Agenda Item 4.3	Species Action Plans Conservation Plan for Harbour Porpoises in the North Sea (North Sea Plan)
Information Document 4.3a	Report of the Joint IMR/NAMMCO International Workshop on the Status of Harbour Porpoises in the North Atlantic
Action Requested	Take note
Submitted by	NAMMCO

ASCOBANS

Note:
Delegates are kindly reminded to bring their own document copies to the meeting, if needed.

Report of the Joint IMR/NAMMCO International Workshop on the Status of Harbour Porpoises in the North Atlantic

December 3rd - 7th 2018, Tromsø, Norway

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This report contains the views of the those attending the workshop and does not necessarily represent the position of the IMR or NAMMCO Scientific Committee and Council.

Although every effort has been made to compile the most accurate and up to date information, the workshop participants do not claim that this report represents a comprehensive account of all available information.

Acknowledgements

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1. INTRODUCTION

The harbour porpoise (*Phocoena phocoena*) is one of the smallest toothed whales (typically less than 2m in size) that inhabits coastal and continental shelf waters. It is widely distributed in the cooler waters of the North Pacific and North Atlantic oceans and the Black Sea (Haug, Desportes, Vikingsson, & Witting, 2003b). It operates as opportunistic piscivore predator (Bjørge, 2003), with diet varying significantly according to prey availability. The lifespan of harbour porpoises varies between populations and geographic areas, although not significantly between sexes. They live for notably less time than most other marine mammal species, with an average lifespan of 8-13 years (Lockyer, 2003). This shorter lifespan increases the sensitivity of the harbour porpoise population growth rate to fluctuations in other factors such as juvenile mortality or reproductive rates.

The small size and elusive behavior of the harbour porpoise make them particularly difficult to study in the wild and much remains to be understood about their general biology and ecology. Estimating their abundance is challenging because detection probability is low. Methods have been developed for surveys targeting small cetaceans (e.g. SCANS) that have resulted in robust estimates of harbour porpoise abundance (Hammond et al., 2013), however estimates from surveys not using such methods are likely negatively biased. The abundance of harbour porpoises in fjords is not well known because of the logistical difficulties associated with surveying these areas. While it is well known that harbour porpoises are by-caught in large numbers in fishing gear, it is not clear whether current levels of by-catch are sustainable due to the limited and patchy availability of reliable information in most fisheries, as well as limited data on population size and life history. In addition to by-catch, harbour porpoises are also highly prone to impacts from other human activities, including depletion of prey stocks due to overfishing, disturbance from noise generating activities (such as shipping and wind farm construction), and chemical pollution. Chemical pollution has been particularly highlighted as a potential factor negatively affecting reproductive success (Murphy et al., 2015). This combination of factors has seen several international organisations, including NAMMCO, the International Whaling Commission (IWC), the International Council for the Exploration of the Sea (ICES) and the Agreement on the Conservation of Small Cetaceans of the Baltic and the North Sea (ASCOBANS), emphasise the need for sound scientific assessments of harbour porpoises and more knowledge on the effects of pressures such as by-catch, and noise and chemical pollution.

In response to these needs, and as a follow up to the international symposium on harbour porpoise in the North Atlantic organized by NAMMCO in 1999 (see Haug, Desportes, Vikingsson, & Witting, 2003a), in December 2018 a workshop on the status of harbour porpoises in the North Atlantic was held in Tromsø, Norway. This meeting was co-organised by the Norwegian Institute of Marine Research (IMR) and the North Atlantic Marine Mammal Commission (NAMMCO). With an overarching aim to improve the knowledge base for ecosystem-based management, the central objectives of the workshop were to:

a) assemble current information on the biology, abundance and by-catch of harbour porpoises,
b) perform assessments of the status of harbour porpoises in different areas of the North Atlantic, and
c) identify the gaps in existing knowledge that need to be addressed to understand the status and ecological role of harbour porpoises in these waters.

The workshop began with Chairman Ulf Lindstrøm welcoming participants and summarinsing the background for the workshop. The first session on stock identity and structure focused on better understanding the spatial distribution of populations and their level of interaction to develop agreement on how to reasonably delineate assessment units. Following this first session on stock identity and assessment areas, presentations were given on different human generated threats and pressures faced by harbour porpoises, including by-catch, disturbance, noise and chemical pollution. The focus then turned to questions of general biology, with presentations on feeding ecology, life history and health. This was followed by presentations and discussions on different models available for performing assessments. The second part of the workshop then used population dynamic models to assess the status of harbour porpoises in each of the agreed areas, based on the information collated by expert participants prior to the workshop. After each of the area assessments were generated, presented and discussed, the final day focused on drawing out general conclusions and recommendations concerning the available knowledge and the assessments of populations in the different areas.

The structure of this report follows the general structure of the workshop. It provides summaries of the presentations made by expert participants and the discussions that followed. It then presents each of the area assessments and closes by outlining general conclusions and recommendations. The background information assembled for each area is available in the annexes and supplementary files. By collating this information, the report provides a useful overview of the current status of harbour porpoise populations in the North Atlantic and adjacent waters, and identifies knowledge gaps that need to be filled for sound ecosystem-based management.

2. BACKGROUND

a. Stock Identity

To better understand stock identity and determine relevant units for assessment, a number of presentations were given by expert participants at the workshop. This included presentations on genetic analyses of harbour porpoise populations, as well as research on movement and stock identity in specific areas of the North Atlantic. Each of these presentations is summarised below, followed by a discussion of the division of the North Atlantic into assessment units and the map developed of these proposed assessment areas.

Genetic Structure & Evolution of North Atlantic Porpoise Populations (Michael C. Fontaine)
Despite no obvious barriers to gene flow in the marine realm, environmental variation and ecological specialization can lead to genetic differentiation in highly mobile predators. We have investigated the genetic structure of the harbour porpoise over the entire species distribution range in western Palearctic waters (Central and Eastern North Atlantic + Black Sea) (Fontaine, 2016; Fontaine et al., 2014, 2017), and more recently also including the Western North Atlantic (Ben Chehida, et al. in prep).

Combined analyses of 10 microsatellite loci and a 5085 base-pair portion of the mitochondrial genome for 762 individuals sampled between 1990-2000 revealed three distinct evolutionary units or sub-species, equally divergent at the mitochondrial genome. These were: (1) *P. p. relicta* in the Black Sea (BS), (2) *P. p. phocoena* continuously distributed on the European continental shelf waters (NATL) from the northern Bay of Biscay up to the Arctic waters of Norway and Iceland, and (3) *P. p. merridionalis,* a previously overlooked ecotype /subspecies inhabiting the upwelling zones (UP). It includes two genetically distinct populations inhabiting Iberian (IB) and Mauritanian (MA) waters, respectively, with genetic evidence of population decline in the Iberian population (Fontaine et al., 2014).

In collaboration with PE Rosel (NOAA-NMFS), we analyzed 265 samples from Rosel et al. (1999) using the same mitochondrial and nuclear microsatellite loci and combined them with our previous data sets (Ben Chehida, et al. in prep). The first results of this ongoing work suggest that Western North Atlantic porpoises are part of the continuous unit of *P. p. phocoena.* However, we showed that this is not a random mating unit. Significant isolation by distance, especially at the mitochondrial level, indicates limited intergenerational individual dispersal and also provides strong evidence of female philopatry. A surprising finding shows that a 4th distinct mitochondrial lineage has been found in one porpoise from Western Greenland Waters, which raises the possibility that a 4th sub-species may exist. Also, additional population subdivisions may occur within *P. p. phocoena* and may be revealed by increasing the number of loci (SNPs) and analyzing a sample targeting the summer breeding period.

Genetic inference of historical demography revealed that the three subspecies diverged during the last glacial maximum (c. 23–19 kilo-years ago, kyrBP). The BS and UP subspecies share a more recent common ancestor (c. 14 kyrBP) than either does with the NATL subspecies (c. 28 kyrBP), suggesting that they descended from the extinct populations that once inhabited the Mediterranean during the glacial and post-glacial period. Each of these subspecies may have evolved specific adaptations that are the focus of ongoing population genomic studies. We showed that the two Atlantic subspecies (southern and northern) came back in contact and established a narrow admixture zone in the Bay of Biscay during the last millennium, with highly asymmetric gene flow.

Combining the microsatellite data obtained so far with 592 newly genotyped individuals sampled around the British coasts, has allowed us to investigate the fine-scale delimitation of the admixture zone (Fontaine et al., 2017). These data showed that porpoises stranded along the South-Western coasts facing the Celtic Sea displayed an admixed ancestry similar to the other porpoises stranded from the French coasts of the Bay of Biscay, with a sharp transition toward "pure" *P. p. phocoena* occurring in the Irish Sea and in the Atlantic side of the Channel. These admixed porpoises displayed larger body size, once accounting for sex and age variation, which correlated with the genetic ancestry of southern sub-species (UP). The geographic delimitation of this admixture zone may be just a temporal snapshot or could be actively maintained by unknown ecological preferences or constraints. This question is being addressed by an ongoing study of the temporal and spatial evolution of this admixture zone across the NE Atlantic over the last 30 years (Ben Chehida et al. in prep).

Take home messages

- At least three genetically distinct subspecies occur in the North Atlantic (with possibly a 4th one in Western Greenland waters). They follow distinct evolutionary trajectories, with morphological, ecological and life history differences.

- The North-West Atlantic porpoises are part of *P. p. phocoena*, but this is NOT a random mating unit, since isolation by distance is detected, especially when considering female specific genetic markers. This strengthens previous evidence that females are strongly philopatric. Additional population subdivision and finer estimates of admixture and dispersal may be uncovered by increasing the number of genetic loci by at least two or three orders of magnitude and by analyzing a specific sampling targeting the breeding period.
- A hybrid zone in the Bay of Biscay exists between *P. p. merridionalis and P. p. phocoena*, with a sharp transition from one sub-species to the other. It is, however, not clear whether this is due to it being a temporal snapshot or as a result of ecological preferences/constraints.

Knowledge gaps of particular relevance for assessment

- It is not clear whether there is local adaptation among sub-species (ecotypes) that would warrant specific conservation attention (e.g. Iberia, Mauritania, Western Greenland)
- There are certain geographic areas for which there is currently significant genetic data deficiency. This includes: (1) Irish waters, (2) Faroe Islands, (3) Eastern Greenland, although Fontaine is currently working to fill some of these gaps (Irish waters).
- The current large-scale genetic studies are focused on a 1990-2000 sampling cohort and there is a need for a new work and time cohorts to assess the dynamics of the population structure.
- There is a need to continue the ongoing effort to assess genetic structure from 2005 to 2017 and compare this to the 1990 – 2000 cohort (this work is currently focused on European waters)
- Large scale geographic studies are currently based on ~10 microsatellite and mtDNA loci. A larger SNPs data set (in the order of thousands) shows better performance at detecting subtle population structure and assessing more precisely the mixing proportion and migration among populations. This could include a RAD-seq effort (thousands of SNPs & larger sampling) + 400 SNPs ascertained for *P. p. phocoena*, but it may not be applicable to other sub-species. Work may also be done on whole genome sequencing (millions of SNPs, small sample size) + 500 SNP defined from all known subspecies of porpoises including the North Atlantic and North Pacific.
- Analyses of samples during the breeding season could reveal finer population structure.

SNPs and Close Kin Analysis Improve Population Resolution for the Harbour Porpoise (Ralph Tiedemann)

Population structure inferences were presented on harbour porpoises originating from *Iceland* (n=1856 for 15 microsatellites (microsats); n=1851 for the mitochondrial Control Region (mtDNA); n=3 for 1874 Single Nucleotide Polymorphisms (SNPs)), *Eastern North Sea* (n=97 for 15 microsats; n=94 for mtDNA; n=11 for 1874 SNPs; n=39 for 2518 SNPs), and *Baltic Sea* (n=255 for 15 microsatellites; n=252 for mtDNA; n=26 for 1874 SNPs; n=70 for 2518 SNPs).

North Sea and Baltic Sea populations were clearly distinguished by all analyses, with a transition zone in the Kattegat. Within the Baltic Sea, a further subdivision was detected between a western Belt Sea and an eastern inner Baltic Sea sub-population, with a transition zone around the southern tip of Sweden. The distinction was most prominent during reproduction time (April to September), indicating some seasonal migration across population boundaries outside reproduction times.

The Icelandic population was generally similar to the North Sea population. There were consistent differences though in mtDNA haplotype and microsatellite allele frequencies, indicating isolation-by-distance. The more pronounced divergence in mtDNA may indicate female philopatry.

Comparing SNP analyses to microsatellite typing on the same individuals, the SNPs clearly outperformed the microsatellites regarding the ability to assign individuals to genetic clusters (“STRUCTURE analyses”). This becomes particularly evident regarding the North Sea/Belt Sea/Inner Baltic Sea boundaries. SNP clusters were significantly associated with mtDNA haplotypes, underscoring that seasonal population admixture does not necessarily translate into gene flow.

Microsatellite and SNP data can be used for kinship inference. This approach was used on the Icelandic microsatellite data set and the inferred number of parent offspring pairs was used for abundance estimation (Table 1). Parent-Offspring pairs within a subarea in the same year were excluded to ensure independent sampling.

Table 1: Abundance estimates (Chapman) by sampling period in Iceland based on Parent-Offspring kinship using 15 microsatellite loci (False Discovery Rate =0.25; Detection Power=0.63; Survival rate=0.9). For effective comparisons calculations (Gunnlaugsson, 2012).

Period	Peak year	Sample size	Effective comparisons	PO pairs	Abundance	CV
1991-2000	1992	1,157	380,944*2	13	54,420	0.22
2011-2018	2017	671	176,424*2	2	117,616	0.42

These estimates should be considered valid as an indicator of population trends rather than as an absolute abundance estimate, as they may be biased due to imbalanced sampling (too few females). This will be analyzed further in ongoing work.

As a full genome sequence is now available for the harbour porpoise, the 4392 polymorphic SNPs shared among 146 typed specimens, as well as the SNPs of an additional 67 samples from East Canada, Greenland and Iceland (see presentation of Nynne Lemming (previously Nielsen) as summarised below) have been mapped to their chromosomal position. From this, a panel of informative SNPs is currently being created for population delimitation and kinship inference in North Atlantic and Baltic porpoises.

Take-home messages

- Single Nucleotide Polymorphisms (SNPs) are very reliable to genotype and enable a better population delimitation/assignment than microsatellites.
- Icelandic and North Sea porpoises are genetically similar, Belt Sea and inner Baltic Sea populations are more distinct.
- For the well sampled Icelandic porpoise population, inference of close kinship (Parent-Offspring) based on 15 typed microsatellites creates abundance estimates of 54,420 (in the period 1991-2000) and 117,616 (2011-2018).

Knowledge gaps of particular relevance for assessment

- Virtually no genetic information is available for East Greenlandic and Faroese porpoises.
- Available genetic information on North Atlantic porpoises is currently distributed across several laboratories. An integrative analysis across the entire North Atlantic (including the North and Baltic Seas) with a common set of molecular markers would be desirable.
- The kinship-based abundance estimate should be expanded to increase precision. Further analysis shall be performed to minimize sampling bias.

Genetic Structure of Harbour Porpoise in Norwegian Waters (Maria Quintela)

A total of 134 individuals (58 females and 76 males) by-caught along the Norwegian coast during 2016 and 2017 were analyzed using 78 SNP markers. No genetic differentiation was recorded between years (F_{ST}=0.001, P=0.2112) nor between sexes (F_{ST}=0.002, P=0.075). STRUCTURE analyses showed the highest average likelihood at K=1, although both *a posteriori* Evanno test and STRUCTURESelector pointed at K=2 as the most likely number of clusters. At K=2, the 134 individuals could be partitioned into two clusters of almost identical size (N=66 and N=68 respectively) showing low yet significant population differentiation due to genetic structure - F_{ST} (0.022, P=0.022). However, no obvious underlying pattern such as geographic position, sex, or year of sampling could account for this statistically significant F_{ST}.

Take home messages:

- The current data does not provide solid evidence to accept or reject that the 134 samples of harbour porpoise analyzed in the Norwegian waters belong to two different genetic clusters.

Knowledge gaps of particular relevance for assessment:

- A population genetic analysis conducted on a broader geographic range (preferably including both sides of the Atlantic), using both robust sampling sizes and a suite of molecular markers is needed to resolve the geographic population structure of harbour porpoises in the North Atlantic, including the Norwegian coastline.

The Movement of Greenlandic Harbour Porpoises (Nynne Lemming)
Harbour porpoises are hunted in Greenland for their meat and skin. The hunt is currently unregulated. However, catches do have to be reported to the Ministry of Fisheries, Hunting and Agriculture in Greenland. From the catch history, it is clear that catches increased between 1990 and 2017, up to an average annual harvest of approximately 2200 animals. To date there has been very limited data available on the population of harbour porpoises in Greenland. To enhance the level of knowledge on their ecology, my PhD work (Lemming, 2018) has used satellite-linked transmitters to gain information on harbour porpoise movement and diving. In collaboration with local hunters, we caught 30 harbour porpoises in West Greenland and attached satellite transmitters to document their seasonal movements and diving behaviour.

Nineteen females and thirteen males were tagged between 2012-2014 and transmitted up to 1047 days. Fifteen porpoises displayed offshore movement into the North Atlantic during winter and six displayed site fidelity to the tagging area due to the mating season. Despite the extreme distribution, no harbour porpoises tagged in West Greenland crossed the continental shelf of Canada, Iceland or East Greenland. The remaining 15 porpoises did not move into the North Atlantic, but this could be due to the limited time of tag duration. Seventeen animals dived to a median depth of 200m and one female dived to an impressive 410m. The extreme behaviour of porpoises from West Greenland stands in great contrast to porpoises tagged in the Danish waters of the North Sea, which did not leave the continental shelf but showed a preference for areas with shallow waters all year-round. This behavioural difference together with ecological preferences indicates that porpoises from West Greenland could be a unique ecotype. Muscle/skin samples from Canadian (n=26), Greenlandic (n=30) and Icelandic (n=12) porpoises were also used for genomic analysis using SNPs to better understand the ecotype mechanisms. A clear isolation of porpoises from West Greenland from animals in Iceland and Canada was detected, probably due to limited contact with neighbouring populations during the mating season, as was also clearly supported by the tagging data.

Take-home messages:

- Porpoises from West Greenland can perform long periods of offshore movement, however, they also return to the tagging site the following year.
- Porpoises from West Greenland display deep dives to a mean of 200m and with maximum depth of 410m.
- From the genomic analysis using SNPs, a clear isolation of porpoises from West Greenland from animals in Iceland and Canada was detected, as was also clearly supported by the tagging data.

Knowledge gaps of particular relevance for assessment:

- It is not known whether harbour porpoises from Greenland consists of one population or are divided in two populations (West and East Greenland) and further research to clarify stock structure is desirable.

Stock Identity: North Sea & Baltic (Signe Sveegaard)
The presentation was based on the background for and the results of Sveegaard et al. (2015). Studies of genetic structure and morphometric separation suggest three distinct populations of harbour porpoises with limited geographic overlap: The North Sea population (in the North Sea, Skagerrak and the Northern Kattegat), the Belt Sea population (in the Southern Kattegat, the Belt Seas, the Sound and the Western Baltic) and the Baltic Proper population. The study aimed to identify the best management unit for the Belt Sea population (which is a population that is distributed across the Kattegat, Belt Sea, western Baltic and Sound). By using data from satellite tagged porpoises and acoustic data from 40 passive acoustic data loggers, the management areas with the least overlap between populations and thus the least error when abundance and population status is estimated, was determined. Discriminant analysis of the satellite tracking data from the Belt Sea and North Sea populations showed that the best fit of the management unit border during the summer months was an east–west line from Denmark to Sweden at latitude 56.95°N. For the border between the Belt Sea and the Baltic Proper populations, satellite tracking data indicate a sharp decline in population density at 13.5°E, with 90% of the locations being west of this line. This line was supported by the acoustic data with the average daily detection rate being 27.5 times higher west of 13.5°E compared to east of 13.5°E. Based on the data from this multidisciplinary approach, the best western management border for the Baltic Proper population lies further east as a line from Sweden to Poland.

Take home messages

- Studies on genetic structure, morphometrics, telemetry and passive acoustic monitoring suggest three distinct populations of harbour porpoises with limited geographic overlap: the North Sea population, the

Belt Sea (and adjacent waters) and the Baltic Proper population. Summer management units have been determined for the latter two.

Knowledge gaps of particular relevance for assessment

- The summer population area of the critically endangered Baltic Proper harbour porpoise population should be confirmed, as well as the winter distribution and the degrees of mixing between the Belt Sea and the Baltic Proper populations.
- Genetic studies of the sub-populations within the North Sea and SNP-analysis within the Baltic Proper could usefully further elucidate the population structure.

Discussion of Stock Identity Presentations

Following the presentations on the topic of stock identity, the main focus of the discussion was on how to define the areas that would be used to generate the population assessments.

A draft map indicating one potential way to draw the boundaries and delineate different assessment areas was shown (Figure 1). This was then discussed and revised in light of the presentations made and the currently available knowledge on stock structure and identity. Several areas for which there was significant uncertainty (e.g. in terms of whether the populations are interbreeding or not) or a lack of knowledge (e.g. in terms of the range of a population's movement) were highlighted and discussed. It was noted, for example, that there was a significant lack of genetic data from harbour porpoises around the Faroe Islands and Greenland and indeed that all genetic analyses should ideally be updated using recent samples if we are to see how distributions may be shifting, e.g. due to environment and climate change. It was noted that some of the data being used was up to 15 years old. It was also proposed that genetic analyses could be re-run using only data from the summer period, as this would help to define breeding stocks. This would however reduce the sample size used in the analysis.

It was agreed that dividing populations into smaller units for assessment was less problematic than failing to recognise where populations may be distinct and isolated. It was also agreed that the approach taken for the harbour porpoise should mirror that used by the IWC in which even though small areas may be defined, the models used to generate population assessments allow and account for the potential for animals to mix across certain areas. It was also agreed that a valuable approach would be to create assessments using different scenarios for the division of these uncertain areas and to compare the results so as to better understand the significance of dividing the areas in one way or another.

It was also acknowledged that of course firm borders between areas may not always exist in practice and in some areas, there will necessarily be a gradual differentiation. This means that it would be important to differentiate between those areas that seem to contain pure stocks and others where the area contains more of a mixed stock. In this sense, the discussion noted that it was very important to realise that what was being discussed was not necessarily a map of different populations, but rather a map of proposed management or assessment areas.

It was also noted that the map that was developed showed shaded areas that were larger than where information was available to perform the actual assessments. In practice these lines are not as distinct as they appear on the map. Revisions of the marked offshore areas may be required to better represent where the available data has come from and to also possibly more clearly indicate the areas where information on key factors such as abundance and by-catch is missing. Of course, the map could also be further improved through an expanded use of telemetry and mark-recapture data. It was proposed that ICES fishing areas could also be added to the map and used to aid delineation of assessment unit boundaries. In this context, it was noted that some boundaries have been decided by other nations or organisations based on practical, geographic or political criteria rather than on the distribution and range of populations.

The draft map that was discussed during the workshop is shown in Figure 1 below. The outer boundaries utilise EEZ for some countries and do not necessarily reflect the outer boundaries of the harbour porpoise distribution.

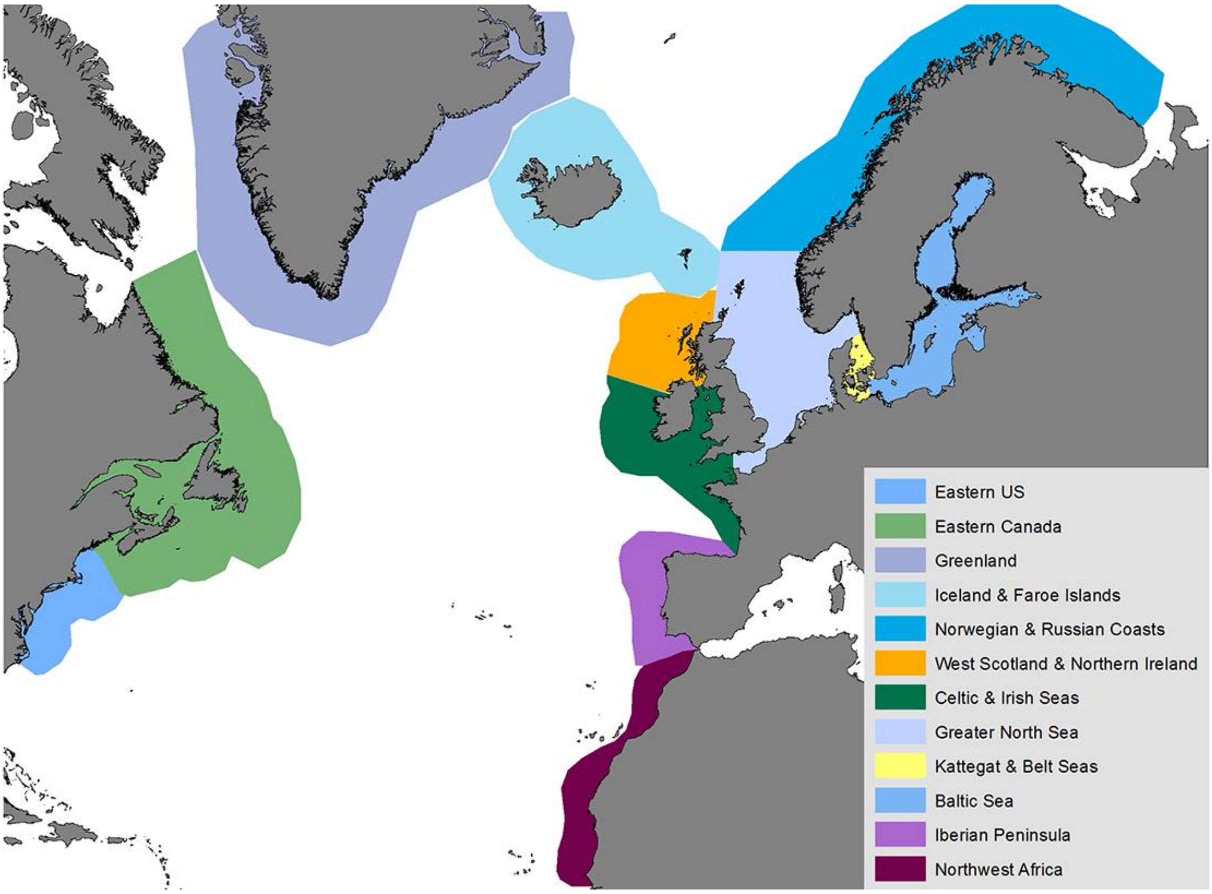

Figure 1. First draft map showing the proposed division of assessment areas for group discussion. This initial proposal was informed by the ICES porpoise assessment areas, as well as the ASCOBANS boundaries for species action plans. Although not shown on this map, there was a proposal before the workshop to divide Canada, Greenland and Iceland & Faroe Islands into sub-areas. Data Source: Wessel & Smith, 1996. Cartography: Solveig Enoksen; NAMMCO.

Some of the areas that were discussed during the workshop as particularly challenging for the delineation of assessment units and potentially in need of some revision included:

- **East Greenland**
  Here the key question of whether it should be joined to Iceland or left open was discussed. Furthermore, whether east and west Greenland should be separated or combined was also a topic of discussion.
- **Faroe Islands**
  It was not clear whether the Faroe Islands should be assessed as: a) its own management unit, b) part of western Scotland, c) part of Iceland, or d) within the North Sea area. It was decided that the Faroe Islands should remain separate as a cautionary measure until more data is available on the populations there.
- **US-Canada**
  The line used on the draft map to separate the US and Canada was noted to be a national border and not necessarily representative of the harbour porpoise populations or the most relevant areas for assessment. It was proposed that this dividing line should move more into the Canadian waters, to correspond with data from the US. Furthermore, whether the US should be assessed as a single area or divided was also discussed.
- **Norway**
  It was noted that the 62° border that was being used to define the lower bound of the Norwegian area is a kind of administrative border used by several organisations involved in the management of marine resources. Although it was recognised that this may not accurately refer to a population border, it did make sense as an assessment and management unit due to its already widespread use.
- **West Scotland/Ireland and the Irish & Celtic Seas**
  Although the lines in this region as proposed on the draft map were defined by an ICES working group, microsatellite data suggests that porpoises from Western Ireland are more closely related to North Western Scotland (NWS) than with the Celtic Sea / Bay of Biscay (Fontaine et al. 2014; 2017). Based on the present (limited) sampling, this was proposed as justifying combining western Ireland and NW Scotland as an assessment unit. The Irish Sea is an area of genetic transition between the admixed porpoises located in the Celtic Sea, Bay of Biscay, and Western Channel (CS/BB/WC) and the "pure" porpoises of the northern waters (Fontaine et al. 2014; 2017). It was therefore discussed as to whether this area should thus be either joined

with the NWS or with CS/BB/WC for assessment purposes. For the purposes of the assessment, the Irish Sea was tentatively joined with the CS/BB/WC.

- **Baltic region**

Based on the available information, arguments were made for redrawing the dividing line in the draft map between the Belt and North Sea populations of porpoises, moving it further south into the Kattegat. The proposed management units of the Belt Sea and Baltic Proper population do not line up exactly and thus a gap area in the transition zone between the populations exists (see hatched area in figure 2). This area will likely be inhabited by individuals from both populations. However, the density is considered too low for it to be relevant to include in the management units.

On the basis of these discussions, the workshop produced a revised map (Figure 2) of the areas that would be used as assessment units.

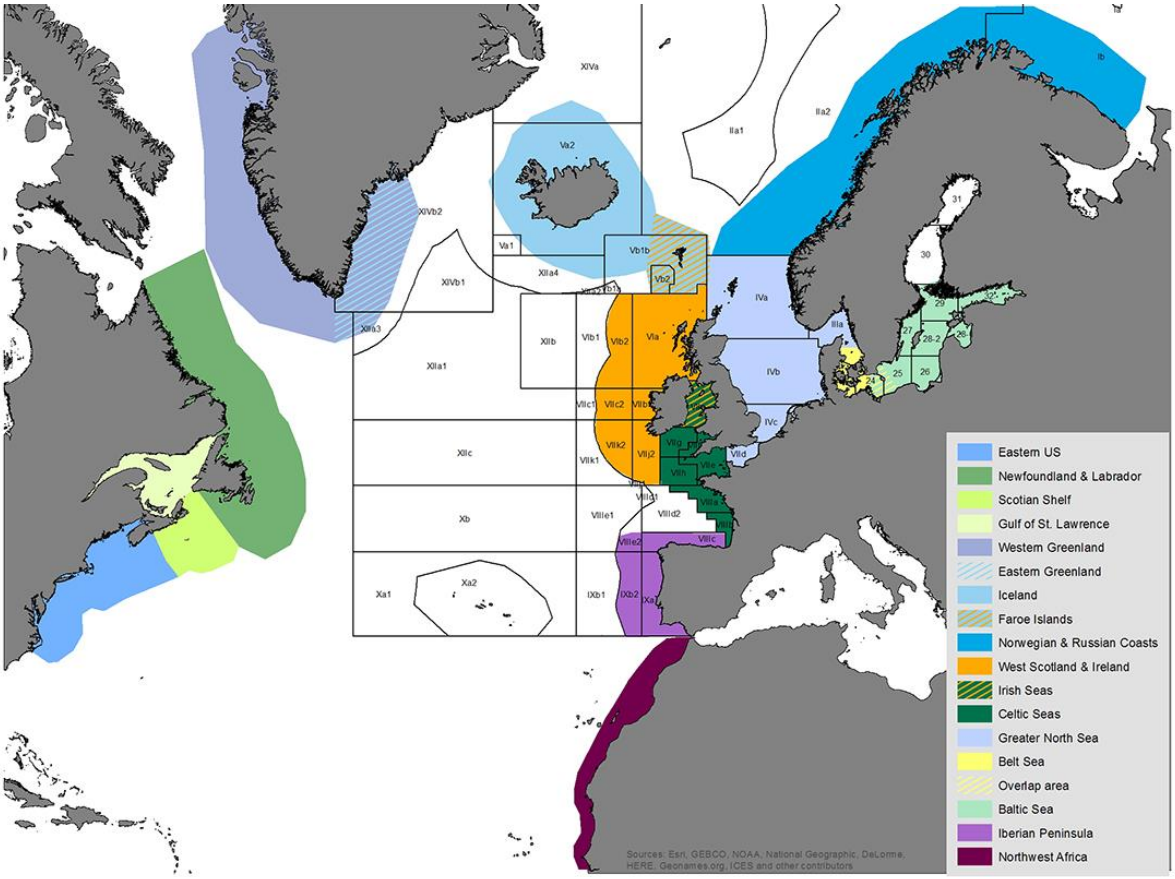

Figure 2: Map of the assessment areas for harbour porpoise in the North Atlantic as decided and used during the workshop, with the ICES fishing areas super-imposed. Data sources: ICES; SAMBAH; (Wessel & Smith, 1996). Cartography: Solveig Enoksen; NAMMCO.

b. Lethal pressures

By-catch (Finn Larsen)

Harbour porpoises have been by-caught in a variety of fishing gears including longlines, purse seines, trawls, weirs, pound nets, trammel nets and gillnets, the last type including both bottom-set gillnets, tangle nets and drifting gillnets. However, gillnets are responsible by far for the majority of harbour porpoise by-catch.

Several factors are known to or suspected to affect by-catch rates - here taken to mean by-catch per unit of fishing effort - and these factors can be divided into four groups. Environmental factors include *e.g.* wind/weather, turbidity and water depth, while operational factors include location, season and soak duration, and gear specific or technical factors include net height, mesh size, twine size, twine type (mono-, multi- or multimono-filament), stiffness, floatline type, tie-downs and hanging ratio. Behavioural factors include *e.g.* acoustic and visual deterrents, although the latter have not yet been shown to have an effect. Finally, the density of porpoises in a given area will also affect the by-catch rate. It is important to realise that many of these factors are confounded and can be very difficult to disentangle. There is, however, similarities among the fisheries responsible for the majority of harbour porpoise by-catch in the various regions of the North Atlantic. These fisheries tend to be those using medium to large mesh size gillnets set for species such as cod, hake, turbot, monkfish and lumpfish. The reason for this is not only the gear they use but also the large total effort of these fisheries.

Estimation of total by-catch

Estimation of total by-catch requires as a minimum an estimate of the by-catch rate expressed as the number of animals by-caught per unit of fishing effort (BPUE) and data on the total fishing effort of the relevant fleet.

BPUE can be based on several different types of data including, in order of increasing reliability:

- Interviews
- Logbooks
- Reference fleets
- Fishery observers
- Dedicated by-catch observers
- Video monitoring (REM)

All these types of data have potential biases, including (but not limited to) mis-reporting numbers bycaught, mis-reporting fishery, area, season etc. and non-representative sampling coverage. They are also all biased downwards to an unknown degree by not including drop-outs, i.e. animals that fall out of the nets before being brought to the surface.

The best measure of total gillnet fishing effort is length of nets times soak time, but this is almost never available at the fleet level. Instead, data on total fleet effort comes in the form of days-at-sea (DAS) reported by the fishermen or is estimated based on reported landings, but both data sources are subject to important biases. Using landings as a proxy for effort assumes that both target species CPUE (Catch Per Unit of Effort) and the by-catch/landings relationship are constant over the period being analysed and this is rarely the case. A further potential bias for this measure of effort is underreporting of landings.

Using DAS as a measure of fishing effort is subject to other potential types of biases arising from e.g. considerable variability in fishing effort (number of nets) between and within fishing vessels, the latter due to seasonal variation in the fisheries pursued. Using DAS is also affected by changes over time in fleet structure, in quotas and in regulations, e.g. regarding which vessel classes are included in the reporting. However, these biases can to a large degree be reduced by representative by-catch sampling coverage that takes these potential biases into account.

Assessing the effect of by-catch

Assessing the effect of by-catch on the populations of harbour porpoises requires ideally a time series of total by-catch going back in time as far as possible. In the ideal world this would be based on observations of by-catch with high coverage in both time and space and by metiers, resulting in unbiassed estimates of BPUE by year, fishery, season, etc. Combined with high quality data on fleet effort (in kilometres*hours) by year, fishery, season, etc. this would allow robust stratified estimates of total by-catch by year for each population to be made. However, the reality (with a few notable exceptions) is that in the North Atlantic most by-catch estimates are derived from short-term projects, i.e. there are no time series, the by-catch sampling coverage is sub-optimal, i.e. BPUE is pooled across year, fishery, season, etc., there is bias from non-representative sampling, and total fleet effort is only available in DAS or through landings statistics.

By-catch mitigation

Mitigation of by-catch can only happen by making changes to the two factors that goes into the estimate of total by-catch: the total fleet effort and the BPUE. There is a straightforward relationship in a given fishery between total fleet effort and total by-catch so reducing total effort will lead to a reduction in total by-catch.

Reducing BPUE can be accomplished through changes to one or more of the many factors mentioned above that affects the BPUE. For example, if a particular area or season has been shown to have higher BPUE, time-area closures can be used to reduce BPUE by displacing the fishing effort into areas with lower BPUE. Deploying acoustic alarms has been shown to be very efficient in reducing porpoise BPUE in several fisheries without affecting target species CPUE. Some of these factors may be effective at reducing BPUE but will also reduce target species CPUE to such an extent that the mitigation method will be unacceptable to the fishery.

Take home messages

- Across the North Atlantic, gillnets, including bottom-set gillnets, tangle nets and drifting gillnets, are responsible by far for the majority of harbour porpoise by-catch.

- The fisheries responsible for the majority of harbour porpoise by-catch tend to be those using medium to large mesh size gillnets set for species such as cod, hake, turbot, monkfish and lumpfish. The reason for the high by-catch rates in these fisheries is a combination of net type and fishing effort.
- Apart from reductions in fishing effort, deployment of acoustic alarms is at present the most effective means of by-catch mitigation.

Knowledge gaps of particular relevance for assessment

- Estimates of by-catch rate by season, area, metiér etc.
- Fishing effort; more reliable data on fleet effort in kilometres*hours.
- Loss rate of by-caught animals, i.e. the proportion of by-caught porpoises that drop out of the nets before they reach the surface.
- The importance (at a population level) of habitat exclusion and habituation when using acoustic alarms.
- Why pingers are not working in some fisheries.

Discussion of By-catch

The observed general decrease in by-catch of harbour porpoises is most likely due to a reduction in fishing effort, which is in turn due to a reduction in total allowable catches. For some small-scale fisheries, there is no information on fishing effort or, in many cases, by-catch rate based on observer effort, leading to challenges for estimating by-catch levels. Options for obtaining information on by-catch rate on small vessels include Remote Electronic Monitoring (REM) or having observers on boats next to the fishing vessels. An alternative approach to estimating by-catch has been developed in France using cause of death data from strandings and drift models to dertermine 'morality areas' associated with fisheries interactions (Peltier et al., 2016). However, as discussed by the IWC Scientific Committee (International Whaling Commission, 2018) "further work to address uncertainties in the analysis" is needed before this approach can be adopted as an alternative to methods based on observations.

An important prerequisite to obtaining robust estimates of by-catch is to have accurate measures of fishing effort. Norway currently uses landings to estimate total by-catch, while Iceland uses km of nets from observed effort data, although the effort data reported by the industry are not particularly detailed. In the ICES Regional Data Base (RDB), fishing effort is reported in number of trips and days at sea (DAS). Vessel length can also provide information on fishing effort because small vessels typically use shorter nets than larger vessels. However, the ICES RDB data does not include vessel size.

To fully explore the impact of by-catch on populations, annual time series of by-catch estimates are required. However, such time series are rarely available. Norway has generated annual by-catch estimates from 2006 to 2018 for two fisheries. The USA has an annual time series of by-catch estimates from the gillnet fisheries from 1990 to 2017. Iceland has annual by-catch estimates for 2013-2017. Canada has estimates for 3 years. Denmark has by-catch estimates from 1987-2001 (Vinther & Larsen, 2004) and an ongoing effort with REM systems onboard a varying number of vessels since 2010, the data of which is currently being analysed. The UK has by-catch data for a range of fisheries since 1996.

EU Member States are required under Council Regulation 812/2004 to report information on monitoring incidental catches of cetaceans by onboard observers on vessels over a certain size in certain fisheries. Annual review of these reports is a task of the ICES Working Group on By-catch of Protected Species (WGBYC), which maintains a database from which by-catch rates can be estimated for specified areas and fishery métiers. Although an overview of the data was not available when this topic was being discussed, it was proposed that when the area divisions are agreed, the data from ICES could be used to estimate estimates of by-catch rate for some assessment areas. Data from the ICES RDB could also be explored to extract information on DAS for the same assessment units to generate estimates of by-catch for the assessments.

