise, grey and harbour seals, common eider, common scoter, velvet scoter and great cormorant

I. Introduction

Incidental captures of air-breathing animals is documented in many Baltic gillnet fisheries, at times with a demonstrated impact at population level on specific species (e.g. Vinther, 1999; Žydelis *et al.*, 2009; Marchowski *et al.*, 2020). In general, bycatch data collected from direct observations, using for instance on-board observers or Electronic Monitoring (EM) with video, provide the most accurate source of information, but are expensive and can be challenging to implement. With limited financial resources, fisheries managers often need to focus monitoring effort on a portion of the national fleet. In recent years, before the implementation of the landing obligation in the EU in 2019, Baltic countries dedicated most of their DCF funding to monitor fish discards in large-scale fisheries. Meanwhile, small-scale gillnet fisheries, the most problematic in terms of bycatch of marine mammals and seabirds in the region, remained largely unmonitored. EM systems with videos have shown great potential in documenting bycatch of protected species in small-scale fisheries (Kindt-Larsen *et al.*, 2012; Bartholomew *et al.*, 2018; Glemarec *et al.*, 2020). In the Western Baltic, the Danish EM programme has been documenting bycatch of protected species on small-scale commercial gillnet vessels since 2010. These data, combined with the best available fishing effort data, were used in the following section to estimate the total number of animals captured in Swedish and Danish commercial gillnet fisheries operating in the Western Baltic.

II. Methods

We estimated the total number of casualties resulting from the fishing activity of the Danish and Swedish commercial gillnetters operating in the Western Baltic in 2018. The assessment covered several species frequently bycaught in the region: the harbour porpoise, the grey and harbour seals (hereafter, seals), the common eider, the common and velvet scoters (hereafter, seaducks), and the great cormorant.

First, we calculated the average bycatch rates in the region for each species (or group of species) using the long time-series of EM data collected on commercial vessels (Kindt-Larsen *et al.*, 2012; Glemarec *et al.*, 2020). Bycatch rates, expressed as the number of animals captured per day at sea, were estimated from the analysis of the EM data with videos of a sample of 9 Danish commercial gillnet vessels, operating in ICES subdivisions IIIa21, IIIb23 and IIIc22 between 2010 and 2018. In the Kattegat (ICES subdivision IIIa21), bycatch rate estimates were calculated based on a limited number of fishing trips (n = 27). In two of those trips, happening a few days apart, the same fishing vessel captured an extremely large number of harbour porpoises (respectively 17 and 24 individuals). Given the low number of observations in this area, these fishing trips were highly influential on the mean point estimate, leading to large bycatch estimates for that species. Despite the reality of these bycatch events, we assumed that they were exceptional and not representative of the general/standard situation in the gillnet fishery taking place in the Kattegat. Therefore, we excluded both fishing trips from the dataset to estimate the harbour porpoise bycatch rate in that area.

In parallel, logbook registrations from 2018 provided an estimate of the fishing effort in the area that year. The fishing activity from all the Swedish and Danish commercial gillnetters operating in ICES subdivisions IIIa21, IIIb23 and IIIc22 was collected from logbook and sales notes registrations for the year 2018. The fishing effort included data from all vessels with an overall length of 8 meters and up. Data from German commercial gillnetters for this period were not available at the time of writing this report. Misclassified fishing trips, in terms of métiers or main target species, were removed from the dataset. As the risk of bycatch of marine mammals in gillnet fisheries using small mesh sizes (e.g. fisheries targeting common sole *Solea solea* or herring *Clupea harrengus*) is generally considered negligible, a subset of the fishing effort data was used to estimate marine mammals bycatches. That is, the fishing trips registering mesh sizes below 120 mm were excluded from the dataset for estimating the bycatches of harbour porpoise and seals. Conversely, seabird bycatch estimates were calculated using the full dataset. The fishing effort data were stratified by ICES subdivision, per quarter.

Finally, the total number of individuals bycaught in gillnets in the year 2018 in the Swedish and Danish commercial fleet was estimated as the product of the estimated mean bycatch rates and the total fishing effort. These estimates were stratified per quarter and ICES subdivision, and reported as the overall bycatch mortality for the whole area. The associated 95% confidence intervals were calculated using the bootstrap method (100 000 iterations; the details of the methods can be found in Glemarec *et al.* (2020)).

III. Results

i. Harbour porpoise

The number of harbour porpoise individuals bycaught in 2018 in the combined Danish and Swedish commercial gillnet fleets in ICES subdivisions IIIa21, IIIb23 and IIIc22 was estimated to 601 (95%CI: 500-710). Most casualties were predicted in spring in the Kattegat (IIIa21) and in spring and summer in the Belt Seas (IIIc22). However, in the Kattegat, the low number of observations and the high variability of the bycatch numbers per trip led to very large confidence intervals (CI), with the lower 95% CI rounded down to zero bycatch in that area in Spring. Furthermore, the German gillnet effort was not accounted for in these bycatch estimates calculations. Since most of the German small-scale gillnetters are expected to fish in areas close to their home harbours in area IIIc22, porpoise bycatches predicted in ICES subdivision IIIc22 are likely underestimated (Table 6).

Table 6: Estimated bycatch in Danish and Swedish commercial gillnets of harbour porpoise in ICES areas IIIa21, IIIb23 and IIIc22 in 2018 and the number of trips observed with EM.

Season	**ICES subdivision**	**Estimated bycatch**	**Lower 95% CI**	**Upper 95% CI**
Harbour porpoise bycatch estimates per season per area				
spring	IIIa21	191	0	510
summer	IIIa21	0	0	0
fall	IIIa21	-	-	-
winter	IIIa21	-	-	-
spring	IIIb23	35	17	54
summer	IIIb23	40	24	60
fall	IIIb23	36	14	61
winter	IIIb23	30	12	52
spring	IIIc22	105	67	146
summer	IIIc22	121	74	174
fall	IIIc22	61	35	89
winter	IIIc22	39	17	65
Overall harbour porpoise bycatch estimates				
Year	**All areas**	**601**	**500**	**710**

ii. Seals

Seals were not identified down to species level in the EM data provided for this report. Therefore, bycatch of grey and harbour seals were pooled together in the same category. In 2018, the number of seals captured in the combined Danish and Swedish commercial gillnet fleets in ICES subdivisions IIIa21, IIIb23 and IIIc22 was estimated to 286 individuals (95%CI: 213-368). Most casualties were predicted in spring in Kattegat (IIIa21) and in spring and summer in the Belt Seas (IIIc22). As was the case with porpoise bycatch, the confidence intervals were large in the Kattegat in spring and should be considered with caution. Again, the German gillnet effort was not accounted for in these bycatch estimate calculations, so seal bycatch in subdivision IIIc22 are likely higher than what is reported here (Table 7).

Table 7: Estimated bycatch in Danish and Swedish commercial gillnets of grey and harbour seals in ICES areas IIIa21, IIIb23 and IIIc22 in 2018 and the number of trips observed with EM.

Season	ICES subdivision	Estimated bycatch	Lower 95% CI	Upper 95% CI
Seal bycatch estimates per season per area				
spring	IIIa21	177	0	472
summer	IIIa21	0	0	0
fall	IIIa21	-	-	-
winter	IIIa21	-	-	-
spring	IIIb23	37	19	58
summer	IIIb23	30	14	50
fall	IIIb23	0	0	0
winter	IIIb23	37	15	65
spring	IIIc22	13	0	29
summer	IIIc22	60	32	96
fall	IIIc22	9	0	21
winter	IIIc22	0	0	0
Overall seal bycatch estimates				
Year	**All areas**	**286**	**213**	**368**

iii. Seaducks

Seaducks (i.e. common eider, common scoter and velvet scoter) constituted most of the incidental captures of birds observed with EM in Western Baltic commercial gillnets (Glemarec *et al.*, 2020). Together, the number of bycatch casualties for these three species in ICES subdivisions IIIa21, IIIb23 and IIIc22 in 2018 was estimated to be 2201 individuals (95%CI: 1507-3029). Most bycatches were predicted in subdivision IIIb23 in fall, and in spring in subdivisions IIIb23 and IIIc22. Again, bycatches from German commercial gillnets is not taken into account here, so that these estimates are likely underestimating the total number of drowned seabirds in the study area (Table 8).

Table 8: Estimated bycatch in Danish and Swedish commercial gillnets of seaducks (common eider, common scoter and velvet scoter) in ICES areas IIIa21, IIIb23 and IIIc22 in 2018 and the number of trips observed with EM.

Season	ICES subdivision	Estimated bycatch	Lower 95% CI	Upper 95% CI
Seaduck bycatch estimates per season per area				
spring	IIIa21	0	0	0
summer	IIIa21	0	0	0
fall	IIIa21	-	-	-
winter	IIIa21	-	-	-
spring	IIIb23	246	123	397
summer	IIIb23	38	16	64
fall	IIIb23	927	428	1579
winter	IIIb23	139	67	256
spring	IIIc22	356	121	736
summer	IIIc22	14	0	39
fall	IIIc22	42	12	82
winter	IIIc22	57	26	96
Overall seaduck bycatch estimates				
Year	**All areas**	**2201**	**1507**	**3029**

iv. Great cormorant

Bycatches of great cormorants in ICES statistical areas IIIa21, IIIb23 and IIIc22 in 2018 was estimated at 635 individuals (95%CI: 518-760). Most bycatches were predicted to occur in ICES subdivision IIIb23 in fall and Winter (respectively, 324 and 90 individuals on average). As bycatches in the German gillnet fleet being ignored in these estimates, the total number of casualties is expected to be higher than what we report here (Table 9).