Estimates of by-catch are rarely available for all fisheries in an assessment area and obtaining an estimate of total by-catch is challenging. Estimates of by-catch rate depend on the characteristics of the fishery (e.g. net type, mesh size, net length) so assumptions need to be made when extrapolating from one fishery to another. Similarly, extrapolating information on by-catch from one assessment area to another also requires assumptions to be made.

A by-catch subgroup was formed within the workshop to consider extracting the required data for the agreed assessment areas from the ICES RDB and WGBYC by-catch databases. The subgroup was tasked with assessing the data to determine for which areas there was sufficient information to generate reliable by-catch estimates.

c. Sub-lethal pressures

Chemical Pollutants (Sinéad Murphy and Florence Caurant)

Like other marine mammals, the harbour porpoise has been exposed to numerous contaminants: Polycyclic aromatic hydrocarbons (PAHs), radionuclides and inorganic contaminants, as well as the organic compounds such as Persistent Organic Pollutants (POPs). Among inorganic chemicals, some are toxic with no biological role (mercury, cadmium, lead etc) while others are essential to life and deficiency in concentrations are thus suboptimal. Monitoring these chemicals, interpreting concentrations, and estimating effects can be challenging since numerous biological (length, age, sex, reproductive status) and ecological factors (e.g. diet) influence exposure (e.g. Aguilar, Borrell, & Pastor, 1999; Das, Debacker, Pillet, & Bouquegneau, 2003; Wagemann & Muir, 1984). Consequently, individuals and also populations exhibit large variability.

Cetaceans have been exposed to metals throughout their history and they have evolved physiological mechanisms that both regulate their uptake and mitigate their toxic effects. One of these processes has been demonstrated in the case of mercury (Hg) the toxic effects of which are counteracted by the essential element selenium (Se) through the formation of mercuric selenide, which accumulates in the liver of the marine mammals (Koeman, Peters, Koudstall-Hol, Tjioe, & De Goeij, 1973; Martoja & Berry, 1980). Thus, in that respect, the deficiency of an essential trace element such as Se would be as problematic as high concentrations of Hg. With regards to POPs, cetaceans have been shown to accumulate these with age for metabolically refractory polychlorinated biphenyls (PCBs), but not for those PCBs that are subject to metabolism by the cytochrome P450 (CYP)-mediated enzymes (Murphy et al., 2018).

Within the UK, the harbour porpoise is used as a sentinel species for monitoring long-term trends in chemical contaminant exposure in the marine environment, namely organochlorine pesticides, brominated flame retardants, and hexabromocyclododecane (HBCD). Accumulating levels of brominated flame retardants observed in UK- stranded porpoise blubber in the 1990s was partially responsible for the EU-wide ban of the commercial penta- and octa-mix polybrominated diphenyl ether (PBDE) products in 2004 (Law, Barry, et al., 2012). Following this ban, a significant (and consistent) decline was observed in concentrations of brominated diphenyl ethers (BDEs) in the marine sentinel species during the period 2008 to 2012 (Law, Barry, et al., 2012). A decline was also observed in HBCD, tributyltin (TBT) and organochlorine pesticides such as dichlorodiphenyltrichloroethane (DDT) and dieldrin concentrations in UK-stranded porpoise blubber for the same period (Law, Barry, et al., 2012; Law, Bolam, et al., 2012). However, although levels of these pollutants are declining, combined toxic effects of multiple exposures to pollutants at low dose levels cannot be ruled out. In contrast, and although they have been banned for over three decades, concentrations of PCBs, a known endocrine disruptor, in harbour porpoise blubber have remained stable since 1997, with mean ΣPCBs concentrations in adult male and female porpoises (sampled between 1990 and 2012) exceeding an established mammalian toxicity threshold of 9 mg/kg ΣPCBs for onset of physiological (immunological and reproductive) endpoints in marine mammals (Jepson et al., 2016; Kannan, Blankenship, Jones, & Giesy, 2000; Law, Barry, et al., 2012).

Endocrine disrupting chemicals (e.g. chemicals with hormone-like properties) differ somewhat from general toxicants as they have the ability to act at low doses, exhibit nonmonotonic dose responses (e.g. U-shaped curves), show varying effects over an individual's lifespan, result in delayed effects (of sexual dysfunction and physical abnormalities) that are not evident until later in life or until future generations, and have the potential to show combination effects when exposure to multiple pollutants occurs (reviewed in Murphy et al., 2018). Despite some evidence of Hg effects on health status (Bennett et al., 2001; Ferreira et al., 2016; Mahfouz, Henry, Jauniaux, Khalaf, & Amara, 2014; Siebert et al., 1999) and immunological functions (e.g. Frouin, Loseto, Stern, Haulena, & Ross, 2012) other toxic effects have not been described for inorganic compounds, like they have been for POPs. Exposure to POPs has been suggested to induce immunological effects as well as reproductive failure in cetaceans (Hall et al., 2006; Jepson et al., 2005; Murphy et al., 2015, 2018). Compared to the effects of POPs, toxic metal and trace elements probably have to be considered more as susceptibility factors, able to modulate and increase the risk of POPs effects.

The development of new synthetic chemicals, and the emergence and use of some of those chemical substances on the market, has been increasing at a rapid rate in recent years (Bernhardt, Rosi, & Gessner, 2017). It is unknown as to the number and variety of synthetic chemicals that harbour porpoises are exposed to, and if those chemicals are having an adverse health effect. Indeed little attention has been paid to the raft of new emerging pollutants on wildlife in general (Bernhardt et al., 2017).

Take home messages

- Inorganic compounds are likely not to induce direct effects in marine mammal populations, but they must be considered as factors of susceptibility that may increase the effects of POPs.
- Legacy pollutants continue to have adverse health effects, which may continue for decades to come (for those pollutants that have long half-lives).
- The harbour porpoise should be used as a pollutant indicator species within Descriptor 8 of the MSFD (Marine Strategy Framework Directive).
- There is a raft of new synthetic chemicals on the market, and the potential of their effects on the harbour porpoise and particularly their additive and synergetic effects in the presence of other pollutants at low dose levels, in unknown.

Knowledge gaps of particular relevance for assessment

- Knowledge of the exposure of harbour porpoises to new emerging pollutants is limited
- The modelling of pollutant effects should include both POPs and toxic elements, including Se when Hg is analysed
- Pollutants should also be included in cumulative impacts modelling
- It would be valuable to have pollutant assessment monitoring in other EU countries akin to the long-term monitoring strategy employed in the UK.

Discussion of Chemical Pollutants

The importance of chemical pollutants as stressors to harbour porpoise was reemphasised during the discussion, even if direct effects may be hard to quantify and our current understandings of causal relationships limited. Reduced fitness from pollution may not directly result in the death of the animal, however, efforts to better understand sub-lethal effects, such as the impacts of pollution, is important. Certainly, bioaccumulation and toxicity at given thresholds should be considered when modelling the effect of anthropogenic disturbances. As with other sub-lethal effects, their incorporation into population models is necessary if a comprehensive appraisal of deleterious population effects is to be undertaken.

The way in which chemical pollutants may be useful in stock discrimination was also discussed. This is because the presence of certain elements and compounds sequestered within animals may act as area-specific "signatures". The characteristics of chemical run-off from the land, and the presence of heavy metals released from nearby industry, for example, may leave a specific trace within local populations of harbour porpoise. The assignment of animals to a specific stock may be achieved if the sequestered chemicals conform to those known to be present in each area. It was argued that the use of this technique in a multivariate approach should be explored for harbour porpoise assessments. Cuarant informed the workshop that there is a plan to use this approach in the assessment of common dolphins.

Disturbance (Jakob Tougaard)

A disturbance is initiated by one or more sensory stimuli to the animal and/or an interference with sensory perception. This can lead to a change in behaviour, a missed opportunity (for foraging, mating etc.) or both; which consequently could affect the energy budget of the animal. Each disturbance may be small and the effect insignificant but could cumulate across repetitive disturbances. Secondary disturbances can occur if some disturbing factor causes displacement of prey, however this should be treated as habitat degradation and not a disturbance as such.

In principle, disturbance can be induced through all sensory modalities. However, for marine mammals, underwater sound is likely to be the overwhelmingly dominant source due to their good underwater hearing capacity and the very long transmission distances for underwater sound. Intense infrasound remains a possible source of disturbance, potentially mediated through stimulation of the vestibular organs in the inner ear (see for example Salt & Lichtenhan, 2014), however limited evidence is available for this. Due to the high levels of natural ambient noise in the infrasound range (due to earthquakes and wave action), disturbances from man-made structures are likely to be local to the sources.

Disturbances mediated through vision are limited by the low visibility under water and the (presumed) poor vision in porpoises above water and thus will be very local around a potential disturbing object. Disturbance from chemical substances, either in the air or dissolved in water, is unlikely to be a significant problem as odontocetes have no functional sense of smell (Oelschläger, 1989) and presumably also a much reduced sense of taste (Zhu et al., 2014). Disturbance from electromagnetic fields around subsea power cables cannot be ruled out, however data on this form of disturbance is lacking. If effects are present, they are likely to be local to the area around the cable and experience from fish and invertebrates suggests that it is unlikely that the electromagnetic fields can constitute barriers to movement and migration (see Hutchinson et al., 2018 for recent measurements and experiments on fish and invertebrates).

Disturbance from sound is better studied in harbour porpoises than in most other marine mammals. Considerable amounts of data are thus available from experiments both in captivity and in the field. In almost all cases studied, the reaction of porpoises to sounds has been negative (evasion). A tentative reaction threshold has been suggested for impulsive sounds to be 45 dB above the hearing threshold - also referred to as the sensation level (Tougaard, Wright, & Madsen, 2015). This means that reaction thresholds are higher (less sensitive) at lower frequencies, where hearing is poor, compared to higher frequencies, where hearing is best.

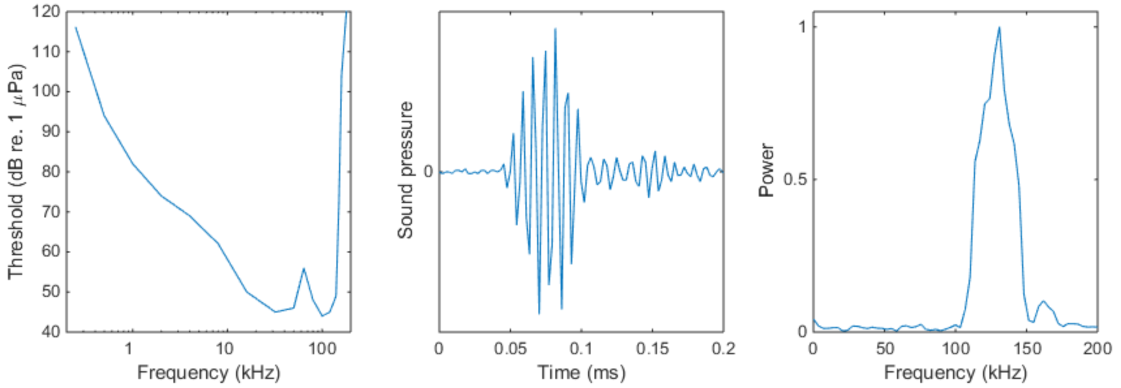

Figure 3: Audiogram of harbour porpoise (from Kastelein, Hoek, de Jong, & Wensveen, 2010) and echolocation signal (time signal, middle; frequency spectrum, right).

Another detrimental effect of noise is through masking the detection of other sounds that are important to the animal. Masking is instantaneous and disappears in the same instant that the noise is gone. It furthermore requires an overlap in frequency range between the masking noise and the sound to be masked. This means, among other things, that it is difficult for a porpoise to experience masking of its echolocation sounds, which have all energy well above 100 kHz. As the frequency dependent absorption of sound with distance is very high at these frequencies, masking of echolocation sounds is virtually impossible at distances beyond a few km, even for the most powerful noise sources (see Figure 4). Masking does not strictly qualify as a disturbance, as it manifests itself by the lack of a response: the animal fails to respond (in the appropriate way) to a stimulus, which would otherwise have elicited a reaction. This could be sounds from prey, conspecifics or sounds from an approaching predator. In this way, the effect of extensive masking is a loss of opportunity (for feeding, reproducing and evasion of predators), which will have consequences for the energy budget and fitness of the individual.

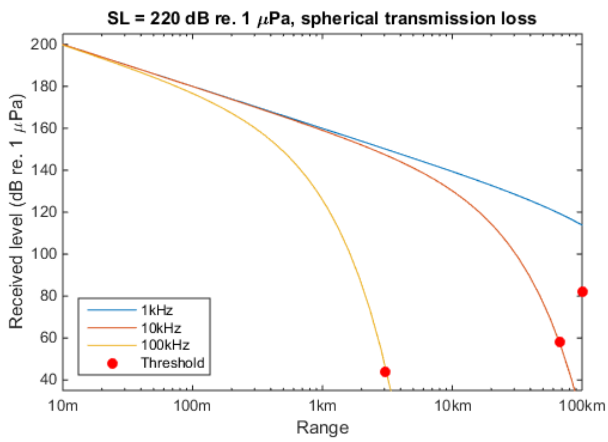

Figure 4: Simple prediction of received levels with range from a powerful sound source. Transmission loss modelled as spherical spreading plus frequency dependent absorption ($RL = SL - 20\,log_{10}\,r + \alpha r$). Indicated with red circles is also the pure tone thresholds at the respective frequencies, which provides an indication of maximum detection distance for a porpoise, under the highly simplifying transmission conditions.

A third effect of loud noise exposure is direct damage to the auditory system and in the case of very powerful transients, as from underwater explosions, damage to tissue and in severe cases even death. Tissue damage and death is unlikely to occur as a direct effect of noise exposure to all other sources than explosions (Lance & Bass, 2015). Injury to the hearing is manifest at the lowest exposure levels as permanent threshold shifts (PTS). At lower levels of exposure, a temporary threshold shift (TTS – a short term 'discoteque effect') is observed. TTS can be measured reliably on captive animals (see review by Finneran, 2015) and can thus be used as the basis for a precautionary establishment of safe exposure limits. TTS and PTS is predominantly localised at frequencies around or slightly above the frequency of the sound causing it (Finneran, 2015; Kastelein, Gransier, Marijt, & Hoek, 2015). This means that for a porpoise to aquire PTS at frequencies relevant for echolocation (around 130 kHz), the noise exposure must be in the ultrasonic range as well (50 kHz or higher), which limits the ranges where PTS can be acquired to being local to the source.

Sources of underwater noise

A wide range of noise producing activities occur in the ocean, some of which are relatively well known in terms of occurrence and effects, whereas for others, very limited knowledge is available. Noise sources are commonly divided into impulsive sources and continuous sources and although the division is somewhat arbitrary, the distinction is often useful. This distinction is also mirrored in the requirements for implementation of the EU Marine Strategy Framework Directive, where two separate criteria for Good Environmental Status with respect to underwater noise have been defined: loud, impulsive sounds below 10 kHz and continuous low frequency noise in the 63Hz and 125Hz third-octave bands.

Porpoises and impulsive noise sources

Impulsive noise is somewhat loosely characterised as sound pulses of short duration (seconds or less), occurring with a low duty cycle. The loudest sources are (in no particular order): underwater explosions, seismic surveys, percussive pile driving and certain types of powerful low- and mid-frequency military sonars (see for example Hildebrand, 2009), but other impulsive sources of interest include seal scarers (AHDs), net pingers (ADDs), and less powerful fish-finding and navigational sonars, echosounders etc. These four main sources, as well as other loud sources with significant energy below 10 kHz, are reported by EU member states to the ICES' impulsive noise register (http://ices.dk/marine-data/data-portals/Pages/underwater-noise.aspx), which serves as a source of information about the extent of these sources.

Explosions: By their very nature, underwater explosions generate extremely high sound pressures, which can be lethal at shorter distances and inflict injury to tissue and hearing at distance (many km for large charges) (Lance, Capehart, Kadro, & Bass, 2015; Yelverton, Richmond, Fletcher, & Jones, 1973) In many areas, including the North Sea and the Baltic, the main source of explosive shock waves is detonation of unexploded ordnance (UXOs), primarily from WW II, whereas explosions related to construction activities dominate other areas.

Seismic surveys: These are known to have effects on larger whales (e.g. bowhead whales) at distances of several km (Blackwell et al., 2015), but experience with porpoises is lacking (however see Pirotta et al., 2014; Stone & Tasker, 2006). The limited data available suggests that behavioural reactions could extend out to distances of several km.

Pile driving: Porpoises are known to react to large pile drivings (such as in connection to construction of offshore wind farms) out to distances of at least 20 km (Dähne, Tougaard, Carstensen, Rose, & Nabe-Nielsen, 2017; Tougaard, Carstensen, Teilmann, Skov, & Rasmussen, 2009). The level of activity has increased gradually since the early 2000s and shows no sign of levelling off. Efficient mitigation measures, in the form of bubble curtains and insulation sleeves are available and required for large pile drivings in some countries.

Sonars*:* Many different types of sonar are used, from small fish-finding sonars that operate at frequencies above the hearing range of porpoises, to very powerful low-frequency military sonars. The low- and mid-frequency anti-submarine sonars are known to have pervasive behavioural effects on odontocetes (Harris et al., 2015; Southall, Nowacek, Miller, & Tyack, 2016), although experience is lacking for porpoises in the wild. Experiments in captivity (Kastelein, 2013; Kastelein, Steen, de Jong, Wensveen, & Verboom, 2011; Kastelein, van den Belt, Helder-Hoek, Gransier, & Johansson, 2015; Kok et al., 2018) are consistent with distances of tens of km. Other types of side-scan, fish-finding and navigational sonars, operating at frequencies below 100 kHz, could be of relevance as well, but almost no information is available.

Seal scarers: These are powerful pingers designed to deter seals from fish farms and fishing gear. They are known to deter porpoises at distances of many km, and likely more than 10 km (Johnston, 2002; Mikkelsen, Hermannsen, Beedholm, Madsen, & Tougaard, 2017; Olesiuk, Nichol, Sowden, & Ford, 2002). Seal scarers are used in some areas, such as Western Scotland, as deterrent devices at fish farms. In other areas they are primarily used in connection with other loud and potentially damaging sounds, such as pile drivings. In some such cases, the seal scarer may constitute a larger impact than the original impact it is intended to mitigate (Dähne et al., 2017).

Pingers*:* These are devices mandatory in some gill net fisheries and areas to prevent by-catch of porpoises. Deterrence ranges are small, some hundred metres (Carlström, Berggren, & Tregenza, 2009; Culik, Koschinski, Tregenza, & Ellis, 2001; Kyhn et al., 2015).

Other impulsive sources, including seabed surveys and echosounders: Covers a wide range of techniques for sub-bottom profiling, ranging from side-scan sonars, to various types of boomers, sparkers, pingers and all sorts of echosounders. Experience is very limited and direct measurements lacking, but various impact assessments suggest that reaction distances of up to several km could be expected for the more powerful sources (sparkers and pingers), whereas limited impact is predicted from individual echosounders due to their narrow and vertical beam. The magnitude of the combined impact of the thousands of echosounders active at any one time is, however, unknown.

Continuous noise sources

Continuous noise sources are of longer duration (hours to days) and without clear onset and offset. At close range they are typically identifiable above the background noise, but at longer distances they blend into and add to the natural ambient noise from wind, waves etc. and result in an elevation of the ambient noise. The most dominant contribution by far comes from ship noise (propeller noise and engine noise). The most significant effect of continuous anthropogenic noise is likely to be masking, which results in a reduction of communication distances across open sea (Erbe, Reichmuth, Cunningham, Lucke, & Dooling, 2016; Møhl, 1980; Payne & Webb, 1971). The noise, especially at close range, can also serve as a source of disturbance, but the available information is limited.

Ships*:* Considerable information has become available in recent years about noise from individual ships and the combined ship noise in highly trafficked areas. Direct evidence on reactions of porpoises to ship noise is scarce, but visual observations and recordings from tagged animals suggest reaction distances in the range of hundreds of meters to a few km (Evans, 1996; Evans, Fisher, Jordan, Limer, & Rees, 1994; Palka & Hammond, 2001; Wisniewska et al., 2018).

Offshore renewables: Available measurements of noise from offshore renewable installations in operation (offshore wind turbines, wave energy converters and tidal turbines) indicate that noise levels are low and energy exclusively at low frequencies (Robinson & Lepper, 2013; Tougaard, 2015; Tougaard, Henriksen, & Miller, 2009). Reaction distances are thus expected to be very small, within some hundred meters. Direct studies of porpoise presence in and around offshore wind farms are scarce but a study from the Dutch North Sea coast demonstrated no negative effect of the wind farm, and possibly even a positive effect on porpoise activity (Scheidat et al., 2011). The area covered by offshore wind farms has expanded very fast since the early 2000s and is likely to increase even further in coming years. Impacts from service ships, rather than noise from the turbines themselves, could be the most significant source of disturbance from such installations. Also the size of both turbines and foundations have increased considerably since the earlier studies and this may have consequences for the noise emission as well.

Small boats: Although very abundant in coastal waters and known to be a substantial source of high-frequency noise, very little direct evidence is available on reactions of porpoises to small pleasure boats (Evans, 1996; Evans et al., 1994). Experience from dolphins suggests that reaction distances could be in the range of km, with a correlation between engine size/boat speed and reaction magnitude (Mattson, Thomas, & St. Aubin, 2005; Nowacek, Wells, & Solow, 2001).

Dredging and offshore construction: There is limited direct evidence of reactions, but noise levels are comparable to ships sailing at cruise speed (Todd, Todd, Pearse, Tregenza, & Lepper, 2009) . This suggests that reaction distances could be comparable, i.e. from hundreds of meters to a few km.

Pipelines: A few measurements and the modelling available suggests that the noise from oil and gas pipelines in operation (caused by oil and gas flowing through the pipeline) is very low, in most cases below the natural ambient noise levels, and at very low frequencies, so inaudible to porpoises (Birch, Glaholt, & Lemon, 2000; Glaholt, Marko, & Kiteck, 2008).

Oil rigs and drill ships: Limited direct measurements are available. Noise levels suggest that disturbance comparable to that of larger ships could occur. However, other studies appear to indicate high levels of porpoise activity (presumably foraging) close to and even directly below platforms (Todd et al., 2009), suggesting a strong habituation to the noise.

Take home messages

- Underwater noise can stem from a wide range of sources and is an important source of disturbance for harbour porpoises. Noise can do direct damage to the auditory system or tissues, mask the detection of other sounds and/or have cumulative impacts.
- In almost all studies (done both in captivity and in the field) the reaction of porpoises to sounds has been negative (evasion).
- Sources of noise can be impulsive (sound pulses of short duration) or continuous (longer duration without clear onset and offset).
- Underwater explosions, seismic surveys, percussive pile driving and certain types of powerful low- and mid-frequency military sonars are the loudest sources of impulsive noise and together with other loud sources with significant energy below 10 kHz, should be reported by EU member states to the ICES' impulsive noise register (http://ices.dk/marine-data/data-portals/Pages/underwater-noise.aspx).

Knowledge gaps of particular relevance for assessment

- The largest knowledge gaps relate to establishing links between behavioural reactions to noise and vital parameters relevant for population development (adult survival, fecundity etc.). It appears unlikely that such links can be established directly through observation, and currently the best option appears to be individual based modelling schemes, such as the iPCoD (New et al., 2014) and DEPONS (Nabe-Nielsen et al., 2018) frameworks.
- Considerable effort is required to obtain accurate and relevant input data for these models. The required information includes, but is not limited to, better description of reaction thresholds and distances for different sound sources and metabolic consequences of different types of behavioural disturbances.
- Equally important for the quality of the output from the models is reliable information about source characteristics and abundance of the different sound sources in the North Sea.
- Additional knowledge gaps relate to the long-term consequences of smaller or larger noise-inflicted hearing losses in porpoises, as well as the natural and noise-induced hearing loss in wild porpoises.

Discussion of Disturbance

The group discussed how to assess the impact of disturbance at the population level and how this can be included in an assessment.

Negative effects from disturbance (mediated through a sensory input) can provoke a modification of the time and consequently energy budget of porpoises, leading to a reduced fitness. Assessing the impact of disturbance on harbour porpoises will then involve estimating whether a decrease in fitness is occurring, with the crucial question being how to measure fitness and how to measure the population effect. Participants at the workshop agreed that answering the question: "Has decreased fitness as a direct consequence of disturbance been observed in harbour porpoises?" was difficult.

Among all the possible sources of disturbance (sound, light, electromagnetic fields, etc.), it was agreed that noise may be the only one with the potential to negatively impact harbour porpoise at the population level. The population level effect of individual sources will depend on their cumulative impact. For example, windfarms represent a risk during the construction phase. If many are built in an area occupied by a small population, then the population effect in that specific case is likely to be higher than it would be for a wider population dispersed over a larger range. One way of qualifying the risk from noise for each assessment unit was discussed as estimating the overlap between the distribution of risk (presence, intensity and frequency of noise from individual sources) and the distribution of species density. The integration of the layers to produce a risk map could then be generated through an elicitation of expert opinion and would help identify whether risks from noise represent a determining factor for the conservation process and whether it should be specifically acted upon.

A proposed risk classification was:
0 - no, or small effect, unlikely to lead to a significant impact on the population level;
1 - an effect that may extend to the population level, but not without having a significant impact (although an increase may warrant concern);
2 - an effect on the population level creating cause for concern.
It is important to note that within this scheme, mitigation efforts would not necessarily need to be limited to only level 2 risks.
The quantification could also be phrased as:
0 - there is an effect on individuals,
1 - there is an effect on the population level;
2 - there is an effect on the population level that may last for several generations.

This type of qualitative assessment would help prioritising what type of research and conservation actions should be taken for each population exposed to disturbance.

ICES compiles an impulsive noise register (IINR), which could be used to prepare such a risk map. Presently, Iceland, Norway, Greenland and the Faroes do not contribute to this register though.

The workshop also briefly discussed the specific risks associated with continuous active sonar, which is increasingly used by European and US/Canadian navies. Although the peak pressures are somewhat lower than conventional pulsed sonars, the total radiated energy is much higher and this cause for concern with respect to both masking and behavioural reactions.

Tougaard and Gilles agreed to prepare a risk to noise table for the assessment units (based on the different sources present in each unit) to be considered by the workshop. This is available in Table 3 and Appendix 1 of this report.

At the conclusion of the discussion on disturbance it was agreed that Norway, Faroe Islands, Greenland and Iceland should contribute data to the ICES Impulsive Noise Register (IINR). Even if for some activities there is nothing to report, this information is important for the quality of the data in the register. It also agreed that there is a general need for more research on the link between noise exposure and population level effects and to obtain reliable estimates of noise exposure in the different areas.

d. Feeding Ecology

Harbour Porpoise Feeding (Graham Pierce)

Diet data provide insights into the ecology and conservation status of predators, e.g. in relation to predator and prey distribution, diet selection behaviour and exposure to threats. For example, because porpoise have a high metabolic rate, low abundance of their preferred prey may increase the risk of starvation (as suggested by MacLeod, Pierce, & Begoña Santos, 2007) .

Results on prey importance are sensitive to sample sources and methodology, notably how authors account for digestive erosion and loss of prey remains, which should always be borne in mind when comparing studies. This is likely to have the most impact on estimates of the biomass eaten and the least impact on simple presence/absence. The wide confidence limits on diet composition, due to sampling and other errors, should also be noted.

Porpoises have a broad diet, however in most areas, their diet is dominated by a just few prey species from six families (in terms of biomass): Gadidae, Clupeidae, Osmeridae, Ammodytidae, Gobiidae, Carangidae. In terms of prey numbers, other groups with small individual body size, notably gobies, assume more importance. In the south of the range, off the Iberian Peninsula, where there is a narrow continental shelf, pelagic and offshore species are more important than in most other areas.

The concept of functional responses and optimal diet theory provide a possible framework for understanding prey selection because diet choice is likely to reflect a trade-off between prey energy richness and hunting/capture costs feeding. Herring and sandeels (in season) are relatively energy rich but gadids may be easier to catch.

Assessing whether porpoise show clear dietary preferences or are opportunistic is difficult and ideally requires information on fish abundance at an appropriate scale. ICES fish stock assessments provide large scale indicators of availability but may not indicate availability of relevant size classes at smaller scales.

Generalised additive models (using individual porpoises as the unit of the response variable and thus accounting for sampling error) indicate significant year to year variation in importance of some prey. Apparent declines in the importance of herring and sandeel in the diet of porpoises in Scotland coincided with declines in the stocks. However, despite stock recovery, herring remains apparently unimportant in porpoise diet. An obvious caveat is that the catchment area of porpoise strandings and areas of high herring abundance may not coincide. However, overwintering herring are found in the Moray Firth where many porpoise strandings occur.

Correlation analysis identifies some significant relationships between annual stock abundance and annual importance of some prey species in diets in data from Scotland, Ireland and the Netherlands. Some of these correlations (negative correlations between abundance of one species and importance of others in the diet) are consistent with preference for certain prey (herring, whiting, sandeel). Others (positive correlations between importance in the diet and stock size for a species) are more consistent with opportunistic predation. However, apparently meaningless correlations are also found so these results may not be a reliable indicator of diet selection behaviour.

Fatty acid analysis (of blubber) and stable isotope analysis (of muscle, skin or teeth) can provide access to larger sample sizes and potentially less biased samples (e.g. including biopsy samples) but provide more limited data on diet composition. Nevertheless, they can reveal changes in diet over time (e.g. seasonal and long-term year to year variation in diet).

Take home messages

- Porpoise diet varies in time and space and continued monitoring is necessary.
- All methods used to infer porpoise diet composition and diet selection behaviour are subject to limitations and biases.
- Porpoises are largely piscivorous and fish from one or more of the families Gadidae, Clupeidae, Osmeridae, Ammodytidae, Gobiidae and Carangidae typically form a high proportion of the prey biomass consumed.
- Dietary shifts have been seen when important prey have declined in abundance – and such prey species do not necessarily reappear in the diet when their stocks recover. This behaviour, coupled with the high metabolic rate, makes porpoises especially vulnerable to prey depletion.

Knowledge gaps relevant to assessment

- Further development of techniques such as compound-specific stable isotope analysis could potentially allow collection of detailed quantitative dietary behaviour from representative samples of animals in a relatively non-invasive manner.
- Understanding of prey selection behaviour could be improved using fish abundance data with high spatial and temporal resolution combined with tracking data on individual porpoise movements.

Discussion of Feeding Ecology

One of the main topics of discussion was that processes regarding e.g. prey availability, prey selection and foraging behaviour were not always well understood, and without clear and strong signals, one should be cautious in drawing firm conclusions. Diet composition often showed high variability and was affected by the methods used. In order to learn more and shed light on the different driving factors, multispecies modelling, and modelling porpoise distribution, with prey distribution as a covariate, was proposed. The modelling challenges discussed included selecting and integrating parameters linking predators and prey, and that parameters were often biased by inappropriate sampling, and that scaling worked on both the porpoise level and on prey level.

Another key topic of discussion was the importance of prey quality, in terms of lipid content, but perhaps also in terms of protein content (for animals in puberty growing muscles). Here the energetic quality (lipids) was considered to provide the strongest signal for diet quality. The discussion further brought up the issues of prey selection and optimal foraging, that harbour porpoises should aim at maximizing energy intake. Studies had demonstrated a positive correlation between a high energy diet, body condition and reproductive success. However, the picture here was also uncertain, since porpoises feeding on low energy prey were performing comparably well and some studies had demonstrated that porpoises had not switched prey, as expected, when high quality prey were re-introduced to the feeding ground. Other studies have, however, noted the opposite (see North Sea assessment for further elaboration). Here, the present status of predator and/or prey (with respect to K) was a factor to take into consideration. Interestingly, interspecific competition (e.g. porpoises overlapping with bottlenose dolphins at the feeding ground), had led to negative impacts for porpoises, in terms of leaner animals being documented.

A third discussion topic was the value of primarily fatty acids, but also stable isotopes, in feeding studies. The main message from the discussion was that these methods provided more limited insight into the diet, with no quantitative value, but were more promising for picking up changes in diet over a longer time scale.

e. <u>Life History</u>

Life History of Harbour Porpoises (Sinéad Murphy)

Harbour porpoises live a fast life, with early maturation, relatively short gestation and lactation periods, annual reproduction and earlier deaths than most other marine mammals. Harbour porpoises have a promiscuous mating system and participate in sperm competition, which explains the variation observed in the reproductive anatomy of males and female porpoises. Females have evolved a long cumulative fold and vaginal length, whereas males have correspondingly evolved long penises and, seasonally, large testes (Keener, Webber, Szczepaniak, Markowitz, & Orbach, 2018; Orbach, 2016; Orbach, Kelly, Solano, & Brennan, 2017).

Murphy et al. (2015) assessed reproductive material from stranded and by-caught harbour porpoises sampled between 1990 and 2012 from all UK waters (England, Wales and Scotland, n = 329). Based on all available samples, a low pregnancy rate of 34% and an Age at Sexual Maturity (ASM) of 4.73 years were estimated, while a slightly higher pregnancy rate of 50% and a higher ASM of 4.92 years were determined for 'healthy' females – females that died of traumatic causes of death such as by-catch, boat/ship strike, bottlenose dolphin attacks or dystocia. The pregnancy rate estimated for 'healthy' porpoises was almost half that reported in other geographical locations such as the Gulf of Maine and Bay of Fundy in the North-west Atlantic (93%, 3.27 years) (Read & Hohn, 1995), and waters off Iceland (98%, 3.2 years) (Ólafsdóttir, Víkingsson, Halldórsson, & Sigurjónsson, 2003).

Reproductive failure was reported in UK porpoises that may have been related to exposure to endocrine disrupting chemicals. 19.7% of sexually mature females showed direct evidence of reproductive failure (foetal death, aborting, dystocia or stillbirth). A further 21/127 (16.5%) had infections of the reproductive tract or tumours of reproductive tract tissues that could contribute to reproductive failure. Resting mature females (non-lactating or non-pregnant) had significantly higher mean ΣPCBs (18.5 mg/kg) than both lactating (7.5 mg/kg) and pregnant females (6 mg/kg), though not significantly different to sexually immature females (14.0 mg/kg). Using multinomial logistic regression models ΣPCBs was found to be a significant predictor of mature female reproductive status, adjusting for the effects of confounding variables. Resting females were more likely to have a higher PCB burden. Health status (proxied by "trauma" or "infectious disease" causes of death) was also a significant predictor, with lactating females (i.e. who successfully reproduced) more likely to be in good health status compared to other individuals. Based on contaminant profiles (>11 mg/kg lipid), at least 29/60 (48%) of resting females had not offloaded their pollutant burden via gestation and primarily lactation. Where data were available, these non-offloading females were previously gravid, which suggests foetal or newborn mortality. Whether or not PCBs are part of an underlying mechanism, we used individual PCB burdens to show further evidence of reproductive failure in the North-East Atlantic harbour porpoise population, results that should inform conservation management.

More recent unpublished analysis of reproductive material in UK harbour porpoises assessed the life history parameters for the Celtic and Irish Seas (CIS) and North Sea (NS) Management Units (MUs) using samples and data collected between 1990 and 2013 (n=1226). The dataset was divided into two time periods (period 1: 1990-1999 and period 2: 2000-2013) to assess temporal variations in life history parameters. Sexual variation in asymptotic lengths, length at 50% mature (L50) and age at 50% mature (A50) were observed, with females attaining a larger asymptotic length, larger L50 and delaying attainment of sexual maturity compared to males. Porpoises in the Celtic and Irish Seas were significantly larger than porpoises in the North Sea (larger asymptotic length), and attained a larger size at L50, though there was no difference in A50 between management units. Although no significant temporal variation was observed in the asymptotic size in either sex within each MU, what was apparent was at a given age porpoises were of a larger size in the 1990s compared to the 2000s and 2010s. Further, a significant decline in the growth rate parameters was observed during the study period that was more evident in the female data. Interestingly, although males showed no significant difference in A50 between the time periods in either MU, females significantly delayed sexual maturity in period 2 by one year (delaying it from 3.8 years in period 1 to 4.8 years in period 2) in both MUs. A significant difference was observed in the pregnancy rates, 60% and 29% for the CIS and NS MUs, respectively. Though for the latter region, 78% of the mature females sampled died from either infectious disease or other causes such as starvation, live stranding, neoplasia or not established. Whereas 60% of animals used to determine the pregnancy rate in the CIS MU area were animals that died from trauma. Thus, cause of death, which was used a proxy for health status, had important implications for estimating the pregnancy rate. In contrast, cause of death did not come out as a significant covariate for estimations of the L50 or A50 – did not appear in the top ten best fitting models.

Take home messages

- Preliminary results suggest that reproductive dysfunction in UK porpoises may be related to PCB exposure occurring either through endocrine disrupting effects or via immunosuppression and increased disease risk. Declines of major organochlorine concentrations in biota have been slow due to global cycling and long-half lives of pollutants, and as of 2005, 1.1 million tons of PCB containing equipment, (corresponding to 350,000 tons of PCB containing liquid), still required disposal by EU Member States. Taking this into consideration, as well as inherited maternal pollutant burdens in first born offspring and generational epigenetics effects, raises concerns about the current and future population-level effects of PCBs on the continuous-system of the North-East Atlantic harbour porpoise population.
- The Celtic and Irish Seas MU and the North Sea MU are significantly different in a number of life history parameters and taking on board the genetic structure in the region (Fontaine et al. 2014; 2017), should be conserved and managed separately.

Knowledge gaps relevant to status or assessment

- There is a need for continued collection of samples and data, as well as analysis of life history parameters in harbour porpoises in UK waters.
- Regional efforts should also be increased, and Management Unit wide assessments of life history parameters and pollutant levels should be undertaken. This is particularly the case for the North Sea region, where a lower pregnancy rate was determined than for UK waters.

Discussion of Life History
It was suggested that to better understand reproductive performance, researchers should analyse porpoise samples from a broad area as it appears that there are geographic differences in several health and reproductive measures (e.g. North Sea versus Ireland etc.)

To further examine the impacts of such differences in reproductive performance, it was proposed that it may be useful if researchers add these age-at-maturity and pregnancy rate estimates to a life table model to examine the predicted population trends for the relevant porpoise populations.

Since many of the samples taken in the UK from strandings come from diseased porpoises, a question was raised as to how much the group should account for this potential bias in its porpoise population modelling?

It was noted that Iceland may have data indicating poorer health status in stranded harbour porpoises (e.g., larger parasite loads).

f. Modelling the Population Consequences of Disturbance

The PCoD framework for capturing impacts from disturbance (Leslie New)
In 2005, a National Research Council working group attempted to address the issue of the population consequences of acoustic disturbance (PCAD) on marine mammals (National Research Council, 2004). The first test of the PCAD framework began in 2009, taking advantage of advances in statistical tools and computational power. Four marine species were chosen for the initial application of the PCAD framework; elephant seals (*Mirounga* sp.) (New et al., 2014; Schick, New, et al., 2013), coastal bottlenose dolphins (*Tursiops* sp.) (New, Harwood, et al., 2013; Pirotta et al., 2014) North Atlantic right whales (*Eubalaena glacialis*) (Schick, Kraus, et al., 2013) and beaked whales (family *Ziphiidae*) (New, Moretti, Hooker, Costa, & Simmons, 2013). These case studies led to the expansion of the framework to include all potential forms of disturbance and their physiological effects in addition to the behavioral ones, thus renaming it the Population Consequences of Disturbance (PCoD) framework (New et al., 2014). PCoD also differentiates between disturbances that have acute, immediate effects on vital rates (e.g., survival or fecundity) and disturbances that have a chronic effect on vital rates through individual health. Health, defined as internal factors that impact an individual's fitness, then becomes the main route by which indirect effects on vital rates take place (New et al., 2014). Ultimately, given the severity and extent of a species response to disturbance, it is possible to link any changes in vital rates to potential population effects.

A limitation of the PCoD framework has been its extensive data needs, and the fact that these data, particularly around the health metric, are not available for many species of conservation and management concern. This has led to the development of alternate approaches to the PCoD framework, known as PCoD-lite and Interim PCoD, that circumvent the need to define a mechanistic transfer function connecting changes in behavior and physiology to health, and health to vital rates. PCoD-lite skips health completely, even for chronic disturbances, and links the effects of disturbance on behavior and physiology directly to vital rates. In Interim PCoD, expert elicitation is used to estimate the effects of disturbance on vital rates. In the absence of data, expert elicitation serves as a structured approach to extracting experts' knowledge on values of interest, to produce relatively robust and unbiased estimates. In the context of PCoD, elicited values may include parameters such as survival, but can also be estimates of values such as the number of days of disturbance required to affect an individual's vital rates. Interim PCoD can facilitate informed management and conservation decisions while data gaps are being filled but is not intended to replace the need for data collection. Of particular relevance to the workshop, the interim PCoD approach was first used to assess the effect of off-shore wind farm construction on harbour porpoise (*Phocoena phocoena*) in the North Sea (King et al., 2015).