Table 9: Estimated bycatch in Danish and Swedish commercial gillnets of great cormorant in ICES areas IIIa21, IIIb23 and IIIc22 in 2018 and the number of trips observed with EM.

Season	ICES subdivision	Estimated bycatch	Lower 95% CI	Upper 95% CI
Great cormorant bycatch estimates per season per area				
spring	IIIa21	0	0	0
summer	IIIa21	0	0	0
fall	IIIa21	-	-	-
winter	IIIa21	-	-	-
spring	IIIb23	4	0	11
summer	IIIb23	38	22	56
fall	IIIb23	324	245	414
winter	IIIb23	90	57	124
spring	IIIc22	4	0	13
summer	IIIc22	11	0	25
fall	IIIc22	19	5	35
winter	IIIc22	9	0	22
Overall great cormorant bycatch estimates				
Year	**All areas**	**635**	**518**	**760**

IV. Discussion

Harbour porpoise bycatch mortality has been estimated by ICES WGBYC (2016) in subdivisions IIIa21, IIIb23 and IIIc22 for the year 2014. Estimates ranged between 165 and 263 individuals. Nevertheless, fishing effort data were likely to be underestimated as fishing effort from smaller vessels was not fully represented in both areas. Since 2014, there has been continued monitoring, increasing the number of observed fishing days. In the estimation presented in this report, we also included fishing effort from small vessels by extrapolating effort from AIS data, sales notes and logbooks. In the ICES WGBYC report, porpoise bycatch estimations, small vessels from Danish fisheries had not been included. The bycatch estimates from this analysis are substantially higher than the latest estimation from ICES WGBYC. The most likely factor driving the increase in bycatch is the increase in fishing effort, in particular the inclusion of Danish effort for small vessels is likely an important factor. However, it should be noted that the fishing effort in the area has not increased over the years, rather the contrary. ICES WKEMBYC reported a 44 % decrease of gillnet effort in the past 10 years in the Baltic Sea (ICES, 2020b). In Swedish waters, gillnet fishing effort, in fisheries targeting cod, which is the dominant fisheries in the southern and central Baltic, have decreased by 80 % from 2006 to 2017 (Königson *et al.*, 2020). The area where the estimated bycatch mortality is carried out is an area where the abundance of harbour porpoise population is considered stable. with the estimated abundance of the Kattegat and Belt Sea population being 42,324 individuals (Hammond *et al.*, 2017). It is mainly the Kattegat and Belt Sea population that forages in these waters. The data do not indicate any season during the year when bycatch in any specific area is higher, except for ICES subdivision IIIa21, where a large bycatch mortality occurs in spring. However, these estimations are based on very few observations and in the other seasons (summer, fall and winter), there are only six or no observed fishing days.

Mortality of seals (grey and harbour) in gillnets in subdivisions IIIa21, IIIb23 and IIIc22 has not been estimated before. This is an area where harbour seals are common, while the number of grey seals has increased in recent years. While the data do not currently allow for the species to be distinguished it is most likely that harbour seals constitute most of the captures. In subdivisions 21 to 26, the population estimate for grey seals is 3,700 individuals. The number of harbour seals in subdivisions 21 to 24 is estimated to be 16,500 individuals. The bycatch numbers reported here are substantial, yet, the width of the confidence intervals are very large. As with harbour porpoises, the highest number of casualties was estimated in spring in subdivision IIIa21. However, with only 27 fishing days monitored with EM, the confidence intervals are large and include zero. Excluding area IIIa21 may thus engender a more likely scenario with narrower confidence intervals for the yearly total bycatch estimates.

The Western Baltic is also an important area for seabirds, whose distribution at-sea may coincide with commercial gillnet fisheries (Sonntag *et al.*, 2012). In the Kattegat, aerial surveys showed that diving seabirds, including seaducks and the great cormorant, constitute most of the wintering birds present in the area (Petersen and Sterup, 2019). However, most diving species are present year-long and thus susceptible to bycatch in gillnets both for the wintering and the breeding populations (Nielsen *et al.*, 2019). Although bycatch of seabirds in gillnets has not been systematically assessed in the past in subdivisions IIIa21, IIIb23 and IIIc22, local assessments have demonstrated that captures are common in coastal gillnet fisheries over the whole the region (Bregnballe and Frederiksen, 2006; Degel *et al.*, 2010; Bellebaum *et al.*, 2013; Petersen and Nielsen, 2015; Glemarec *et al.*, 2020). The bycatch estimates published in this report are based on the assumption that the mean bycatch rates calculated from observations on Danish gillnetters equipped with EM are representative of the whole Danish and Swedish commercial gillnet fisheries. This assumption may hold in the Belt Seas and in the Øresund, but the low coverage in the Kattegat (27 fishing trips observed with EM) likely fails to cover the variability of the gillnet fisheries taking place there. In particular, in the Kattegat, the fishery targeting lumpsucker is hardly covered in the dataset used here, yet very large seabird bycatch rates have been reported in lumpsucker fisheries across the whole Northern Atlantic (Christensen-Dalsgaard *et al.*, 2019). Similarly, the absence of data from German gillnet fishing vessels will lead to underestimating overall seabird bycatch mortality in the region, especially in subdivision IIIc22 where the German fleet is the most active. With this in mind, the bycatch mortality estimates in 2018 shown in Table 8 and Table 9, which sum up to more than 2800 individuals (95%CI: 2025-3789) for both seaducks and great cormorants, should be considered as conservative. Even if these numbers constitute only a small fraction of the overall populations present in the Baltic Sea (Annex 1, Table 13), they may be sufficiently high to affect the populations present in the study area. To address this question, it will be necessary in the future to assess bycatch at the species level. In addition, within species, bycatch will need to be determined for each sex and age classes when possible. Sex- or age-biased bycatch mortality may indeed have an impact at the population level (Gianuca *et al.*, 2017). If enough data are available, population viability analyses could be used to estimate the impact of bycatch on population dynamics (ICES, 2018a; BirdLife International, 2019), and ultimately determine threshold values above which bycatch mortality should be considered unsustainable, in line with the indicators under development notably in the HELCOM and OSPAR regions and in the EU biodiversity criteria D1C1 (EU, 2017; HELCOM, 2018b; Palialexis *et al.*, 2019).

In this section, we estimated the spatiotemporal variability of bycatch mortality in gillnets for a number of vulnerable species, or groups of species, particularly at risk in the Western Baltic. We calculated the averaged bycatch rates from data collected over 9 years of electronic monitoring and multiplied these rates with the fleet-wide fishing effort in the study area for the year 2018. Bycatch rates in the EM dataset varied considerably from year to year, possibly because of changes in species and/or fishing effort distributions, e.g. following interannual variations in fisheries regulations. Besides, the confidence intervals around the mean bycatch mortality were large in areas where EM sampling effort was low. Moreover, fleet-wide fishing effort was estimated by combining self-reported logbook and sales notes data, with satellite monitoring data (AIS/VMS). This approach resulted in a considerable increased in sampling effort, by taking into account small as well as large fishing vessels. However, the approach is not exempt of bias (Mangi *et al.*, 2015; Natale *et al.*, 2015). Additionally, other co-factors, not taken into account in this study, may have explained the observed levels of bycatch and in turn affected the fleet-wide estimates. For instance, Northridge *et al.* (2017) reviewed the factors affecting bycatch rates for marine mammals, sea turtles and sea birds, and identified mesh size as one important parameter to explain bycatch rates. As a result, because of these possible caveats in the data used to estimate fleet-wide bycatch mortality, the numbers presented here should be consider as an indication of the range of bycatch mortality in the study area, rather than absolute numbers.

5. Effectiveness and cost implication when pingers are used as a mitigation tool for reducing harbour porpoise bycatch

I. Introduction

As bycatch of harbour porpoises has been recognised in many fisheries and is considered to be one of the main threats to the species, research has been conducted in order to prevent such events. Bycatch can be prevented in two ways. As the total bycatch by a given gear is the product of (i), the total effort of the gear and (ii), the bycatch per unit effort of that gear, bycatch can thus be mitigated by reducing effort, reducing bycatch per unit effort, or both (Hall, 1996). To reduce either of these two factors, several methods exist, including temporal or spatial closures of fisheries, bycatch quotas, or gear modifications. Annex 2 lists some of the relevant literature for a number of different mitigation methods.

Pingers used in gillnet fisheries have been shown to considerably reduce the bycatch of harbour porpoise in gillnet fisheries (Kraus *et al.*, 1997; Gönener and Bilgin, 2009; Dawson *et al.*, 2013; Larsen and Eigaard, 2014) and are widely used in commercial gillnet fisheries around the world (Palka *et al.*, 2008; Northridge, 2018). Bycatch rates can decrease by 50 to 60 % when pingers are used (Dawson *et al.*, 2013), demonstrating the potential value of pingers in commercial fisheries in order to reduce porpoise bycatch mortality.

Implementing pingers can be done either by regulating the fisheries and forcing fishers to use pingers, i.e. regulate that to be able to fish in a specified area or with specified gear pingers are required, or it can be done on a voluntary basis.

In 2004, the Council Regulation (EC) No 812/2004 regarding the bycatch of cetaceans was put in place (EC, 2004). This legislative text required EU fishing vessels of ≥12m, fishing with large mesh gillnets, to use pingers in certain areas. However, there has been no or limited law enforcement in Swedish, Danish and German waters, thus the compliance to this Regulation is unknown (ICES, 2018b). EC (2004) was repealed in 2019, but the same requirements remain regarding the use of pingers in the subsequent (EU) 2019/1241 Regulation (EU, 2019).

In order to increase the use of pingers in Swedish gillnet fisheries in the Southern Baltic Sea, pingers were provided for free to small-scale gillnet fishers (operating on board vessels <12 meters in overall length), as part of an implementation project coordinated by the Swedish University of Agriculture Sciences (SLU) and the Swedish Agency for marine and Water Management (SWAM) (Benavente and Königson, 2020). This project, the largest harbour porpoise bycatch mitigation project that has been carried out in Sweden since 2004, is done on a voluntary basis.

However, the important part when implementing pingers, irrespective of whether it is by fisheries regulation or on a voluntary basis, is that the fishers get educated on how to use pingers and that pinger functionality, as well as pinger placement on nets, are regularly checked by the fishers themselves.

The costs for implementing pingers through fisheries regulations will most likely differ from implementing pingers on a voluntary base. Implementing a pinger fisheries regulation includes enforcement costs as well administrative costs which are not included if pingers are implemented on a regular basis.

To get an estimation on the costs for implementing pingers we have taken the costs for implementing pingers on a voluntary basis. We do not have the possibility to estimate costs for enforcement and administration around fisheries regulations.

II. Methods and Results

To get an estimation of the costs for implementing pingers, the Swedish logbook in the area 21, 22, 23 and 24 were analysed, using number of active fishers in the area and the amount of nets they cast. In this area, there are 97 active fishermen, fishing with a range of nets measuring 5580 to 9159 meters (95 %CI 1282) (Table 10). Pingers should be spaced with a distance of 200 meters, depending on the pinger type used. In this example, we are using the banana pinger from Fishtek Marine Ltd, where a 200 meters distance between pingers is suggested. Thereby, if you have a net link which is 1000 meters, five pingers per net are required as a minimum. In turn, each fishermen will need to have 24 to 37 pingers. The cost of pingers is around €50 per device, so the total cost for pingers for all fishers in the area would range between €116,400 and €179,450. Moreover, fishers may need to acquire a bat detector for checking if the pingers are emitting a sound or not, which adds supplementary cost for the equipment and the batteries. There are also costs for education, information and pinger functionality checks.

Table 10: Example from Sweden ICES subdivisions 21, 22, 23, 24. Costs are in Euro and cover a five-year period assuming that pingers are functional over this time period.

Number of active boats	97
Mean meter of net used	5,580 – 9,189
Number of pingers per fishermen	28 - 46
Costs for pingers (every 5 years)	135,800 – 223,100
Additional costs (bat detector)	7,275
Costs for data collection/education/controls (Yearly cost of €300 000)	150,000
Cost per fisherman	3,021 – 3,921
Total cost for implementing pingers voluntary (Euro)	**293,075 – 380,375**

These calculations are based on a situation where no enforcement and institutional administration costs are needed, because pingers are being implemented in the fishery on a voluntary basis. If pingers are to be regulated in fisheries, additional costs for enforcement, administration, as well as costs for taking violators to court need to be added. These costs are hard to evaluate and have therefore not been included in the cost implications when implementing pingers.

6. Key conclusion

Below the reports key conclusions are presented.

- Significant levels of bycatch estimated for mammals and birds in all assessed areas
- Different methodologies applied to accommodate data specificities when producing risk maps
- Larger bycatch estimates than previous studies likely due to inclusion of fishing effort of smaller vessels (smaller vessels being a large component of the Baltic fleets)
- Total bycatch mortality estimates likely underestimated in certain regions due to missing effort from other countries active in those regions
- First costing of large scale pinger application in the Baltic Sea
- Need for further data and reporting improvements for improved bycatch assessment (actual and risk maps)

Parts of the work presented in the report was used in the ICES Workshop on fisheries emergency measures to minimize by-catch of short-beaked common dolphins in the bay of Biscay and harbour porpoise in the Baltic Sea (WKEMBYC). ICES established the Workshop on Emergency Measures to mitigate BYCatch of harbour porpoise in the Baltic Sea and common dolphin in the Bay of Biscay (WKEM-BYC) to follow up a submission of two reports from 26 European environmental non-governmental organisations (NGOs) to the European Commission (DG MARE) concerning emergency measures to mitigate bycatch of common dolphins in the Bay of Biscay and harbour porpoises in the Baltic Sea. Together with WGMME (Working group of marine mammal ecology) and WGBYC (Working group of bycatch of protected species) WKEMBYC was tasked to assess the emergency measures proposed by the NGOs, to explore alternative measures, and suggest emergency measures that are necessary to ensure a satisfactory conservation status of these stocks. The WKEMBYC report can be found on the following site: https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/Special_Requests/eu.2020.04.pdf. In Annex 2 of that report, a list of references relevant for different mitigation measures to prevent bycatch of harbour porpoise is presented. The mitigation measures listed is time-area closures, gillnet modifications, acoustic deterrence and bycatch quotas.

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Annex 1: Tables from GAP analysis

Table 11: Sources and findings of the literature review performed 2019 for the GAP-analysis of bycatch rate, individual counts, population estimates for seals, porpoises and waterbirds (eiders, scoters and cormorants) in the Baltic Sea.

Finding	Number or Rate	CI	Area	Common name	Species name	Period	Reference
Bycatch rate	0,144		26	Black-throated loon	Gavia arctica	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Individual bycatch recorded. Observed effort 125 days	18		26	Black-throathed loon	Gavia arctica	2012	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Bycatch rate	0		20	Common eider	Somateria mollissima	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		21	Common eider	Somateria mollissima	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		22	Common eider	Somateria mollissima	2012	ICES WGBYC (2014) Report of the Working Group on Bycatch of Protected Species (WGBYC 2014).
Bycatch rate	0,048		22	Common eider	Somateria mollissima	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		22	Common eider	Somateria mollissima	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		22	Common eider	Somateria mollissima	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		23	Common eider	Somateria mollissima	2011	ICES WGBYC (2013) Report of the Working Group on Bycatch of Protected Species (WGBYC 2013).
Bycatch rate	0		23	Common eider	Somateria mollissima	2012	ICES WGBYC (2014) Report of the Working Group on Bycatch of Protected Species (WGBYC 2014).
Bycatch rate	0,059		23	Common eider	Somateria mollissima	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		24	Common eider	Somateria mollissima	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0		24	Common eider	Somateria mollissima	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		24	Common eider	Somateria mollissima	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		25	Common eider	Somateria mollissima	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		26	Common eider	Somateria mollissima	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Individual bycatch recorded. Observed effort 125 das	0		26	Common Eider	Somateria mollissima	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Bycatch rate	0		27	Common eider	Somateria mollissima	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." PloS one 9.11 (2014): e113836.
Bycatch rate	0,565		29	Common eider	Somateria mollissima	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).

Bycatch rate	0,28		30	Common eider	Somateria mollissima	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		30	Common eider	Somateria mollissima	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." PloS one 9.11 (2014): e113836.
Bycatch rate	0,375		32	Common eider	Somateria mollissima	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Individual bycatch recorded. Observed effort 125 das	35		24	Common goldeneye	Bucephala clangula	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Individual bycatch recorded. Observed effort 125 das	35		24	Common pochard	Aythya farina	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Individual bycatch recorded. Observed effort 125 das	105		24	Common Scoter	Melanitta nigra	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Bycatch rate	0,176		24	Eurasian coot	Fulica atra	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Individual bycatch recorded. Observed effort 125 das	22		24	Eurasian coot	Fulica atra	2012	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Bycatch rate	0,304		24	Great crested grebe	Podiceps cristatus	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Individual bycatch recorded. Observed effort 125 das	38		24	Great crested grebe	Podiceps cristatus	2012	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Bycatch rate	0		20	Great cormorant	Phalacrocorax carbo	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		21	Great cormorant	Phalacrocorax carbo	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		22	Great cormorant	Phalacrocorax carbo	2012	ICES WGBYC (2014) Report of the Working Group on Bycatch of Protected Species (WGBYC 2014).
Bycatch rate	0,032		22	Great cormorant	Phalacrocorax carbo	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		22	Great cormorant	Phalacrocorax carbo	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		22	Great cormorant	Phalacrocorax carbo	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		23	Great cormorant	Phalacrocorax carbo	2011	ICES WGBYC (2013) Report of the Working Group on Bycatch of Protected Species (WGBYC 2013).
Bycatch rate	0		23	Great cormorant	Phalacrocorax carbo	2012	ICES WGBYC (2014) Report of the Working Group on Bycatch of Protected Species (WGBYC 2014).
Bycatch rate	0,059		23	Great cormorant	Phalacrocorax carbo	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).