Discussion of the PCoD Model
Significant discussion was had about the expert elicitation process and its facilitation within the PCoD approach. The response was that using expert elicitation to inform regulatory decision-making can be difficult and recommended against using expert elicitation for deriving all inputs to the PCoD framework as the variability would be too large to output useful results. It was also emphasised that expert elicitation is always only providing

an interim input until data collection is performed. She noted that scientists can be hesitant to accept personal belief as a legitimate input to modelling efforts and often do not classify themselves as experts. In Dr. New's experience with expert elicitation, every expert has felt that they did not know enough to make conclusions in the absence of data. However, during the elicitation process, and when presented with the range of responses of other experts, participants became more comfortable in providing opinions. Dr. New emphasized that this elicitation process should not replace data collection to verify conclusions when such data collection is possible. Having decision makers take part in the expert elicitation process also seems to increase their acceptance of this aspect of the PCoD process.

Questions were also asked about how we might quantify the PCoD model's prediction of risk in the assessment derived using expert elicitation. It was shown that one way is to use response "heatmap plots" with which to display the range of experts' beliefs (which can be large) and may also show risk (e.g. as large bounds for vital rate changes). Heat-map plots showing the range of expert opinions can be shown to the participating experts and managers, which may trigger further reflection on what is reasonable and lead to the amendment of opinions. Recently, heat map outputs have been augmented using a web-based, user-modifiable Shiny App (a more interactive way to place beliefs by showing their impact on the final distribution). "PCoD Plus" provides an update to the PCoD protocol for expert elicitation approach, with online training modules (at the SMRU consulting website), response templates, and the Shiny App code.

Questions were also asked about how many experts were typically engaged in the expert elicitation processes used in the PCoD approach. The speaker stated that study leads usually aim to include 8-12 experts; using more experts is typically less effective as it is too difficult to ensure engagement in larger groups and such group discussion is important to understand the range of responses. Less than eight experts tends to provide too little opinion diversity. As an alternative strategy, it is possible to conduct remote expert elicitation (via email and web interactions) and this can allow for a large number of participants. However, such large opinion elicitations often have low invitation response rates (approximately 20%).

It was noted that during the initial elicitation process, study leads should attempt to keep the expert responses as anonymous as possible to help capture differences of opinion. It is also important to solicit opinions from experts with different backgrounds (foraging ecology, reproductive ecology, and physiology). A decision-tree framework is available to help guide decisions about whether the PCoD approach is appropriate/valuable for the case at hand.

Finally, it was noted that it is important that PCoD users acknowledge that the way disturbance regimes alter vital rates may change over time, as the mechanisms underlying this alteration may be other than the disturbance trigger.

3. Area Assessments

Assessment models represent a quantitative way to evaluate the status of a population. Generally, this is accomplished by estimating the ratio of the current abundance of a population relative to its level at some pre-specified prior time, such as at a time before a population was exploited by humans. Assessments can come in many forms, each of which may use different amounts and types of input data. For example, assessment methods that require the most input data are those implemented using age-structured population dynamics, or predictive models such as the PCoD approach (described above) that includes a mechanistic transfer function connecting changes in behavior and physiology to health, and health to vital rates. At the other end of the spectrum, are the assessments that use nearly no input data, such as those implemented using only expert judgement where information from a related population is used to infer the status of a population for which there is nearly no data. The assessment method used in this workshop is outlined in detail below and was applied to the assessment units that were agreed during the workshop and highlighted on the revised map presented in section one. The area status reports that were developed prior to, and revised during, the workshop served as the basis for providing the inputs needed to run the models and each of these appears as an annex to this report.

The Status Assessment Methodology Selected & Implemented during the Workshop (Debra Palka)
Assessing the status of harbour porpoise in an assessment area was a two-step process. The first step was to derive a time series of "closed-population" abundance and by-catch estimates. A closed population is defined as one in which there is no net immigration or emigration between adjacent populations and the number of animals changes only through births and deaths. The second step was to use the series of abundance and by-catch estimates to draw inferences about the population trajectory through time. This step could be implemented using simple empirical methods such as linear or log-linear regression techniques on the time series of abundance estimates. Another method is to model the biological processes governing how the population changes over time,

i.e. the dynamics of the population. This model could include sub-models for each biological process (birth, survival, aging, etc.), or, as done here, the model could describe the net effect of these processes.

For most North Atlantic harbour porpoise assessment units, a deterministic density dependent sex and age aggregated population dynamic production model (Zerbini, J. Ward, Kinas, Engel, & Andriolo, 2011) was used to assess the status of the population in an assessment unit:

$$N_{t+1} = N_t + \left[r_{max} * N_t * \left(1 - {N_t/_K}^z\right)\right] - C_t$$

where Nt and Nt+1 are the population sizes in years t and t+1, respectively; r_{max} is the maximum net recruitment or population growth rate; Ct is the by-catch in year t; and z is a parameter used to account for density dependence, which determines at what population level between 0 and K the productivity is maximum, where K is the historical carrying capacity population level. The parameter z was set at a value of 2.39, which corresponds to a maximum net productivity level of 60% of the historical K, as assumed by the International Whaling Commission Scientific Committee. When indices of relative abundance were used instead of absolute abundance estimates, the indices were scaled to the model predicted population size by a scale coefficient defined in equation 3 in Zerbini et al. (2011).

The status of each assessment unit was determined as the present depletion level (usually for 2016: N_{2016}/K') and the predicted future depletion level (for 2025: N_{2025}/K'). Both depletion levels are relative to K', where K' is defined as the population size at the earliest year possible defined by the available data (the first year of either the by-catch or abundance time series, whichever was earlier). To predict the depletion level in 2025, it was assumed that future by-catch levels were the average of the last five observed years or a value appropriate for the assessment unit.

The Bayesian statistical Sampling-Importance-Resampling algorithm, coded in R, was used to calculate the probability distributions of the model parameters. Prior distributions were set on r_{max} (Uniform [0, 0.09]) and on the abundance (Uniform [~50% of current abundance, ~ 2 times the current abundance]). Medians and 90% Bayesian probability credible intervals (CI) of the posterior probability distributions of the population size, depletion levels, r_{max} and K' were reported along with the by-catch trajectories.

For assessment units that did not have sufficient data to include in the population dynamic model, it was not possible to conduct a traditional status assessment. Instead, the workshop attempted to determine if the estimated removal levels were sustainable. This was evaluated by comparing by-catch/catch levels to the Potential Biological Removal (PBR) level (Wade, 1998). The PBR method was first developed for the use in the USA using the policy driven quantitative objectives mandated by the US Marine Mammal Protection Act, which are to allow stocks of marine mammals to be maintained at or above their optimum sustainable population level (Wade, 1998). PBR was calculated as:

$$PBR = N_{min} \cdot {}^1/_2\, r_{max} \cdot F_r$$

where N_{min} is the population size that provides reasonable assurance that the true size is equal to or greater than N_{min}, which given the US policy objectives, is practically estimated as the 20th percentile of a log-normal distribution of the abundance estimate. The parameter r_{max} is the same as in the population dynamic model, the maximum net recruitment rate. F_r is defined as a recovery factor that can be between 0.1 and 1 depending on the level of uncertainty in the data and in the level of previous exploitation. Wade (1998) developed defaults for the estimation of the net productivity rate and recovery factor. Using the limited available information from cetaceans on r_{max}, the default value for r_{max} was set at 0.04. Using the US policy objectives, the default value for F_r for species considered to be endandered was set at 0.1 and to 0.5 for species of unknown status. During this workshop, the value used for F_r was the most appropriate for the specific assessment area.

In these data poor situations, for example when only one estimate of abundance is available, PBR was calculated using the default parameter values and then compared to estimates of removals to give an indication of whether current by-catch/catch is sustainable. In the data poor situation where no abundance estimate was available, but some estimate(s) of removals were available, it was possible to rearrange the PBR equation to obtain the abundance estimate that would be required to sustain the known level of removals. In this case, whether or not estimated by-catch/catch were sustainable was evaluated by using expert knowledge as to whether it was possible that the true abundance was higher or lower than the best abundance estimate.

In the future, depending on the amount of mixing that occurs between the various harbour porpoise assessment units and if the mixing varies throughout the year and by age group, the most appropriate way to assess the status of harbour porpoise in the North Atlantic may be to implement a multi-assessment area age-time-structured population dynamics model.

The results of the population dynamics model analysis were summarised in 6 figures (e.g. see Figure 5):

- The upper left panel displays the abundance estimates (points), with 95% confidence internvals (vertical bars), along with the model predicted abundance trend (red solid line) and its 90% Bayesian probability credible interval (red dashed lines). Blue lines are predicted future abundance trends.
- The middle left panel displays the inputted estimated annual by-catch/catch trend over the same time period. Blue indicates future predicted by-catch/catch.
- The upper right panel displays the predicted posterior distribution of r_{max} (black histogram). The median value is denoted as a bold red dashed line and the 90% credible interval is denoted by light red dashed lines. A relatively uniform (flat) histogram indicates an imprecise estimate.
- The middle right panel displays the predicted posterior distribution of K', its median value and 90% credible interval using the same format as the r_{max} panel. K' is the predicted abundance estimate for the beginning of the time series.
- The lower left panel displays the predicted posterior distribution of the current depletion level, its median value and 90% credible interval using the same format as the r_{max} panel. Current depletion level is the current predicted abundance estimate (usually for 2016 or 2017) relative to the abundance at the beginning of the time series (K').
- The lower right panel displays the predicted posterior distribution of the future depletion level, its median value and 90% credible interval using the same format as the r_{max} panel. Future depletion level is the predicted abundance estimate for 2025 relative to the abundance at the beginning of the time series (K').

Underlying Assumptions of the Selected Status Assessment Methodology

There are many underlying assumptions in population dynamic models (see review in Punt, 2017), related to model structure, model parameters, and the input data. One of these underlying assumptions of the model used here is related to the carrying capacity (K) parameter. K is assumed to be the population size in the assessment area prior to human exploitation. However, practically it is only possible to reliably model the population dynamics during a time period for which estimates are available for either the abundance or removals. Thus, the assessment analyses performed in this workshop started in the first year for which by-catch/catch or abundance estimates were available. The population size at that time was defined as K'. In most of the assessments conducted during the workshop, however, the assessment units were exposed to by-catch prior to the first year in which there were formally recorded by-catch estimates. Thus, in most cases, the assessment's current depletion level is the change in population size between the current data year (usually 2016) and the first-year data were available (K'), not depletion relative to historical K.

K and K' is also assumed to remain constant over the time period modelled; i.e. the carrying capacity of the ecosystem to support the population is constant. However, this may not be the case.

Another problem that afflicts many population dynamics models is that correlation among model parameters may lead to longer runtimes to achieve the true joint posterior distribution. However, both algorithmic robustness and interpretability will be unaffected assuming a given MCMC routine is provided with enough time to sufficiently explore the parameter spaces. In our case, r_{max} and K are statistically correlated and when there are only a few abundance estimates within a short time period, the algorithm may not be able to accurately estimate both parameters. In these cases, the posterior distribution of r_{max} was relatively flat (uniformly distributed) resulting in the median being simply a value near the middle of the possible range (0 – 0.09) and a wide 90% credible interval. This indicates that the estimate of r_{max} is imprecise and may not provide biologically accurate or useful information. As the time series of abundance and/or removals lengthens, the more precise the estimates of both K and r_{max} become and the posterior distributions become less uniformly distributed (i.e. less flat).

In the implementation of the population dynamic model it was assumed that z = 2.39, which corresponds to maximum net productivity (MNP) at 60% of K, the MNP level (MNPL). This level is also the population level at which the largest yield (by-catch in our case) can be taken from the population in an assessment area over an indefinite period (maximum sustainable yield – MSY). The value of MNPL=MSYL=60% is commonly assumed for cetacean populations. The effect of using a smaller value (e.g. z = 1.0, so that MSYL is 50% of historical K) is that more by-catch would be allowed and the abundance estimate would eventually theoretically equilibrate at a lower level.

Another important assumption is that the input abundance estimates are representative of the same biological population through the entire time series; that is, that a population in an assessment area is closed to the movement of individuals in and out of the area. However, genetic analyses indicate that there is likely some (as yet unknown) level of movement between at least some of the assessment areas (see Figure 2). To explore the impact of this, assessment analyses could be conducted for different possible assessment areas. In the future, a more rigorous strategy would be to conduct joint assessments on combinations of assessment areas, taking into account the levels of mixing between the assessment units.

Similarly, it is assumed that the time series of by-catch estimates represents true by-catch. Assumptions associated with the generate of estimates of by-catch used in assessments are discussed below.

The biological assumptions underlying the PBR calculation are essentially the same as for the population dynamics model described above because the same model was used to derive the default values of the PBR parameters. As usual, if the default parameter values are used, there are additional assumptions that these values are biologically appropriate for the assessment unit and also that the underlying policy objectives that influenced the choice of the default values are appropriate for the current situation. For example, the default values were derived through simulations to meet two criteria: (1) that populations starting at the maximum net productivity level (MNPL) stayed there or above after 20 yrs, and (2) that populations starting at 30% of carrying capacity recovered to at least MNPL after 100 yrs (Wade 1998).

Discussion of Selected Assessment Methodology

The discussion on the assessment model used in the workshop focused on clarifying the operation of the model, the selection of relevant data inputs and values, and how the outputs should be interpreted and communicated.

This included, noting that the first year that by-catch or abundance estimates were available was being used as the reference for the unexploited population size, or carrying capacity, K and it was thus important to distinguish between K - the historical pre-exploitation carrying capacity population size - and K’, - the population size in the first year when abundance or by-catch data were available. However, since in several cases there was likely a significant amount of by-catch before the first year by-catch estimates were available, the historical carrying capacity K may have actually been higher than the K’ value estimated in the model. Omitting earlier known by-catch has two other effects on model results. First, current abundance as a proportion of historical abundance is overestimated, i.e. the population appears less depleted than it actually is. Second, because of this, the maximum population growth rate (r_{max}) is underestimated in all assessments, perhaps with the exception of Iceland and the North Sea, and because density dependent effects constrain growth rate as the population approaches K, any estimates of increasing current trend will also be suppressed. Caution is therefore needed when interpreting results on depletion and current trend if by-catch is known to have occurred prior to the year that by-catch estimates were first available.

Regarding PBR calculations, a value for r_{max} (i.e., the maximum rate of growth of the population) of 0.04 was used because this is the default value used in the USA. However, even as suggested in US guidelines, if reliable estimates of r_{max} are available, then these could be used instead of the default. For example, in some assessments run at the WS, the available data generated median estimates of r_{max} that were different from 0.04 from a non-flat posterior distribution. Such values could be considered if using the PBR calculation.

The question of what value should be used for the recovery factor in PBR calculations was also discussed. It was concluded that in most cases the choice of the recovery factor is a management decision and it was agreed that it would be important to provide written justifications for the choices made so that the reasoning for the choice is transparent. It was also agreed that the population dynamic assessment model was the preferred method to evaluate the status of an assessment unit, but the PBR calculation could provide some general indications, particularly if the available data were insufficient to use the population dynamic method.

a. Eastern USA: Gulf of Maine/Bay of Fundy Assessment

Data Inputs & Limitations

The data for the Scotian Shelf stratum was amalgamated with the NE U.S. stratum for analyses given the known genetic exchange between these two areas, and the overlap in survey effort and knowledge.

The population dynamic model input data from the Gulf of Maine/Bay of Fundy harbour porpoise assessment unit included:

(a) Six abundance estimates, and associated CVs from 1992 – 2016, were derived from multi-species ship and plane line transect surveys (see the abundance estimates tables available as supplementary files on the NAMMCO website (https://nammco.no/topics/scientific-workshops-symposia-reports/#2018) and,

b) 28 annual by-catch estimates from 1990 to 2017 that were the summation of the following: 28 annual estimates from US waters derived from annual observer data collected on a sample of commercial US fisheries (nearly all from gillnets); 4 annual estimates from Canadian waters derived from an observer program in the Bay of Fundy gillnet fishery; observed annual mortalities in the Bay of Fundy herring weir fishery; and predicted by-catch estimates from Canadian Bay of Fundy and Scotian shelf waters for years without an observer program that were approximately proportional to levels of gillnet fishing effort (see Table 2 in area report – Annex 1).

The quality of the abundance estimates used in the assessment is considered to be high because all estimates were collected from appropriately designed and analyzed surveys and all were corrected for perception bias. However, minor additional work is recommended to fully standardize the estimates to consistently correct them for availability bias (when appropriate) and area surveyed.

The quality of the US by-catch estimates is also considered high because they were derived from an annual observer program and accounted for differences in fishing practices, management measures, and season and areal differences. However, during some years and sub-areas, the observer coverage was low (about 2%) and so may not be representative. The quality of the Canadian by-catch estimates is considered to be more uncertain because most of the estimates were derived from only a limited scientific program that estimated by-catch rates. More details on the input data are available in the area report given in Annex 1 of this report.

Results & Conclusions

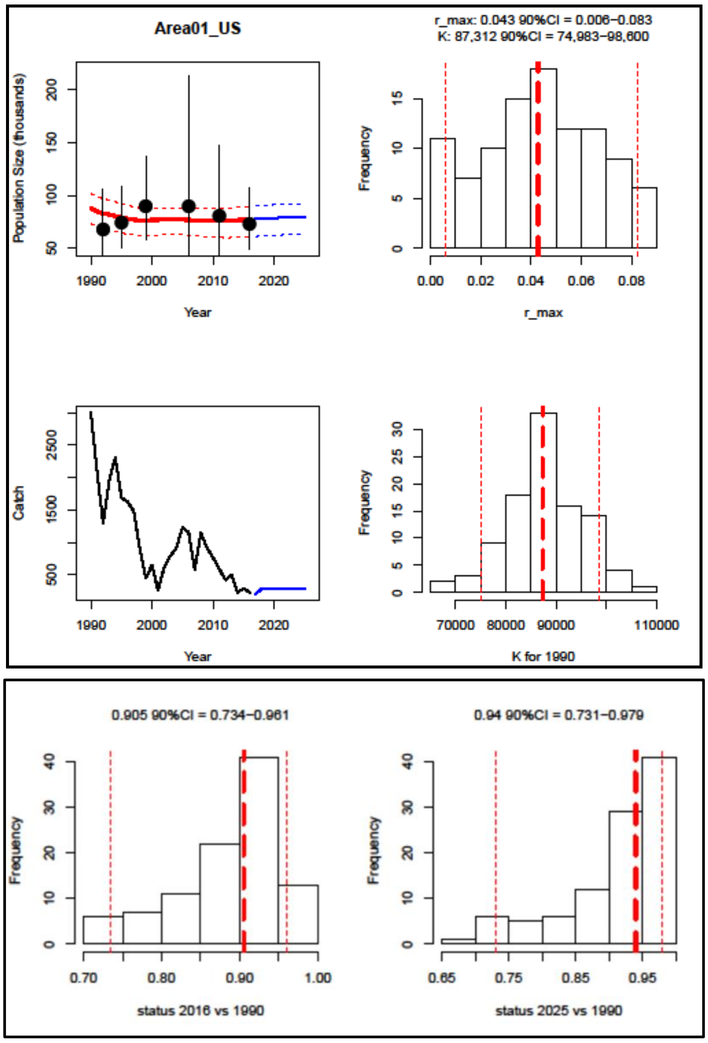

Figure 5: Assessment of the harbour porpoise population in the Eastern US assessment area using a population dynamic model (Zerbini et al. 2011). Upper left panel: Estimated population abundance in the given period. Upper right panel: Estimated median maximum population growth rate, r_{max} (bolded hatched line) given with a 90% credible interval. Middle left panel: Estimated annual by-catch over the given period (used as model input). Middle right panel: Estimated median K_{1990} given with a 90% credible interval. Lower left panel: Estimated abundance median current depletion level (2016 abundance relative to K_{1990}) with a 90% credible interval. Lower right panel: Predicted median future depletion level (2025 predicted abundance relative to K_{1990}) with 90% credible interval.

The population dynamic model indicated that the population size of the Gulf of Maine/Bay of Fundy harbour porpoise assessment unit is currently increasing slowly (Figure 5). The current level of depletion (N_{2016}/K_{1990}) = 0.91 (90% CI 0.734 – 0.961) of K_{1990} (= 87,312; 90% CI 74,983 – 98,600). The predicted level of depletion in

2025 (N_{2025}/K_{1990}) = 0.94 (90% CI 0.731 – 0.979) of K_{1990}. The estimated r_{max} value (0.043; 90% CI 0.006 – 0.083) is consistent with previous estimated values (0.046) as reported in Moore and Read (2008).

As another measure of status, PBR was calculated as 614 and 1229 using the most recent absolute abundance estimate (72,573 CV=0.20), where r_{max} = 0.04 and either F_r = 0.5 and F_r = 1.0, respectively. Both values of PBR are above the average annual by-catch estimate for the 5 most recent years, 2013 - 2017 (292).

The workshop concluded that the population dynamic assessment model methodology was appropriate for the data available and that based on the model outputs, declining by-catch estimates, and the relatively large abundance estimates, there is a low level of concern for harbour porpoise within this assessment unit.

Discussion

It was noted as interesting that in 2016, the USA saw a population drop while there was a huge increase seen in Canada during this time. This could be an indication that animals are moving between these areas, but it may also be mostly males that are moving since females tend to show a high level of spatial fidelity. From the by-catch reported in the Gulf of Maine, more males are being caught offshore while more femals are caught closer to shore, while the sex ratio of strandings is not known. This highlighted the need for more samples to clarify if the stock structure is changing in this area. In the fall and winter, harbour porpoises move south into the mid-Atlantic while in summer they are breeding in the cooler waters further to the north. The Gulf of Maine is one of the areas with the most change in sea surface temperature, which can change the distribution of prey and the distribution of the harbour porpoise. It was noted that it was unusual to see so many flat fish in the diet of harbour porpoises as is seen in this area and it was highlighted as valuable to look at how climate change (as well as other forms of disturbance) may be affecting distribution and therefore abundance in this area.

In the US, harbour porpoises are protected under the USA's Marine Mammal Protection Act and should not be hunted. In the past high by-catch rates were observed, however these have now been reduced through the closures at certain times, the use of different sized gear and pingers and it was noted that the assessment shows a dramatic drop in by-catch in this area.

It was noted that there are knowledge gaps related to current life history parameters and pollutant loads. Disturbance from noise is being considered and recently discussions have started taking place about how to mitigate this disturbance in relation to a new windfarm development in US Atlantic waters. Most of the people working on wind farm developments in the USA are coming from Europe and bringing their knowledge with them. It is also worth noting that since this area has a lot more species diversity than Europe (particularly in terms of large whale species), the USA is developing categories of sensitivity to noise for the different species.

Recommendations

The workshop recommends that the assessment could be improved by developing a standardized time series of abundance estimates that consistently account for availability bias in aerial survey data and are from a common survey area. In addition, the sensitivity of the assessment could be investigated by developing a longer time series of by-catch estimates going back in time by using gillnet fishing effort statistics and an appropriate estimate of the by-catch rate.

The workshop recommends continued monitoring of the abundance of harbour porpoises in US waters, preferably using a schedule synoptic with surveys conducted in eastern Canada and west Greenland.

Because of the fast-changing environment in the Gulf of Maine, the stock structure relationship between harbour porpoises in eastern US and Canadian waters could potentially be changing. Further population genetic studies and satellite tracking could usefully inform stock structure issues in these waters.

The available information on biological parameters of the Gulf of Maine/Bay of Fundy harbour porpoise assessment unit is primarily based on studies conducted decades ago. Since then, significant changes have occurred in the marine environment of the Atlantic US and Canadian waters. The collection of more recent data on biology and feeding ecology would therefore be valuable to evaluate the potential effects of these changes on porpoises in the area.

b. Eastern Canada: Newfoundland and Labrador & Gulf of St. Lawrence

It is difficult to make a firm determination of the status of the eastern Canadian assessment unit because the indicators over the period of this assessment are not data rich.

Data Inputs & Limitations

The eastern Canadian assessment unit was subdivided into three strata based on genetic and distributional information (see the revised map presented in section 2 above and the Canada area report in Annex 2). As noted above, the data for the Scotian Shelf stratum was amalgamated with the NE U.S. stratum for subsequent analyses given the known genetic exchange between these two areas, and the overlap in survey effort and knowledge. The workshop agreed to use these assessment unit boundaries to structure the modelling effort.

The largest and most recent abundance estimate for harbour porpoise in Atlantic Canadian waters was gathered from the large-scale North Atlantic International Sightings Survey (NAISS) in 2016. This aerial survey used line transect data collection methods and distance sampling to produce corrected estimates for the Newfoundland and Labrador (NL) stratum of 48,723 (95% CI 23,566-100,754), for the Gulf of 185,258 (95% CI 101,006-286,117), and the Scotian Shelf of 20,464 (95% CI 6,831-37,317).

The degree of change between the 2007 TNASS and 2016 NAISS aerial survey estimates (63,232 and 256,355, respectively) is too large to be a product of reproduction alone. Changes in the distribution of porpoises in this assessment unit and slightly earlier survey timing in 2007 may have been responsible for much of the difference over the 9-year inter-survey interval between the 2007 and 2016 aerial surveys, for both Canadian strata. It may be worth including the 2007 estimates in a model re-run and a 1996 aerial survey estimate for the Gulf might be corrected for perception and availability biases and added as a model input as well. At this stage though, the workshop agreed that using the single 2016 abundance estimate was appropriate for the modelling effort.

Harbour porpoises suffer incidental by-catch in fisheries, much of which is due to encounters with bottom-set gillnets, and in smaller nets in nearshore areas being deployed to collect bait for fixed trap fisheries. For the NL stratum by-catch estimates from 2001 to 2003 were used, and a median value for the other modelled years; for the Gulf stratum by-catch estimates for 2001 and 2002 were used, and a median value for the other modelled years.

Although reductions in the number of gillnet fishing gear have happened since the collapse of a number of nearshore groundfish stocks, gillnet use does continue. Given the uncertainties in the by-catch estimation process, it is not possible to conclude that by-catch of harbour porpoise has declined or increased.

The annual value for the magnitude of porpoise standings is highly variable, but may be increasing in the Gulf, and in the NL stratum may be underestimated due to the large proportion of uninhabited coastline. Due to limitations in the strandings response programmes and large geographic area, non-by-catch losses within this assessment unit are unknown.

Results & Conclusions

For the NL assessment unit, and using the 2016 abundance estimate, the assessment model predicts that the abundance in 2000 (K; the first year of the by-catch series) was 69,678 (90% CI – 44,719-102,808). The model predicts the number of porpoises in this assessment unit may be experiencing a slow decline (the rate of which may be decreasing), where it was predicted that the abundance estimate in 2025 will be 76% (90% CI – 0.479-0.892) of K (Figure 6). As another measure of status, PBR with a recovery factor of 1.0 was calculated to be 697, or 349 with a recovery factor of 0.5. Both values are below what was estimated as the average annual by-catch (1,428). The r_{max} value (0.048) is consistent with reproductive rates (83%) observed in eastern Canada.

For the Gulf assessment unit, and using the 2016 abundance estimate, the assessment model predicts that the abundance in 2000 was 212,860 (90% CI – 145,457-310,801). The model predicts that the number of porpoises in this assessment unit may be experiencing a slow decline (the rate of which may be decreasing), where it was predicted that the abundance estimate in 2025 will be 88% (90% CI – 0.754-0.948) of K (Figure 7). As another measure of status, PBR with a recovery factor of 1.0 was calculated to be 2,697, or 1,349 with a recovery factor of 0.5. Both values are below what was estimated as the average annual by-catch (2,305). The r_{max} value (0.046) is similar to the NL stratum value, and also consistent with reproductive rates (83%) observed in eastern Canada.

The workshop concluded that the methodology applied was appropriate for the data available. The extrapolations based on fishery landings in the gillnet fisheries are based on an assumption of constant by-catch rates since the early 2000s. Changes in the fishing patterns in eastern Canada since the collapse of a number of groundfish stocks suggests that the net-based fishing effort may have declined, and therefore by-catch of porpoises may have declined below levels we assumed in this modelling exercise. If this is proven true, the assessment unit abundance trends may be positive instead.

Based on the model outputs, possible declining by-catch rates, and the relatively large strata abundances, the conclusion is that this assessment unit is of a low level of concern.

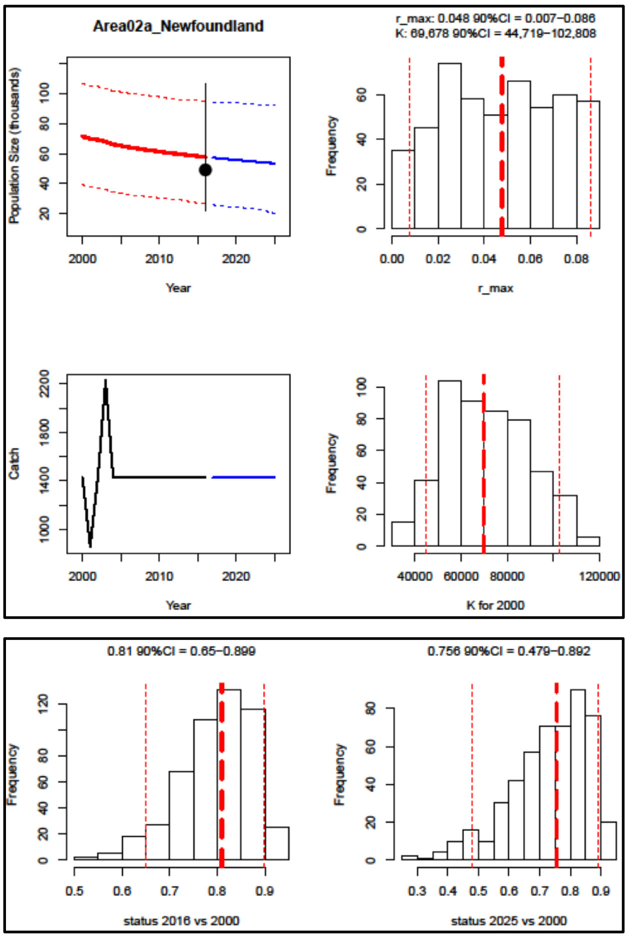

Figure 6: Assessment of the harbour porpoise population in the Newfoundland assessment area using a population dynamic model (Zerbini et al. 2011). Upper left panel: Estimated population abundance in the given period. Upper right panel: Estimated median r_{max} (bolded hatched line) given with a 90% credible interval. Middle left panel: Estimated annual by-catch over the given period (used as model input). Middle right panel: Estimated median K_{2000} given with a 90% credible interval. Lower left panel: Estimated abundance median current depletion level (2016 abundance relative to K_{2000}) with a 90% credible interval. Lower right panel: Predicted median future depletion level (2025 predicted abundance relative to K_{2000}) with 90% credible interval.

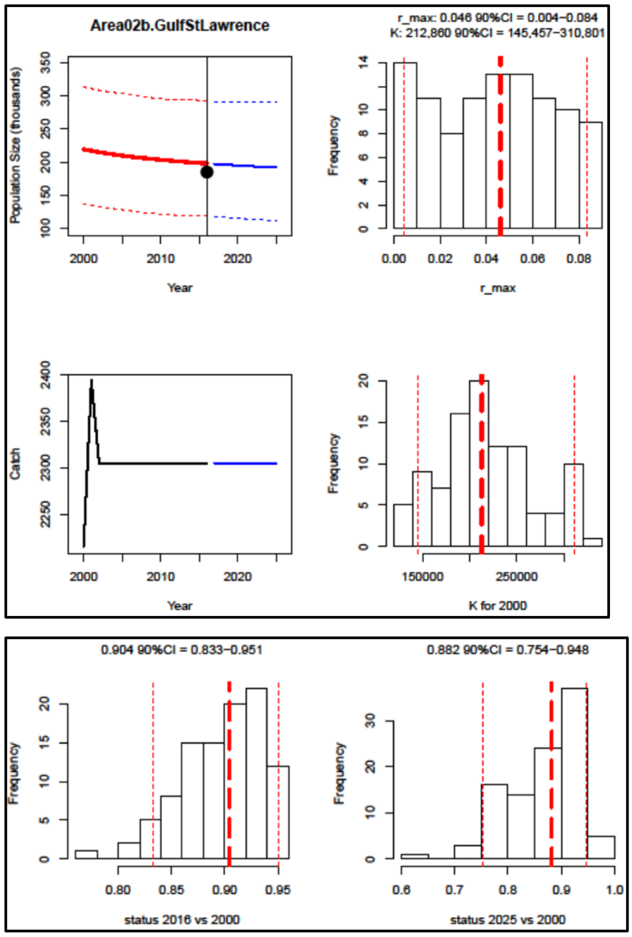

Figure 7: Assessment of the harbour porpoise population in the Gulf of St. Lawrence assessment area using a population dynamic model (Zerbini et al. 2011). Upper left panel: Estimated population abundance in the given period. Upper right panel: Estimated median r_{max} (bolded hatched line) given with a 90% credible interval. Middle left panel: Estimated annual by-catch over the given period (used as model input). Middle right panel: Estimated median K_{2000} given with a 90% credible interval. Lower left panel: Estimated abundance median current depletion level (2016 abundance relative to K_{2000}) with a 90% credible interval. Lower right panel: Predicted median future depletion level (2025 predicted abundance relative to K_{2000}) with 90% credible interval.

Discussion

Since there was only data available on abundance from 2 years and the figures were very different, instead of taking an intermediate number from these two points, it would also be possible to enter them into the model as upper and lower limits. Because the fisheries in the area have changed significantly between the two years for which data is available, the by-catch will also likely be different. There remain significant challenges for achieving accurate reporting on by-catch in this area. There is currently an attempt to use telephone interviews to try and get a good by-catch estimate, however this work remains ongoing. Getting good information on by-catch has become even more important (politically) now that there is a US policy demanding that all fishery imports limit their impacts on marine mammals. The Gulf of St Lawrence stock is listed as a special concern in Canada and therefore improving by-catch estimates is particularly important in this area. It was noted that although better survey data would be useful to have, it may not necessarily be a priority.

This area has recently had an influx of white-beaked dolphins, which are aggressive and may be killing porpoises, but this is not taken into account in the model.

Recommendations

Better information is needed on the abundance of porpoises in eastern Canadian waters. The available data on abundance are from only two multispecies cetacean surveys. Continued monitoring of the abundance of harbour porpoises in eastern Canadian waters, preferably using a schedule synoptic with surveys in west Greenland and the United States, is therefore recommended.

Estimation of by-catch levels in eastern Canadian fisheries should be improved. There is a telephone by-catch survey underway in the NL stratum currently, and this should be extended to the Gulf and Scotian Shelf strata.

The assessment is based in part on data for porpoise collected in the eastern Canadian continental shelf area. It is uncertain whether this constitutes a discrete population (although it seems likely that they are part of a larger unit that includes those in U.S. waters). Further genetic studies and satellite tracking could inform stock structure questions in the northwest Atlantic.

The available information on porpoise biological parameters and feeding ecology is primarily based on studies conducted decades ago. Since then, significant changes have occurred in the marine environment of eastern Canada. More recent data on biology and feeding ecology would be valuable for evaluating potential effects of these changes on porpoises in the area.

c. Greenland

The assessment of harbour porpoises in Greenland was carried out by NAMMCO's harbour porpoise working group in Spring 2019. The final results, including status and recommendations, are presented in the working group report (see https://nammco.no/topics/hpwg_reports/#2019).

d. Iceland

Data Inputs & Limitations

Assessment runs were made using the combined by-catch estimates for cod and gillnet fisheries 2013-2017 with extrapolations back to 1950 from the fisheries data as described in the area status report (see annex 3 of this report). The estimate used for the cod fishery was that agreed by the NAMMCO Scientific Committee as an upper bound and may thus be an overestimate. For abundance, the 2007 estimate for coastal Icelandic waters was used together with the two relative abundance estimates based on the genetic close-kin analysis. The aerial survey was not optimized for harbour porpoises and was conducted 11 years ago. Fitting two other relative abundance series (from the NASS aerial surveys and MFRI's gillnet fishery surveys) could not be completed at this meeting due to time constraints.

The extrapolations based on fishery landings in the gillnet fisheries are based on the assumption of constant by-catch rates through time. As the point estimate for recent by-catch is that agreed as an upper bound, the whole by-catch series is affected.

The high gillnet fishery effort in the latter half of the 20th century has likely led to a population decline until around 2005 but recent by-catch rates are likely to lead to continued population growth.

Results & Conclusions

According to these runs, the carrying capacity (K) in 1950 was estimated as 138,107 porpoises and r-max as 0.073 (Figure 8). The estimated r_max is higher than that estimated for some other populations, but it is consistent with high reproductive rates (98%) observed in Icelandic waters. The stock trajectory shows a steady decrease in the latter half of the 20th century reflecting the fishery effort data, and subsequently an increase in abundance from around 2005. Compared to the population level in 1950, the present status is at 63% (0.628) and the model predicts it to increase to 72% (0.721) by 2025 under the current level of by-catch.

Based on the model run outputs, the PBR for 2018 is around 3500 porpoises.

The workshop concluded that the methodology applied was appropriate for the available data.

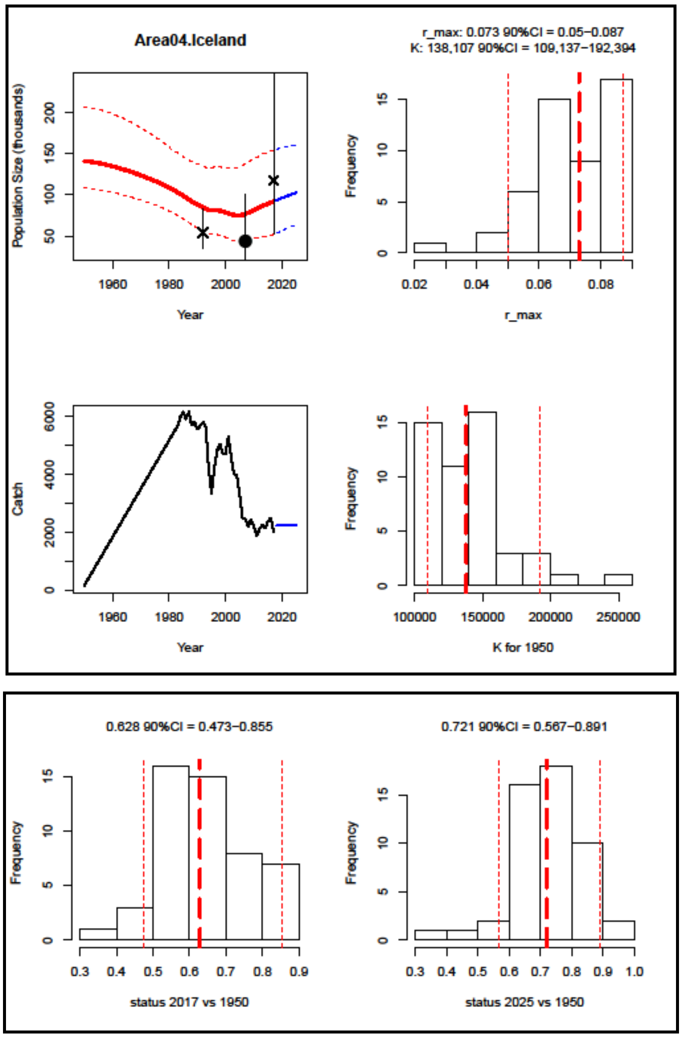

Figure 8: Assessment of the harbour porpoise population in the Iceland assessment area using a population dynamic model (Zerbini et al. 2011). Upper left panel: Estimated population abundance in the given period. Upper right panel: Estimated median r_{max} (bolded hatched line) given with a 90% credible interval. Middle left panel: Estimated annual by-catch over the given period (used as model input). Middle right panel: Estimated median K_{1950} given with a 90% credible interval. Lower left panel: Estimated abundance median current depletion level (2017 abundance relative to K_{1950}) with a 90% credible interval. Lower right panel: Predicted median future depletion level (2025 predicted abundance relative to K_{1950}) with 90% credible interval.

Discussion

The conclusion of the assessment is that the population in the Icelandic area seems to be recovering.

However, the assessment presented used by-catch estimates for cod and gillnet fisheries from 2013-2017, with an extrapolation back to 1950 based on the available data on fishing effort and there was significant discussion about the appropriateness/desirability of using this extrapolation. For other assessments, estimates of by-catch begin when actual data becomes available. The question was therefore whether this (and all) assessments should use by-catch estimates that begin only when data on this becomes available or if extrapolations back should be made based on fishing effort.