Bycatch rate	0		24	Great cormorant	Phalacrocorax carbo	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	2,5		24	Great cormorant	Phalacrocorax carbo	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		24	Great cormorant	Phalacrocorax carbo	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		25	Great cormorant	Phalacrocorax carbo	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0,744		24	Great cormorant	Phalacrocorax carbo	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Individual bycatch recorded. Observed effort 125 das	93		24	Great cormorant	Phalacrocorax carbo	2012	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Bycatch rate	0		27	Great cormorant	Phalacrocorax carbo	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." PloS one 9.11 (2014): e113836.
Bycatch rate	0,182		29	Great cormorant	Phalacrocorax carbo	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	1,16		30	Great cormorant	Phalacrocorax carbo	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		30	Great cormorant	Phalacrocorax carbo	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." PloS one 9.11 (2014): e113836.
Bycatch rate	3,625		32	Great cormorant	Phalacrocorax carbo	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Individual bycatch recorded. Observed effort 125 das	104		24	Greater scaup	Aythya marila	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Bycatch rate	0,008		24	Horned grebe	Podiceps auritus	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Individual bycatch recorded. Observed effort 125 das	1		24	Horned grebe	Podiceps auritus	2012	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Individual bycatch recorded. Observed effort 125 das	230		24	Long-tailed duck	Clangula hyemalis	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Individual bycatch recorded. Observed effort 125 das	4		24	Red-breasted merganser	Melanitta merganser	2012	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Bycatch rate	0,024		24	Red-necked grebe	Podiceps grisegena	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.

Individual bycatch recorded. Observed effort 125 das	3		24	Red-necked grebe	Podiceps grisegena	2012	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Bycatch rate	0,92		24	Red-throated loon	Gavia stellata	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Individual bycatch recorded. Observed effort 125 das	115		24	Red-throathed loon	Gavia stellata	2012	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Individual bycatch recorded. Observed effort 125 das	63		24	Tufted duck	Aythya fuligula	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Individuals bycaught annually	100,000-200,000		North and Baltic Seas	Waterbirds			Žydelis, Ramūnas, Cleo Small, and Gemma French. "The incidental catch of seabirds in gillnet fisheries: A global review." *Biological Conservation* 162 (2013): 76-88.
Bycatch rate	0		20	Ducks	Aythya sp, Anatidae sp.	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		21	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		22	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2012	ICES WGBYC (2014) Report of the Working Group on Bycatch of Protected Species (WGBYC 2014).
Bycatch rate	0	10	22	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0,465		22	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0,533		22	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		23	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2011	ICES WGBYC (2013) Report of the Working Group on Bycatch of Protected Species (WGBYC 2013).
Bycatch rate	0		23	Ducks	Aythya marila, Anatidae sp., Aythya sp., Melanitta sp.	2012	ICES WGBYC (2014) Report of the Working Group on Bycatch of Protected Species (WGBYC 2014).
Bycatch rate	0,059		23	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		24	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0		24	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0,155		24	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).

Bycatch rate	0		25	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0,504		24	Tufted duck	Aythya fuligula	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Bycatch rate	0,832		24	Greater scaup	Aythya marila	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Bycatch rate	0,28		24	Common poachard	Aythya ferina	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Bycatch rate	0,28		24	Common goldeneye	Bucephala clangula	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Bycatch rate	1,84		24	Long-tailed duck	Clangula hyemalis	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Bycatch rate	0,304		24	Velvet scoter	Melanitta fusca	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Bycatch rate	0,456		24	Velvet scoter	Melanitta fusca	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Bycatch rate	0,032		24	Common merganser	Mergus merganser	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Bycatch rate	0,84		24	Common scoter	Melanitta nigra	2008-2009	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." Aquatic Conservation: Marine and Freshwater Ecosystems 23.2 (2013): 210-221.
Bycatch rate	0		27	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." PloS one 9.11 (2014): e113836.
Bycatch rate	0		29	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0,04		30	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		30	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." PloS one 9.11 (2014): e113836.
Bycatch rate	0,125		32	Ducks	Aythya sp., Anatidae sp., Melanitta sp.	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Individual bycatch recorded. Observed effort 125 das	38		24	Velvet Scoter	Melanitta fusca	2012	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.

Individual bycatch recorded. Observed effort 125 das	57		24	Velvet Scoter	Melanitta fusca	2012	Bellebaum, Jochen, et al. "Decreasing but still high: bycatch of seabirds in gillnet fisheries along the German Baltic coast." *Aquatic Conservation: Marine and Freshwater Ecosystems* 23.2 (2013): 210-221.
Bycatch rate	0		20	Grey seal	Halichoerus grypus	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		21	Grey seal	Halichoerus grypus	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0		21	Grey seal	Halichoerus grypus	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		22	Grey seal	Halichoerus grypus	2012	ICES WGBYC (2014) Report of the Working Group on Bycatch of Protected Species (WGBYC 2014).
Bycatch rate	0		22	Grey seal	Halichoerus grypus	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0		22	Grey seal	Halichoerus grypus	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		22	Grey seal	Halichoerus grypus	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		22	Grey seal	Halichoerus grypus	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		23	Grey seal	Halichoerus grypus	2011	ICES WGBYC (2013) Report of the Working Group on Bycatch of Protected Species (WGBYC 2013).
Bycatch rate	0		23	Grey seal	Halichoerus grypus	2012	ICES WGBYC (2014) Report of the Working Group on Bycatch of Protected Species (WGBYC 2014).
Bycatch rate	0		23	Grey seal	Halichoerus grypus	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0		23	Grey seal	Halichoerus grypus	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		24	Grey seal	Halichoerus grypus	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0		24	Grey seal	Halichoerus grypus	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		24	Grey seal	Halichoerus grypus	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0,023		25	Grey seal	Halichoerus grypus	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0,003		27	Grey seal	Halichoerus grypus	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." PloS one 9.11 (2014): e113836.
Bycaught individuals. Sample effort: 1402 (km-days), total effort: 7904 (km-days)	20		27	Grey seal	Halichoerus grypus	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." *PloS one* 9.11 (2014).
Bycatch rate	0		29	Grey seal	Halichoerus grypus	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0,023		30	Grey seal	Halichoerus grypus	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." PloS one 9.11 (2014): e113836.

Bycaught individuals. Sample effort: 1540 (km-days), total effort: 1611 (km-days)	35		30	Grey seal	Halichoerus grypus	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." *PloS one* 9.11 (2014).
Individuals bycaught. Effort: 1767 fishing days, 4-6 fyke nets annualy over five years	32		31	Grey seal	Halichoerus grypus	2008-2013	Oksanen, Sari M., et al. "A novel tool to mitigate bycatch mortality of Baltic seals in coastal fyke net fishery." *PloS one* 10.5 (2015).
Bycatch rate	0		32	Grey seal	Halichoerus grypus	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Estimated individual bycaught from all gear types including fisheries of Sweden, Finland and Estonia	1000		Baltic	Grey seal	Halichoerus grypus	2001	Westerberg, H. Å. K. A. N., et al. "Reconciling fisheries activities with the conservation of seals throughout the development of new fishing gear: A case study from the Baltic fishery-gray seal conflict." American Fisheries Society Symposium. Vol. 49. No. 2. American Fisheries Society, 2008.
Estimated individuals bycaught from all gear types by swedish fisheries	462	360-575 (95% CI)	Baltic	Grey seal	Halichoerus grypus	2001	Lunneryd SG, Hemmingsson M, Tärnlund S, Fjälling A (2005) A voluntary logbook scheme as a method of monitoring the bycatch of seals in Swedish coastal fisheries. In *ICES CM* (X:04). International Council for the Exploration of the Sea, Köpenhagen, Denmark
Individuals bycaught. 925 DaS (according to official loggbook), 5096 net hauls (according to video footage)	39		20-21	Harbor porpoise	Phocoena phocoena	2011	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.
Estimated individuals bycaught	242–423		Baltic	Harbor porpoise	Phocoena phocoena	2009	ICES (2010): Report of the Working Group on Bycatch of Protected Species (WGBYC). ICES CM 2010/ACOM:25. 121 pp
Bycatch estimate per year	165 to 263	(95% CI)	21-23	Harbor porpoise	Phocoena phocoena	2014	ICES (2016a) Report of the Working Group on Bycatch of Protected Species (WGBYC). ICES CM 2016/ACOM:27. International Council for the Exploration of the Sea, Copenhagen, Denmark. 77 pp.
Bycatch rate	0		20	Harbour porpoise	Phocoena phocoena	2013	ICES WGBYC (2015) Report of the Working Group on Bycatch of Protected Species (WGBYC 2015).
Bycatch rate	0,31		20	Harbour porpoise	Phocoena phocoena	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		21	Harbour porpoise	Phocoena phocoena	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0,15		21	Harbour porpoise	Phocoena phocoena	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0,008		22	Harbour porpoise	Phocoena phocoena	2012	ICES WGBYC (2014) Report of the Working Group on Bycatch of Protected Species (WGBYC 2014).
Bycatch rate	0,06		22	Harbour porpoise	Phocoena phocoena	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0,072		22	Harbour porpoise	Phocoena phocoena	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).

Bycatch rate	0,04		22	Harbour porpoise	Phocoena phocoena	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		22	Harbour porpoise	Phocoena phocoena	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0,004		23	Harbour porpoise	Phocoena phocoena	2011	ICES WGBYC (2013) Report of the Working Group on Bycatch of Protected Species (WGBYC 2013).
Bycatch rate	0,015		23	Harbour porpoise	Phocoena phocoena	2012	ICES WGBYC (2014) Report of the Working Group on Bycatch of Protected Species (WGBYC 2014).
Bycatch rate	0,03		23	Harbour porpoise	Phocoena phocoena	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0,118		23	Harbour porpoise	Phocoena phocoena	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		24	Harbour porpoise	Phocoena phocoena	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0		24	Harbour porpoise	Phocoena phocoena	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		24	Harbour porpoise	Phocoena phocoena	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		25	Harbour porpoise	Phocoena phocoena	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		27	Harbour porpoise	Phocoena phocoena	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." PloS one 9.11 (2014): e113836.
Bycatch rate	0		29	Harbour porpoise	Phocoena phocoena	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		30	Harbour porpoise	Phocoena phocoena	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." PloS one 9.11 (2014): e113836.
Bycatch rate	0		32	Harbour porpoise	Phocoena phocoena	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0,042		20-21	Harbour porpoise	Phocoena phocoena	2010	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.
Bycatch rate	0		25-32	Harbour porpoise	Phocoena phocoena	2013	ICES WGBYC (2015) Report of the Working Group on Bycatch of Protected Species (WGBYC 2015).
Bycatch rate	0		20	Harbour seal	Phoca vitulina	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		21	Harbour seal	Phoca vitulina	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0		21	Harbour seal	Phoca vitulina	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		22	Harbour seal	Phoca vitulina	2012	ICES WGBYC (2014) Report of the Working Group on Bycatch of Protected Species (WGBYC 2014).
Bycatch rate	0		22	Harbour seal	Phoca vitulina	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0	-	22	Harbour seal	Phoca vitulina	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		22	Harbour seal	Phoca vitulina	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		22	Harbour seal	Phoca vitulina	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		23	Harbour seal	Phoca vitulina	2011	ICES WGBYC (2013) Report of the Working Group on Bycatch of Protected Species (WGBYC 2013).

Bycatch rate	0		23	Harbour seal	Phoca vitulina	2012	ICES WGBYC (2014) Report of the Working Group on Bycatch of Protected Species (WGBYC 2014).
Bycatch rate	0		23	Harbour seal	Phoca vitulina	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0		23	Harbour seal	Phoca vitulina	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		24	Harbour seal	Phoca vitulina	2014	ICES WGBYC (2016) Report of the Working Group on Bycatch of Protected Species (WGBYC 2016).
Bycatch rate	0		24	Harbour seal	Phoca vitulina	2015	ICES WGBYC (2017) Report of the Working Group on Bycatch of Protected Species (WGBYC 2017).
Bycatch rate	0		24	Harbour seal	Phoca vitulina	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		25	Harbour seal	Phoca vitulina	2016	ICES WGBYC (2018) Report of the Working Group on Bycatch of Protected Species (WGBYC 2018).
Bycatch rate	0		27	Harbour seal	Phoca vitulina	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." PloS one 9.11 (2014): e113836.
Bycatch rate	0		29	Harbour seal	Phoca vitulina	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0		30	Harbour seal	Phoca vitulina	2012-2013	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." PloS one 9.11 (2014): e113836.
Bycatch rate	0		32	Harbour seal	Phoca vitulina	2017	ICES WGBYC (2019) Report of the Working Group on Bycatch of Protected Species (WGBYC 2019).
Bycatch rate	0,001		20-21	Harbour seal	Phoca vitulina	2010	Kindt-Larsen, Lotte, et al. "Observing incidental harbour porpoise Phocoena phocoena bycatch by remote electronic monitoring." Endangered Species Research 19.1 (2012): 75-83.
Individuals bycaught. 926 DaS (according to official loggbook), 5096 net hauls (according to video footage)	1		20-21	Harbour seal	Phoca vitulina	2011	Kindt-Larsen, Lotte, et al. "Observing incidental harbour porpoise Phocoena phocoena bycatch by remote electronic monitoring." *Endangered Species Research* 19.1 (2012): 75-83.
Estimated individuals bycaught from all gear types by swedish fisheries	461	333-506 (95% CI)	Baltic	Harbour seal	Phoca vitulina	2001	Lunneryd SG, Hemmingsson M, Tärnlund S, Fjälling A (2005) A voluntary logbook scheme as a method of monitoring the bycatch of seals in Swedish coastal fisheries. In *ICES CM* (X:04). International Council for the Exploration of the Sea, Köpenhagen, Denmark
Individuals bycaught. Effort: 1767 fishing days, 4-6 fyke nets annualy over five years	103		31	Ringed seal	Pusa hispida	2008-2013	Oksanen, Sari M., et al. "A novel tool to mitigate bycatch mortality of Baltic seals in coastal fyke net fishery." *PloS one* 10.5 (2015).
Estimated individuals yearly bycaught in all gear types by swedish fisheries	52	34-70 (95% CI)	Baltic	Ringed seals	Pusa hispida	2001	Lunneryd SG, Hemmingsson M, Tärnlund S, Fjälling A (2005) A voluntary logbook scheme as a method of monitoring the bycatch of seals in Swedish coastal fisheries. In *ICES CM* (X:04). International Council for the Exploration of the Sea, Köpenhagen, Denmark

Table 12: Sources and findings of the literature review performed 2019 for the GAP-analysis of individual counts, population estimates for seals, porpoises and waterbirds (eiders, scoters and commorants) in the Baltic Sea.

Finding	Number	CI	Area	Common name	Species name	Collected	Reference
Abundance and distribution data (sighted individuals per area)	584		20	Common eider	Somateria mollissima	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	332		20	Common eider	Somateria mollissima	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	4507		20	Common eider	Somateria mollissima	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	6586		20	Common eider	Somateria mollissima	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	7546		20	Common eider	Somateria mollissima	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	30813		20	Common eider	Somateria mollissima	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	6336		20	Common eider	Somateria mollissima	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	2552		20	Common eider	Somateria mollissima	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	3741		20	Common eider	Somateria mollissima	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1005		20	Common eider	Somateria mollissima	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1288		21	Common eider	Somateria mollissima	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	331		21	Common eider	Somateria mollissima	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	4819		21	Common eider	Somateria mollissima	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	5546		21	Common eider	Somateria mollissima	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	3591		21	Common eider	Somateria mollissima	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	8531		21	Common eider	Somateria mollissima	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	2090		21	Common eider	Somateria mollissima	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)

Abundance and distribution data (sighted individuals per area)	1538		21	Common eider	Somateria mollissima	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1538		21	Common eider	Somateria mollissima	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1515		21	Common eider	Somateria mollissima	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance estimate digital aerial survey	110,882	SE (± 42, 234	22	Common Eider	Somateria mollissima	2015	Žydelis, Ramūnas, et al. "Comparison of digital video surveys with visual aerial surveys for bird monitoring at sea." *Journal of Ornithology* 160.2 (2019): 567-580.
Abundance estimate visual survey	147,307	SE (± 48, 031)	22	Common Eider	Somateria mollissima	2015	Žydelis, Ramūnas, et al. "Comparison of digital video surveys with visual aerial surveys for bird monitoring at sea." *Journal of Ornithology* 160.2 (2019): 567-580.
Seasonal sample size used for density distribution	winter: 3690,5		22	Common eider	Somateria mollissima	2008 - 2010	Heinänen, Stefan, et al. "High-resolution sea duck distribution modeling: Relating aerial and ship survey data to food resources, anthropogenic pressures, and topographic variables." *The Condor: Ornithological Applications* 119.2 (2017): 175-190.
Seasonal sample size used for density distribution	spring: 3434		22	Common eider	Somateria mollissima	2008 - 2010	Heinänen, Stefan, et al. "High-resolution sea duck distribution modeling: Relating aerial and ship survey data to food resources, anthropogenic pressures, and topographic variables." *The Condor: Ornithological Applications* 119.2 (2017): 175-190.
Abundance and distribution data (sighted individuals per area)	1404		23	Common eider	Somateria mollissima	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	663		23	Common eider	Somateria mollissima	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1321		23	Common eider	Somateria mollissima	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	2607		23	Common eider	Somateria mollissima	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	16782		23	Common eider	Somateria mollissima	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	13088		23	Common eider	Somateria mollissima	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	3856		23	Common eider	Somateria mollissima	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	3215		23	Common eider	Somateria mollissima	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	3099		23	Common eider	Somateria mollissima	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)

Abundance and distribution data (sighted individuals per area)	5631		23	Common eider	Somateria mollissima	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	27		24	Common eider	Somateria mollissima	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1		24	Common eider	Somateria mollissima	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	17		24	Common eider	Somateria mollissima	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	37		24	Common eider	Somateria mollissima	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	8		24	Common eider	Somateria mollissima	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	14		24	Common eider	Somateria mollissima	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	4		24	Common eider	Somateria mollissima	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	30		24	Common eider	Somateria mollissima	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	5		24	Common eider	Somateria mollissima	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1		24	Common eider	Somateria mollissima	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	38		25	Common eider	Somateria mollissima	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	12		25	Common eider	Somateria mollissima	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	18		25	Common eider	Somateria mollissima	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	55		25	Common eider	Somateria mollissima	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	52		25	Common eider	Somateria mollissima	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	24		25	Common eider	Somateria mollissima	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	10		25	Common eider	Somateria mollissima	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	32		25	Common eider	Somateria mollissima	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)