It was noted that extrapolating back to a timepoint before 1950 would be of little value because nylon nets were not really used before the 1950s and it is monofilament nets that have been particularly implicated in high levels of harbour porpoise by-catch.

The group agreed that the extrapolation used in the case of Iceland was reasonable. However, it was also proposed that it could be worthwhile to run the model again using only the available data (without the extrapolation) and therefore only going back to 1980. Having this second run would allow the sensitivity of the model to this type of change to be seen. Based on what such a second run reveals, a choice could then be made and applied to all assessments to try and ensure consistency on when by-catch estimates begin.

It was also noted that the abundance being used in the model includes relative abundance, not only absolute abundance, but since the model still seems to be capturing the trajectory based on these relative estimates, this may not be problem.

Finally, there was a question about which recommendation may be the most important to focus on for improving the assessment. It was proposed that collecting genetic samples is important but that would be important to include any samples that may be taken from East Greenland in the genetic analysis as this will help clarify whether the population there is closer to that found in West Greenland or to the Icelandic population.

Recommendations

Better information is needed on the abundance of harbour porpoises in Icelandic waters. The available data on abundance comes from surveys that have large cetacean species as their primary target. It is therefore recommended that continued monitoring of the abundance preferably by done through the use of dedicated surveys for harbour porpoise.

Kinship analysis can be improved by increasing sample size and increasing the number of genetic markers analysed. It is therefore recommended that the sampling program in Iceland continue and include a higher number of genetic markers.

The assessment is based on data on the stock structure for the Icelandic continental shelf area. It is, however, uncertain whether this constitutes a separate population of harbour porpoises or if they are a part of a larger population. Further population genetic studies and satellite tracking could usefully inform stock structure questions in this area.

At present there is no approved best estimate for the Icelandic cod gillnet fishery so it is recommended that the estimation of by-catch levels in Icelandic fisheries be improved.

The available information on biological parameters and feeding ecology is primarily based on a large study conducted in 1991-1997. Since then, significant changes have occurred in the marine environment of Icelandic waters. More recent data on biology and feeding ecology would be valuable for evaluating potential effects of these changes on the harbour porpoises in this area.

e. Faroe Islands

Data Inputs & Limitations

The Faroe Islands represents a very data poor area for harbour porpoise assessment. The data available as an input into assessment is one abundance estimate (2010) providing a fully corrected abundance of 5.175 (CV=0.44, 95% C.I.: 3.457-17.637) porpoises. The estimate is considered a minimum estimate, because it covers only part (73%) of the area inside the 300 meters depth curve and excludes deeper waters.

Current knowledge about direct and by-catch mortality is inadequate. However, there are indications that the current mortality is low because there is no gillnet fishing effort inside 380 meters and a low interest in hunting porpoises by recreational hunters.

The assessment approach was therefore to calculate potential biological removal (PBR), with a recovery rate of 0.5 and 1.0. For a minimum estimate of abundance, the point estimate was used instead of the lower 95% confidence level estimate, acknowledging that the estimate had to be considered as an absolute minimum estimate.

Results & Conclusions

The PBR calculated was 36-73 porpoises, dependent on the conservation buffer (recovery rate) chosen.

The PBR was calculated in order to give an idea of what would be an upper limit for safe levels of removal that would still allow the unit to maintain the current population level. Based on this calculation and the assumed low levels of direct and by-catch, it is believed that current mortality rates are inside the sustainable level given by PBR.

Discussion

The value of performing a genetic analysis of samples from the Faroes was discussed and agreed since this has been identified as an area in which samples and analysis have previously been lacking.

There was also significant discussion about the most appropriate way to handle the Faroe Islands in the assessment – i.e. as a separate area, integrated with Iceland or integrated with Scotland. The genetic data does not seem to indicate a difference between Iceland, Scotland or Faroes (although it needs to be noted there are very limited samples). There was a sense that if it is integrated into the Iceland area, the numbers will simply be swallowed and will become insignificant. It was agreed that it may not currently matter where the Faroes are integrated in the assessment since it currently has too little data to actually make a difference. Since a PBR was calculated for the Faroes, there was agreement to keep it separate in this case.

At the moment the PBR has been calculated for the minimal abundance estimate but this may change if equal density in the western area of Iceland (which was poorly surveyed) is assumed and used to make an extrapolation. It may also change if the CV is used in the model instead of the minimum estimate. It was agreed that using the minimum is appropriate at this point.

Recommendations
It is recommended that further research take place (e.g. through tagging and/or genetic analysis) to investigate whether the porpoises in Faroese waters represent a separate population or should be considered part of a larger assessment unit.

It is important to obtain reliable removal data (e.g. by-catch and hunting statistics) and an updated abundance estimate, preferably for as large a part of the Faroese EEZ as possible (e.g. through a sightings survey).

Life history data should be collected in the Faroese area.

f. Norwegian & Russian Coasts

Data Inputs & Limitations
The abundance estimate for Norwegian waters is based on a combination of data from ship line transect surveys, (primarily for minke whales), carried out in the Barents Sea and eastern Norwegian Sea north of 62ºN. These data yield a best abundance estimate for the year 2016 of 83,707 porpoises, with a CV of 0.29. Abundance estimates from Norwegian fjords are still missing. Data from a limited number of surveys have shown higher densities of porpoises in fjords than observed in the open waters of the North and Barents Seas. A study is underway to develop methods for combining data from several different sources (ship-based surveys with two independent platforms, aerial surveys, small boat surveys with one platform, and drone data) for estimating abundance in fjord waters. Adding abundances from fjord waters has the potential to increase the total abundance by approximately 15%.

The current estimates of by-catch are based on a by-catch rate (number of porpoises per kg catch of the target species) estimated from data from the Coastal Reference Fleet and extrapolated to the entire commercial fleet using landing statistics of the target species (cod and monkfish) as a proxy for fishing effort. The best qualified judgement is that by-catch in these two fisheries constitutes about 80% of the total by-catch of harbour porpoise in Norway. Obtaining data for the remaining gillnet fisheries is important for a complete picture of the by-catch in Norway. Information from Russian waters is missing but there is little coastal fishing effort with gillnets along the north coast of the Kola peninsula. Based on the above data, by-catch estimates were available for the period 2006-2015 and ranged from 885 in 2015 to 4036 in 2008 with a weakly decreasing trend due to decreasing fishing effort in the monkfish fishery. The average estimated by-catch from 2013-2015 was used as the best estimate for by-catch during the period 2016-2025 and amounted to 2069 animals.

There are several assumptions associated with using landings as a proxy for effort when estimating fleet-wide by-catch from reported numbers, and some of these assumptions are violated in the current estimates from Norwegian waters. Effort reporting is not mandatory for vessels less than 15 m overall length, and an estimate of effort is therefore lacking for this smaller category of fishing vessels. The Directorate of Fisheries is currently exploring automated, electronic means for effort reporting from small vessels. If direct effort data become available, the accuracy and precision of the by-catch estimates will improve.

Results & Conclusions
The first year of data on by-catch was 2006. The initial abundance used in the assessment model is therefore for 2006, with an absolute abundance estimated at K_{2006} = 83,707 (CV 0.29). This abundance is based on Norwegian line transect surveys in the Barents Sea and Norwegian coastal waters north of 62ºN. The results of the assessment based on these date inputs are presented in Figure 9.

The PBR for Norwegian waters is about 700, and the current estimates of by-catch exceed this level. This means that the population is expected to decline under the current regime. The population status in 2016 is 84% of the initial populations size in 2006. If the by-catch in the period 2016-2025 is equal to the average of the three last years of annual estimates, the decline will continue. The population status in 2025 will then be 79% of the initial abundance in 2006. However, initial experiments with acoustic alarms (pingers) on gillnets have demonstrated a 70% reduction of harbour porpoise by-catch (see recommendations below). The pinger experiments will be continued with more pingers and more vessels included. The use of pingers has the potential to bring Norwegian by-catch within the limits of PBR.

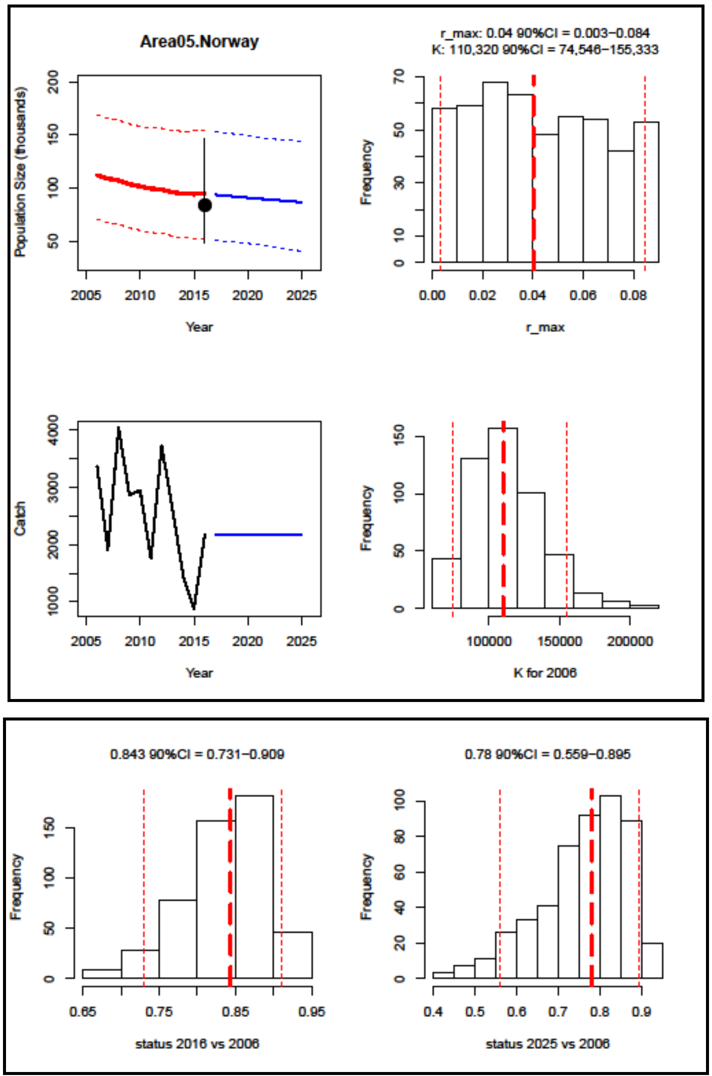

Figure 9: Assessment of the harbour porpoise population in the Norwegian and Russian coasts assessment areausing a population dynamic model (Zerbini et al. 2011). Upper left panel: Estimated population abundance in the given period. Upper right panel: Estimated median r_{max} (bolded hatched line) given with a 90% credible interval. Middle left panel: Estimated annual by-catch over the given period (used as model input). Middle right panel: Estimated median K_{2006} given with a 90% credible interval. Lower left panel: Estimated abundance median current depletion level (2016 abundance relative to K_{2006}) with a 90% credible interval. Lower right panel: Predicted median future depletion level (2025 predicted abundance relative to K_{2006}) with 90% credible interval.

Discussion

There was a question as to whether by-catch was concentrated in certain areas, because if so, it might be important to have more frequent surveys in these areas, particularly if by-catch is above sustainable levels as indicated. When methods to survey fjords in a good way are available, there is an intention to apply for a specific budget to survey these areas more frequently. It was proposed that it could be particularly valuable to have more frequent surveys in 'hotspot areas'. The hotspot areas would be those where there is both a high number of harbour porpoises and a high level of by-catch – e.g. the inner part of Vestfjorden – since the impacts on populations are probably higher in these areas. It is clarified that more frequent surveys would mean having surveys conducted more often than every 5-6$^{th.}$ year as is the current norm for line surveys, and possibly double this frequency.

There was a question of whether there could there be an effect of the salmon drift net fishery, but the answer was that this only went on a few years and was stopped in 1988.

It was noted that the IMR is already working with the Directorate of Fisheries to get more direct fishing effort statistics in the coastal zone.

Recommendations

The work on developing a method to combine data from different sources to estimate abundance in Norwegian fjord waters should be completed and abundance in fjord waters added to the total abundance.

The Norwegian shipborne line-transect surveys provide data for updating the abundance in offshore areas every sixth year. It would be advantageous if SCANS surveys could be carried out with a similar frequency.

The current monitoring of by-catch is assumed to cover about 80% of total by-catch in Norway. The monitoring should be improved and expanded to include all gillnet fisheries with the potential to catch harbour porpoises.

The collaboration between IMR and the Directorate of Fisheries to explore methods for effort reporting from small vessels should continue and methods for electronic reporting established.

Initial experiments with acoustic alarms (pingers) on gillnets show a 70% decrease in harbour porpoise by-catch. The simulation for estimating the effect of deployment of pingers on different proportions of the Norwegian gillnet fisheries should be continued and actual experiments carried out.

g. West Scotland/Ireland and Celtic/Irish Seas (Joint Analysis)

Assessment units for harbour porpoise west of the UK, Ireland and France have previously been defined by ICES and used to inform MSFD assessments: West Scotland; and Celtic & Irish Seas, including French Atlantic waters (Figure 10a). However, new genetic and biological data support changing the boundary between these two areas from the boundary between ICES divisions VIa,b2 and VIIb,c2 to the boundary between ICES divisions VIIj2 and VIIg,h, with the Irish Sea (ICES division VIIa) as a zone of uncertainty (Figure 10b). This new boundary was captured in the map of assessment units agreed for use during the workshop (Figure 2).

The assessment reported below was conducted using the new boundary to form a new West Scotland/Ireland assessment area (including ICES divisions VIa, b and VIIb, c, j, k), and a revised Celtic & Irish Seas assessment area (ICES divisions VIIa, e, f, g, h and VIIIa, b, d) (Figure 10b).

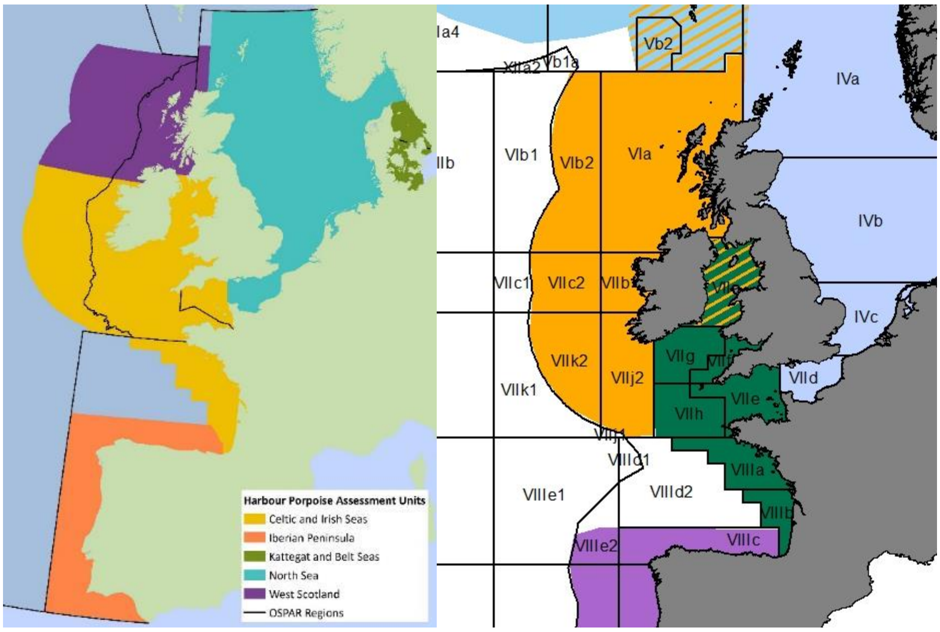

Figure 10: Harbour porpoise assessment units defined by ICES (a - left), and areas used in the assessment (b - right). The Irish Sea (green/gold hatched area) was included with the Celtic Sea (green).

Data Inputs & Limitations

Abundance estimates used in the assessment were from the SCANS-II survey in summer 2005 and the SCANS-III and ObSERVE surveys in summer 2016.

By-catch rate was estimated for each assessment area from data collated by the ICES Working Group on By-catch (WGBYC) from monitoring conducted 2006-2016 and reported under EU Commission Regulation 812/2004 (see the Area Status Report in Annex 7 for a table summarising these data for the two assessment areas). An "uninformed multiplier" was introduced to compensate for any potential sources of negative bias for which there is no information, for example animals dropping out of the net underwater. However, it is unknown whether such a value is at all realistic (or even justified) and not all participants agreed with the use of the multiplier.

To generate time series of days at sea to calculate estimates of annual by-catch, days at sea data from the ICES Regional database (RDB) were collated for ICES divisions within the assessment areas: ICES divisions VIa, b, VIIb, c, j, k for the West Scotland/Ireland assessment area; and ICES divisions VIIa, e, f, g, h, VIIIa, b, d) for the revised Celtic & Irish Seas assessment area. These data were provided by ICES for the years 2009-2017 only.

During collation of these data, problems were identified with the days at sea for ICES divisions VIIIa, b, d so these data were not included in the assessment.

Total annual by-catch was estimated using the estimated upper 95% confidence limits of by-catch rates from Table 2 (0.1162 and 0.2073 for the West Scotland/Ireland assessment area; 0.0312 and 0.0595 for the revised Celtic & Irish Seas assessment area). By-catch occurred in these areas in earlier years (e.g. Tregenza, Berrow, Hammond, & Leaper, 1997) but it was not possible at the meeting to generate time series of by-catch prior to 2009.

Although there was disagreement about whether or not the "uninformed multiplier" was appropriate, in the spirit of a precautionary approach, the assessments were run using the upper 95% confidence limit of the multiplied by-catch rate. The assessment thus aimed to account for both uncertainty and any negative bias in the data used. The assessment ran from 2005 to incorporate the earlier abundance estimate; in the absence of information, by-catch was set to zero for 2005-2008. For prediction in the future period 2018-2025 the annual by-catch was assumed to be equal to the mean of the previous five years (2013-2017): 720 for West Scotland/Ireland and 852 for the Celtic & Irish Seas.

Results & Conclusions

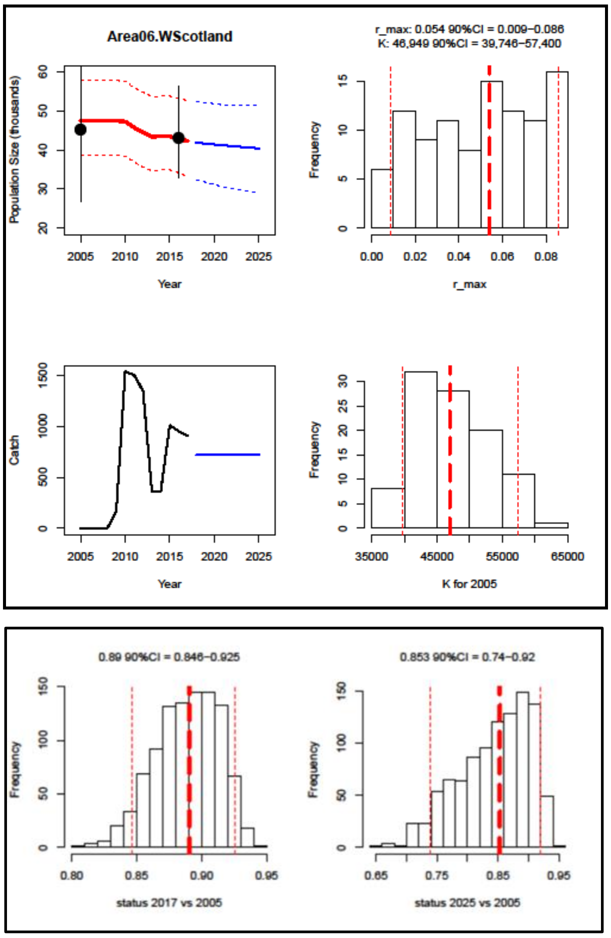

Figure 11: Assessment of the harbour porpoise population in the West Scotland/Ireland assessment area using a population dynamic model (Zerbini et al. 2011). Upper left panel: Estimated population abundance in the given period. Upper right panel: Estimated median r_{max} (bolded hatched line) given with a 90% credible interval. Middle left panel: Estimated annual by-catch over the given period (used as model input). Middle right panel: Estimated median K_{2005} given with a 90% credible interval. Lower left panel: Estimated abundance median current depletion level (2017 abundance relative to K_{2005}) with a 90% credible interval. Lower right panel: Predicted median future depletion level (2025 predicted abundance relative to K_{2005}) with 90% credible interval.

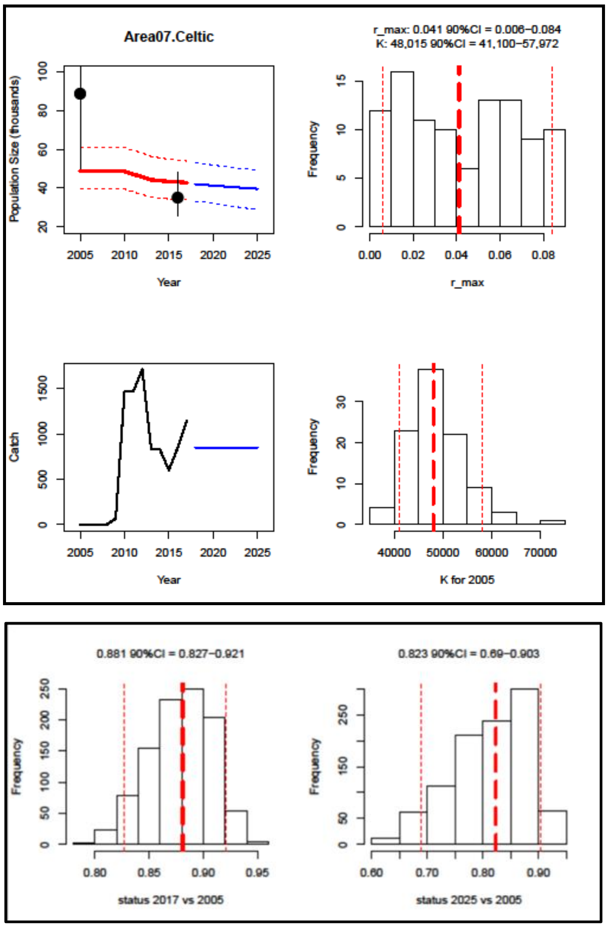

Figure 12: Assessment of the harbour porpoise population in the Celtic & Irish Seas assessment area using a population dynamic model (Zerbini et al. 2011). Upper left panel: Estimated population abundance in the given period. Upper right panel: Estimated median r_{max} (bolded hatched line) given with a 90% credible interval. Middle left panel: Estimated annual by-catch over the given period (used as model input). Middle right panel: Estimated median K_{2005} given with a 90% credible interval. Lower left panel: Estimated abundance median current depletion level (2017 abundance relative to K_{2005}) with a 90% credible interval. Lower right panel: Predicted median future depletion level (2025 predicted abundance relative to K_{2005}) with 90% credible interval.

West Scotland/Ireland

The model estimated that the population of harbour porpoise in the Western Scotland & Western Ireland assessment area is declining slowly since 2009 (Figure 11). The current level of depletion (N_{2017}/K_{2005}) is estimated to be 0.89 (90% CI: 0.85-0.93) declining slightly to a depletion in 2025 (N_{2025}/K_{2005}) of 0.86 (90% CI: 0.74-0.92). Carrying capacity (K) in 2005 was estimated to be around 48,000 animals. The posterior distribution for the maximum rate of increase (r_{max}) is similar to the uniform prior distribution for this parameter, resulting in a wide and uninformative 95% Credible Interval.

Celtic & Irish Seas

The model estimated that the population of harbour porpoise in the Celtic & Irish Seas assessment area is declining slowly since 2009 (Figure 12). The current level of depletion (N_{2017}/K_{2005}) is estimated to be 0.88 (90% CI: 0.83-0.92) declining slightly to a depletion in 2025 (N_{2025}/K_{2005}) of 0.82 (90% CI: 0.69-0.90). Carrying capacity (K) in 2005 was estimated to be around 49,000 animals. The posterior distribution for the maximum rate of increase (r_{max}) is similar to the uniform prior distribution for this parameter, resulting in a wide and uninformative 95% Credible Interval.

The assessments conducted for the West Scotland/Ireland and the Celtic & Irish Seas areas are a step forward but cannot be taken as realistic assessments of the impact of by-catch on harbour porpoises in these areas and the results should not be used at this time. The main problem is that by-catch that occurred prior to the available time series (2009-2017) of days at sea (e.g. Tregenza et al., 1997 for the Celtic Sea in 1993) has not been included in the assessments. The levels of current depletion estimated by the assessments are relative to 2005 and they thus provide information only on the most recent 10-15 years. The expected effect of including earlier by-catch in the assessments is twofold. First, depletion (current abundance as a proportion of historical abundance) would be lower. Second, because current abundance would be lower, the current rate of change would be more positive because of density dependent effects. Assessments for these areas will not provide useful information until by-catch from earlier years can be incorporated.

Discussion

Since this assessment was not prepared in sufficient time to be presented at the workshop, formally there was no discussion of the results and conclusions amongst the group.

Recommendations

It would be informative to run the assessments using the by-catch time series without the "uninformative multiplier" to illustrate the effect of using this.

However, it is more important to model the effect of by-catch in earlier years prior to 2009. Attempts should be made to derive time series of by-catch as far back in time as possible using fishing effort information and estimates of by-catch rate from earlier years. As part of this, problems identified with the days at sea data in the ICES Regional database should be investigated and resolved.

h. North Sea

The North Sea assessment area is defined as ICES divisions IVa, b, c, VIId and the northern part of IIIa (as indicated in Figure 2).

Data Inputs & Limitations

Abundance estimates used in the assessment were from the SCANS, SCANS-II and SCANS-III surveys in summer 1994, 2005 and 2016, as further described in the Area Status Report available in Annex 8.

Estimates of by-catch for 1966-2017 were generated as described in the Area Status Report available in Annex 8.

The estimates of abundance used were from systematically designed surveys using the same methodology and are believed to be unbiased. The robustness of the estimates of by-catch, however, is questionable.

The method of incorporating uncertainty in by-catch rate is believed to be appropriate. However, the estimates of by-catch rate are likely to be subject to both positive and negative biases and the use of "low", "medium" and "high" values for most of the time series (1966-2008) and of the "uninformed multiplier" for recent years (2009-2017) is very crude, and these may not be appropriate ways to try to capture the potential biases.

There are also limitations with the days at sea data used to create time series of annual by-catch. The information generated for non-English/Danish days at sea using relative values calculated from the STECF database (https://stecf.jrc.ec.europa.eu/dd/effort) is undesirable because of apparent inconsistencies within this database.

Problems also exist with the days at sea data provided by ICES from its Regional database, raising questions about the usefulness of these data for creating time series of by-catch estimates. In particular, the days at sea data provided by Germany were inconsistent and were not used in the assessment.

Results & Conclusions

The model estimated that the population of harbour porpoise in the North Sea has been stable (increasing very slowly) since around 2005 (Figure 13), whilst subject to an average annual by-catch of around 4,500 animals (range 2,500-6,700) during this period. The current level of depletion (N_{2017}/K_{1966}) was estimated to be 0.87 (90% Credible Interval: 0.67-0.93) increasing very slightly to a depletion in 2025 (N_{2025}/K_{1966}) of 0.89 (90% CI: 0.67-0.94). Carrying capacity (K) in 1966 was estimated to be around 400,000 animals. The model estimated r_{max} to be 0.061 (90% CI: 0.023-0.088). The posterior distribution for r_{max} shows some improvement on the uniform prior distribution for this parameter but still with rather a wide spread resulting in the wide 95% Credible Interval.

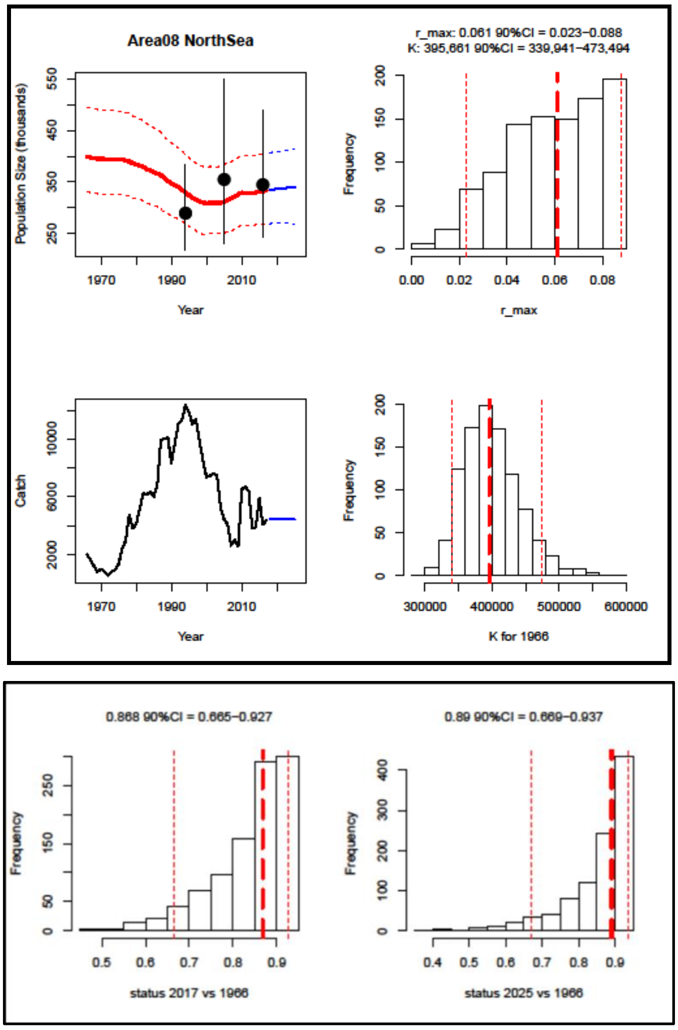

Figure 13: Assessment of the harbour porpoise population in the North Sea assessment using a population dynamic model (Zerbini et al. 2011). Upper left panel: Estimated population abundance in the given period. Upper right panel: Estimated median r_{max} (bolded hatched line) given with a 90% credible interval. Middle left panel: Estimated annual by-catch over the given period (used as model input). Middle right panel: Estimated median K_{1966} given with a 90% credible interval. Lower left panel: Estimated abundance median current depletion level (2017 abundance relative to K_{1966}) with a 90% credible interval. Lower right panel: Predicted median future depletion level (2025 predicted abundance relative to K_{1966}) with 90% credible interval.

The assessment attempted to account for the impact of by-catch from around the time that gillnetting is believed to have developed in the area. There may have been some by-catch before that time, but it is likely that levels were low relative to the peak period of by-catch in the late-1980s and 1990s. The assessment therefore likely provides a reasonable description of the impact of by-catch on harbour porpoise in the North Sea. The assessment model indicates that the population seems able to sustain a by-catch of around 4,500 animals a year, which is around 1.1% of the estimated carrying capacity and around 1.3% of current abundance, while maintaining the population level at around 85-90% of carrying capacity. The precautionary approach to use high values for by-catch rate should ensure that the assessment has not underestimated the impact of by-catch on harbour porpoises in the North Sea but the robustness of the assessment also depends on how well the derived days at sea reflect reality.

Discussion

Since this assessment was not prepared in sufficient time to be presented at the workshop, formally there was no discussion of the results and conclusions amongst the expert group.

Recommendations

It would be informative to run the assessments using the by-catch time series based on a by-catch rate other than the high value used for 1966-2008 and without the "uninformative multiplier" used for 2009-2017 to illustrate the effect of using values closer to those observed.

However, it is more important to improve the time series of days at sea both by resolving the problems identified with the days at sea data in the ICES Regional database and by extending those data to years prior to 2009 for all fleets to compare with the time series created using English/Danish data and extrapolated to other fleets using the STECF data. Checking that the ICES WGBYC data on by-catch rate includes all available information would also be useful.

i. Belt Sea (and adjacent waters)

Data Inputs & Limitations

The population dynamic model input data from Belt Sea assessment area (which covers the Kattegat, Belt Sea, western Baltic and the Sound) included:

(a) Four abundance estimates and associated CVs from 1994, 2005, 2012 and 2016 (derived from ship and aerial line transect surveys) were included. Since the geographical areas of each of the four surveys were not completely comparable, the absolute abundance estimates of the assessment area were adjusted to comparable survey area size by calculating density of the original survey strata and multiplying this by the the area size (40,707km^2)

(b) By-catch rates were calculated from by-catch numbers reported in gillnet fisheries to ICES WGBYC in ICES areas 21, 22 and 23 from 2007 until 2016. Monitoring was carried out mainly by remote electronic monitoring but also by onboard observers. A 95% confidence interval (CI) was calculated by assuming a Binomial distribution (source excel code: John Pezzullo–Kissimmee Florida USA, (Clopper & Pearson, 1934)), resulting in an upper limit of estimated number of by-catches per day at sea.

(c) Estimates of total by-catch were calculated for 2009-2017 by multiplying gillnet a by-catch rate estimate from data from the Belt Sea area based on data from 2007-2016 to time series of days at sea per year and ICES areas within the assessment areas collated from the ICES Regional Database. From 1994-2009 the annual by-catch was calculated as an average over the years from 2009-2011. From 2018-2025 the annual by-catch was assumed to equal the 2017 estimate of 758 porpoises. These estimates are subject to a number of biases (see Annex 9, section 3) as well as what appears to be errors in the format of reported effort, which for instance resulted in the exclusion of all German effort data.

The quality of the abundance estimates was considered high, because all estimates were based on appropriately designed and analyzed surveys and all were corrected for perception bias. However, future estimates should be based on model-based estimates instead of design-based estimates, which would allow for correct estimates within the management unit and not the current "rough and dirty" method (i.e. extrapolating total abundance from average densities of survey areas that do not exactly correspond with the geographical range of the management unit).

The quality of the by-catch estimates is considered relatively low because of the biases and uncertainties noted in Annex 9, section 3.

Results & Conclusions

The population dynamic model indicated that the population size of the Belt Seas harbour porpoise assessment unit is currently increasing slowly.

The current level of depletion (N_{2016}/K_{1994}) is estimated to be 0.78 (90% PI 0.61 – 0.86) (Figure 14). The predicted level of depletion in 2025 (N_{2025}/K_{1994}) is estimated to be 0.81 (90% PI 0.56 – 0.88). Carrying capacity (K) in

1994 was estimated to be 40,503 (90% PI 33,140 – 49,263). The estimated r_{max} value (0.067; 90% PI 0.025 – 0.088) is relatively high.

As another measure of status, Potential Biological Removal (PBR) was calculated as 330 and 661 using the most recent absolute abundance estimate (42,324; CV=0.30), r_{max} = 0.04 and either F_r = 0.5 and F_r = 1.0, respectively. Both values of PBR are less than the average annual by-catch estimate for years 2009 - 2017.

The workshop concluded that the population dynamic assessment model methodology was appropriate for the data available, although better by-catch estimates are essential for improved accuracy. Based on the model outputs, the declining by-catch estimates, and the relatively large abundance estimates in 2012 and 2016, the workshop concluded that there is a low to medium level of concern for this assessment unit. The "medium level of concern" mainly derives from the uncertainty associated with the by-catch estimates and the fact that the estimated annual by-catch is above the calculated PBR.

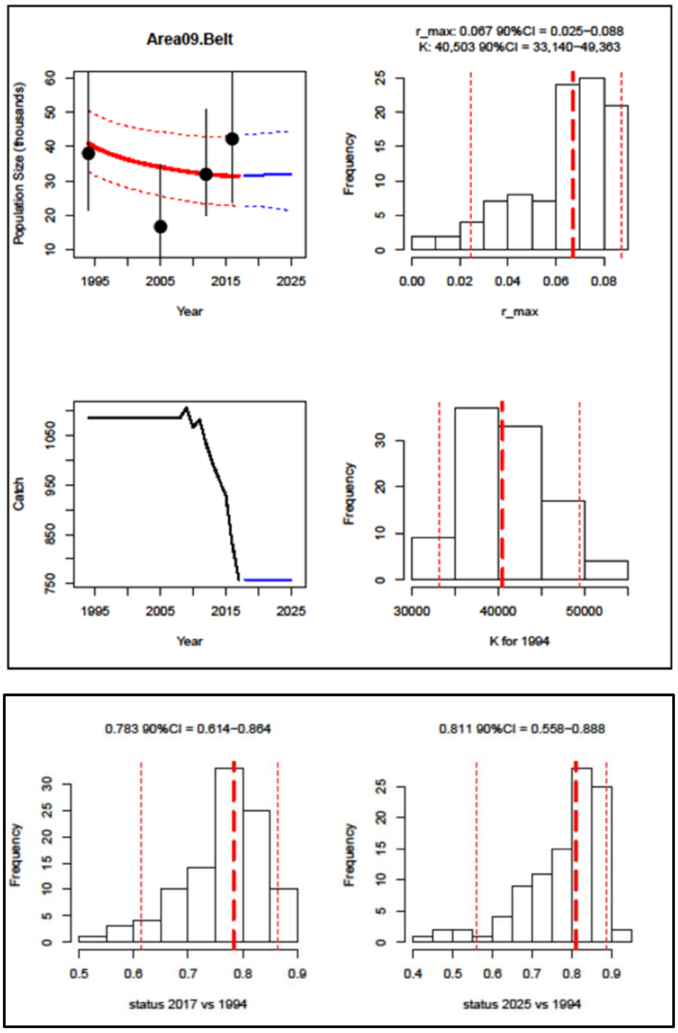

Figure 14: Assessment of the harbour porpoise population in the Belt Sea assessment areausing a population dynamic model (Zerbini et al. 2011). Upper left panel: Estimated population abundance in the given period. Upper right panel: Estimated median r_{max} (bolded hatched line) given with a 90% credible interval. Middle left panel: Estimated annual by-catch over the given period (used as model input). Middle right panel: Estimated median K_{1994} given with a 90% credible interval. Lower left panel: Estimated abundance median current depletion level (2017 abundance relative to K_{1994}) with a 90% credible interval. Lower right panel: Predicted median future depletion level (2025 predicted abundance relative to K_{1994}) with 90% credible interval.

Discussion

It was noted that the r_{max} in this case is 0.06, which is higher than normal and means that the model is trying to reach the abundance points given in model. Some of the SCANS surveys have, however, also indicated high calf rates and anecdotal evidence from fishermen reports also suggests that the presence of porpoises in the area has increased. Questions were asked about whether this r_{max} made sense given how close the population is to the Baltic and the high level of pollutants that have been documented there. It was noted that the r_{max} used in the PBR calculations was actually lower than that coming out of the population model. The level of concern for the Belt Sea population was discussed as potentially dependent on to what extent this population serves as the only source for repopulating the Baltic– i.e. if it is, then concern may need to be higher.

Although assumptions and biases in the data were recognised, the model outputs did seem to fit with what appears to be happening with this population. Tagging efforts have indicated a lot of movement out of the area but it seems that young animals leave and then return when they are approaching maturity, while adults tend to stay. Indications are that the population as a whole is stable, and therefore it may be important to just keep monitoring and collecting data that can be used in future assessments. It may also be relevant to continue monitoring the predator pressure from grey seals. This is because grey seals have been shown to be preying on harbour poropoises in other regions (ICES, 2017) and grey seal population increases in this area could pose an additional threat to the impacts already being experienced from by-catch.

A question was asked about why by-catch had dropped so dramatically in this area and although it was noted that this was an extrapolation, it was also emphasised that there is less commercial fishing in this area than previously. It was, however, important to note that there is a very high number of small vessels and part-time fisheries using set nets operating in the area and that by-catch from these vessels are not included in the calculations based on reported fishing effort.

Recommendations

Continuing regular abundance surveys in the area is important and developing better by-catch estimates with less associated uncertainty is essential for the ability to deliver accurate assessments.

Collecting data on predator pressure and impact from grey seals that have been returning to the area in large numbers from the Baltic Sea Proper over the last decade will also be valuable.

j. Baltic Proper

Data Inputs & Limitations

For the Baltic Proper assessment unit, one absolute abundance estimate was available from 2012. The by-catch data used in the model was derived from a by-catch rate (upper limit of the 95% confidence interval) assessed for the Belt Sea population, adjusted for the lower density of harbour porpoises in the Baltic Proper, and multiplied with reported gillnet fishing effort within ICES sub-areas 25-29 during the years 2009-2017. Data on minimum by-catch was also compiled from records of strandings and voluntary by-catch reports for the years from 1984 to 2012. By-caught numbers derived from strandings are most likely an underestimation of the total number.