Abundance and distribution data (sighted individuals per area)	31		25	Common eider	Somateria mollissima	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	17		25	Common eider	Somateria mollissima	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Common eider	Somateria mollissima	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Common eider	Somateria mollissima	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Common eider	Somateria mollissima	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Common eider	Somateria mollissima	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Common eider	Somateria mollissima	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1		27	Common eider	Somateria mollissima	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Common eider	Somateria mollissima	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Common eider	Somateria mollissima	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Common eider	Somateria mollissima	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Common eider	Somateria mollissima	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Population estimate	515000		Baltic	Common eider	Somateria mollissima	2007 - 2009	Skov, Henrik. *Waterbird populations and pressures in the Baltic Sea*. Vol. 550. Nordic Council of Ministers, 2011.
Abundance estimate digital aerial survey	38,723	SE (± 18, 864)	22	Common Scoter	Melanitta nigra	2015	Žydelis, Ramūnas, et al. "Comparison of digital video surveys with visual aerial surveys for bird monitoring at sea." *Journal of Ornithology* 160.2 (2019): 567-580.
Abundance estimate visual survey	44,113	SE (± 7808)	22	Common Scoter	Melanitta nigra	2015	Žydelis, Ramūnas, et al. "Comparison of digital video surveys with visual aerial surveys for bird monitoring at sea." *Journal of Ornithology* 160.2 (2019): 567-580.
Seasonal sample size used for density distribution	winter: 3989		22	Common Scoter	Melanitta nigra	2008 - 2010	Heinänen, Stefan, et al. "High-resolution sea duck distribution modeling: Relating aerial and ship survey data to food resources, anthropogenic pressures, and topographic variables." *The Condor: Ornithological Applications* 119.2 (2017): 175-190.
Population estimate	410000		Baltic	Common Scoter	Melanitta nigra	2007 - 2009	Skov, Henrik. *Waterbird populations and pressures in the Baltic Sea*. Vol. 550. Nordic Council of Ministers, 2011.

Breading pair numbers	33008		Denmark	Common Scoter	Melanitta nigra	2009	Bregnballe, T., Lynch, J., Parz-Gollner, R., Marion, L., Volponi, S., Paquet, J.-Y., David N. Carss & van Eerden, M.R. (eds., 2014a). Breeding numbers of Great Cormorants Phalacrocorax carbo in the Western Palearctic, 2012-2013. IUCN-Wetlands International Cormorant Research Group Report. – Scientific Report from DCE – Danish Centre for Environment and Energy, Aarhus University, No. 99, 224 pp
Breading pair numbers	27237		Denmark	Common Scoter	Melanitta nigra	2012	Bregnballe, T., Lynch, J., Parz-Gollner, R., Marion, L., Volponi, S., Paquet, J.-Y., David N. Carss & van Eerden, M.R. (eds., 2014a). Breeding numbers of Great Cormorants Phalacrocorax carbo in the Western Palearctic, 2012-2013. IUCN-Wetlands International Cormorant Research Group Report. – Scientific Report from DCE – Danish Centre for Environment and Energy, Aarhus University, No. 99, 224 pp
Breading pair numbers	43500		Sweden	Common Scoter	Melanitta nigra	2009	Bregnballe, T., Lynch, J., Parz-Gollner, R., Marion, L., Volponi, S., Paquet, J.-Y., David N. Carss & van Eerden, M.R. (eds., 2014a). Breeding numbers of Great Cormorants Phalacrocorax carbo in the Western Palearctic, 2012-2013. IUCN-Wetlands International Cormorant Research Group Report. – Scientific Report from DCE – Danish Centre for Environment and Energy, Aarhus University, No. 99, 224 pp
Breading pair numbers	40598		Sweden	Common Scoter	Melanitta nigra	2012	Bregnballe, T., Lynch, J., Parz-Gollner, R., Marion, L., Volponi, S., Paquet, J.-Y., David N. Carss & van Eerden, M.R. (eds., 2014a). Breeding numbers of Great Cormorants Phalacrocorax carbo in the Western Palearctic, 2012-2013. IUCN-Wetlands International Cormorant Research Group Report. – Scientific Report from DCE – Danish Centre for Environment and Energy, Aarhus University, No. 99, 224 pp
Abundance and distribution data (sighted individuals per area)	111		20	Cormorant	Phalacrocor acidae	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	78		20	Cormorant	Phalacrocor acidae	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1012		20	Cormorant	Phalacrocor acidae	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1010		20	Cormorant	Phalacrocor acidae	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1063		20	Cormorant	Phalacrocor acidae	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1801		20	Cormorant	Phalacrocor acidae	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	570		20	Cormorant	Phalacrocor acidae	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)

Abundance and distribution data (sighted individuals per area)	758		20	Cormorant	Phalacrocoracidae	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	835		20	Cormorant	Phalacrocoracidae	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	214		20	Cormorant	Phalacrocoracidae	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	377		21	Cormorant	Phalacrocoracidae	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	324		21	Cormorant	Phalacrocoracidae	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1019		21	Cormorant	Phalacrocoracidae	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1019		21	Cormorant	Phalacrocoracidae	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	886		21	Cormorant	Phalacrocoracidae	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1815		21	Cormorant	Phalacrocoracidae	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	992		21	Cormorant	Phalacrocoracidae	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	898		21	Cormorant	Phalacrocoracidae	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	923		21	Cormorant	Phalacrocoracidae	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	591		21	Cormorant	Phalacrocoracidae	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	783		23	Cormorant	Phalacrocoracidae	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	568		23	Cormorant	Phalacrocoracidae	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1276		23	Cormorant	Phalacrocoracidae	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1220		23	Cormorant	Phalacrocoracidae	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1431		23	Cormorant	Phalacrocoracidae	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1798		23	Cormorant	Phalacrocoracidae	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)

Abundance and distribution data (sighted individuals per area)	1036		23	Cormorant	Phalacrocoracidae	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1790		23	Cormorant	Phalacrocoracidae	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1933		23	Cormorant	Phalacrocoracidae	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	2447		23	Cormorant	Phalacrocoracidae	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	59		24	Cormorant	Phalacrocoracidae	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	99		24	Cormorant	Phalacrocoracidae	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	81		24	Cormorant	Phalacrocoracidae	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	136		24	Cormorant	Phalacrocoracidae	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	321		24	Cormorant	Phalacrocoracidae	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	35		24	Cormorant	Phalacrocoracidae	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	387		24	Cormorant	Phalacrocoracidae	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	305		24	Cormorant	Phalacrocoracidae	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	381		24	Cormorant	Phalacrocoracidae	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	264		24	Cormorant	Phalacrocoracidae	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	451		25	Cormorant	Phalacrocoracidae	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	340		25	Cormorant	Phalacrocoracidae	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1030		25	Cormorant	Phalacrocoracidae	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	580		25	Cormorant	Phalacrocoracidae	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1285		25	Cormorant	Phalacrocoracidae	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)

Abundance and distribution data (sighted individuals per area)	3204		25	Cormorant	Phalacrocoracidae	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	792		25	Cormorant	Phalacrocoracidae	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1902		25	Cormorant	Phalacrocoracidae	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	3391		25	Cormorant	Phalacrocoracidae	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	2350		25	Cormorant	Phalacrocoracidae	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Cormorant	Phalacrocoracidae	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Cormorant	Phalacrocoracidae	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1		27	Cormorant	Phalacrocoracidae	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Cormorant	Phalacrocoracidae	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	65		27	Cormorant	Phalacrocoracidae	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	2		27	Cormorant	Phalacrocoracidae	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Cormorant	Phalacrocoracidae	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Cormorant	Phalacrocoracidae	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	4		27	Cormorant	Phalacrocoracidae	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1		27	Cormorant	Phalacrocoracidae	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance estimate digital aerial survey	7465	SE (± 2773)	22	Long-tailed Duck	Clangula hyemalis	2015	Žydelis, Ramūnas, et al. "Comparison of digital video surveys with visual aerial surveys for bird monitoring at sea." *Journal of Ornithology* 160.2 (2019): 567-580.
Abundance estimate visual survey	2474	SE (± 1498)	22	Long-tailed Duck	Clangula hyemalis	2015	Žydelis, Ramūnas, et al. "Comparison of digital video surveys with visual aerial surveys for bird monitoring at sea." *Journal of Ornithology* 160.2 (2019): 567-580.
Seasonal sample size used for density distribution	winter: 3989		22	Long-tailed Duck	Clangula hyemalis	2008 - 2010	Heinänen, Stefan, et al. "High-resolution sea duck distribution modeling: Relating aerial and ship survey data to food resources, anthropogenic pressures, and topographic variables." *The Condor:*

							Ornithological Applications 119.2 (2017): 175-190.
Population estimate	14800 00		Baltic	Long-tailed duck	Clangula hyemalis	2007 - 2009	Skov, Henrik. *Waterbird populations and pressures in the Baltic Sea*. Vol. 550. Nordic Council of Ministers, 2011.
Abundance estimate digital aerial survey	1648	SE (± 82 4)	22	Loon	Gavia spp	2015	Žydelis, Ramūnas, et al. "Comparison of digital video surveys with visual aerial surveys for bird monitoring at sea." *Journal of Ornithology* 160.2 (2019): 567-580.
Abundance and distribution data (sighted individuals per area)	0		20	Scoters	Melanitta sp.	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		20	Scoters	Melanitta sp.	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	175		20	Scoters	Melanitta sp.	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	117		20	Scoters	Melanitta sp.	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	193		20	Scoters	Melanitta sp.	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	84		20	Scoters	Melanitta sp.	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	15		20	Scoters	Melanitta sp.	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	34		20	Scoters	Melanitta sp.	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	45		20	Scoters	Melanitta sp.	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	72		20	Scoters	Melanitta sp.	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	289		21	Scoters	Melanitta sp.	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	27		21	Scoters	Melanitta sp.	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	3442		21	Scoters	Melanitta sp.	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	5656		21	Scoters	Melanitta sp.	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	9977		21	Scoters	Melanitta sp.	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	13239		21	Scoters	Melanitta sp.	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)

Abundance and distribution data (sighted individuals per area)	3113		21	Scoters	Melanitta sp.	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	10462		21	Scoters	Melanitta sp.	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	8900		21	Scoters	Melanitta sp.	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	17212		21	Scoters	Melanitta sp.	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	18		23	Scoters	Melanitta spp.	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	30		23	Scoters	Melanitta spp.	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	2		23	Scoters	Melanitta spp.	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	326		23	Scoters	Melanitta sp.	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1542		23	Scoters	Melanitta spp.	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	11		23	Scoters	Melanitta spp.	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	3		23	Scoters	Melanitta sp.	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	11		23	Scoters	Melanitta sp.	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	4		23	Scoters	Melanitta spp.	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		23	Scoters	Melanitta sp.	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	13		24	Scoters	Melanitta pp.	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		24	Scoters	Melanitta sp.	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		24	Scoters	Melanitta sp.	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1		24	Scoters	Melanitta sp.	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	4		24	Scoters	Melanitta sp.	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)

Abundance and distribution data (sighted individuals per area)	8		24	Scoters	Melanitta sp.	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	2		24	Scoters	Melanitta sp.	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	16		24	Scoters	Melanitta sp.	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	1		24	Scoters	Melanitta sp.	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	32		24	Scoters	Melanitta sp.	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	77		25	Scoters	Melanitta sp.	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	91		25	Scoters	Melanitta sp.	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	213		25	Scoters	Melanitta sp.	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	898		25	Scoters	Melanitta sp.	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	104		25	Scoters	Melanitta sp.	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	318		25	Scoters	Melanitta pp.	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	111		25	Scoters	Melanitta sp.	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	397		25	Scoters	Melanitta sp.	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	120		25	Scoters	Melanitta sp.	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	808		25	Scoters	Melanitta sp.	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Scoters	Melanitta sp.	2010	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Scoters	Melanitta sp.	2011	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Scoters	Melanitta sp.	2012	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Scoters	Melanitta sp.	2013	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)

Abundance and distribution data (sighted individuals per area)	0		27	Scoters	Melanitta sp.	2014	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Scoters	Melanitta sp.	2015	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Scoters	Melanitta sp.	2016	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Scoters	Melanitta sp.	2017	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Scoters	Melanitta sp.	2018	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Abundance and distribution data (sighted individuals per area)	0		27	Scoters	Melanitta sp.	2019	Data från januariinventeringen av sjöfågel (Svensk Fågeltaxeringen, Lunds universitet)
Population estimate	2300		Baltic	Steller's eider	Polysticta steller	2007 - 2009	Skov, Henrik. *Waterbird populations and pressures in the Baltic Sea*. Vol. 550. Nordic Council of Ministers, 2011.
Population estimate	415000		Baltic	Velvet Scoter	Melanitta fusca	2007 - 2009	Skov, Henrik. *Waterbird populations and pressures in the Baltic Sea*. Vol. 550. Nordic Council of Ministers, 2011.
Population estimate	30000		Baltic	Grey seal	Halichoerus grypu	2014	Oksanen, Sari M., et al. "A novel tool to mitigate bycatch mortality of Baltic seals in coastal fyke net fishery." *PloS one* 10.5 (2015).
Estimated population size	2,180-2,380		Sweden, Finland. Estonia (Baltic)	Grey seal	Halichoerus grypu	2012	Vanhatalo, Jarno, et al. "Bycatch of grey seals (Halichoerus grypus) in Baltic fisheries—A Bayesian analysis of interview survey." *PloS one* 9.11 (2014).
Abundance and distribution data (sighted individuals per area)	4856		24	Harbour porpoise	Phocoena phocoena	2012	ICES WGBYC 2012
Estimated population size	21390	(CI 95% 13461-38024)	24	Harbour porpoise	Phocoena phocoena	2015	SAMBAH, 2016a. Final report for LIFE+ project SAMBAH LIFE08 NAT/S/000261 covering the project activities from 01/01/2010 to 30/09/2015. Reporting date 29/02/2016, 80pp.
Population estimate	42324	(95% CI 23368-76658)	21-22	Harbour porpoise	Phocoena phocoena	2016	Hammond, P. S., et al. *Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys*. Wageningen Marine Research, 2017.
Population estimate	23368	(CI 95% 76658-3,28)	21-23	Harbour porpoise	Phocoena phocoena	2016	Helcom core indicator report, 2018: Number of drowned mammals and waterbirds in fishing gear
Population estimate	40,475	(95% CI 6111-15786)	21-23	Harbour porpoise	Phocoena phocoena	2012	Viquerat, Sacha, et al. "Abundance of harbour porpoises (Phocoena phocoena) in the western Baltic, Belt Seas and Kattegat." *Marine biology* 161.4 (2014): 745-754.
Population estimate	497	(CI 95% 80-1091)	25-32	Harbour porpoise	Phocoena phocoena	2015	SAMBAH, 2016a. Final report for LIFE+ project SAMBAH LIFE08 NAT/S/000261 covering the project activities from 01/01/2010 to 30/09/2015. Reporting date 29/02/2016, 80pp.

Abundance and distribution data (sighted individuals per area)	20575 1		20	Harbour porpoise	Phocoena phocoena	2012	ICES WGBYC 2012
Abundance and distribution data (sighted individuals per area)	14030		21	Harbour porpoise	Phocoena phocoena	2012	ICES WGBYC 2012
Population estimate	21390	(95 % CI: 13 461-38 024)		Harbour porpoise	Phocoena phocoena	2011 - 2013	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.
Abundance and distribution data (sighted individuals per area)	10000 (sighted individuals), 15000 (population estimate)		21	Harbour seal	Phoca vitulina	2018	Data från inventering av säl (Naturhistoriska riksmuseet)
Abundance and distribution data (sighted individuals per area)	1500 (sighted individuals) 2100 (population estimate)		25	Harbour seal	Phoca vitulina	2018	Data från inventering av säl (Naturhistoriska riksmuseet)
Population estimate	9100		31	Ringed seal		2015	Oksanen, Sari M., et al. "A novel tool to mitigate bycatch mortality of Baltic seals in coastal fyke net fishery." *PloS one* 10.5 (2015).
Population estimate	13000		Baltic	Ringed seal		2014	Oksanen, Sari M., et al. "A novel tool to mitigate bycatch mortality of Baltic seals in coastal fyke net fishery." *PloS one* 10.5 (2015).
-							Bäcklin, Britt-Marie, et al. "Health and age and sex distributions of Baltic grey seals (Halichoerus grypus) collected from bycatch and hunt in the Gulf of Bothnia." *ICES Journal of Marine Science* 68.1 (2011): 183-188.
-							Königson, Sara, et al. "Seal exclusion devices in cod pots prevent seal bycatch and affect their catchability of cod." *Fisheries Research* 167 (2015): 114-122.
-							Lewison, Rebecca L., et al. "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 (2014): 5271-5276.
-							Skov, Henrik, et al. "Marine habitat modelling for harbour porpoises in the German Bight." *Ecological Research at the Offshore Windfarm alpha ventus*. Springer Spektrum, Wiesbaden, 2014. 151-169.
-							Žydelis, Ramūnas, Cleo Small, and Gemma French. "The incidental catch of seabirds in gillnet fisheries: A global review." *Biological Conservation* 162 (2013): 76-88.
-							Žydelis, Ramūnas, et al. "Bycatch in gillnet fisheries–an overlooked threat to waterbird populations." *Biological Conservation* 142.7 (2009): 1269-1281.
-							Žydelis, Ramūnas, et al. "Conservation of marine megafauna through minimization of fisheries bycatch." *Conservation Biology* 23.3 (2009): 608-616.