The population abundance estimate is very small and has a quite large CV (N = 497, CV = 0.42), which makes the estimated K uncertain. The by-catch rate for the Belt Sea population was mainly obtained by remote electronic monitoring systems and is reliable, however, it is unknown how applicable the extrapolation from the Belt Sea to the Baltic Sea is. The harbour porpoise density estimates for both the Belt and Baltic Seas are robust but with quite high CVs. Regarding the fishing effort, there is no consensus among Members States on how to report the data, meaning that effort data reported is inconsistent. When considered altogether, this results in a large overall uncertainty for the estimated by-catch numbers.

Results & Conclusions

The assessment shows a small decrease in abundance from 2009 to 2017 (9%) (Figure 15). Assuming a constant by-catch rate since 2017, the projection to 2025 also shows a small but continued decline (12% since 2009). In the PBR analysis, a recovery factor of 0.1 should be used as the population is listed as critically endangered (CR). This results in a mortality limit of 0.1 animals per year. Both the estimated by-catch number for 2017 (7 animals) and the minimum by-catch numbers for the years 2000-2012 (average ca 3 animals per year) exceed this level. If a recovery factor of 0.5 would be used instead, the mortality limit would be 3.5 animals. The estimated by-catch number for 2017 still exceeds this limit, and the approximate average annual minimum by-catch number is on this limit.

In conclusion, the Baltic Sea harbour porpoise population is severely depleted, its abundance is estimated to be declining, and the population is not able to recover given the rate at which by-catch is currently occuring.

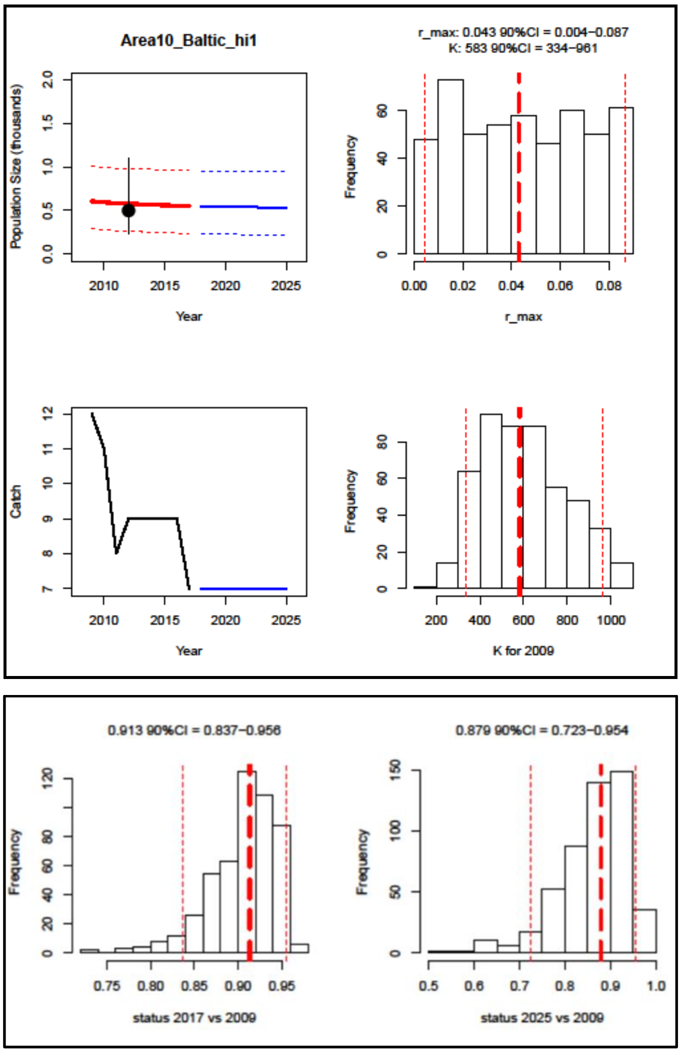

Figure 15: Assessment of the harbour porpoise population in the Baltic Proper assessment area using a population dynamic model (Zerbini et al. 2011). Upper left panel: Estimated population abundance in the given period. Upper right panel: Estimated median r_{max} (bolded hatched line) given with a 90% credible interval. Middle left panel: Estimated annual by-catch over the given period (used as model input). Middle right panel: Estimated median K_{2009} given with a 90% credible interval. Lower left panel: Estimated abundance median current depletion level (2017 abundance relative to K_{2009}) with a 90% credible interval. Lower right panel: Predicted median future depletion level (2025 predicted abundance relative to K_{2009}) with 90% credible interval.

Discussion

Given the high pollutant levels in the Baltic, the r_{max} may actually be lower than the 0.04 assumed and used.

It was noted that the trend is a decreasing population, but this is not a sharp decrese so if abundance was on the higher end or by-catch was low then it may be more stable. Since the lowest by-catch figure was used in the model though, a slight decrease is still being indicated. This suggests that it may be particularly important in this area to try and obtain a good abundance estimate. Questions were also raised about the potential for by-catch to be distributed seasonally – e.g. if porpoises are leaving the Baltic Proper in the winter then by-catch may be occurring further west in places such as the Western Baltic and Belt Sea. There is a desire in Germany to have the by-caught animals in that area be genetically analysed to assess which population they come from, which may help address this question of seasonally distributed by-catch of the Baltic population.

The question was asked as to whether there was the possibility of the population increasing via immigration taking place from the Belt Sea population. There was some discussion about whether the low density in the Baltic may encourage immigration from the Belt Sea, however this was recognised as speculation. It was noted that the two populations do not seem to interbreed very regularly. Although the loss of the Baltic Proper population may lead to individuals from the Belt Sea repopulating the area, this would likely happen over an evolutionary timescale and not within a few years. It would also mean that the distinctive differences between the two populations would have disappeared and only a Belt Sea population would remain, even if it inhabited the waters of the Baltic.

Recommendations
To improve the assessment, it is most important to reduce the CV of the abundance estimate, and to obtain additional abundance estimates. This is accompanied by a need to have improved data on fishing effort and by-catch rates.

k. Iberian Peninsula

Data Inputs & Limitations
The Iberian porpoise population appears to number around 2900 animals, with estimates from SCANS II (2005) and SCANS III (2016) being almost identical at 2880 (CV=0.72) and 2900 (CV=0.32) respectively. The highest estimate from national surveys is over 4200 but this is within the 95% CI of the SCANS estimates. It should be noted that confidence intervals (CIs) on these esitmates are wide and do not preclude upward or downward trends. The animals may also extend offshore in Portuguese waters beyond the SCANS survey area and also occur within the Galician rias (which were not surveyed by SCANS) and this would mean an underestimation of population size.

By-catch estimates are available for Spain and Portugal, but time series are short (slightly over 1 year of dedicated observer coverage for Spain) and coverage was both low and variable. Over the period 2010-2016, 13 porpoise by-catches were reported (to ICES WGBYC) from Spanish gillnets and Portuguese polyvalent and purse seine fisheries. A further 5 by-catches were recorded from beach seining in Portugal. The extrapolated average annual total by-catch is 1374 porpoises, reduced to 1285 if the most extreme extrapolation (from 1 porpoise caught in trammel nets in 2012 to 896 by-catches in that gear in that year) is removed from consideration. Most of the Spanish effort was in the Bay of Biscay rather than in the Iberian Peninsula *per se* and, excluding these data, annual by-catch reduced to 911-1000 animals. Aside from beach seines, the (extremely numerous) <15 m boats are probably not represented in the data. It should be noted that the quality of the available data on fishing effort is questionable.

The estimated annual total mortality rate based on age data is high (18%) and the estimated 54% pregnancy rate would likely lead to a markedly lower birth rate. However, mortality rate may be over-estimated and the pregnancy rate is based on a very small sample. Data on the age of stranded animals suggests that the mortality rate in 2010 had declined slightly since the mid-2000s and was similar to the value in the early 1990s.

Results & Conclusions
Due to the incompatibility of population size and by-catch data, the assessment was run using population size data only. Using a Bayesian logistic population growth model and based on the best estimates of population size, and applying a recovery factor of 0.5, annual PBR is estimated to be 25 animals.

The annual number of *known* by-catches (i.e. reported by-catch and diagnosed by-catch in strandings) does not exceed the estimated Potential Biological Removal (PBR) however fishery by-catch is almost certainly unsustainably higher than 25 animals. The best estimate of annual by-catch rate based on extrapolation is very high relative to the population size. Thus, taking the data at face value, between one third and one half of the best population estimate is being removed by fisheries annually.

Genetic data also indicates that the population may be declining. Genetic (Mt DNA) data indicate a loss of genetic diversity (as well as outward movement of animals into the Bay of Biscay and Celtic Sea) and, although the research is ongoing, the preliminary results support the idea of a declining population. Over the last 10 years the genetic diversity of this population appears to have halved, despite a larger sampling effort. One explanation for this is a significant decrease in the population.

The lack of quality data in this area means that it is difficult to make a firm determination of the status of the Iberian porpoise since the available indicators give contradictory signals.

Discussion
When the assessment model is run using the current estimates, the population runs into extinction. A question was therefore asked as to whether it was appropriate to include the trajectory given by the model or not. Given that there was little confidence in the data being fed into the model, it was decided that it would not be appropriate to include this method as part of the assessment. A precautionary approach would be to note the red flags that are present though. For example, noting that we suspect that the by-catch exceeds the calculated PBR and that the analysis of genetic diversity supports the indication that the population is declining.

The abundance estimates from SCANS for this area have quite large CIs so it is difficult to say what is happening based on this information. The wide range meant that there was the possibility for all trends (increasing, decreasing and stable) to come out as a result of the modelling effort. This made it clear that there was a need to minimise the uncertainty in the abundance estimate. It was however noted that it is always hard to achieve precision on this for a small population and therefore this may not be a high priority recommendation. A better focus may be to improve the by-catch numbers. The life history data could also be improved, although this too would take time for this small population. It was emphasised as particularly important to identify what data we have confidence in (e.g. abundance estimates and genetic analyses) and where we have less confidence (e.g. in by-catch and life history data).

It was noted that there will be an IUCN global assessment in the next couple of months and it may also be possible to use the IUCN approach, which incorporates an estimate of the number of females, to see what this approach may indicate about the status of the stock.

Recommendations

A robust measure of fishery by-catch in this area is essential.

Annual abundance surveys along the Iberian coast would be useful to elucidate population trends and Portuguese offshore waters could be included in future SCANS surveys to try and get broader coverage. More regular surveys in Iberian Peninsula waters in between SCANS surveys would also be valuable.

Comprehensive, coordinated and adequately funded strandings monitoring would permit more robust estimates of life history parameters.

It is likely that a lot of the Galician strandings are Portuguese animals due to the flow and strong currents in this area. This means that it may also be useful to model where the strandings are coming from.

Genetic analysis indicates emigration from this population, but little immigration – so it is a source and not a sink system (this is knowledge based on strandings and by-catch samples). Historical samples could also be analysed to look for trends over a longer period of time.

l. <u>Northwest Africa</u>

Data Inputs & Limitations

There is limited data available on the Northwest African harbour porpoise population. There are no abundance estimates and no reliable records of by-catch levels. Most of the data on this population comes from stranded animals, some of which show evidence of being by-caught. Stranding distribution ranges from the north of Morocco to the southern border of Senegal.

In recent years up to 150 stranded harbour porpoises have been found on the Mauritanian coast during dedicated stranding surveys, most of them exhibiting by-caught marks. Genetic studies have shown strong differences from harbour porpoises around France, and skulls and body size indicate that porpoises from the the Northwest Africa area are as large as the Iberian porpoises. Based on genetic data, the North Western Africa porpoises seem to form a distinct endemic population that is closely related to the Iberian population. Both rely on an upwelling ecosystem and are assigned to a subspecies - P. phocoena meridionalis, which is distinct from the subspecies found north to the Bay of Biscay (P. p. phocoena).

Preliminary evidence to date suggests that fishery interactions may pose a substantial threat to the population. The fleet targeting small pelagic species is rapidly increasing due to the chartering of vessels on a bareboat basis by private Mauritanian operators. However, overall this isolated population is data deficient with a lack of information on all other possible stressors (e.g. seismic activities, exploration and exploitation of oil and degassing in the high seas).

The data deficiency for this population meant that it was not possible to arrive at estimates of either abundance or by-catch. This meant that there was not data available to meaningfully run the population model and arrive at an assessment.

Results & Conclusions

The population of this assessment unit is isolated, and data on abundance, by-catch and other threats is lacking. As a result, the status of this population is uncertain and of concern.

Discussion

There have been some previous attempts to collect samples from this area during 2003-2008. However very few strandings were present and only very degraded carcases were available. This means that the current reports on numbers of strandings involves either an increase in effort or increased impacts on the population resulting in a higher level of stranded animals.

Previously armed conflicts in the area have made it difficult to work along the Mauritanian coast, however these is now a genetic study ongoing in France that is attempting to clarify the exchange taking place between porpoise populations from Iberia and Mauritania. As yet there is no established collaboration between the researchers performing this work and those present at the workshop. This collaboration should ideally be established. There has also been some work studying the ecology of harbour porpoise in this area by looking at stable isotopes and this work may also have relevant information for an assessment.

The level of fishing effort in this area was discussed and it was highlighted that large factory ships such as the Atlantic Dawn are not operating off the Mauritanian coast. There was some disagreement about whether fishing effort in this area had increased or whether fishing activity had always been high in this area.

Recommendations
To perform an assessment of the status of harbour porpoise in this area it is essential to obtain reliable estimates on both abundance and by-catch.

Genetic kinship analysis may be used as a less expensive alternative to surveys to arrive at abundance estimates.

Increased collaboration with Northwest African scientists and all those studying the population in this area is desirable and should be encouraged.

The genetic analysis of this population should be expanded to include more samples

Since the population in this area is small, the cumulative impact of all anthropogenic activities (including pollution) is important to consider and more research is recommended on this topic.

The existing samples should be analysed to assess the level of pollutants present in the population and whether these levels surpass the threshold of concern.

4. Conclusions & Recommendations

Population Structure
The workshop concluded that in addition to ongoing tagging and monitoring efforts, genetic analysis can be very helpful for determining population structure. An overview of the genetic analysis that has been done in the different areas to date is provided in Table 2. This overview reveals that there are several key knowledge gaps that are important to address. This includes: a) the lack of genetic information for porpoises in East Greenland, Faroe Islands and Northwest Africa, b) the lack of an integrative analysis across the entire North Atlantic with a common set of molecular markers (currently made challenging by the distribution of samples across several labs), and c) the lack of a time series analysis able to assess the dynamics of the population structure, the relative change in effective population size and in migration rates (based on microsatellites, mtDNA and SNPs).

To address these knowledge gaps and advance genetic analyses in a way that can put stock specific levels of diversity and divergence into perspective for providing sound advice to management bodies, the workshop ***recommends*** the development of an integrative approach that can provide a comprehensive assessment of genetic population structure with a unified data set. The geneticists present at the workshop held a meeting to determine the required elements of such an integrative approach and this development towards a new collaborative effort represents an important outcome of the workshop. The development of a unified data set and the use of this to advance an integrative and comprehensive assessment of genetic population structure requires the following actions:

- Current efforts to establish an informative SNP panel include samples from across the North Atlantic, the Baltic Sea, Iberian/Mauritanian waters and the Black Sea to make this marker set suitable for an integrative comparative analysis and to minimize ascertainment bias.
- Samples held at different laboratories be exchanged to arrive at more complete data sets. These data sets should include: a) Iberian Peninsula and Mauritania (including samples from around France, the British Isles, southern North Sea (Channel, Belgian and Dutch coasts)), and b) (northern) North Atlantic (including North and Baltic Sea).
- Efforts be made to obtain samples from as yet under/unstudied areas (most notably East Greenland, Faroe Islands and Mauritania, but also East Canada/US, West Greenland, and Norway). This should be done through existing collaborations as well as attempts to establish new collaborations with other relevant partners where necessary and appropriate.
- Established microsatellites and mtDNA be typed in additional specimens to complement existing data sets.

- Datasets for autosomal markers (microsatellites, SNPs) be used for inferences of close kin (parent-offspring, half sibs). These inferences can be used to create abundance estimates.
- Scientific results be disseminated in international peer-reviewed journals co-authored by the respective collaborators.

Advancing knowledge on population structure and the identification of assessment units will not only benefit from a comprehensive genetic analysis using a unified dataset. It would also be beneficial to develop a multidimensional approach that can combine and integrate different forms of data. Combining relevant approaches, such as ecological tracers (POPs, trace elements and stable isotopes), morphometrics, life-history characteristics, and population genetics would provide a more comprehensive picture of the multifarious dimensions of the ecology, stock structure and evolution of the populations of harbour porpoises in the North Atlantic. Since a better understanding of the ecological processes that may be influencing substructuring of populations would aid future assessment and conservation of the harbour porpoise, the workshop also ***recommends*** that work to develop a multidimensional approach capable of integrating information on ecology, stock structure and evolution be undertaken.

Assessment Units

Based on a combination of existing research on the distribution and movement of harbour porpoises, genetic analysis of the degree of isolation and interbreeding between different populations, and the areas defined for fisheries management, the workshop outlined a range of assessment units that could be reasonably used for harbour porpoises in the North Atlantic. These assessment areas or units are depicted on the revised map, Figure 2, presented in section 2 of this report. This map of proposed assessment units for harbour porpoise in the North Atlantic is considered a key outcome of the workshop.

Although the map currently proposes a division of areas that are appropriate for assessment purposes, it may also be used to help structure ongoing investigations into stock structure and the biological distinctions separating different populations and subspecies. In this way, the proposed division of the North Atlantic into these assessment units can be used not only for future assessments but also to help determine important areas for further research. This includes, for example, directing research efforts into the shaded dual colour zones on the map, which indicate those areas where drawing a definite border for the assessment was particularly challenging due to either a mixing of populations, a lack of data, or uncertainty that requires further work for clarification.

The workshop therefore ***recommends*** that the map of proposed assessment units be taken up and further developed by those with responsibility for the assessment of harbour porpoise in the North Atlantic. It can also be used to help direct research efforts towards areas of relevance for assessment and management of human impacts.

Abundance Estimates

Abundance estimates and trends are a key parameter in any population assessment and reliable estimates are required for sound scientific management of stocks. In several of the assessment areas, abundance estimates were absent or too few to reliably indicate trends. The workshop therefore ***recommends*** that work to generate reliable abundance estimates for harbour porpoises in the North Atlantic be continued. The workshop noted that robust design-based analyses of line transect survey data have been routinely used for generating abundance estimates of cetaceans and are widely accepted as providing useful time series estimates. It was, however, also noted that these estimates may be supported through ongoing investigation and use of multiple methods. As was exemplified in the case of Iceland, confidence in abundance estimates may be increased when there is good agreement between estimates from sighting survey data and genetic kinship analyses. The workshop therefore noted the potential value in having data from both methods available, although it was also important to note that genetic close-kin methods are still in their infancy and can be significantly affected by small sample sizes. The workshop did, however, suggest that where sighting surveys may be prohibitively expensive, kinship analysis could be usefully explored as an alternate way to generate abundance estimates and that this would certainly be preferable to having no estimate available at all. Two examples of areas where this may be relevant include the Iberian Peninsula and Northwest Africa.

By-catch Estimates

Given the challenges that exist for accessing reliable by-catch data and estimates, and the importance of this information for generating scientifically sound assessments, the workshop ***recommends*** that it is imperative to: a) construct more reliable time series of by-catch data for the different fisheries in the different areas, b) modify the database available on fishing effort within ICES (RDB) in such a way that the data is consistent and reliable, c) include by-catch data from small vessels in reporting, and d) conduct more reporting of by-catch by different types of gear.

The workshop also noted that by-catch tends to affect some age classes more than others (e.g. young animals appear to be caught more often than adults), although it is not yet clear whether this is connected to the age structure of the population or not. This implies that the by-catch data is potentially age (or sex) biased, which may have a significant impact on population dynamics. The workshop notes that it is not clear exactly how this may affect the assessment and wants to clearly acknowledge that this aspect of by-catch was not accounted for. As a result, the workshop ***recommends*** that the age and sex of harbour porpoises taken as by-catch be documented in official records and that age and sex structured models be developed that can include such factors and data.

Already in 2011, in his report to the IWC Northridge (2011) concluded:

> *It is clear that these [by-catch in European waters] totals provide only a very patchy overview of total cetacean by-catches in Europe for several reasons: firstly, for several fisheries even where by-catches have been observed, data have been deemed too patchy or unrepresentative to provide a reliable by-catch estimate; secondly because only a minority of fisheries has been sampled, and thirdly because most of the attention is being devoted to over 15m vessels that form a minority of the fleet, for gillnets at least. It is also worth noting that several member states either do not currently have by-catch monitoring schemes at all (i.e. are ignoring the [EU] regulation), or include protected species by-catch monitoring under other monitoring activities (fish discard or biology schemes) which may compromise their efficiency.*

The workshop revealed that very little has changed since 2011 regarding the availability of reliable by-catch estimates (especially in the North Sea and adjacent waters) and that the situation remains the same except for a select number of fisheres and some areas. Since it is not realistic to monitor the by-catch of all fisheries, by-catch rate estimates are based on sub-samples and extrapolating this to entire fisheries requires reliable fishing effort data. However, at present there is no reliable and complete fishing effort data available for the North Atlantic; for example, both the ICES and EU databases are unreliable datasets. This is because the data collated is incomplete, does not include small vessels, is reported in wrong units by some countries, or totally unreported, as highlighted in the descriptions of the limitations of the input data for the assessments provided.

Clearly, a sound approach to conservation urgently requires action to improve this situation for both estimating by-catch rate and reporting reliable effort data for all fisheries. This includes implementing a system able to provide reliable estimates of effort in recreational fisheries and therefore their likely impact.

Threats to Harbour Porpoise Populations
Noise Disturbance

Given the large uncertainties in information about the impact of different noise sources, together with similar uncertainties in knowledge on distribution, abundance and status of the different porpoise subpopulations, it is impossible to conduct any form of quantitative comparison of the different sources of disturbance and their impact. Despite this, a qualitative assessment of the risk of impact has been attempted through this workshop and is available as Table 3 of this report. The assessment consists of three separate parts: *Prevalence* of noise sources in the different sub-regions, *Exposure* of porpoises to the noise sources and *Risk of impact*. A detailed description of each of these factors and how they were integrated to provide an assessment of acoustic disturbance on harbour porpoises in the North Atlantic is provided in Appendix 1 of this report. The workshop recommends that such an integrative approach to understanding and representing the risk of noise disturbance to harbour porpoise populations in the North Atlantic be further developed and used to inform population assessments and management decisions.

Substantial monitoring and reporting of activities related to noise disturbance are currently required as part of the implementation of the European Union's Marine Strategy Framework Directive. Current efforts are, however, limited to loud impulsive sounds and ship noise. The workshop ***recommends*** that efforts are made to ensure that data entered into the monitoring database are as complete as possible (with military sonar an issue of particular significance) and with a sufficient level of detail to allow for subsequent meaningful use of the data. The coverage of noise sources included in the monitoring should be increased, in particular to include smaller vessels and the ubiquitous use of echosounders. There is also a need to ensure that monitoring programmes quantify low-frequency ship noise in a way that is meaningful to high-frequency specialists, such as the harbour porpoise. More specifically this means that monitoring effort should be extended above the currently implemented 63 Hz and 125 Hz frequency bands.

Other Anthropogenic Pressures

Potentially, a range of anthropogenic pressures have the capability to affect population dynamics of harbour porpoises in the North Atlantic. However, there is currently limited information available on the different pressures present in a form that can be incorporated into assessments performed for management purposes. The workshop therefore ***recommends*** that research continue, and the mapping of these pressures be improved.

As an effort in this direction, a threat matrix for harbour porpoises was created (see Table 4). This was created on the basis of the threat matrix covering a range of anthropogenic pressures developed by the ICES WGMME in 2015 (ICES, 2015). The threats/pressures listed in that matrix are those thought to have most relevance to marine mammals and have been extracted from the list of pressures (grouped by pressure themes) agreed by the Intersessional Correspondence Group on Biodiversity Assessment and Monitoring (OSPAR ICG-COBAM, 2012).

Threat levels are classified as high, medium or low (i.e. following a traffic light system):

High (red) = evidence or strong likelihood of negative population effects, mediated through effects on individual mortality, health and/or reproduction;

Medium (yellow) = evidence or strong likelihood of impact at individual level on survival, health or reproduction but effect at population level is not clear;

Low (green) = possible negative impact on individuals but evidence is weak and/or occurrences are infrequent.

During this workshop, the ICES threat matrix on anthropogenic pressures was updated for harbour porpoises in each of the different assessment areas by means of consolidated expert judgment. This updated threat matrix for harbour porpoises is available as Table 4 and gives an overview of different threats and their levels in the assessment areas considered.

Area Assessments

A summary of what the results of the assessments performed in this workshop indicate for the different assessment units is provided below. However, the limitations associated with the input data described for each assessment area (e.g. absence of by-catch time series data and trends in abundance) should be remembered and are repeated in the summaries below. Furthermore, the assumptions outlined in the section *Underlying Assumptions of the Selected Status Assessment Methodology* should be acknowledged.

US (Gulf of Maine & Bay of Fundy): The assessment in this area was based on a series of abundance estimates spanning 1992-2016 and annual by-catch estimates from 1990-2017. Based on the assessment performed, the number of harbour porpoises in this area is increasing slowly. Given the results of the assessment, the presence of time series data indicating declining by-catch estimates, and relatively large abundance estimates, there is a low level of concern for harbour porpoises within this area.

Eastern Canada: The results of the modelling conducted in this workshop indicate that the number of harbour porpoises in both the Newfoundland & Labrador and Gulf of St. Lawrence units may be experiencing a slow decline. The slow decline combined with the limited data available lead to the conclusion that this assessment area is of a low to medium level of concern. It should, however, be noted that the assessment relies on few abundance and by-catch estimates and thus must be interpreted with caution.

Greenland: A conclusion on the status of harbour porpoises in this assessment area is available in the comprehensive assessment performed by the NAMMCO harbour porpoise working group in Spring 2019 (see https://nammco.no/topics/hpwg_reports/#2019).

Iceland: This assessment was based on one abundance estimate from 2007 and two relative abundance estimates based on genetic close-kin analysis, together with by-catch estimates from two key fisheries (over 2013-2017) with extrapolation back to 1950 based on available fisheries data. The conclusion of the assessment is that harbour porpoises in the Icelandic assessment area seem to be recovering. The stock trajectory showed a steady decrease in the latter half of the 20^{th} century (reflecting the fishery effort data) but there has been a subsequent increase in abundance from around 2005. This leads to a conclusion that this assessment area is currently of a low level of concern.

Faroe Islands: There is too little information available in this area to perform a full assessment, with no reliable by-catch rate and only a single abundance estimate (2010). However, based on the calculated PBR of 36-73 porpoises and the assumed low levels of catch and by-catch, it is believed that current mortality rates are inside sustainable levels. This means that this assessment unit is currently of a low level of concern, however, the data deficiencies that prohibit a thorough assessment remain worrying and should be addressed.

Norwegian and Russian Coasts: There is only a single abundance estimate (2016) available and although by-catch estimates are available from 2006-2015, the by-catch rate is extrapolated from the Coastal Reference Fleet and total by-catch remains uncertain. According to the assessment performed based on this data, the number of harbour porpoises in this area appears to be declining and if the by-catch in the period 2016-2025 is equal to the average of the last three years of annual estimates, this decline will continue. This assessment, combined with data limitations and the lack of trend in abundance, means that the status of the area is deemed to be of a medium to high level of concern and measures to reduce by-catch are strongly encouraged.

North Sea: An abundance trend is available for this region, however by-catch data is incomplete and patchy. Results from the assessment indicate that the North Sea can sustain a by-catch of around 4,500 animals a year, while maintaining a population level at 85-90% of carrying capacity. The assessment also indicates that the maximum annual rate of increase may be around 6%. The precautionary approach of using values of by-catch rate at the high end of those believed feasible should help to ensure that the assessment has not underestimated the impact of by-catch on harbour porpoises in the North Sea. According to the present assessment, harbour porpoises in this area appear to be stable. This assessment area is therefore deemed to be of a low level of concern, however, anthropogenic threats and their possible impacts should be quantified.

West Scotland/Ireland and Celtic & Irish Seas: Despite robust abundance estimates in 2005 and 2016, by-catch estimates were only available since 2009 and it is known that substantial by-catch occurred prior to this time. The assessments conducted (indicating a slow decline within the Celtic & Irish Seas area) are a step forward but cannot be taken as realistic assessments of the impact of by-catch on harbour porpoises in these areas. On the basis of the lack of knowledge related to by-catch and indications of a slow decline (without sufficient data to confirm whether this is due to a possible redistribution of animals), this area is deemed to be of a medium level of concern.

Belt Sea (and adjacent waters): The assessment was based on four abundance estimates (generated between 1994 and 2016). By-catch rates were calculated based on the ICES database and reporting, however, significant errors, omissions and biases were identified in this data. The assessment performed indicates that the number of harbour porpoises in this area (covering the Kattegat, Belt Sea, western Baltic and Sound) is increasing slowly. Based on the model outputs, the declining by-catch estimates and the relatively large abundance estimates in 2012 and 2016, the conclusion is that there is a low to medium level of concern for this assessment unit. The medium level of concern primarily derives from the uncertainty associated with the by-catch estimates and the fact that the estimated annual by-catch is above the calculated PBR of 330-661 animals.

The Baltic Proper: There is a single unreliable abundance estimate available and although by-catch is regularly documented, the rate is unknown. Based on this data, the assessment in this area indicates that the population is severely depleted, abundance is estimated to be declining and the population is not able to recover given that by-catch continues to occur. The conclusion is therefore that there is a high level of concern for this assessment area.

Iberian Peninsula: Despite being a data poor area, fishery by-catch in this assessment unit is deemed to almost certainly be unsustainably high since a by-catch in excess of 25 animals per year is predicted to lead to a population decline. The decrease in genetic diversity also indicates that the number of harbour porpoises in this area may be declining. The significant lack of data in this assessment unit, combined with the indications of a declining population, mean that this area is a high level of concern.

Northwest Africa: The population of this assessment unit is isolated, and neither abundance, by-catch or other threats can be estimated. The absence of data, combined with the population’s isolation, makes this area a high level of concern and all efforts to improve the data available to perform a scientifically sound assessment are strongly encouraged.

All the participants at this international workshop on the status of harbour porpoises in the North Atlantic thank the organisers for the opportunity to meet, exchange information, collate knowledge, and perform status assessments. Many of the important knowledge gaps and areas requiring further research were identified during the workshop and new collaborative initiatives begun. Recognising an ongoing and urgent need for clear assessment units, complete datasets, reliable estimates and rigorous assessments, the participants saw the workshop and its outcomes not as definitive, but rather as an informative step in an ongoing process towards developing a comprehensive understanding and sound management of harbour porpoise populations in a changing North Atlantic.

Table 2: Overview of genetic analyses conducted on harbour porpoises in the different assessment units of the North Atlantic

Assessment Unit	Subspecies	Isolation status	Other factors	Type of genetic data	Geographic sampling	Update needed	Genetic sampling needed	Look for heterogeneity within pop	Temporal effect / seasonal effect (breeding period)
USA + SC	PPP	Population		MS+MTDNA	Good	YES	SNP (MTDNA+MS)	YES	YES
CA	PPP	Population	Different by-catch rate	MS+MTDNA	Medium	YES	SNP (MTDNA+MS)	YES	YES
				MS+MTDNA+SNPlim	Medium	YES	SNP (MTDNA+MS)	YES	YES
WGL	PPP?	Population		MS+MTDNA+SNPlim	Medium	OK	SNP (MTDNA+MS)	YES	YES
EGL	PPP?	?		–	Absent	YES	SNP (MTDNA+MS)	YES	YES
Iceland	PPP	Population		MS+MTDNA+SNPlim	Good	OK	SNP (MTDNA+MS)	YES	YES
Faroes	PPP	Population?		MS+MTDNA	Poor	YES	SNP (MTDNA+MS)	YES	YES
NNO	PPP	Population with potential IBD	Facies ecologic	MS+MTDNA	Good	YES	SNP (MTDNA+MS)	YES	YES
WI/NWS			Facies ecologic	MS+MTDNA	Poor/Medium	YES	SNP (MTDNA+MS)	YES	YES
NS/SK/K			Facies ecologic	MS+MTDNA+SNP	Good	OK	SNP (MTDNA+MS)	YES	YES
Belt Sea	PPP	Population	Facies ecologic	MS+MTDNA+SNP	Good	OK	SNP (MTDNA+MS)	YES	YES
Baltic Proper	PPP	Population	Facies ecologic	MS+MTDNA+SNP	Good	YES	SNP (MTDNA+MS)	YES	YES
MC/WC/BB	PPP+PPM	Population (AM)	Facies ecologic	MS+MTDNA	Good	YES	SNP (MTDNA+MS)	YES	YES
Iberian	PPM	Population	Facies ecologic	MS+MTDNA	Medium	YES	SNP (MTDNA+MS)	YES	YES
NWA	PPM	Population	Facies ecologic	MS+MTDNA	Poor	YES	SNP (MTDNA+MS)	YES	YES

Sub-species	PPP: *P. p. phocoena*. PPM: *P.p. meridionalis*. PPR: *P.p. relicta*. PPP?: In principle *P. p. phocoena*, but evidence may suggest the occurrence of a distinct subspecies
Isolation status	Population: Population or deme isolated enough to suggest some demographic independence possibly connected as a stepping-stone model under Isolation by Distance (IBD) or Admixture (AM)
	IBD: Isolation by distance indicating that local population are connected to the neighbouring population, but not to such level that would make them a random mating population
Genetic markers	MS: Microsatellites (informative on bi-parental population structure and dispersal)
	MTDNA: Mitochondrial data (informative on female genetic structure and dispersal)
	SNPlim: limited number of SNPs (~100)
	SNP: Large number of SNP (~1000's)
Geographic sampling	Are genetic inference on stock identity based on a suitable number of samples (≤ 15 (poor) > N (medium) > 40 (high))
Genetic sampling needed	SNP (MTDNA+MS) means that the next step is going to use a standardized SNP panel informative for all the sub-species, and that it might bedesirable for some application to add mirosatellites and mitochondrial data for comparative purposes with previous studies or time series.
UPDATE needed	An update may be needed if the samples analyzed are 15 year old (1990-2003). [OK or YES, this is needed]

Table 3: Risk of Impact from Noise Disturbance on Harbour Porpoises in Different Assessment Areas of the North Atlantic

		Eastern US	Eastern Canada	West Greenland	East Greenland	Iceland + Faroes	Norway + Russia	W. Scotland + N. Ireland	Celtic & Irish Sea	North Sea	Belt Sea	Baltic Proper	Iberian Peninsula	NW Africa
Risk of impact														
Vulnerability														
Pile driving														
Sonar														
Seismic surveys														
Explosions														
Seal scarers														
Ships														
Small boats														
Surveying														
Pingers														
Dredging, construction														
Pipelines														
Oil rigs														
Offshore renevables														

Low
Medium
High

Risk

Low
Medium
High

Table 4: Threat Matrix for Harbour Porpoise in the North Atlantic, developed on the basis of work from CES WGMME in 2015 (ICES, 2015);

** reflects Icelandic situation, # needs to be updated (no legislation in place; not protected)*

			Eastern US	Eastern Canada	Gulf SS	Greenland	East Greenland	Iceland & Faroe Islands	Norwegian Coast (south of 62°)	Norwegian & Russian Coasts	Scotland & Northern Ireland	Celtic & Irish Seas	North Sea	Belt Sea	Baltic Proper	Iberian Peninsula	Northwest Africa
POLLUTION & OTHER CHEMICAL CHANGES	Contaminants																
	Nutrient enrichment																
PHYSICAL DAMAGE	Habitat degradation																
OTHER PHYSICAL PRESSURES	Litter (incl. discarded fishing gear)										?	?	?	?	?	?	?
	Underwater noise changes		*A separate and more detailed assessment of noise is available in Table 3 & Appendix 1 of this report*														
	Barrier to species movement (offshore windfarm, wave or tidal device arrays)																
	Death or injury by collision	Death or injury by collision (with ships)															
		Death or injury by collision (with tidal devices)	does not occur	does not occur	does not occur	does not occur	does not occur	does not occur	does not occur	does not occur	?	?	?				
BIOLOGICAL PRESSURES	Introduction of microbial pathogens			?	?									?	?		
	Removal of target and non-target species (prey depletion) and/or decrease in prey quality																?
	Removal of non-target species (marine mammal by-catch)							*									
	Deliberate killing + hunting		does not occur	does not occur	does not occur			#	does not occur	does not occur	does not occur	does not occur	does not occur	does not occur	does not occur	does not occur	

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Assessment of Acoustic Disturbance on Harbour Porpoises in the North Atlantic

Given the large uncertainties in information about the impact of different noise sources, together with similar uncertainties in knowledge on distribution, abundance and status of the different porpoise sub-populations, it is impossible to conduct any form of quantitative comparison of the different sources of disturbance. Despite this, a qualitative assessment of the risk of impact is attempted in the following. The assessment consists of three separate parts: *Prevalence* of noise sources in the different sub-regions, *Exposure* of porpoises to the noise sources and *Risk of impact.*

Prevalence

The prevalence of the different activities are scored on a three-step scale: low (i.e. absent or occasional), medium and high. The three steps are assigned integer values of 0, 1 and 2, respectively.

Exposure

Exposure is the combination of the prevalence (P) of the sources and the estimated impact ranges. Impact distances (R) were scored on a three-step scale: Low (local, < 1 km), medium (< 10 km) and high (>10 km).

As for prevalence, steps are assigned integer values of 0, 1 and 2, respectively. The impact distances are listed in Table A1 Prevalence (P) and distance (D) are combined into the exposure index, E:

$$E = \frac{(D + P)}{2}$$

The exposure index can thus take values between 0 and 2. A value of 0 indicates either absence of the source, or low impact range, or both, whereas a value of 2 indicates high prevalence of the source and high impact range.

Risk of impact

The exposure index is a pressure indicator, i.e. the abundance and vulnerability of animals is not factored into the index. The exposure index informs about the magnitude of the *source* of disturbance, not the actual impact. The exposure index can be high in an area, but if there are no animals (for reasons unrelated to the noise), there cannot be any impact. The vulnerability (V) of the different populations were assessed on a three-step scale: low (favourable conservation status), medium (sensitive) and high (threatened). As above, the steps were assigned values of 0, 1 and 2, respectively. Vulnerability of the populations is given in A2.

The risk index (R) is then computed as

$$R = \frac{(E + 2\,V)}{3}$$

The vulnerability is thus factored in as twice as important as the exposure, which is a precautionary approach.

The resulting assessments, subdivided into combinations of areas and noise sources, are given in Table A2.

Table A1: Impact distances for the different noise sources (left) and vulnerability for populations (right). See text for more detailed explanation.