-							Žydelis, Ramūnas, et al. "Dynamic habitat models: using telemetry data to project fisheries bycatch." *Proceedings of the Royal Society B: Biological Sciences* 278.1722 (2011): 3191-3200.
Population estimate							Hammond, P. S., et al. *Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys*. Wageningen Marine Research, 2017.
See Bregnballe et al 2014							Herrmann, C., Bregnballe, T., Larsson, K., Leivits, M. and Rusanen, P. 2019. Population Development of Baltic Bird Species: Great Cormorant (Phalacrocorax carbo sinensis). HELCOM Baltic Sea Environment Fact Sheets.
See Skov 2011							Larsson, Kjell, and Linnéuniversitetet Sjöfartshögskolan. "Ejder och alfågel-kan vi vända en nedåtgående trend?" *Svealandskusten* 2015 (2015): 29-31.
Population estimate							Nielsen, R. D. *et al.* (2019) 'Fugle 2012-2017: NOVANA', (Videnskabelig rapport nr. 314), p. 264. Available at: https://dce2.au.dk/pub/SR314.pdf.
Population estimate							Mendel, B. *et al.* (2008) *Profiles of seabirds and waterbirds of the German North and Baltic Seas*. Bonn-Bad Godesberg: Bundesamt für Naturschutz (Naturschutz und biologische Vielfalt, 61). Available at: https://www.bfn.de/en/activities/marine-nature-conservation/publikationen-zum-bestellen/profiles-of-seabirds-and-waterbirds.html.

Table 13: Summary of the breeding and wintering population estimates in the HELCOM area and at national level for the common eider, the common scoter, the velvet scoter and the great cormorant (source: "Population status and trends of birds under Article 12 of the Birds Directive", available online at ***Error! Hyperlink reference not valid.****https://nature-art12.eionet.europa.eu/article12.*

Common name	Species name	Country	Breeding population size (pairs)	Winter population size (# individuals)	Population status
Common eider	*Somateria mollissima*	Denmark	23000	140000	Threatened
		Sweden	73000 -- 127000	55000 - 80000	
		Finland	94000 --132600		
		Lithuania			
		Estonia	2000 - 4000	10 -- 50	
		Latvia			
		Poland	0 - 1	600 - 6000	
		Germany	1000 - 1400	320000	
		HELCOM	**193000 -- 288001**	**515610 -- 546050**	
Common scoter	*Melanitta nigra nigra*	Denmark		136000	Secure
		Sweden	5000 -- 7800	18000 -- 55000	
		Finland	1000 -- 2000		
		Lithuania		100 -- 200	
		Estonia		100 -- 1000	

		Latvia		3000	
		Poland		12000 -- 24000	
		Germany		365000	
		HELCOM	**6000 -- 9800**	**534200 -- 584200**	
Velvet scoter	*Melanitta fusca fusca*	Denmark		600	Threatened
		Sweden	8000 -- 12000	2500 -- 7000	
		Finland	3600 -- 11800		
		Lithuania		16800	
		Estonia	150 -- 300	200000	
		Latvia		20000	
		Poland		200000 -- 230000	
		Germany		39000	
		HELCOM	**11750 -- 24100**	**478900 -- 513400**	
Great cormorant	*Phalacrocorax carbo sinensis*	Denmark	25189 -- 39906	24000	Secure
		Sweden	40000		
		Finland	17258		
		Lithuania	5000 -- 6000		
		Estonia	13000 -- 14000	100 -- 300	
		Latvia	2634 -- 3106		
		Poland	25800	10000 -- 20000	
		Germany	22000 -- 26000	58000	
		HELCOM	**150881 -- 172070**	**92100 -- 102300**	

Annex 2: List of literature relevant for mitigating harbour porpoise bycatch

I. Time area closures

Short conclusion

The experiences collected in different areas in relation to time/area closures have been diverse. Nevertheless, time/area closures have been shown to be effective in reducing the bycatch of porpoises. There are, however, several issues that need to be considered before the wider implementation into gillnet fisheries.

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II. Gillnets modification

Short conclusion

The reason for chemically enhancing gillnets was to increase their target strength since porpoises might discover gillnets at too short distances to avoid entanglement. New research has, however, revealed that porpoises can detect gillnets at much longer distances (50-80 m) (Nielsen *et al.*, 2012; Wahlberg *et al.*, 2014). It is thus believed that the reason for porpoise entanglement is not that they cannot detect the barrier at a sufficient distance and thus that entanglement must be due to other reasons, for example lack of attention to the net barrier.

If net modifications such as changing TS, hanging ratios, mesh sizes and tie downs were able to reduce bycatch, they could be easy and cost-efficient to implement. Since no clear bycatch reducing effect has been identified in relation to gear modification without affecting the catch rate of target fish, however, net modifications are not at this stage considered as viable methods to reduce bycatches.

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III. Acoustic deterrent

Short conclusion

Dawson *et al.* (2013) reviewed a total of 14 controlled experiments all testing the effect of pingers on porpoise bycatch and concluded that three of these did not have the statistical power to determine any bycatch reducing effect of the instruments. The reasons for the missing effect were a lack of bycatch on both pinger and control nets. However due to the many positive results in reducing the bycatch of porpoises in gillnets fisheries Dawson *et al.* (2013) concluded that pingers do reduce such catches and that further experimentation was unnecessary. Even though pingers have been shown to be effective in reducing harbour porpoise bycatch, there are some important issues that needs to be considered before installing them, that is, effective range, habituation, habitat exclusion, functionality, implementation and enforcement.

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IV. Bycatch quotas

Short conclusion

Quotas have not been used as a management tool to reduce bycatch of harbour porpoises, although Bisack and Sutinen (2006) published the results of a study where individual transferable quotas (ITQ) and time/area closures were compared as management tools. The results showed that the ITQ was less costly to the industry compared to the season-port closures. The difference between the two changed depending on the bycatch limit although, in all cases, the ITQ had the lowest costs (Bisack & Sutinen 2006).

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Annex 3: Overview of HELCOM Assessment units and ICES squares used in project

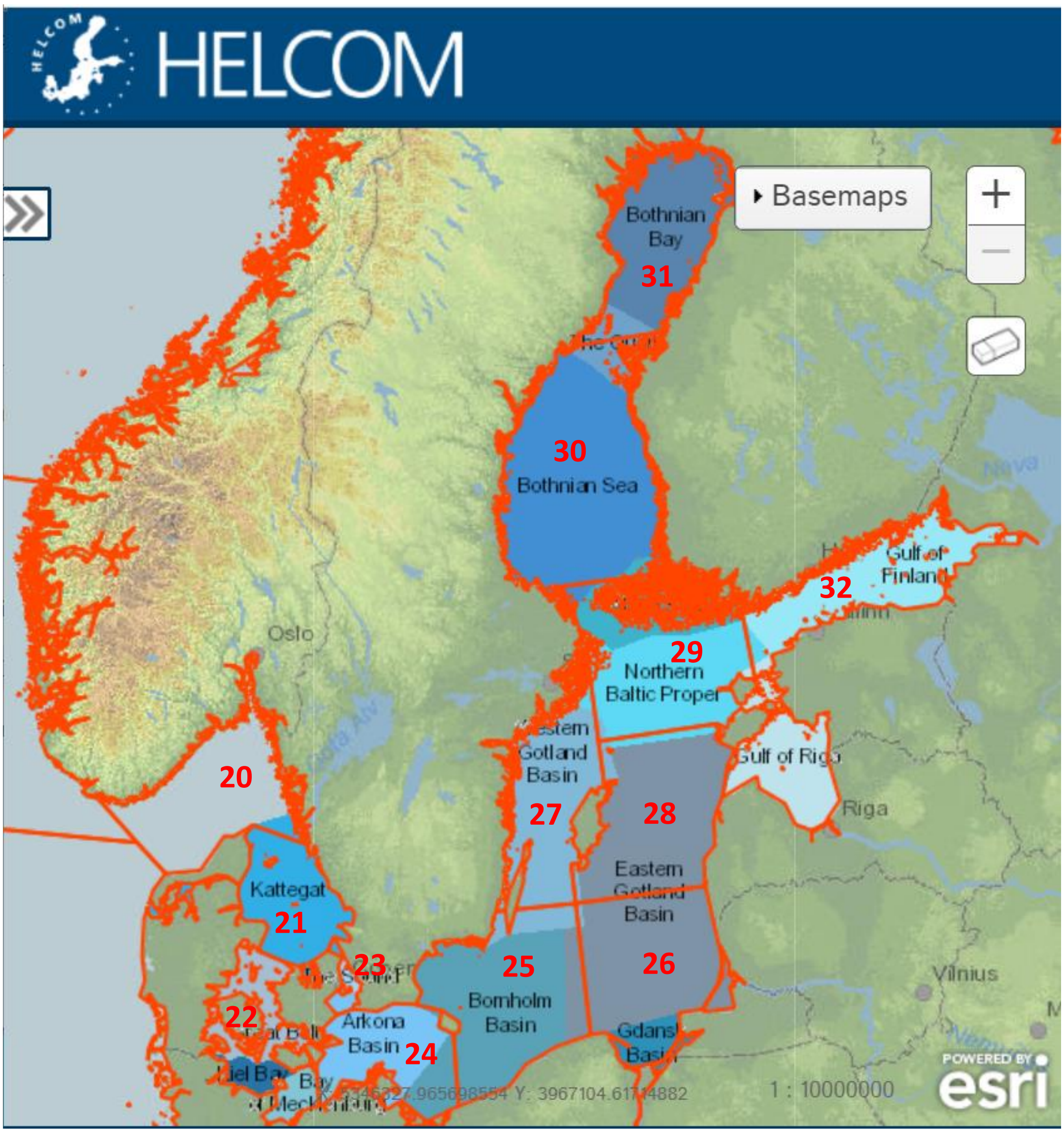

Figure 6: Simple overview to visualise ICES squares used in assessments with the 17 HELCOM sub-basins (i.e., HELOCM Scale 2 assessment units).