Activity	Distance
Pile driving	2
Sonar	2
Seismic surveys	2
Explosions	2
seal scarers	2
Ships	1
Small boats	1
Surveying	1
Pingers	0
Dredging, construction	0
Pipelines	0
Oil rigs	0
Offshore renevables	0

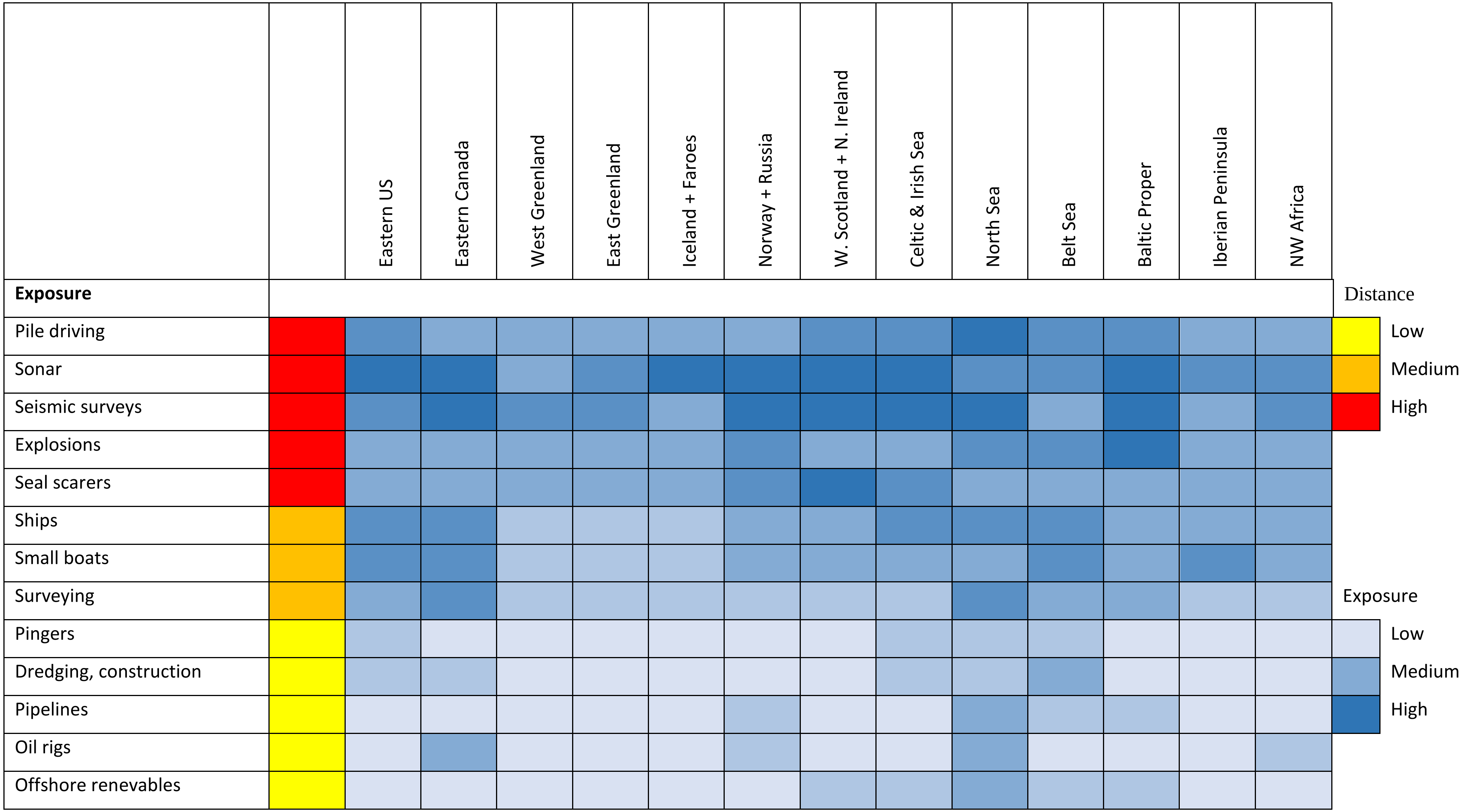
Population	**Vulnerability**
Eastern US	1
Eastern Canada	1
Greenland	0
Iceland + Faroes	0
Norway + Russia	1
W. Scotland + N. Ireland	1
Celtic & Irish Sea	1
North Sea	0
Belt Sea	0
Baltic Proper	2
Iberian Peninsula	2
NW Africa	2

Table A2: Assessment of acoustic disturbance on harbour porpoise populations in the North Atlantic.

		Eastern US	Eastern Canada	West Greenland	East Greenland	Iceland + Faroes	Norway + Russia	W. Scotland + N. Ireland	Celtic & Irish Sea	North Sea	Belt Sea	Baltic Proper	Iberian Peninsula	NW Africa
Prevalence of sources														
Pile driving		Medium	Low	Low	Low	Low	Low	Medium	Medium	High	Medium	Medium	Low	Low
Sonar		High	High	Low	Medium	High	High	High	High	Medium	Medium	High	Medium	Medium
Seismic surveys		Medium	High	Medium	Medium	Low	High	High	High	High	Low	High	Low	Medium
Explosions		Low	Low	Low	Low	Low	Medium	Low	Low	Medium	Medium	High	Low	Low
Seal scarers		Low	Low	Low	Low	Low	Medium	High	Medium	Low	Low	Low	Low	Low
Ships		High	High	Low	Low	Low	Medium	Medium	High	High	High	Medium	Medium	Medium
Small boats		High	High	Low	Low	Low	Medium	Medium	Medium	Medium	High	Medium	High	Medium
Surveying		Medium	High	Low	Low	Low	Low	Low	Low	High	Medium	Medium	Low	Low
Pingers		Medium	Low	Low	Low	Low	Low	Low	Medium	Medium	Medium	Low	Low	Low
Dredging, construction		Medium	Medium	Low	Low	Low	Low	Low	Medium	Medium	High	Low	Low	Low
Pipelines		Low	Low	Low	Low	Low	Medium	Low	Low	High	Medium	Medium	Low	Low
Oil rigs		Low	High	Low	Low	Low	Medium	Low	Low	High	Low	Low	Low	Medium
Offshore renewables		Low	Low	Low	Low	Low	Low	Medium	Medium	High	Medium	Medium	Low	Low

Prevalence

- Low
- Medium
- High


Eastern US
Eastern Canada
West Greenland
East Greenland
Iceland + Faroes
Norway + Russia
W. Scotland + N. Ireland
Celtic & Irish Sea
North Sea
Belt Sea
Baltic Proper
Iberian Peninsula
NW Africa
Exposure
Pile driving
Sonar
Seismic surveys
Explosions
Seal scarers
Ships
Small boats
Surveying
Pingers
Dredging, construction
Pipelines
Oil rigs
Offshore renevables
Distance
Low
Medium
High
Exposure
Low
Medium
High

		Eastern US	Eastern Canada	West Greenland	East Greenland	Iceland + Faroes	Norway + Russia	W. Scotland + N. Ireland	Celtic & Irish Sea	North Sea	Belt Sea	Baltic Proper	Iberian Peninsula	NW Africa
Risk of impact														
Vulnerability														
Pile driving														
Sonar														
Seismic surveys														
Explosions														
Seal scarers														
Ships														
Small boats														
Surveying														
Pingers														
Dredging, construct.														
Pipelines														
Oil rigs														
Offshore renewables														

Low
Medium
High

Risk

Low
Medium
High

JOINT IMR/NAMMCO INTERNATIONAL WORKSHOP ON THE STATUS OF HARBOUR PORPOISES IN THE NORTH ATLANTIC

LIST OF PARTICIPANTS

Martin Biuw
Institute of Marine Research
FRAM Centre
N-9296 Tromsø, Norway
(+47) 40729615
martin.biuw@hi.no

Arne Bjørge
Institute of Marine Research
University of Oslo,
0316 Oslo, Norway
(+47) 91314810
arne.bjoerge@hi.no

Marie-Anne Blanchet
UiT The Arctic University of Norway
PB 6050 Langnes
N-9037 Tromsø, Norway
(+47) 47951621
marie-anne.e.blanchet@uit.no

Julia Carlström
Swedish Museum of Natural History
Box 50007
SE-104 05 Stockholm, Sweden
(+46) 08-519 541 90
julia.carlstrom@nrm.se

Florence Caurant
Centre d'Etudes Biologiques de Chizé
UMR 7372 & Observatoire PELAGIS, UMS 3462
CNRS/Université de La Rochelle 5 allée de
l'Océan, 17000 La Rochelle, France
(+33) 5 46 50 76 29 / 76 69
florence.caurant@univ-lr.fr

Geneviève Desportes
NAMMCO
PO Box 6453
N-9294 Tromsø, Norway
(+47) 95021228
genevieve@nammco.no

Solveig Enoksen
NAMMCO
PO Box 6453
N-9294 Tromsø, Norway
(+47) 92245790
solveig.enoksen@nammco.no

Peter Evans
Sea Watch Foundation/Bangor University
Menai Bridge, Anglesey
LL59 5AB, UK
(+44) (0) 1407 832892
peter.evans@bangor.ac.uk

Michael Fontaine
MIVEGEC, Maladies Infectieuses Et Vecteurs :
Ecologie, Génétique, Evolution Et
Contrôle. UMR IRD 224-CNRS 5290-Université
de Montpellier. Montpellier, FRANCE
Co-affiliation: Groningen Institute for
Evolutionary Life Sciences, The Netherlands
(+31) 50 36 32146
m.c.fontaine@rug.nl

Anne Kirstine Frie
Institute of Marine Research
Fram Centre
N-9296 Tromsø, Norway
(+47) 47463976
anne.kirstine@hi.no

Anita Gilles (also OSPAR representative)
University of Veterinary Medicine Hannover,
Foundation
Institute for Terrestrial and Aquatic Wildlife
Research
Werftstr. 6 | 25761 Büsum, Germany
(+49) 511-8568177
anita.gilles@tiho-hannover.de

Thorvaldur Gunnlaugsson
Marine and Freshwater Research Institute
PO Box 1390
IS-121 Reykjavik, Iceland
(+354) 575 2000
thorvaldur.gunnlaugsson@hafogvatn.is

Philip Hammond
University of St Andrews
Bute Building
St Andrews, Fife
KY16 9TS, UK
(+44) 01334 463222
psh2@st-andrews.ac.uk

Sara Königson
Swedish University of Agricultural Sciences
Kustlaboratoriet Turstigatan 5
SE-453 30 Lysekil, Sweden
(+46) 0104784134
sara.konigson@slu.se

Finn Larsen
National Insititute for Aquatic Resources
Kemitorvet,
DK-2800 Kongens Lyngby, Denmark
(+45) 20672800
fl@aqua.dtu.dk

Jack Lawson
Fisheries and Oceans Canada
NAFC, 80 East White Hills Rd.
Newfoundland, A1C 5X1 Canada
(+1) 709 772-2285
jack.lawson@dfo-mpo.gc.ca

Nynne E. Lemming
Greenland Institute of Natural Resources
c/o Greenland Representation
DK-1401 Copenhagen K, Denmark
(+45) 3283 3825 / (+45) 2712 2717
nel@ghsdk.dk

Ulf Lindstrøm (Chair)
Institute of Marine Research
FRAM Centre
N-9296 Tromsø, Norway
(+47) 91515669
ulf.lindstroem@hi.no

Christina Lockyer
Age Dynamics
Innelvvegen 201
N-9107 Kvaløya, Norway
(+47) 995 85 451
agedynamics@mail.dk

Bjarni Mikkelsen
Museum of Natural History
V.U. Hammersheimbsgøta 13
FO-100 Tórshavn, Faroe Islands
(+298) 790576
bjarnim@savn.fo

André Moan
Institute of Marine Research
University of Oslo,
0316 Oslo, Norway
(+47) 41615636
andre.moan@hi.no

Sinéad Murphy
Galway-Mayo Institute of Technology
Dublin Road
Galway, Ireland
(+353) (0) 91 742086
sinead.murphy@gmit.ie

Debi Palka
NEFSC, NOAA Fisheries
166 Water Street
Woods Hole, MA 02543 USA
(+1) (508) 495 2387
debra.palka@noaa.gov

Graham Pierce
Departamento de Ecología y Recursos Marinos
Instituto de Investigaciones Marinas (CSIC)
Eduardo Cabello 6, 36208, Vigo, Spain
Tel: (+34) 986 860 137
e-mail: g.j.pierce@iim.csic.es

CESAM & Departamento de Biologia,
Universidade de Aveiro
3810-193 Aveiro, Portugal
e-mail: g.j.pierce@ua.pt

Oceanlab, University of Aberdeen,
Main Street, Newburgh, Aberdeenshire,
AB41 6AA, UK
e-mail: g.j.pierce@abdn.ac.uk

Kathrine A. Ryeng
Institute of Marine Research
Fram Centre
N-9296 Tromsø, Norway
(+47) 91315292
kathrine.ryeng@hi.no

Camille Saint-André
Institute of Marine Research
FRAM Centre
N-9296 Tromsø, Norway
(+47) 555238500
camille.saint-andre@hi.no

María Quintela Sánchez
Institute of Marine Research
Fram Centre
N-9296 Tromsø, Norway
(+47) 91868892
maria.quintela.sanchez@hi.no

Samuel Smith
NAMMCO
PO Box 6453
N-9294 Tromsø, Norway
(+47) 776 87371
sam@nammco.no

Signe Sveegaard
Aarhus University
Frederiksborgvej 399
DK-4000 Roskilde, Denmark
(+45) 28951664
ssv@bios.au.dk

Ralph Tiedemann
University of Potsdam
Karl-Liebknecth-Str. 24-25, Haus 26
D-14476 Potsdam, Germany
(+49) 331-977-5249/-5253
tiedeman@uni-potsdam.de

Jakob Tougaard
Aarhus University
Frederiksborgvej 399
DK-4000 Roskilde, Denmark
(+45) 40984585
jat@bios.au.dk

Gísli A. Víkingsson
Marine and Freshwater Research Institute
PO Box 1390
IS-121 Reykjavik, Iceland
(+354) 575 2000
gisli.vikingsson@hafogvatn.is

Fern Wickson
NAMMCO
PO Box 6453
N-9294 Tromsø, Norway
(+47) 776 87371
fern@nammco.no

Nils Øien
Institute of Marine Research
Bergen, Norway
(+47) 91002344
nils.oien@hi.no

Joint IMR/NAMMCO International Workshop on the Status of Harbour Porpoises in the North Atlantic

AGENDA

1. Welcome and Workshop information

1.1. Welcome Remarks
1.2. Introduction Round
1.3. Appointment of Rapporteur(s) and Guidelines
1.4. Review of documents
1.5. Plans for meeting report production and distribution, review of drafts, timetable etc.

2. Thematic Discussion

2.1. Stock identity
- 2.1.1. Keynote on Stock Identity
- 2.1.2. SNPs and close-kinship analysis
- 2.1.3. Movement of porpoises off Greenland
- 2.1.4. Norwegian genetics study
- 2.1.5. Danish waters
- 2.1.6. Discussion

2.2. Lethal pressures: Keynote on By-Catch pressures
2.3. Sublethal pressures
- 2.3.1. Keynote on Pollution pressures
- 2.3.2. Keynote on Disturbance pressures

2.4. Effect of indirect threats – the PCoD framework: Keynote
2.5. Feeding ecology: Keynote
2.6. Life-history & health
- 2.6.1. Keynote on Life-history
- 2.6.2. Keynote on Health (?)

2.7. Population unit assessments: Keynote

3. Finalising of Area Status reports

4. Area presentations

4.1. Eastern USA
4.2. Eastern Canada
- 4.2.1. Sub-area *2a* (Newfoundland and Labrador)
- 4.2.2. Sub-area *2b* (Gulf of St. Lawrence)
- 4.2.3. Sub-area *2c* (Scotian Shelf)

4.3. Greenland
- 4.3.1. Sub-area *3a* (West Greenland)
- 4.3.2. Sub-area *3b* (East Greenland)

4.4. Iceland and Faroe Islands
- 4.4.1. Sub-area *4a* (Iceland)
- 4.4.2. Sub-area *4b* (Faroe Islands)

4.5. Norwegian (North of 62º) and Russian Coasts

4.6. West Scotland-Northern Ireland
4.7. Celtic and Irish Seas
4.8. North Sea
4.9. Belt Sea (“Gap area”)
4.10. Baltic Proper
4.11. Iberian Peninsula
4.12. Northwest Africa

5. Assessments

6. Wrap-up-discussion

7. Any other business

8. Closing remarks

Schedule

Monday:

09:00-09:30: Opening remarks (Chair Ulf Lindstrøm)

09:30-10:00: Stock identity: keynote (Michäel Fontaine)

10:00-10:20: Stock identity: SNPs and close-kinship analysis (Ralph Tiedemann)

10:20-10:40: Stock identity: Movement of porpoises off Greenland (Nynne Lemming)

10:40-10:55: Coffee/fruit break

10:55-11:15: Stock identity: Norwegian genetics study (Maria Quintela)

11:15-11:35: Stock identity: Danish waters (Signe Sveegaard)

11:35-12:30: Stock identity: discussion and draft recommendations

12:30-13:10: Lunch

13:10-13:50: Stock identity: discussion and draft recommendations (cont.)

13:50-14:20: Lethal pressures: by-catch presentation (Finn Larsen)

14:20-14:50: By-catch: discussion and draft recommendations

14:50-15:00: Coffee/fruit break

15:00-15:30: Indirect threats – the PCoD framework and draft recommendations (Leslie New, remote presentation)

15:30-16:00: Indirect threats: discussion and draft recommendations

16:00-16:30: Sublethal pressures: pollution (Sinéad Murphy & Florence Caurant)

16:30-17:00: Pollution: discussion and draft recommendations

Tuesday:

08.30-08:40: Start-up (Chair Ulf Lindstrøm)

08.40-09:10: Sublethal pressures: disturbance (Jakob Tougaard)

09:10-09:40: Disturbance: discussion and draft recommendations

09:40-10:10: Feeding ecology (Graham Pierce)

10:10-10:40: Feeding ecology: discussion and draft recommendations

10:40-11:00: Coffee/fruit break

10:00-11:30: Life history (Sinéad Murphy)

11:30-12:00: Life history: discussion and draft recommendations

12:00-12:30: Stock assessment (Debi Palka)

12:30-13:00: Stock assessment: discussion and draft recommendations

13:00-13:45: Lunch

13:45-15:00: Complete area status reports + break-out groups

15:00-15:15: Coffee/fruit break

15:15-17:00: Complete area status reports + break-out groups (cont.)

WEDNESDAY:

08:30-10:30: Complete area status reports + break-out groups (cont.)

10:30-10:45: Coffee/fruit break

10:45-12:15: Complete area status reports + break-out groups (cont.)

12:15-14:15: Lunch (might change according to work needs)

14:00-15:00: Status of break-out groups => Area presentations and preliminary assessments (2 areas, 30 min each)

14:45-15:00: Coffee/fruit break

15:15-????: Area presentations and preliminary assessments (4 areas, 30 min each)

THURSDAY:

08:30-12:45: Area presentations and preliminary assessments (7 areas, 30 min each)

10:30-10:45: Coffee/fruit break

12:45-13:30: Lunch

13:30-14:45: Area presentations / report discussion

14:45-15:00: Coffee/fruit break

15:15-17:00: Finalising area reports and assessments

19:30: Dinner

FRIDAY:

08:30-10:30: Wrap up-discussion and recommendations (part 1)

10:30-10:45: Coffee/fruit break

10:45-12:00: Wrap up-discussion, as needed and start drafting report (part 2)

12:00-12:30: Lunch

12:30-15:00/16:00: Complete the draft report and closing remarks (part 3)

JOINT IMR/NAMMCO INTERNATIONAL WORKSHOP ON THE STATUS OF HARBOUR PORPOISES IN THE NORTH ATLANTIC

Area Status Report

US (Gulf of Maine/Bay of Fundy)

Compiled by D. Palka*

** National Oceanic and Atmopheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Protected Species Branch*

1. IDENTIFICATION OF ASSESSMENT UNITS WITHIN EACH SUB-AREA

This stock is found in U.S. and Canadian Atlantic waters (Figure 1). Gaskin (1984, 1992) proposed that there were four separate populations in the western North Atlantic: the Gulf of Maine/Bay of Fundy, Gulf of St. Lawrence, Newfoundland, and Greenland populations. Analyses involving mtDNA (Wang *et al.* 1996; Rosel *et al.* 1999a; 1999b), organochlorine contaminants (Westgate *et al.* 1997; Westgate and Tolley 1999), heavy metals (Johnston 1995), and life history parameters (Read and Hohn 1995) support Gaskin's proposal. Genetic studies using mitochondrial DNA (Rosel *et al.* 1999a) and contaminant studies using total PCBs (Westgate and Tolley 1999) indicate that the Gulf of Maine/Bay of Fundy females were distinct from females from the other populations in the Northwest Atlantic. Gulf of Maine/Bay of Fundy males were distinct from Newfoundland and Greenland males, but not from Gulf of St. Lawrence males according to studies comparing mtDNA (Palka *et al.* 1996; Rosel *et al.* 1999a) and CHLORs, DDTs, PCBs and CHBs (Westgate and Tolley 1999). Nuclear microsatellite markers have also been applied to samples from these four populations, but this analysis failed to detect significant population sub-division in either sex (Rosel *et al.* 1999a). These patterns may be indicative of female philopatry coupled with dispersal of males.

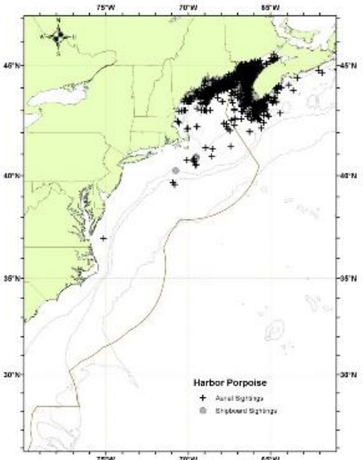


Figure 1. Geographic region of the Gulf of Maine/Bay of Fundy harbour porpoise stock in summer (July - August).

Both mitochondrial DNA and microsatellite analyses indicate that the Gulf of Maine/Bay of Fundy stock is not the sole contributor to the aggregation of porpoises found off the mid-Atlantic states during winter (Rosel *et al.* 1999a; Hiltunen 2006). Mixed-stock analyses using twelve microsatellite loci in both Bayesian and likelihood frameworks indicate that the Gulf of Maine/Bay of Fundy is the largest contributor (~60%), followed by Newfoundland (~25%) and then the Gulf of St. Lawrence (~12%), with Greenland making a small contribution (<3%). For Greenland, the lower confidence interval of the likelihood analysis includes zero. For the Bayesian analysis, the lower 2.5% posterior quantiles include zero for both Greenland and the Gulf of St. Lawrence. Intervals that reach zero provide the possibility that these populations contribute no animals to the mid-Atlantic aggregation.

This report follows Gaskin's hypothesis on harbour porpoise stock structure in the western North Atlantic, where the Gulf of Maine and Bay of Fundy harbour porpoises are recognized as a single US management stock separate from harbour porpoise populations in the Gulf of St. Lawrence, Newfoundland, and Greenland.

It is unlikely that the Gulf of Maine/Bay of Fundy harbour porpoise stock contains multiple demographically independent populations (Rosel et al. 1999a; Hiltunen 2006), but a comparison of samples from the Scotian shelf to the Gulf of Maine has not yet been made.

2. Distribution, abundance and trends

This stock is found in U.S. and Canadian Atlantic waters. During summer (July to September), harbour porpoises are concentrated in the northern Gulf of Maine and southern Bay of Fundy region, generally in waters less than 150 m deep (Gaskin 1977; Kraus *et al.* 1983; Palka 1995), with a few sightings in the upper Bay of Fundy and on Georges Bank (Palka 2000). During fall (October–December) and spring (April–June), harbour porpoises are widely dispersed from New Jersey to Maine, with lower densities farther north and south. They are seen from the coastline to deep waters (>1800 m; Westgate *et al.* 1998), although the majority of the population is found over the continental shelf. During winter (January to March), intermediate densities of harbour porpoises can be found in waters off New Jersey to North Carolina, and lower densities are found in waters off New York to New Brunswick, Canada. There does not appear to be a temporally coordinated migration or a specific migratory route to and from the Bay of Fundy region. However, during the fall, several satellite-tagged harbour porpoises did favor the waters around the 92-m isobath, which is consistent with observations of high rates of incidental catches in this depth range (Read and Westgate 1997). There were two stranding records from Florida during the 1980s (Smithsonian strandings database) and one in 2003 (NE Regional Office/NMFS strandings and entanglement database).

Robust estimates of abundance from shipboard and aerial line transect surveys that account for perception bias are in the abundance spreadsheet (available as a supplementary file at https://nammco.no/topics/scientific-workshops-symposia-reports/#2018) and visually displayed in Figure 2.

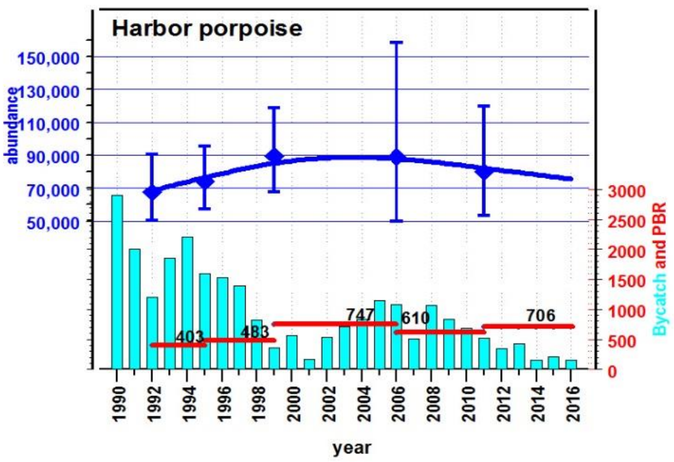


Figure 2. Time series of abundance (in dark blue), by-catch in US fisheries (in green) and the calculated Potential Biological Removal (PBR) value (in red).

3. Anthropogenic removals in time and space

Hunting

There is evidence that harbour porpoises were harvested by natives in Maine and Canada before the 1960s, and the meat was used for human consumption, oil, and fish bait (NMFS 1992). The extent of these past harvests is unknown, though it is believed to have been small. Up until the early 1980s, small kills by native hunters (Passamaquoddy Indians) were reported. In recent years it was believed to have nearly stopped (Polacheck 1989) until media reports in September 1997 depicted a Passamaquoddy tribe member dressing out a harbour porpoise. Further articles describing use of porpoise products for food and other purposes were timed to coincide with ongoing legal action in state court.

By-catch

Harbour porpoises are currently caught in gillnet and bottom trawl commercial fishing gear found in the New England (NE: about Massachusetts and north) and Mid-Atlantic (MA: about Massachusetts to North Carolina), though nearly all takes are in gillnets (Table 1).

Table 1. Presence of protected species observed by-catch in Northern Atlantic US commerical fisheries.

Species	NE gillnet	MA gillnet	NE Bottom trawl	MA bottom trawl	NE midwater trawl	MA midwater trawl	Scallop dredge
Atlantic white sided dolphin	X		X			X	
Bottlenose dolphin		X	X	X			
Gray seal	X	X	X			X	
Harbor porpoise	X	X	X	X			
Harbor seal	X	X	X	X		X	
Harp seal	X	X	X		X		
Minke whale			X				
Pilot whale spp.	X		X	X	X	X	
Risso's dolphin		X	X	X		X	
Short-beaked common dolphin	X	X	X	X	X	X	
Loggerhead turtle		X		X			X

By-catch (gillnets)

By-catch estimates from the gillnet fishery are in the by-catch template spreadsheet and plotted in Figure 2. These estimates are derived by expanded spatial-temporal stratified by-catch rates measured from a sample of the fisheries, where the by-catch rate is defined as number of observed harbour porpoises per observed effort (= mtons of landings). Observer cover varies over time and space and has been between 2% and 11%.
The by-catch estimate dropped dramatically after the implementation of Take Reduction Plans in December 1998 that included a series of time and area closures and gear modifications (Orphanides 2009). After that by-catch increased when compliance to the use of pingers decreased. With increased outreach the compliance increased and estimates decreased.

The risk to gillnet by-catch was highest for animals less than 2 years old (Moore & Read 2008).

By-catch (herring weirs)

In the 1980’s and 1990’s by-catch was observed in the Canadian Bay of Fundy and US Maine herring weirs. Smith et al. (1983) estimated about 27 harbour porpoises died annually in herring weirs. During 1992-1995 herring weirs in the Bay of Fundy recorded 369 caught harbour porpoises where 61 died, 260 released alive and the rest were of unknown status. Annual mortality rates varied from a high of 23% in 1993 and a low of 6% in 1995 (Palka et al. 1996).

4. Impacts from other indirect (sub-lethal) pressures

Indirect pressures are not well documented.

5. Life-history parameters and health status

A life history spread sheet providing more recent information, from the late 1980s and early 1990s (Read 1990a, b; Read and Hohn 1995) is available as a supplementary file to the report on the NAMMCO website (https://nammco.no/topics/scientific-workshops-symposia-reports/#2018). Life history of harbour porpoises from the Bay of Fundy and Gulf of Maine had been previously reported in Fisher and Harrison 1970; Gaskin et al. 1984.

6. DIET AND PREY AVAILABILITY

Studies in the Gulf of Maine and Bay of Fundy showed a heavy reliance on Atlantic herring, which made up 44% of ingested mass in the fall 1989-94, September through December (Gannon et al. 1998) and 64% from June to September 1985-87 (Recchia & Read 1989). Herring accounted for 47.2% of all otoliths from May to September (Punt et al. 2016, Smith & Gaskin 1974), and occurred in 71.3% of all adult stomachs in a separate study from July to September (Smith & Read 1992). Atlantic cod (*Gadus morhua*) were also found to be primary prey items during the summer in two studies (Smith & Gaskin 1974, Recchia & Read 1989), and to a lesser extent in a third (Smith & Read 1992), but no cod were present in any stomach samples of the winter New England waters (Orphanides in review).

Orphanides (in review) showed the winter (January through May 1994-2017) harbour porpoise diet south of New England was more evenly distributed among prey species than in the Gulf of Maine/Bay of Fundy region. In the southern New England winter waters diet consisted of six species groups: squid (*cephalopoda*, %FO=51%, %N=19%), red, white, and spotted hakes (*Urophycis*, %FO=43%, %N=22%), clupeids comprising Atlantic herring, blueback herring, alewife (*Alosa pseudoharengus*), and unknown species of cluepeid (*clupeidae*, %FO=34%, %N=8%), silver hake (*Merluccius bilnearis*, %FO=32%, %N=17%), small flatfish (*Citharichthys arctifrons*, *Etropus microstomus*, unknown Pleuronectiformes, %FO=28%, %N=18%), and cusk eels (*Ophidiidea*, %FO=30%, %N=6%). Average prey size was larger for larger porpoises (>= 140 cm), females versus males, and during the first half of our study (1994-2006 versus 2007-2017). This study also compared the diet to the trawl survey catches in the same time and area. Harbour porpoise selected prey individuals that were less than about 30 cm, which was smaller than that caught in gillnets and trawls. In addition, the species in the diet does not appear to be a random selection of the species caught in the gillnets and trawls.

A single harbour porpoise stomach taken in a pelagic driftnet off Cape Hatteras, NC in Feburary 1993 contained a different prey assemblage. The majority were laternfish (Ceratoscopelus maderensis) along with several other myctophides and other mid-water fishes (Nicolas et al 1996; Palka et al. 1996).

There are two current projects investigating current stomach contents of harbour porpoises from the Gulf of Maine and Mid-Atlantic waters (north and south of that reported in Orphanides (in review)). Results should be available during 2019.

7. KNOWLEDGE GAPS AND UNCERTAINTIES IN ASSESSMENT PARAMETERS

Biology

- Recent life history parameters and pollutants could be investigated using available samples.
- Recent genetic samples from the US and Canadian could be analyzed and compared to other N. Atlantic areas.

Abundance

- Given the known climatic changes in the Gulf of Maine, could investigate the density distribution trends within US and Canadian waters.
- Could develop a standardized abundance time series that covers the exact same area and uniformally accounts for perception and availability bias to be used in an assessment analysis.

Threats

- Could develop a longer by-catch time series by using fishing effort to predict by-catch estimates for the time before the observer programs (before 1990) to be used in an assessment analysis.
- A key uncertainty related to by-catch is the potential that the observer coverage in the Mid-Atlantic gillnet was not representative of the fishery during all times and places, since the observer coverage for some years was, and still is, relatively low, 0.02 – 0.05.
- Given prospective of development of wind farms and seimic surveys for oil and gas exploration, could investigate to determine if this a threat, lethal or sub-lethal.

8. Monitoring requirements, research priorities and opportunities for cooperation

Because the harbour porpoise is subject to a US Take Reduction Plan, the abundance and by-catch is a priority to continue monitoring. Though there are no strict requirements, abundance estimates are attempted every 4-5 years and gillnet by-catch monitoring is continuous, though not high in all times and areas.

9. Assessment unit status

The Gulf of Maine/Bay of Fundy harbour porpoise is not listed as threatened or endangered under the US Endangered Species Act, and this stock is not considered strategic under the US Marine Mammal Protection Act. The total U.S. fishery-related mortality and serious injury for this stock is not less than 10% of the calculated PBR (706) and, therefore, is not considered to be insignificant and approaching zero mortality and serious injury rate. The status of harbour porpoises, relative to OSP, in the U.S. Atlantic EEZ is unknown.

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JOINT IMR/NAMMCO INTERNATIONAL WORKSHOP ON THE STATUS OF HARBOUR PORPOISES IN THE NORTH ATLANTIC

Area Status Report

Eastern Canada

Compiled by J. Lawson*

* *Fisheries and Oceans Canada*

1. IDENTIFICATION OF ASSESSMENT UNITS WITHIN EACH SUB-AREA

Previously, it was thought that porpoise habitat off eastern Newfoundland was fairly well isolated from the other areas by both intervening land masses and deep water. Recent satellite telemetry work suggests that deep water may not be such a barrier for some porpoise populations (Nielsen et al. 2018). Based on organochlorine contaminants, the Newfoundland population was significantly different than the other populations in the western north Atlantic (Westgate and Tolley 1999). Rosel et al. (1999) examined the population genetic structure of this species in the northwest Atlantic using samples from four proposed summer breeding populations (Gulf of Maine, eastern Newfoundland, the Gulf of St. Lawrence, and west Greenland). Control-region sequences revealed a significant partitioning of genetic variation among most of these summer populations, indicating that northwest Atlantic porpoises should not be considered one panmictic population.

Despite these apparent differences it is likely that there is genetic mixing amongst the northeastern U.S., Bay of Fundy and Scotian Shelf areas, plus possibly west Greenland. For the purposes of the NAMMCO workshop, we have subdivided the Canadian Atlantic region into three strata; the Newfoundland and Labrador (NL), Gulf of St. Lawrence (G), and Scotian Shelf (SS). The NL stratum extends from the northern tip of Labrador to the southwest coast of the island of Newfoundland, while the SS stratum includes the Scotian Shelf north of the Bay of Fundy (see Figure 2 in the main report).

2. DISTRIBUTION, ABUNDANCE AND TRENDS

The largest and most recent distribution and abundance information for harbour porpoise in Atlantic Canadian waters was gathered from the large-scale North Atlantic International Sightings Survey (NAISS) in 2016. This aerial survey used line transect data collection methods and distance sampling (Lawson and Gosselin 2009, 2018) to produce corrected estimates for the NL stratum of 48,723 (95% CI 23,566-100,754), the Gulf of St. Lawrence of 185,258 (95% CI 101,006-286,157), and the Scotian Shelf of 20,464 (95% CI 6,831-37,317).

Trends in abundance for harbour porpoise in Atlantic Canada are difficult to determine since there has been only two systematic surveys that have covered all of eastern Canadian waters. The degree of change between the 2007 TNASS and 2016 NAISS aerial survey estimates (63,232 and 256,355, respectively) is too large to be a product of reproduction alone. Changes in distribution and slightly earlier survey timing in 2007 may have been responsible for much of this difference over the 9-year inter-survey interval, for both Canadian strata.

In the 2007 survey porpoise were distributed mainly on the NL south coast and in the northern Gulf. In the 2016 survey many more porpoise were seen and while many were seen in the western Gulf, sightings were broadly dispersed over the survey area and extended as far north as the tip of Labrador, and offshore to the limits of the survey effort (usually the shelf break).

3. ANTHROPOGENIC REMOVALS IN TIME AND SPACE

Harbour porpoises are not hunted in Atlantic Canada, but they do suffer incidental exploitation by commercial fisheries. Much of this mortality is due to encounters with bottom-set gillnets (see for example Benjamins et al.

2007; Lesage et al. 2004; Stenson 2003), with many of the smaller nets in nearshore areas being deployed to collect bait (such as herring) for fixed trap fisheries such as lobster and crab.

By-catch estimates have been derived using fisheries monitoring, mail-out surveys, and telephone surveys, with reported incidents scaled to entire fisheries using fishing effort per unit by-catch. This has yielded estimates which can vary significantly, perhaps as gillnet fishing patterns change or changes in overlap with porpoise distributions. The best porpoise by-catch estimates for the NL stratum range from 862 (95% CI 130-2,135) in 2001 to 2,228 (95% CI 315-5,223) in 2003 (Benjamins et al. 2007). Estimates for the G/SS stratum range from 2,215 (95% CI 1,151-3,662) in 2000 to 2,394 (95% CI 1,440-3,348) in 2001 (Lesage et al. 2004). To the latter could be added an unknown proportion of the 150 porpoise that are thought to be by-caught in the Gulf of Maine/Bay of Fundy each year (Waring et al. 2003).

The majority of porpoise sampled from by-catch collections in Atlantic Canada have been younger animals, usually less than four years old (Richardson et al. 2003), and this is a pattern that matches west Greenland (Lockyer et al. 2001).

Although reductions in the number of gillnet fishing gear have happened since the collapse of a number of nearshore groundfish stocks, gillnet use does continue. Given the uncertainties in the by-catch estimation process, it is not possible to conclude that by-catch of harbour porpoise has declined, or increased.

In addition to the by-catch estimates, porpoises that strand dead, often due to unknown reasons (which may include by-catch), are also subject to annual reporting. For Atlantic Canada in 2017, there were 35 porpoises found dead in the NL stratum, and 249 in the G/SS stratum. The annual value for the magnitude of porpoise standings is highly variable, but may be increasing in the Gulf (Truchon 2010), and in the NL stratum may be underestimated due to the large proportion of uninhabited coastline.

4. Impacts from other indirect (sub-lethal) pressures

Like many cetaceans globally, harbour porpoises in Atlantic Canadian waters potentially face a variety of threats, such as chemical pollution, underwater noise from vessels and seismic exploration, changes in prey abundance and distribution due to human fishing and climate change (see Stachowitsch et al. 2018).

Algal blooms linked to warming waters and agricultural runoff have also been implicated in recent porpoise stranding events in the Gulf (Truchon 2010). While unproven, the cumulative effects of by-catch and changes in prey availability may be the most important factors impacting porpoise stocks in Atlantic Canada.

5. Life-history parameters and health status

In Atlantic Canada there are no estimates of survival rates, although limited sampling in several areas have produced information on growth and reproductive characteristics, with the NL and G/SS strata appearing similar.

Using porpoise by-caught in net fisheries, newborns in Iceland were 75 cm long (Ólafsdóttir et al. 2003).

In NL the females grew to a larger size at maturity (162 cm) than males (155.5), and both became sexually mature at about the same age (3.1 yr (SE = 0.07 for females; 3.0 for males). The maximum age for females (17 yr for a Bay of Fundy sample versus 9 yr in an NL sample) and males (17 yr for a Bay of Fundy sample versus 12 yr in an NL sample)(Read and Hohn 1995; Richardson et al. Unpubl. data). In the NL stratum mature females appear to give birth every year in early June, and are often pregnant and lactating simultaneously, with an APR of 0.83 (Richardson et al. Unpubl. data). The modelled Gulf and NL strata r_{max} values are similar, and also consistent with previous estimated values (0.046) reported in Moore and Read (2008).

6. Diet and prey availability

Bycaught porpoise in Atlantic Canada fed on a variety of prey, with some evident preference for smaller, more energy-rich fish. Porpoise stomach contents have contained a variety of prey such as capelin, the clupeid fishes Atlantic herring and mackerel, gadids such as Atlantic cod and silver hake, redfish, squid (such as *Illex illecebrosus*), with the dominant species being capelin and herring in most cases (Fontaine et al. 1994; Recchia and Read 1989; Smith and Read 1992). Capelin stocks are reduced in Atlantic Canada, as may be herring and mackerel.

7. KNOWLEDGE GAPS AND UNCERTAINTIES IN ASSESSMENT PARAMETERS

The perception bias corrections for porpoise sightings data collected during aerial surveys varied between the NL and Gulf/SS strata. Further double-platform data collection in the Skymaster aircraft could provide a perception bias correction for this platform. The porpoise availability correction factor could be improved through porpoise satellite tagging studies that provide surface and near-surface interval data.

This tagging work, combined with genetic sampling, could also inform stock structure as it relates to habitat use; a better understanding of habitat use will help us to understand the influence of survey timing and coverage on survey abundance results for porpoise.

Finally, estimates of by-catch could be greatly improved through increased at-sea and logbook monitoring in Atlantic Canada, particularly for the many “bait nets” deployed to provide fodder for fixed gear trap fisheries.

8. MONITORING REQUIREMENTS, RESEARCH PRIORITIES AND OPPORTUNITIES FOR COOPERATION

Additional systematic surveys, at shorter intervals, would provide better indications as to the trend in porpoise abundance in Atlantic Canadian waters; and since this is a transboundary stock Canada should continue to seek to coordinate these surveys with American and Greenland survey efforts. A second priority is further genetic sampling to better understand stock structure for this species in Canada. Such genetic information, coupled with habitat use information gained through satellite tagging (Nielsen et al. 2019 Submitted; Nielsen et al. 2018), will be essential to determine if observed changes in abundance are a function of immigration/emigration processes, and where threats to this species exist as fisheries change.

9. ASSESSMENT UNIT STATUS

It would be difficult to assess this properly given that there are only two, relatively recent abundance estimates for this species in Atlantic Canada.

Using an R-based assessment model (see Zerbini et al. 2011), for the NL and Gulf strata we estimated the future abundance trajectory, likely r_{max}, and possible carrying capacity (K), and degree of depletion from K at the time of first by-catch estimation (see Assessment Summary – Eastern Canada). Results from this approach suggest that the number of porpoises in both the NL and Gulf assessment units may be experiencing a slow decline.

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JOINT IMR/NAMMCO INTERNATIONAL WORKSHOP ON
THE STATUS OF HARBOUR PORPOISES IN THE NORTH ATLANTIC

Area Status Report
Greenland

Compiled by S. Enoksen[1] and N. Lemming[2]

[1] *NAMMCO Secretariat, Tromsø, Norway*

[2] *Greenland Institute of Natural Resources*

1. IDENTIFICATION OF ASSESSMENT UNITS WITHIN EACH SUB-AREA

The distribution of harbour porpoises in Greenland comes from reported observations and reporting of the hunt in the Piniarneq catch database (hunter´s lists of game under the Government of Greenland) between 1990-1993, referred in Teilmann and Dietz (1998). An up-to-date Piniarneq was presented in NAMMCO (2013) and it is clear that harbour porpoises are distributed widely around Greenland (Figure 1). Very few catches are reported in East Greenland and north of Disko Island in West Greenland, and it is possible that some of the reported catches on the east coast is an error when hunters reported their catches in the Piniarneq.

A separate West Greenland porpoise population was proposed by the International Whaling Commission in 1996 (IWC 1996) and later confirmed using mtDNA by Andersen et al. (2001) and Tolley et al. (2001). It has not been possible to collect samples of harbour porpoises from East Greenland.

Based on 30 satellite-linked transmitters attached to harbour porpoises from West Greenland, it is clear that they utilise large parts of the North Atlantic before returning to West Greenland (Nielsen et al. 2018). A few tagged animals that had transmitted more than a year, visited the East Greenland shelf area. However, it is unknown if these visits were one-off affairs or if animals from East Greenland actually constitute of animals from West Greenland, meaning that there is one population of harbour porpoises in Greenland.

2. DISTRIBUTION, ABUNDANCE AND TRENDS

Two aerial surveys have been conducted in 2007 and 2015 (see Hansen et al. 2018) and the abundance estimate for harbour porpoises in West and East Greenland (2015 only) are based on these surveys. The surveys were targeting large whales, thus the estimated abundance for porpoises should be considered a minimum:

West Greenland

- 54,284 (95% CI: 27,627-106,664, T-NASS 2007, from the coast crossing the shelf break, 69ºN-59ºN).
- 83,321 (NASS 2015, from the coast and offshore (up to 100 km from the shelf break).

East Greenland

- 1,642 (NASS 2015, from the coast and up to 50 km off the shelf break).

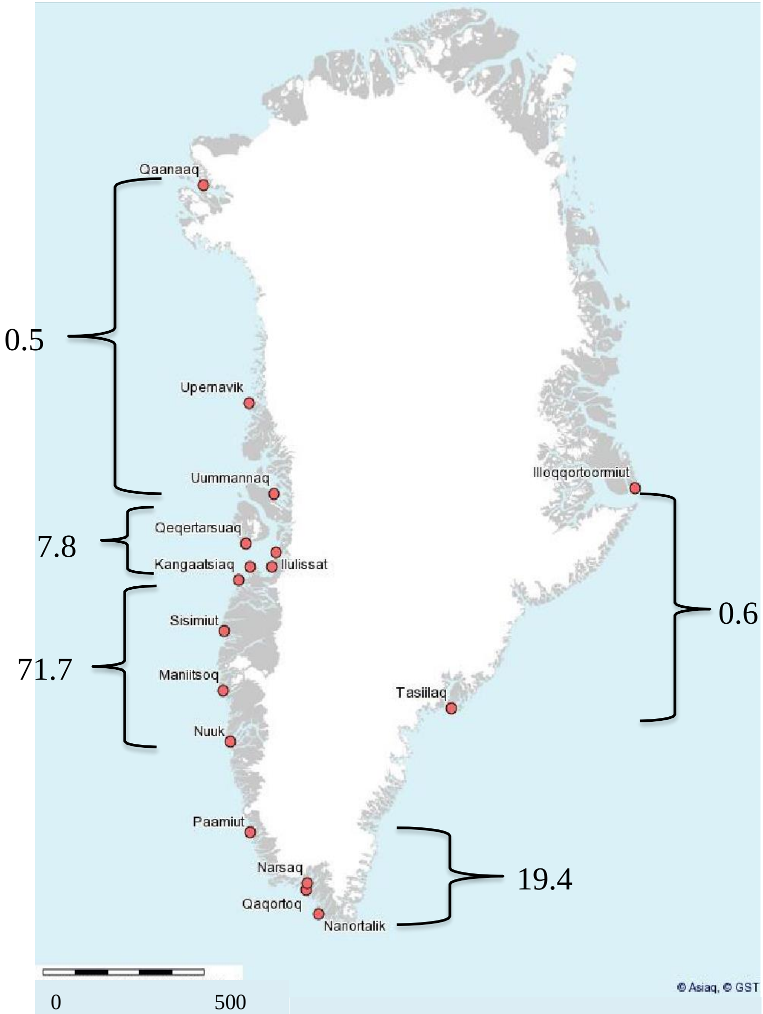

Figure 1. (Modified from NAMMCO 2013). The percentage of harbour porpoise catches for five different areas in Greenland (reporting between 1993 – 2012) are shown next to the curly brackets.

3. ANTHROPOGENIC REMOVALS IN TIME AND SPACE

Harbour porpoises are an important source of meat and mattak (skin and blubber) in Greenland and there are at present no quota regulations for the hunt of harbour porpoises. The information on catches of harbour porpoises, dates back to 1900 and provides a minimum estimate of the history of exploitation and provides the only quantitative information on harbour porpoise population history in Greenland (Teilmann and Dietz 1998). Between 1900 and 1992 catch reporting was based on the Hunter´s List of Game (Ministry of Greenland) where list keepers in each settlement kept a record of the catches of birds and mammals. Catch statistics after 1992 are based on a reporting system, where everybody who hunt (both full-time and part-time) are required to report their monthly catches once a year (Piniarneq, Government of Greenland).

A series of interviewed hunters by GINR personal, revealed a degree of unreporting to the Piniarneq catch database, but the exact extend is not known.

Piniarneq catch database (1993-2017)

East and West Greenland

- Total catches: 55,495
- Annual average catch: 2,220

East Greenland

- Total catches: 290
- Annual average catch: 15

- Minimum catch: 0
- Maximum catch: 83

West Greenland

- Total catches: 55,205
- Annual average catch: 2,208
- Minimum catch: 1,427
- Maximum catch: 3,200

As seen from the catch history (Figure 2), the catches have increased since the 1990s, however this might be due to a change in the reporting system.

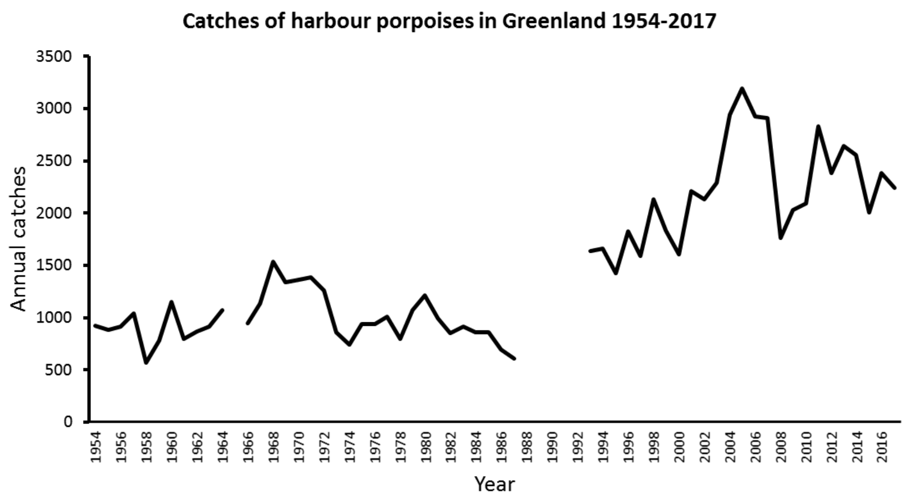

Figure 2. Catch history of harbour porpoises in Greenland 1954-2017.

Historically, harbour porpoises have been by-caught in the salmon driftnet fishery, which ceased in 1976 (Kapel 1983, in Teilmann & Dietz, 1998) and today an unknown level of by-catch takes place in e.g. lumpsucker (*Cyclopterus lumpus*) fisheries. Until recently, these by-catches have been reported in the hunt statistics (and the animals have been sold at the local market).

4. Impacts from other indirect (sub-lethal) pressures

Not available.

5. Life-history parameters and health status

<u>West Greenland</u>

Data on life history was uptained from >320 freshly killed porpoises purchased (either whole carcasses or samples) from the hunters in West Greenland in the years 1988-2014 (Lockyer et al., 2001, 2003, Heide-Jørgensen et al., 2011; Nielsen 2018). West Greenland harbour porpoises seem to be shorter but fatter than porpoises in other areas (Canadian Atlantic coast, eastern North Atlantic) (Lockyer et al., 2003).

- Female ASM at 3.6 years, and 2.5 years for males (Nielsen 2018)
- Maximum age: females: 12 and males: 17 (NAMMCO 2013)
- Female max body length: 166 (Lockyer et al 2003), male max body length: 158 (Lockyer et al. 2001; Lockyer 2003)
- Female LSM: 138-142, male LSM: 127 (Lockyer et al. 2003)

- Ovulation rate/yr: 0.73 (1.37 interval/yr) (Lockyer et al. 2003)
- Lactation period: <1 yr ? (Lockyer et al. 2003)
- Calving interval: 1 yr (NAMMCO 2013)
- Calving season: summer (Lockyer et al. 2003)
- Mating season: August (Lockyer et al. 2003)

6. Diet and prey availability

West Greenland

- Capelin, Greenland halibut, Norway haddock, sculpin, codfish, squid, long-tailed decapods (Teilmann & Dietz 1998)
- Capelin, polar cod (*Boreogadus saida*), *Sebastes* sp., Greenland halibut, *Ammodytes* sp., *Liparis* sp., *Lycodes* sp., squid, *Pandalus* sp., *Parathemisto libellula*, Euphasiids, varying with district, but capelin (90-100% of all samples) and polar cod (42-60%) were major constituents in all districts (Lockyer et al 2003; Heide-Jørgensen et al 2011)
- Mesopelagic prey (Heywood 1996, Heide-Jørgensen et al. 2011, from Nielsen et al 2018)

7. Knowledge gaps and uncertainties in assessment parameters

There is no data available on harbour porpoises from East Greenland

8. Monitoring requirements, research priorities and opportunities for cooperation

Validating the catch history from West and East Greenland would be a priority.

9. Assessment unit status

A formal assessment of the status of harbour porpoise populations in Greenland will be conducted by the NAMMCO harbour porpoise working group in Spring 2019.

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JOINT IMR/NAMMCO INTERNATIONAL WORKSHOP ON
THE STATUS OF HARBOUR PORPOISES IN THE NORTH ATLANTIC

Area Status Report

Iceland

Compiled by G. Víkingsson*

* *Marine and Freshwater Research Institute, Iceland*

1. IDENTIFICATION OF ASSESSMENT UNITS WITHIN EACH SUB-AREA

Information on population(s) identity

Tolley et al. 2001 described differentiation at the mtDNA Control region of Icelandic harbour porpoises from porpoises off Norway and West Greenland, but no differentiation was found between Iceland and Canada (New Foundland, St. Lawrence).

Fontaine et al. 2007 typed 10 microsatellite loci from porpoises spanning the entire North Atlantic, including samples from different regions in Iceland. There was no indication of sub-structuring, neither between Iceland and other areas nor within Icelandic waters.

Lah et al. 2016 used 2872 SNPs to assess harbour porpoise population structure, including specimens from North Sea (n=6) and Iceland (n=3). There was no difference between North Sea and Iceland, but the populations of these areas are well diverged from the Baltic Sea (Baltic Proper) population. SNP data of further 12 Icelandic samples (together with samples from Greenland and Eastern Canada) were produced by Tiedemann and analyzed by Lemming (2018) and co-workers. This data suggests no differentiation between Icelandic and Eastern Canadian porpoises, while Western Greenland stands apart.

Tiedemann (in collaboration with Vikingsson and Gunnlaugsson) analyzed 13 microsatellite loci and the mitochondrial Control Region in 1918 porpoises from Icelandic waters. Microsatellite analyses did not reveal any reveal any differentiation within Icelandic waters and kinship analysis inferred several parent-offspring (PO) pairs. Genetic comparisons to North Sea porpoises (data from Wiemann et al. 2010) on this comprehensive data set are underway.

At the NAMMCO Workshop on the Status of Harbour Porpoises in the North Atlantic in December 2018, Tiedemann will report on the kinship analysis based on almost 2000 Icelandic porpoises as well as the differentiation of Icelandic porpoises from other NA populations (in particular North Sea) based on almost 3000 SNPs, 13 microsatellite loci and the mitochondrial Control Region.

The general finding of almost no differentiation among North Atlantic porpoises at nuclear loci, but some differentiation at the mitochondrial DNA could indicate some female philopatry, as reported also for the Baltic Sea (Wiemann et al. 2010).

2. DISTRIBUTION, ABUNDANCE AND TRENDS

Robust estimates of abundance, e.g. from line transect sampling Icelandic and Faroese ship surveys (NASS, TNASS) have not had porpoises as a primary target species. These surveys have been conducted frequently in Beaufort to high and observers concentrating at greater distances than optimal for porpoises. These surveys had fin whales as a primary target species and generally had poor coverage of coastal waters. Aerial surveys have been flown at about 750ft in the coastal waters, with common minke whales as primary target species. An exception from this is the 2007 survey flown at 600ft. Minke whales were still the primary target species but harbour porpoise was defined as a secondary target species and the survey included one trained porpoise observer. The resulting estimate for 2007 was 43,179 (CV 0.45). Since the survey was not designed for harbour porpoises as a primary target species, this estimate should be considered with caution. It should also be borne in mind that the aerial surveys in Icelandic waters presumably cover only an unknown fraction of the distribution area of the population.

Trends in relative abundance

Pike et al (2009) found a significant downward trend in harbour porpoise densities in Icelandic coastal waters 1986-2001 from aerial survey data. However, the authors made several reservations concerning the validity of the apparent trend. The surveys were designed for estimation of a much larger species, the common minke whales and there were considerable changes in composition of observers during the period. The estimated trend was primarily driven by very low densities in the last datapoint (2001) without which there was not significant trend. However, this was considered a cause for concern that warranted further investigations.

Since the analyses mentioned above (Pike et al. 2009) five aerial surveys have been conducted in the area. Apart from the 2007 survey, these surveys are not considered suitable to produce reliable estimates of absolute abundance of harbour porpoises due to survey design and/or poor coverage. However, as the methods were consistent over time the can be used as indications of relative abundance as in the previous analysis (Pike et al. 2009). Two measures of relative abundance are shown in Table 1 and Figure 1. Densities varied considerably between surveys and a linear regression analysis did not reveal a significant trend over the period 1986-2016 (slope=1.137; R^2=0.085, p = 0.447).

Table 1. Sightings rates (no of animals per 100 hours of observation) of harbour porpoises from aerial surveys in Icelandic waters 1986-2016.

year	hours	PP	PP/100hr
1986	116	72	61
1987	76	33	43
1995	113	53	46
2001	106	16	15
2004	64	6	9
2007	108	118	109
2009	92	42	45
2015	51	14	27
2016	64	90	139

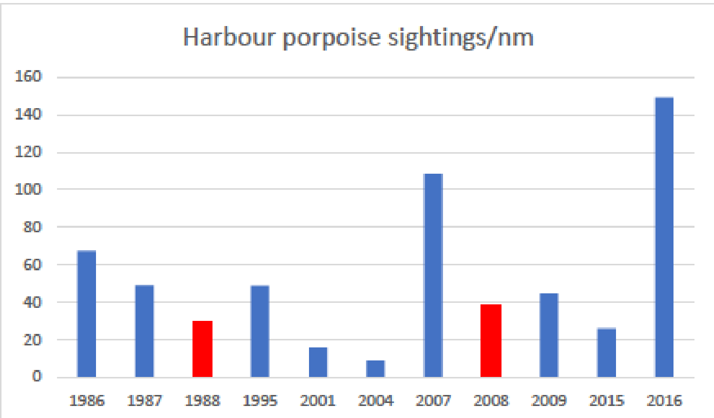

Figure 1. Sightings rates (no of sightings per 100 nm of observation) of harbour porpoises from aerial surveys in Icelandic waters 1986-2016. Red bars indicate a partial survey in Faxaflói bay.

Another independent indicator of relative trend can be obtained from porpoise by-catch rates in MFRI's gillnet surveys during 2003-2018 (Table 2). These surveys are standardized and designed to be representative for the gillnet fishery in Icelandic waters during the peak of the gillnet season in late winter (March-April). A linear regression indicates an upward trend, although marginally insignificant (slope=1.579; R^2=0.204, p = 0.079).

Table 2. Number of porpoises by-caught in the standardized gillnet fishery survey conducted by the MFRI in March-April 2003-2018.

Year	Porpoises
2003	19
2004	8
2005	9
2006	9
2007	8
2008	18
2009	19
2010	50
2011	28
2012	29
2013	69
2014	12
2015	17
2016	35
2017	28
2018	30

Although statistically insignificant, the slope is upwards for both these measures of relative abundance for the whole series, confirming that the apparent downward trend reported by Pike et al. (2009) was due to unusually low densities observed in 2001 survey.

Preliminary analysis comparing relatedness within 1225 by-caught porpoises in Icelandic waters collected mainly in 1992 to the relatedness observed within 680 recent samples (mainly from 2017 and 2018) show an increase in stock size. These are based on 13 microsatellite loci. Further genotyping and/or additional samples are needed to strengthen these results. These two estimates (54,420 CV=0.22 and 117,616 cv=0.42) can be used as relative indices of abundance in the assessments.

3. Anthropogenic removals in time and space

Direct hunting of harbour porpoises has not been a widespread tradition in Iceland. Although it is known to have occurred in some communities for local consumption and bait, the catch levels are generally not considered to be at a level that could affect the population. While no direct statistics exist on the numbers caught a guestimate would likely be in the low 10's annually.

There is significant by-catch of harbour porpoise in Icelandic waters, particularly in the cod gillnet, and lumpfish fishery. Efforts to reliably estimate the extent of this by-catch have been underway in recent years and are still under development (NAMMCO 2018, Pálsson et al 2015, MFRI 2018). An estimate for the cod fishery currently under review by the NAMMCO WG on by-catch estimates has not been endorsed by the WG nor the SC. However, the SC agreed that as an interim measure, the stratified estimate presented, i.e. 1841 porpoises a year, could be considered as an upper bound for the by-catch in cod gillnets for the period 2013-2017.

There is no recent information on the age structure of by-caught harbour porpoises in Icelandic waters. However, from a study in the 1990's (Ólafsdóttir et al. 2003), more than 2/3 of the 969 aged animals were 0-1 years of age and around 90% less than 6 years old. The sex composition in this sample was also heavily skewed towards males, that comprised 63% of the by-caught animals.

The NAMMCO Working Group on by-catch has adopted four estimates of by-catch from the lumpfish fisheries and recommended the use of the stratified estimates over the non-stratified. All these estimates are for the period 2014-2017 and range from 428 to 662 porpoises per year. For the assessment at this meeting, the average of the three stratified estimates (546) was be used.

Total by-catch of harbour porpoises has likely decreased appreciably in accordance with greatly reduced gillnet fishery effort. Gillnet fisheries for cod and lumpfish, and presumbably the associated by-catch, have a long history in Icelandic waters. Since the only available estimates of by-catch relate to recent years (2013-2017) it was considered worthwhile to examine options with approximations of by-catches through time based on effort data from these two fisheries assuming a linear relationship between fishery landings and porpoise by-catch. Such extrapolations have been calculated using fishery landings as a proxy for gillnet effort back to the middle of the 20th Century. Data were obtained from the MFRI database (Guðjón M. Sigurðsson). Data were extrapolated based on available fisheries data and the, in accordance with trend observed in the lumpfish fishery (Kennedy et al 2018), assumed to decrease linearly to 0 in 1949 (see Appendix I).

4. Impacts from other indirect (sub-lethal) pressures

Das et al., (2006) reported evidence of interfollicular fibrosis in the thyroid of the harbour porpoise that could lead to endocrine disruption? This fibrosis was much more prominent in porpoises from Germany and Norway than in Icelandic porpoises.

Harbour porpoises from Iceland displayed far lower PCB, PBDE, DDE, and DDT concentrations in the blubber than porpoises collected along the German or Norwegian coasts while toxaphene concentration was higher in porpoises from Iceland (Thron et al. 2004 cited in Das et al 2006).

A study by Prendergast (2017) concluded that boat traffic negatively affected diel rhythmic behavior in harbour porpoises in one of the busiest whale watching areas in Iceland, Skjálfandi Bay.

5. Life-history parameters and health status

Life history parameters for harbour porpoises in Icelandic waters were estimated in a large study (n = 1268) in the 1990's (Halldórsson & Víkingsson 2003, Ólafsdóttir et al. 2003).

Asymptotic length was estimated as 149.6 cm for males and 160.1 cm for females. Pregnancy rate was 98% indicating a reproductive cycle of one year. Estimated age and length at sexual maturity was 1.9 to 2.9 years and 135 cm for males and 2.1 to 4.4 years and 138-147 cm for females. Births do, most likely peak in June and July and lactation lasts at least 7 to 8 months.

The estimated parameters are provided in more detail in a separate life history spread sheet that is available on as a supplementary file to the report on the NAMMCO website (https://nammco.no/topics/scientific-workshops-symposia-reports/#2018)

A pathological study of harbour porpoises from Icelandic and Norwegian waters (Siebert et al 2006) showed that most were in good or moderate nutritional condition and none was severely emaciated. Mild infection with lungworms was found in 84% of the Icelandic and 91% of the Norwegian animals, usually associated with bronchopneumonia which was rarely severe. Most (91%) of the animals had parasites in the stomach and intestine.

6. Diet and prey availability

In a large scale study conducted by the MFRI in the 1990's, the stomach content of 1,047 harbour porpoises from Icelandic waters was analysed (Víkingsson et al. 2003). Most examined stomachs contained identifiable food remains (97%). More than 40 fish and invertebrate prey taxa were identified. Overall, capelin (*Mallotus villosus*) comprised the predominant prey, followed by sandeel (*Ammodytidae sp.),* then gadids, cephalopods and redfish (*Sebastes marinus*). The length distributions of fish consumed by the porpoises ranged from 1 to 51 cm although most fish prey were less than 30 cm. Considerable geographical and seasonal variation was found in the diet. Predominance of capelin in the diet coincided with the spawning migration of capelin from northern waters along the east,south and west coasts of Iceland.

Apart from this, very limited data exists on the feeding ecology of harbour porpoises in Icelandic waters. The stomach content of 23 porpoises from Skjálfandi Bay in NE Iceland by-caught in 2011 and 2012 showed dominance of capelin in the first year and cod in the second year (Koponen 2013). However, sample size vas very small in 2012 (n=5).

The large-scale study mentioned above is based on material more than 20 years old and given the changes in the marine environment around Icelandic in recent years, that appear to have affected the feeding ecology of other species (Víkingsson et al. 2014, 2015), it is timely to collect more new data on the diet of harbour porpoises.

7. Knowledge gaps and uncertainties in assessment parameters

Better information is needed on abundance of harbour porpoises in Icelandic waters. The surveys conducted so far have been designed for other species and dedicated harbour porpoises surveys may be needed to obtain a reliable abundance estimate. Estimation of abundance from genetic methods is promising and the ongoing study should be completed by further sampling and analysis of more genetic markers.

Improved estimates of removal rates (by-catch) are urgently needed.

Harbour porpoises in Icelandic waters may constitute an unknown proportion of a wider population. To address this, further studies on stock structure are needed, e.g. using genetic and satellite tracking methods.

Estimates of life history parameters need to be updated.

In a wider perspective, estimates of sustainable removal levels for harbour porpoises should be reviewed. Population modelling using all suitable data on removals, abundance and trends should be conducted.

8. Monitoring requirements, research priorities and opportunities for cooperation

Better information is needed on both the abundance and by-catch rates of harbour porpoises in Icelandic waters.

As the available data on abundance comes from surveys that have large cetacean species as their primary target, a dedicated survey for harbour porpoise is desirable. The new kinship analysis for estimating abundance is promising and may be improved by increasing sample size and increasing the number of genetic markers analysed. It is important that the sampling program in Iceland continues and includes a higher number of genetic markers. Further population genetic studies and satellite tracking could usefully inform stock structure questions in this area.

Estimation of by-catch levels in the Icelandic gillnet fisheries for lumpfish and cod could be improved. While the the Scientific Committee of NAMMCO has agreed an estimate for the lumpfish fishery, there is no approved best estimate for the Icelandic cod gillnet fishery at present.

The available information on biological parameters and feeding ecology is primarily based on a large study conducted in 1991-1997. More recent data on biology and feeding ecology would be valuable for evaluating potential effects of these changes on harbour porpoises in this area.

9. Assessment unit status

The lack of a series of absolute abundance estimates and robust by-catch estimates poses a challenge to the assessment of harbour porpoises off Iceland. Although by-catch from gillnet fisheries is appreciable, the population appears to be stable or increasing from relative indices. This is consistent with the observed high reproductive rates. Assessments using a single absolute abundance estimate (aerial survey) and two relative estimates (kinship analysis) confirm this increasing trend.

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APPENDIX I TO ANNEX 4

Abundance data used in the assessment.

Abundance

Year	Abundance	CV	Type
2007	43,179	0.45	Absolute
1992	54,420	0.22	Relative
2017	117,616	0.42	Relative

APPENDIX II TO ANNEX 4

By-catch data used in assessments. Extrapolated from fishery landings from the cod and lumpfish gillnet fisheries. ByCod: Extrapolated porpoise by-catch in the cod gillnet fishery. ByLump: Extrapolated porpoise by-catch in the lumpfish gillnet fishery. By-catch estimates used for extrapolation are shown in Bold.

Year	Cod catch	Lumpfish catch	ByCod	ByLump	Total By-catch
1950			144	23	167
1951			288	47	334
1952			432	70	501
1953			575	93	668
1954			719	116	836
1955			863	140	1003
1956			1007	163	1170
1957			1151	186	1337
1958			1295	210	1504
1959			1438	233	1671
1960			1582	256	1838
1961			1726	279	2005
1962			1870	303	2172
1963			2014	326	2340
1964			2158	349	2507
1965			2301	372	2674
1966			2445	396	2841
1967			2589	419	3008
1968			2733	442	3175
1969			2877	466	3342
1970			3021	489	3509
1971			3164	512	3676
1972			3308	535	3844

1973			3452	559	4011
1974			3596	582	4178
1975			3740	605	4345
1976			3884	629	4512
1977			4027	652	4679
1978			4171	675	4846
1979			4315	698	5013
1980			4459	722	5180
1981			4603	745	5348
1982			4747	768	5515
1983			4890	791	5682
1984			5178	815	5993
1985		9764	5326	839	6165
1986		6897	5326	592	5918
1987		9764	5326	839	6165
1988		4359	5326	374	5700
1989		5765	5326	495	5821
1990		2781	5326	239	5565
1991		4230	5326	363	5689
1992		5553	5326	477	5803
1993	56360	3804	5326	327	5653
1994	39849	4982	3766	428	4194
1995	31226	4810	2951	413	3364
1996	40841	4455	3860	383	4242
1997	45948	5712	4342	491	4833
1998	50981	2778	4818	239	5056
1999	47189	2959	4459	254	4713
2000	48057	2159	4541	185	4727
2001	53653	2870	5070	247	5317
2002	44118	4424	4169	380	4549
2003	37499	5459	3544	469	4013
2004	37345	5067	3529	435	3964
2005	31714	3273	2997	281	3278
2006	23376	3531	2209	303	2512
2007	23338	2897	2205	249	2454
2008	19109	4451	1806	382	2188
2009	21885	4457	2068	383	2451

2010	16553	7353	1564	632	2196
2011	16049	4220	1517	362	1879
2012	16917	6076	1599	522	2120
2013	19749	4546	1866	390	2257
2014	18993	4034	1795	346	2141
2015	19482	6357	**1841**	**546**	2387
2016	21475	5475	2029	470	2500
2017	17182	4565	1624	392	2016

JOINT IMR/NAMMCO INTERNATIONAL WORKSHOP ON THE STATUS OF HARBOUR PORPOISES IN THE NORTH ATLANTIC

Area Status Report

Faroe Islands

Compiled by B. Mikkelsen*

* *Museum of Natural History, Faroe Islands*

Knowledge about the harbour porpoise (*Phocoena phocoena*) in Faroese waters is very limited. There have been no systematic collection of specimen for biological examinations; therefore, the knowledge on biology and life history of the species from these waters is nearly absent. A dedicated harbour porpoise aerial survey was performed in summer 2010, which for the first time provided knowledge on density and abundance on the Faroe Shelf (Gilles et al. 2011). The *North Atlantic Sightings Surveys* (NASS) have not been designed for harbour porpoise abundance estimations. But the NASS surveys have, together with a few shipborne seabird surveys, provided some insight into the distribution of harbour porpoise in Faroese waters (Skov et al. 1995), and have been used for examining the habitat characteristics of the distribution of harbour porpoise on the Faroe Shelf (Skov et al. 2003). Seven specimens collected in inshore waters in 1987-88 were made available for an investigation on parasite and pollutant loads (Larsen 1995b). In this study, also age and sexual status was assessed.

Harbour porpoises in Faroese waters are not protected by law and can be hunted year-round with shotguns loaded with pellet cartridges. Executive order no. 9 from 26. January 2017 regulate the harvest, and stipulate that all takes have to be reported to the district Sheriff. Some harvest has been reported, and provided in Progress Reports, up to 1995 (Larsen 1995a), but since then no take of harbour porpoise have been reported to the Sheriff (or the Natural History Museum). Therefore, information on the exploitation of harbour porpoise in Faroese waters is limited, and no reliable hunting statistics exist. An interview survey among fishermen and other islanders in 1987 concerning distribution, harvest and by-catch gave some insight into the removals and importance of harbour porpoise for the islanders (Larsen 1995a).

By-catch of harbour porpoises have been reported relatively extensive in some areas, especially in gillnet fisheries in shallow waters (NAMMCO 2017). In the Faroes, gillnet fisheries inside the 30 nautical mile zone have not been licensed since the 1960s (Larsen 1995a), resulting in that by-catch of harbour porpoises in both past (Larsen 1995a) and present (Mikkelsen 2016) time has been very limited; the only reported by-catch being a very few animals caught on longlines.

1. IDENTIFICATION OF ASSESSMENT UNITS WITHIN EACH SUB-AREA

There is only very scarce genetic information on porpoises from the Faroe Islands: 10 typed microsatellite loci were reported in Fontaine et al. 2007, where no separation was found from other North Atlantic populations.

One harbour porpoise was tracked by satellite telemetry in the Faroes in 2008. During the tracking period 7. September to 25. October (49 days), this animal was stationary in between the islands, with only very limited range in movements.

Figure 1. Track of a single harbour porpoise from early September to late October.

Incidental sightings of harbour porpoises in Faroese waters by months show that they are observed year-round, but the frequency pattern could indicate (not corrected for effort) that the main season of occurrence in Faroese waters is April to September.

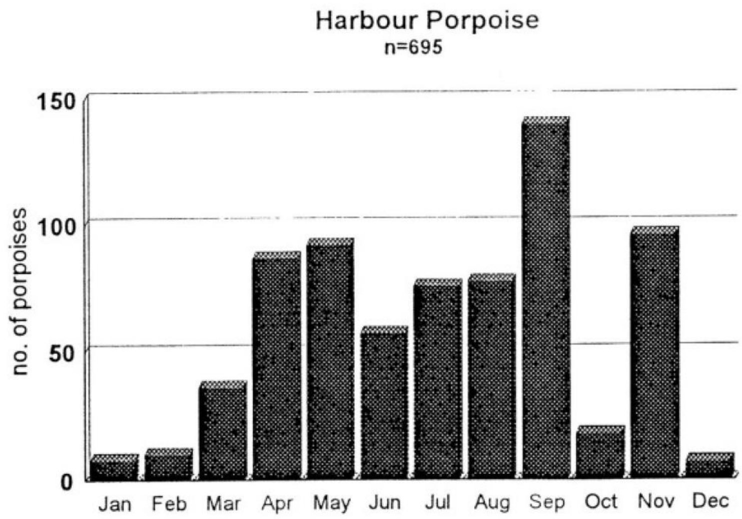

Figure 2. Records by months of harbour porpoises in Faroese waters.

2. DISTRIBUTION, ABUNDANCE AND TRENDS

Observations show that harbour porpoises are distributed not only in shallow waters, but relatively frequently also in more offshore waters of the Faroe Plateau, with water depths exceeding 500 meters (Bloch 1995).

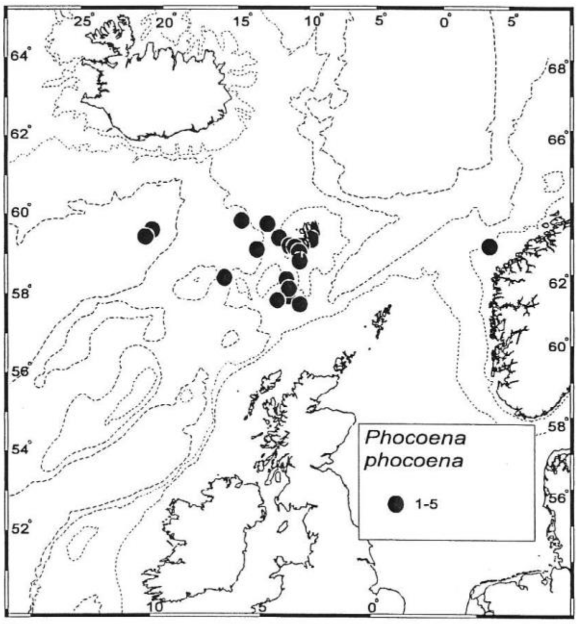

Figure 3. Sightings locations of harbour porpoises from Faroese waters.

A dedicated harbour porpoise aerial abundance survey in June 2010 estimated the abundance to be 5.175 (CV=0.44, 95% C.I.: 3.457-17.637) animals. The estimate, which only covered the area inside the 300 meters depth contour, has to be considered a minimum estimate, since one stratum (27% of the survey area) was excluded due to poor coverage.

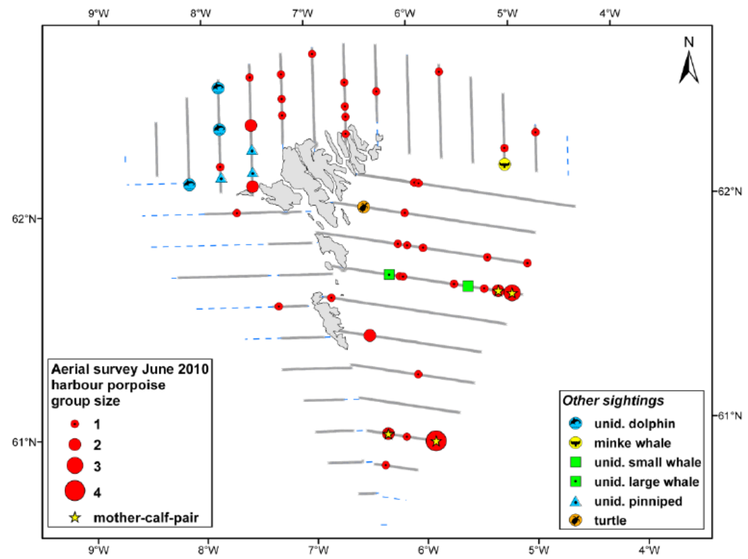

Figure 4. Effort inside 300 meters depth and sightings during an aerial survey in Faroese waters.

3. Anthropogenic removals in time and space

Harbour porpoises in Faroese waters are not protected by law, and can be hunted year round with shotguns (loaded with pellet cartridges). Executive order no. 9 from 26. January 2017 regulate the harvest, and stipulate that all takes have to be reported to the district Sheriff. Information on the exploitation of harbour porpoise in Faroese waters is limited, and no reliable hunting statistics exist. Some harvest has been reported, and provided in Progress Reports, with a total of 44 animals reported to be take in the period 1987-1995 (Bloch, 1995). After this, no harvest of harbour porpoise has been reported to the Sheriff (or to the Natural History Museum).

An interview census among islanders in 1987 concerning distribution and takes of harbour porpoises gave some insight into the harvest and importance as a food resource (Larsen 1995b). The study indicated which also seems to be the status today that harbour porpoises are not hunted in high numbers, or are of any importance as a food source, in the Faroe Islands.

By-catch of harbour porpoises, taken especially in gillnet fisheries in shallow waters, have been reported extensive for some areas (NAMMCO 2017). In the Faroes, gillnet fisheries inside the 30 nautical mile zone have not been licensed since the 1960s (Larsen 1995b), and has resulted in that by-catch of harbour porpoise is nearly absent, the only reported by-catch being a very few animals caught on longlines (Mikkelsen 2017).

4. Impacts from other indirect (sub-lethal) pressures

Parasite and pollutant loads, and overall condition, was examined for seven porpoises taken in the Faroes in 1987-88 (Larsen 1995). Both parasite burdens and pollution levels were comparable with results from other areas of the North Atlantic, and the overall condition did not seem to be have be affected by the parasite loads.

5. Life-history parameters and health status

The sexual status of only four females have been examined. The presence of *Corpus luteum* in an animal age 4 show that they could become sexually mature at age 3 (although one animal age 5 had not matured). For one male age 5, *spermiae* was not present; this could indicate that males are maturing at an older age than the females.

6. Diet and prey availability

The stomach content of one porpoise, by-caught on longline in shallow (<80 meter) waters, was found to be exclusively hagfish (*Myxine glutinosa*).

7. Knowledge gaps and uncertainties in assessment parameters

Big knowledge gaps! Important to identify what knowledge has the highest priority to be collected for Faroese waters.

8. Monitoring requirements, research priorities and opportunities for cooperation

Abundance (update aerial survey), total removals (reliable hunting statistics), life history and movements (seasonal occurrence/distribution).

9. Assessment unit status

Current knowledge is too limited to address this question.

10. References

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JOINT IMR/NAMMCO INTERNATIONAL WORKSHOP ON THE STATUS OF HARBOUR PORPOISES IN THE NORTH ATLANTIC

Area Status Report

Norwegian waters north of 62ºN and western Russian waters

Compiled by A. Bjørge*

With contributions from M. Biuw*, A. K. Frie*, S. Hartvedt*, U. Lindström*, A. Moan*, N. Øien* and M. Q. Sanchez*

* *Institute of Marine Research, Norway*

1. IDENTIFICATION OF ASSESSMENT UNITS WITHIN EACH SUB-AREA

Gaskin (1984) hypothesized that the deep waters of Vestfjorden separated a northern component from a southern component of harbour porpoises in Norwegian waters. Bjørge & Øien (1995) used sighting from the Norwegian line transect surveys (designed for abundance estimation of minke whales) to explore Gaskin's hypothesis. They found a hiatus in offshore distribution of porpoise but south of Vestfjorden (at about 66ºN).

The population identity of porpoises based on genetic studies have been examined by Tolley *et al*. (1999), Andersen *et al*. (2001), and Quintela *et al*. (2018, unpublished).

Tolley *et al*. (1999) sequenced the D-loop in mtDNA from 38 porpoises from the Barents Sea region and 45 porpoises from the Norwegian North Sea to test Gaskin's hypothesis. No significant difference in haplotype frequency between the Barents Sea and the North Sea was found and the hypothesis of two spatially separated distinct populations in Norwegian waters was rejected. This conclusion was further substantiated by an analysis by Andersen *et al.* (2001) of porpoises from Norwegian waters, inner Danish waters, Danish North Sea, British North Sea, Ireland, Netherlands and West Greenland. Andersen *et al*. (2001) suggested close relationship between Norwegian porpoises and porpoises in inner Danish waters and the Danish North Sea.

Quitela *et al.* (2018, unpublished) studied a total of 134 individuals (58 females and 76 males) that were by-caught at the Norwegian coast during 2016 and 2017, within a latitudinal range from 59,07º N to 71,05ºN. In addition, 21 of the females were bearing fetuses of unknown sex, which were excluded from the population structure analyses. The porpoises were analyzed using 78 SNP markers. No genetic differentiation was recorded between years (F_{ST}=0.001, P=0.2112) nor between sexes (F_{ST}=0.002, P=0.075). STRUCTURE analyses showed the highest average likelihood at K=1, although both Evanno test and STRUCTURESelector pointed at K=2 as the most likely number of clusters. At K=2, the 134 individuals could be partitioned into two clusters of almost identical size (N=66 and N=68 respectively) showing low yet significant F_{ST} (0.022, P=0.022). However, no obvious underlying pattern such as geographic position, sex, year of sampling could account for this statistically significant F_{ST}.

Quintela *et al.* concluded that the 134 individuals genotyped at 78 SNP loci and analyzed in the present study did not reveal the existence of more than one population of harbour porpoise in Norwegian coastal waters in an unequivocal manner. However, a more extensive sampling, both in terms of numbers of individuals and in geographic scope, preferably covering both sides of the Atlantic, would be essential to elucidate the genetic structure of this highly mobile marine species.

All three genetic studies corroborated the existence of one panmictic population of harbour porpoises in Norwegian waters. There is no evidence for two parapatric populations as suggested by Gaskin (1984) and Bjørge & Øien (1995).

2. DISTRIBUTION, ABUNDANCE AND TRENDS

Geographic range of the assessment unit

The porpoises in Norwegian waters north of 62ºN are mainly distributed on the continental shelf, in the relatively shallow coastal zone and in the rather deep fjords. The distribution extends northward to the west coast of Svalbard and to Polar Front (where Atlantic meets Arctic waters, Figure 1) in the Barents Sea, and eastwards to the Cape Kanin and southern Novaja Semlya. However, porpoises have also been sighted in deep waters between mainland Norway and Jan Mayen (see Figure 2). As previously stated under item 1, there is no genetic differentiation between Norwegian waters north and south of 62ºN.

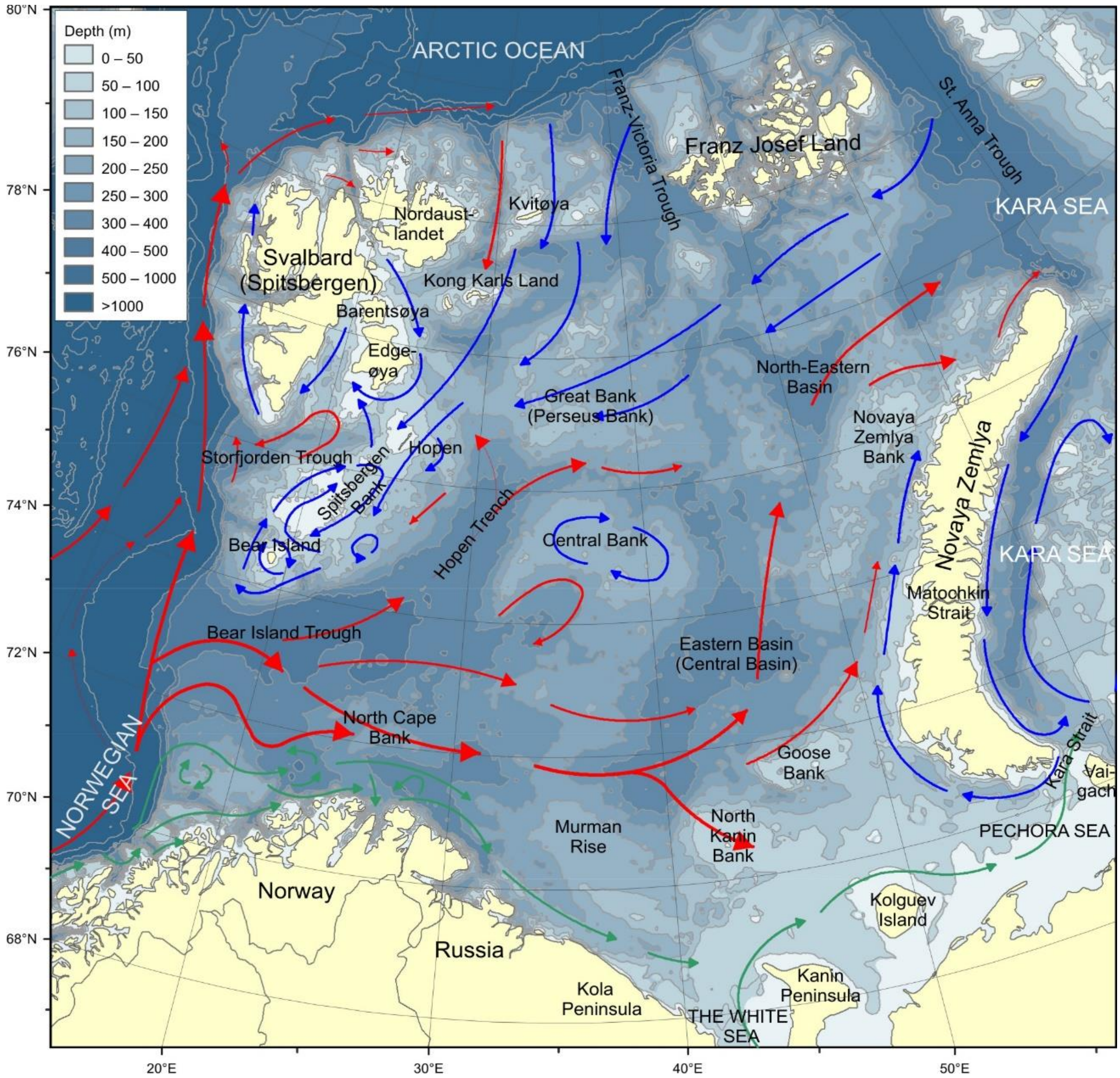

Figure 1. The influx from southwest of warm Atlantic waters into the southern and central Barents Sea and along the west coast of Svalbard is shown with red arrows. The influx of cold Arctic water from northeast is shown with blue arrows. The highly productive mixing zone between the warm Atlantic and cold Arctic waters I called the Polar Front. This mixing zone very precisely define the norther limit of harbour porpoise in Norwegian waters.

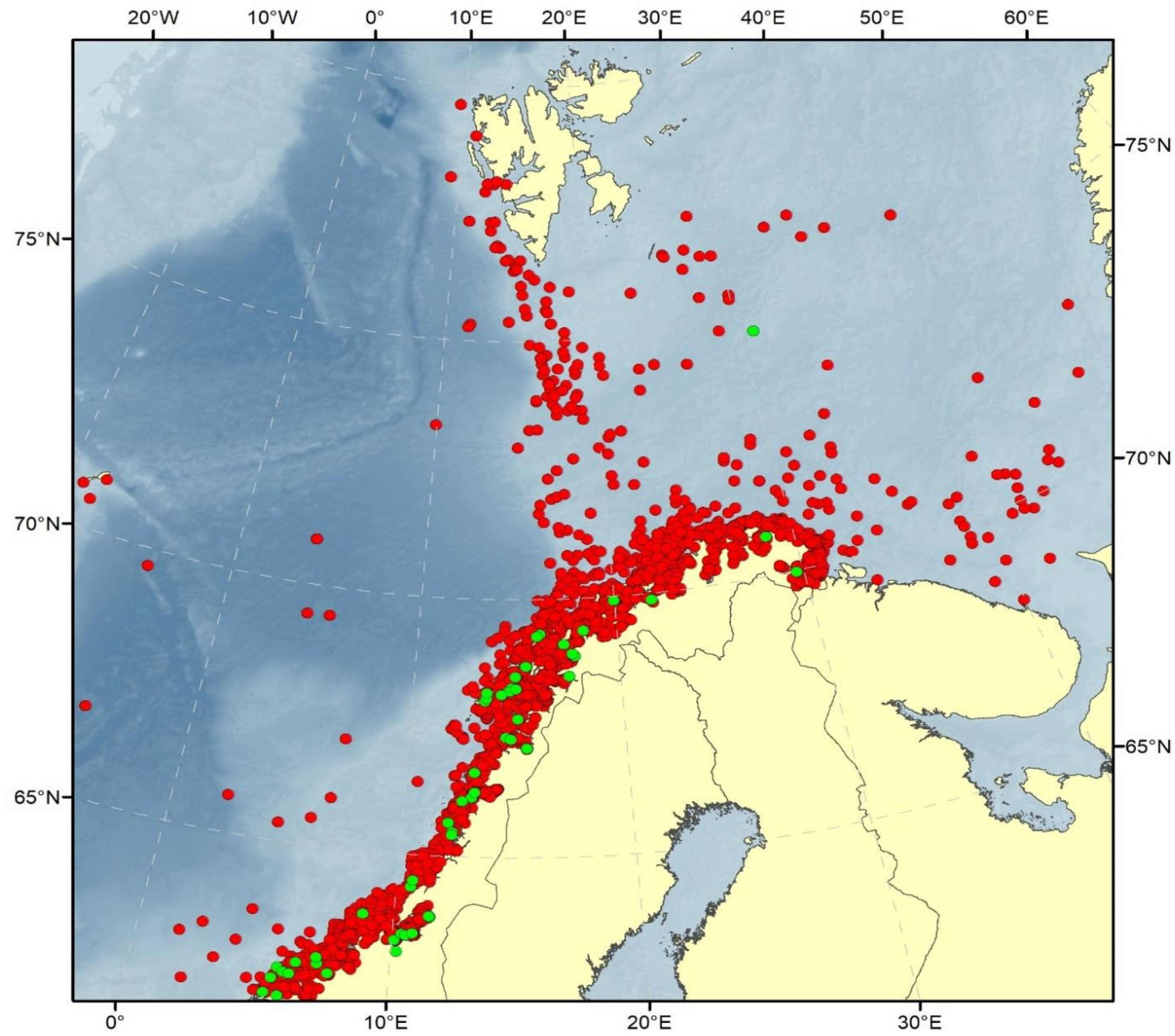

Figure 2. Sightings of harbour porpoise in Norwegian waters north of 62°N and Russian waters. Red dots are live porpoises, green dots are dead porpoises.

<u>Robust estimates of abundance, e.g. from line transect sampling</u>

There is no abundance estimate available for the entire assessment area. In 2016 the coastal waters from 62°N to the Lofoten Islands (including the two fjords Vestfjorden and Trondheimsfjorden) were surveyed by an aircraft as part of the SCANS III survey. A total of 4448.1 km of search effort in good or moderate conditions were included in the analysis. The abundance for this area was estimated at 24,526 porpoises (CV 0.28 CL low 14,035 CL high 40,829) (Hammond *et al*. 2017). The flown transects and observations of porpoises are shown in Figure 3.

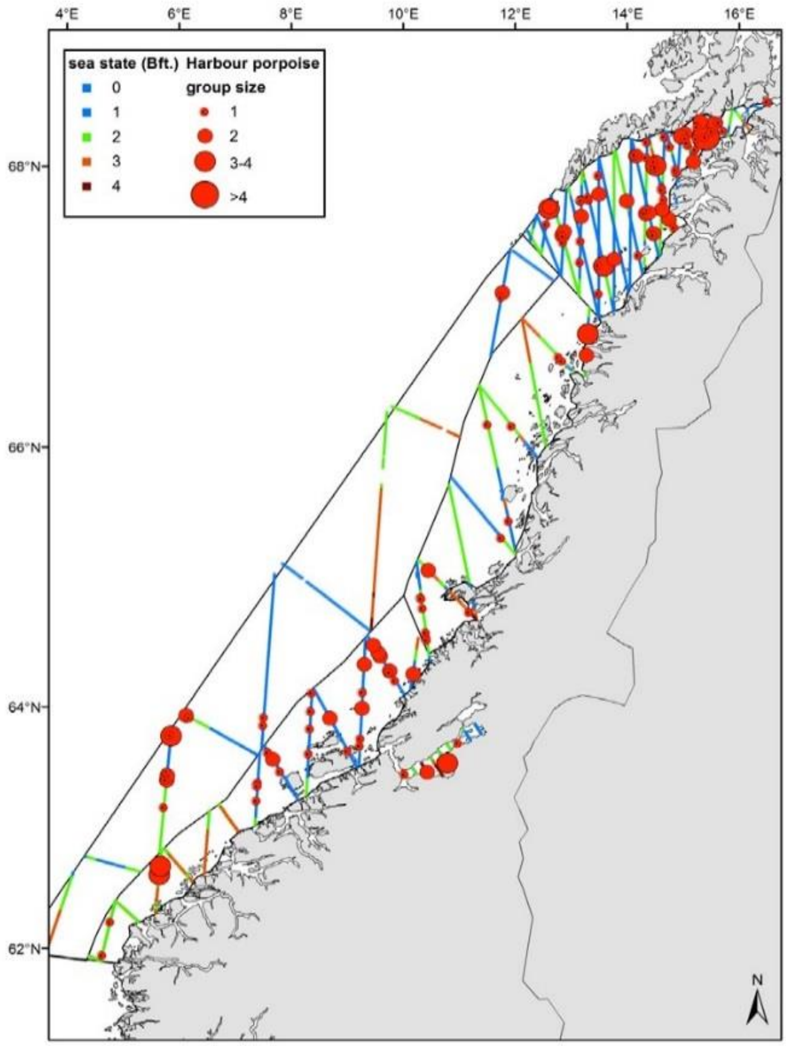

Figure 3. Transects flown in 2016 as part of SCANS III and observations of harbour porpoises.

The ship-borne Norwegian line-transect surveys designed for abundance estimation of minke whales also provides data for estimation of porpoise abundance. However, these surveys do not cover fjord waters and the survey design is not optimal for porpoises. In the survey period 2002-2007, the abundance in the Barents Sea was estimated to 55,394 and 30,352 porpoises in the Norwegian Sea (Figure 4).

An old estimate of 10 100 porpoises (CV 0.45 CL 4 379 – 23 200) is available for the offshore areas from Lofoten and further north into the Barents Sea based on sightings from Norwegian line transect surveys designed to estimate abundance of minke whales. (Bjørge & Øien 1995). This estimate is not corrected for *g(0),* and is therefore an underestimate.

The SCANS III Survey showed that abundances of porpoises were high in fjord waters e.g. inner part of Vestfjorden and central parts of Trondheimsfjorden. Nils Øien has surveyed some fjords including Varangerfjorden and Vestfjorden by ship. The observations shown in Figure 5 confirm high density of porpoises in these fjords. He has also surveyed fjords south of 62°N and he found consistently high density in nine fjords and very high density in one fjord (Hardangerfjorden). According to Øien (pers. comm.) the density was several times higher in the fjords than in the open North Sea (Figure 6).

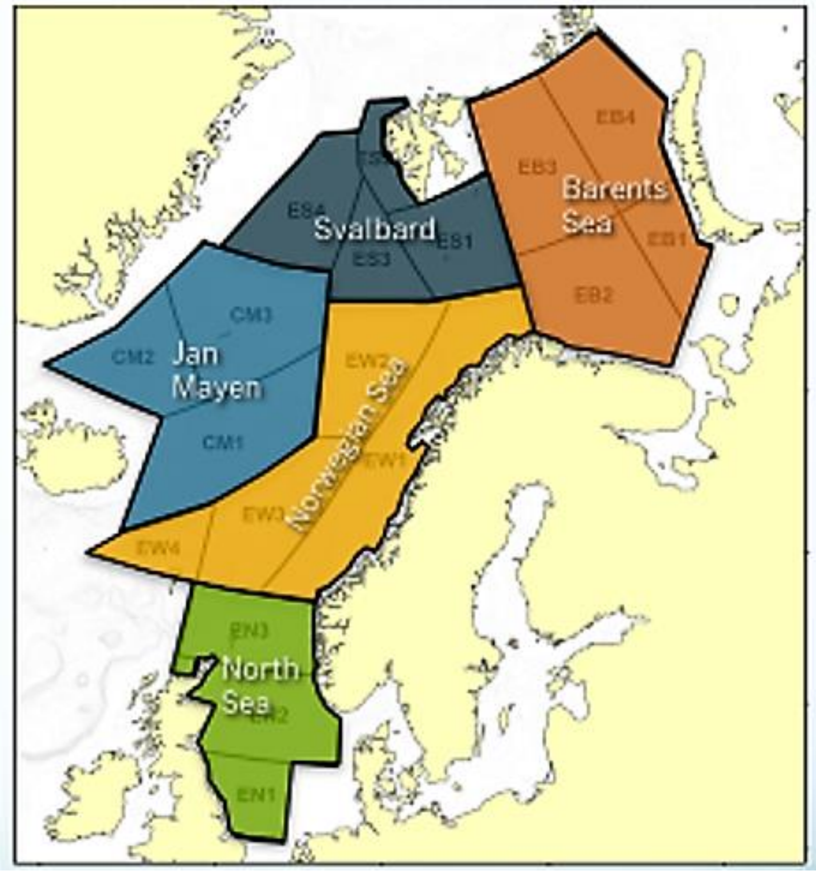

Figure 4. The Norwegian shipborne line-transect surveys designed for abundance estimation of minke whales provide data for estimation of harbour porpoise abundance. The abundance in the Barents Sea (brown area) was estimated to 55,394 and 30,352 porpoises in the Norwegian Sea (yellow area) in the period 2002-2007.

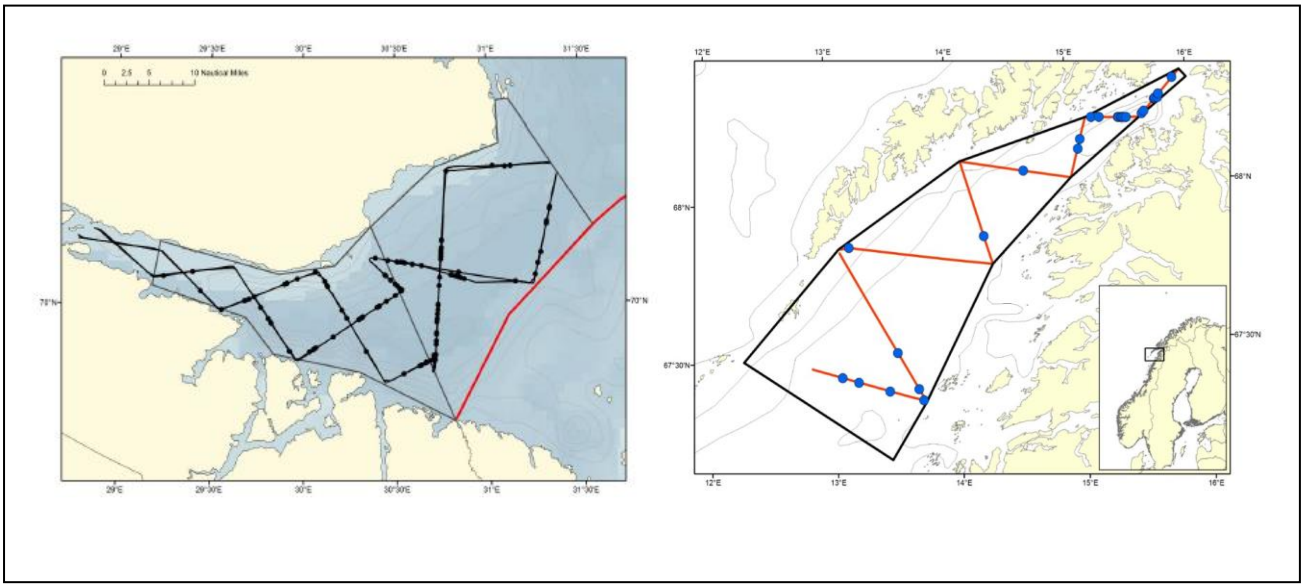

Figure 5. Ship track lines and observations of harbour porpoises in Varangerfjorden (left panel) and Vestfjorden (right panel). Data from Nils Øien.

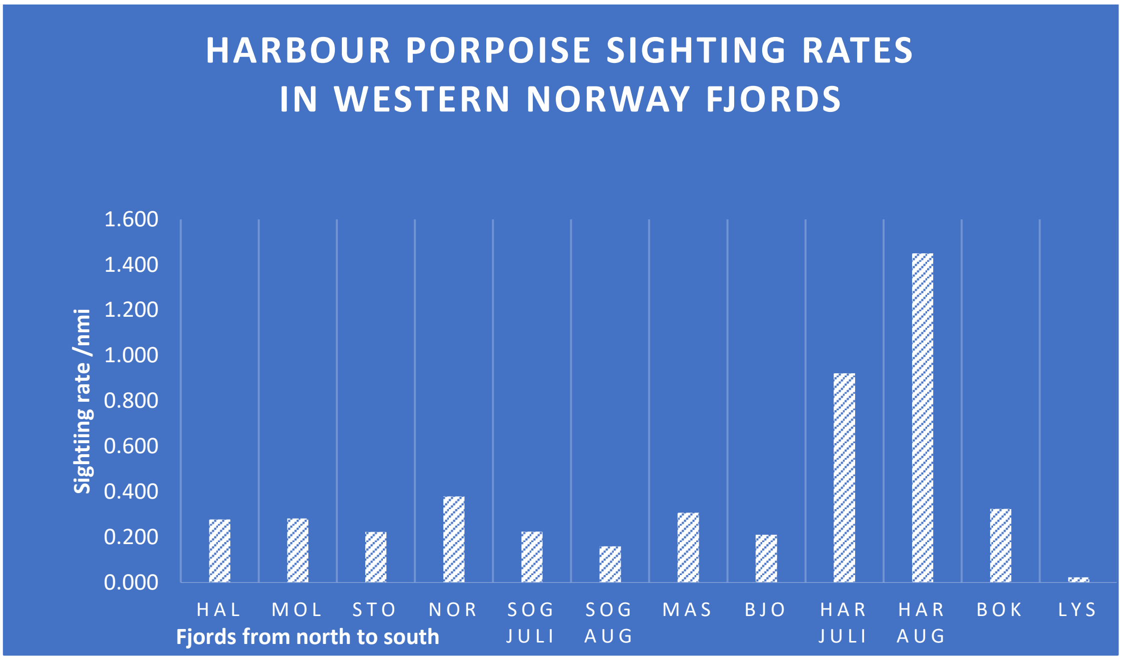

Figure 6. Harbour porpoise sighting rates in eleven fjords in Western Norway. Data from Nils Øien.

Trends in relative abundance

There exists no trend information for harbour porpoise abundance from the Norwegian waters north of 62ºN. No information was available from Russian waters.

3. Anthropogenic removals in time and space

Hunting statistics (including struck/lost) with uncertainties, where available

The harbour porpoise is protected in Norway. There is therefore no hunting statistics from Norway. No information was available from Russian waters.

By-catch estimates with uncertainties, where available

Data collected by 40 vessels in the Coastal Reference Fleet (CRF) were used to estimate the average annual by-catch rate of harbour porpoises in the Norwegian gillnet fisheries targeting cod and monkfish for the years 2006 – 2015. Fishing trips targeting cod and monkfish were extracted from the rest of the data set based on reported gear use. The remaining fishing trips were assigned to either the cod or the monkfish fishery based on the mesh size of the gears used. Gillnets with a mesh size of 180 mm were defined as monkfish gears. Gillnets with a mesh size between 76 and 105 mm were defined as cod gears.

Fish landed per fishing trip were used as a measure of fishing effort. The by-catch rate was calculated as the ratio between number of harbour porpoises taken and total landed cod/monkfish by weight. Observations that lacked effort data were discarded. Takes of harbour porpoises and fishing effort were aggregated by all combinations of areas (Figure 7) and months. By-catch rates were then calculated separately for the two fisheries

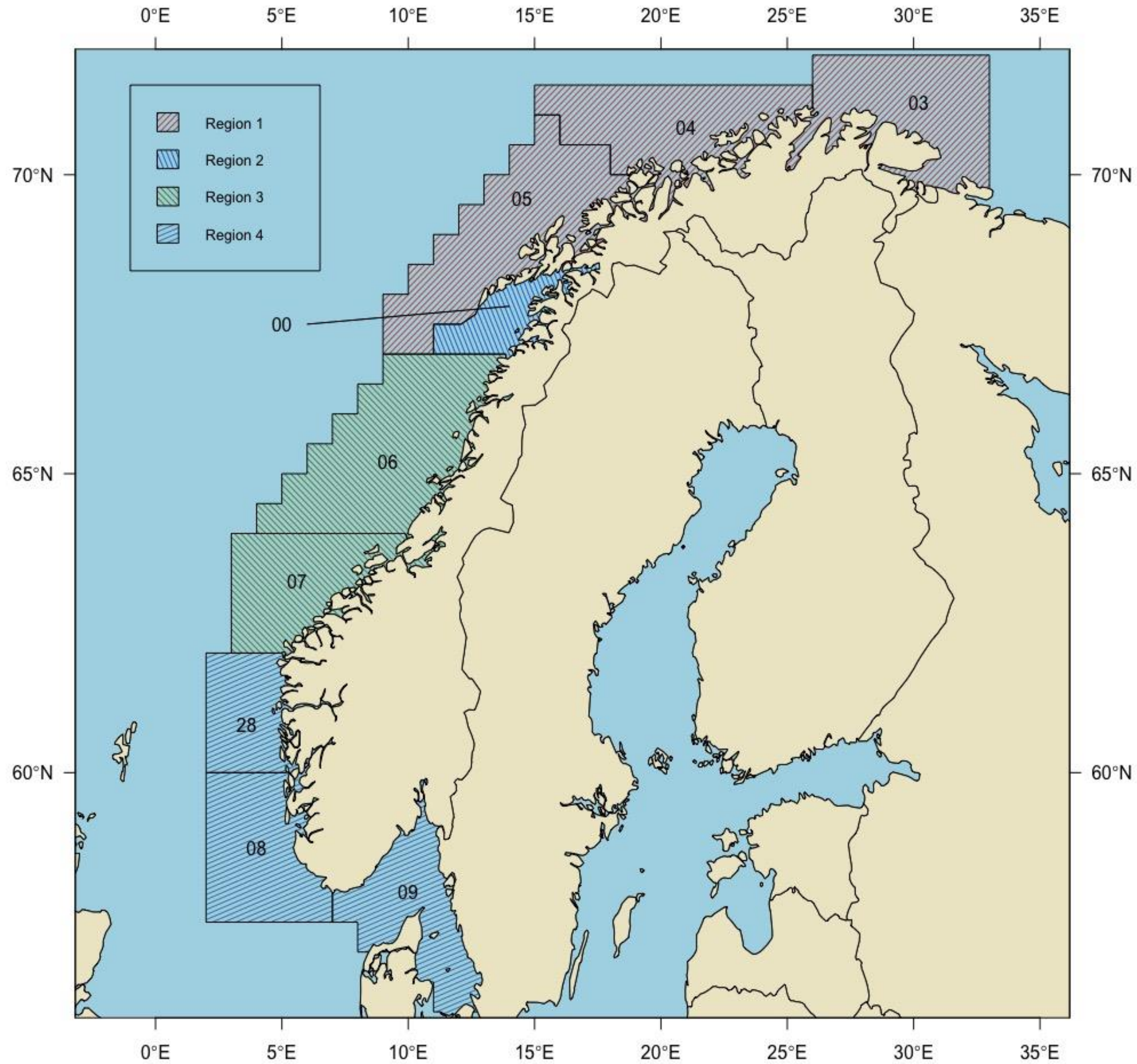

Figure 7. Spatial stratification of the study region into nine fishery statistics areas (denoted by numbers) and four regions (shaded).

These rates were then applied to the corresponding landing data for the whole commercial coastal fishing fleet of about 6000 vessels less than 15 m overall length. Predicted by-catch in the cod and monkfish fisheries were then summed.

Confidence intervals were calculated using a stratified bootstrap procedure with 1000 replications. In each replication, observations were resampled with replacement within each area, and new estimates were calculated from these new samples in the same manner described above. Confidence intervals were calculated from the quantiles of the resulting distribution of predicted values.

By-catches in areas 03, 04, 05, 00, 06 and 07 and Regions 1, 2 and 3 are relevant for this Area Status Report.

Table 1 lists the by-catch estimated for each of the nine fishery statistical areas and for the four regions. These are yearly averages over 10 years of data. Areas 03, 04, 05, 00 06 and 07, and Regions 1, 2 and 3 correspond to the Norwegian coast north of 62ºN

Table 1. Predicted annual by-catch per area and per region with associated CVs and 95% confidence intervals.

Area	Estimate	CV	95% CI
03	11	1.05	0 – 40
04	103	0.17	71 – 139
05	299	0.13	224 – 375
00	656	0.14	503 - 842
06	432	0.21	288 – 663
07	472	0.10	383 – 568
28	159	0.32	83 – 312
08	87	0.33	45 – 156
09	82	0.40	40 – 146
Region	**Estimate**		**95% CI**
1	413	0.11	328 – 501
2	656	0.14	503 – 842
3	904	0.12	733 – 1156
4	328	0.23	229 – 509

Age structure removal information

The age distribution of 120 females collected in 1988-1990 on the Norwegian coast (N=56) and Swedish west coast (N=64), and 75 males from the Norwegian coast is shown in Table 2.

Table 2. Age distribution of 120 female and 75 male harbour porpoises by-caught in Norway and Sweden in 1988-1990.

Age	0	1	2	3	4	5	6	7	8+
Females	15	36	27	13	8	3	6	1	7
Males|	12	19	6	12	5	5	7	2	7

Trends in relative by-catch rates

Time series of annual by-catches are presented in separate excel sheets.

4. Impacts from other indirect (sub-lethal) pressures

Concentrations of 47 trace elements were quantified in the muscles and livers of 134 harbour porpoises sampled along the coast of Norway in 2016 and 2017. Preliminary results suggest relatively low concentrations of hazardous elements in the muscles and livers of Norwegian porpoises compared with other areas. Increasing levels of Cd and As determined in populations from northern part of Norway could be related to their distinct feeding preferences. Significant relationships of Hg with Ag and Li were found in hepatic and muscle tissue, whereas Se was significantly correlated with most of toxic elements such as Ag, Cd, Hg, Pb, Sn. Statistically significant negative relationships for Cu between Ag and Cd were probably related to competitive binding to metallothionein. The body length was found to be significantly related to Ag, Au, Bi, Cd, Ce, Co, Cs, Hg, Mo, Nd, Pb, Pr, Sb, Se, Sm, Sn, V, Zr, whereas Ca and Cu revealed negative significant relationship. The differences between females and males were found for several elements. Au, Ag, As, Cu Ba, Cs in liver and Ti, Cu, Sb, Rb in muscle was higher in females than males, whereas males had higher content of Se and Ni in liver and Sn in muscle. Hepatic tissue reached commonly higher concentration than muscle with exception of Al, Cr, Cs, K, Mg and Ni. The values obtained from spatial differences demonstrate that there is a large variability in the accumulation of essential and toxic metals.

The concentrations of Hg and Se (Teigen *et al*. 1993) and PCBs and DDTs (Kleivane *et al*. 1995) were also analyzed in harbour porpoises by-caught in Norwegian, Swedish, and Danish waters in 1988-1990. Kleivane *et al*. (1995) found a declining northward trend in total PCBs and total DDTs, but the highest concentartions of chlordane metabolites were found in a group of porpoises from Tufjord in Finnmark.

5. LIFE-HISTORY PARAMETERS AND HEALTH STATUS

Life history parameters of Harbour porpoises from Northern Norway 2016-17

Updated estimates of life history parameters are available from 133 harbour porpoises (*Phocoena phocoena*), incidentally by-caught in coastal fisheries in Northern Norway during autumn 2016 and spring 2017 (Table 3). The study area is located between 59°N and 71°N and most animals were by-caught either in Vestfjorden (2016) or Varangerfjorden (2017). The combined sample comprised a total of 58 females and 75 males.

Asymptotic length of females based on a Gompertz growth curve was estimated at 165.2 (155.7-176.9). This is considerably larger than for most other populations, but associated with large uncertainty due to absence of females older than 7 years in the material. The age distribution of males was less truncated with individuals up to the age of 12 years. The estimated asymptotic length of males was 149.0 (145.4-152.8), which is similar to estimates for other populations (e.g. Lockyer, 2003).

Forty-eight females had complete reproductive data records. For these, age at sexual maturity was estimated based on age specific proportions of females with a foetus or a *Corpus albicans* (CA) using fitted Richards maturity curves based on Frie et al. (2012) (Table 4). The estimated value was 4.3±0.6 years. Pregnancy rate was calculated as the proportion of females with a foetus among all females with a foetus or a CA. The total sample size was 20 individuals of which 85% had a foetus.

Males were considered sexually mature if they had a combined testes weight ≥200 g. Visual examination of a plot of testes weights versus age resulted in an estimated male age at sexual maturity of 2-3 years.

Table 3. Reproduction parameters of harbour porpoises from Northern Norway 2016-17.

Area: Northern Norway 2016-17	Value (CI if available)	Sampling period	Sample size	Method used*	Reference
Newborn length (cm)	Not analysed	Sept-Oct 2016 Feb-Apr 2017			
Female ASM ± SE/SD (yrs)* Female maximum age (yrs)	4.3 (±0.6) cm 7 years		48 48	Age specific proportions with a fetus or a CA Stained thin sections	Frie et al. (2012) Lockyer (1995a)
Male ASM ± SE/SD (yrs)*	2-3 years (No SE/SD)		75	Combined testes weight≥200 g	Lockyer (1995b)
Male maximum age (yrs)	12 years		75		
Female LSM ± SE/SD (cm)*	Not analysed				
Female maximum body length (cm)	173 cm		58		
Male LSM ± SE/SD (cm)*	Not analysed				

Male maximum body length (cm)	158 cm		75		
Female asymptotic length at physical maturity ± SE/SD (cm)*	165.2 (155.7-176.9)		58	Gompertz growth curve	Lockyer (2003)
Male asymptotic length at physical maturity ± SE/SD (cm)*	149.0 (145.4-152.8)		75	Gompertz growth curve	Lockyer (2003)
APR (%)	0.85 ± 0.16		20		Lockyer (2003)
Ovulation rate/yr	Not available				
Gestation period (yrs)	Not analysed				
Lactation period (yrs)	Not available				
Resting period (yrs)	Not available				
Calving interval (yrs)	Not available				
Calving season	~June-July			Qualified guess based on fetus appearances in september-october	
Mean birth date	Not available				
Mating season – Activity of mature males	Not available				
Mating season – Ovulation/conception period in females	Not available				
Mean conception date in females	Not available				

Table 4. Maturity ogive for female Norwegian Harbour porpoises 2016-17. Model = Richards' maturity curve.

Age	N total	N mature	N mature / N total	Model
0	3	0	0	0.00
1	13	0	0	0.00
2	8	0	0	0.00
3	8	1	0.13	0.13
4	8	6	0.75	0.71
5	7	6	0.86	0.90
6	1	1	1	0.97
7	3	3	1	0.99
8				1.00

6. DIET AND PREY AVAILABILITY

The feeding ecology of harbour porpoises (HP's) in Norwegian waters has not been studied since the studies of Aarefjord et al. (1995) in 1990. Here we present preliminary diet results from 134 harbour porpoises (Saint-Andre et al. in prep), incidentally caught in gillnets in Norwegian coastal waters in autumn 2016 and spring 2017 (Figure 8).

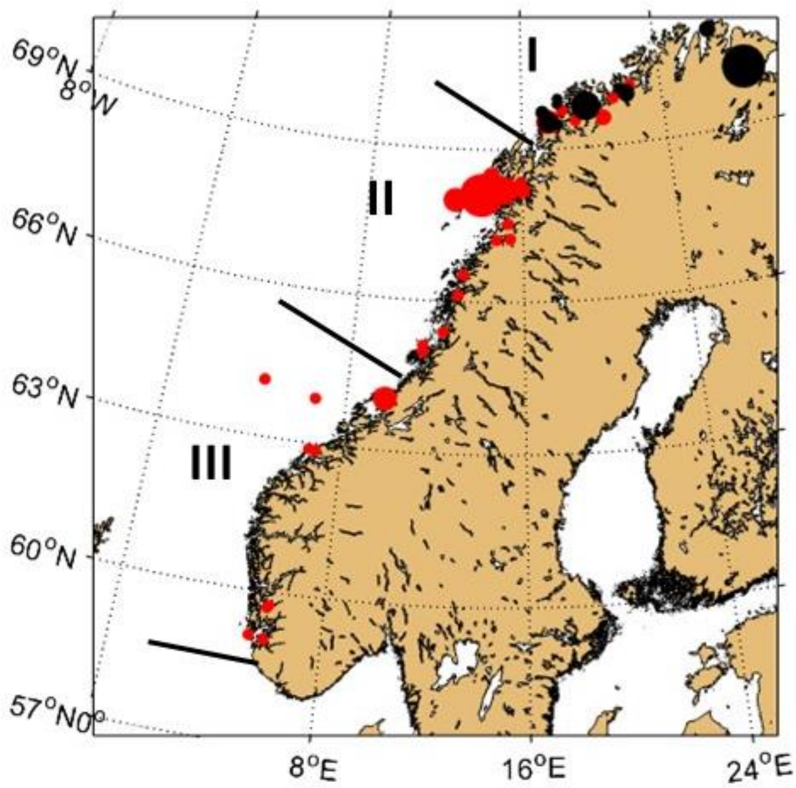

Figure 8. Sampling locations of HPs caught in gillnets along the Norwegian coast in September-October 2016 (red circles) and February-April 2017 black circles). The size of the circles is proportional to the number of animals.

The stomach contents show that saithe is by far the most important prey (53-85%), in terms of biomass (Figure 9) followed by capelin (15%), blue whiting (15%) and herring (6%) in areas 1, 2 and 3, respectively. The relatively small spatial variability in diet composition, based on the stomach contents, is also supported by the stable isotope (SI) analysis (not presented here), suggesting that HP prey use is relatively homogenous in both time and space.

This study supports a previous diet study (Aarefjord & Bjørge 1995) in that HPs feed almost exclusively on fish. However, the prey composition in these studies differ. In contrast to our study, in which saithe dominated in all areas, capelin, poor cod and saithe dominated in areas 1, 2 and 3, respectively. This appears to be in line with prey resource situation in the 1980's, when the saithe stock was at a much lower level compared with today; the spawning stock biomass was ca. 5 times lower than today (ICES 2017). It should be mentioned that the SI results of this study varied less in space compared with a previous study (Fontaine et al. 2007), which displayed significant spatial heterogenity.

The resource availability situation in Norwegian coastal areas (including fjords), from 62˚N to the Russian boarder, has been assessed annually since 1995. These data are not available as of today.

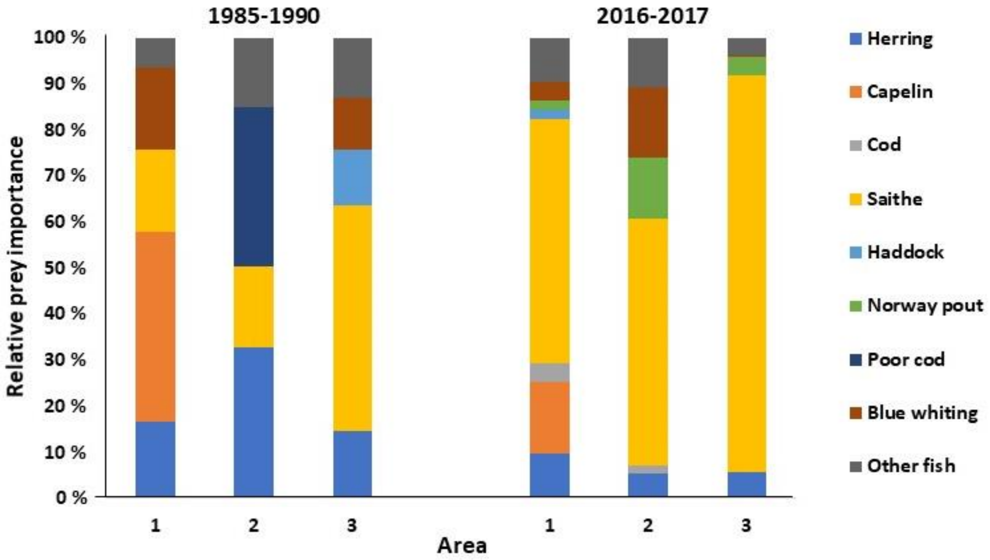

Figure 9. Relative prey importance, in terms of biomass, of harbour porpoises in three areas along the coast of Norway in the periods 1985-1990 (Aerefjord and Bjørge 1995) and 2016-2017 (Saint-Andre *et al*. in prep).

7. KNOWLEDGE GAPS AND UNCERTAINTIES IN ASSESSMENT PARAMETERS

The current estimates of abundance of harbour porpoises in Norwegian coastal waters north of 62ºN and Russian waters are primarily based on offshore ship line transect surveys designed for estimating abundance of minke whales. The sampling design is therefore not optimal for harbour porpoises and abundance estimates from Norwegian fjords are still missing. Data from a limited number of surveys have shown higher densities of porpoises in fjords than observed in the open waters of the North and Barents Seas. A study is underway to develop methods for combining data from several different sources (ship-based surveys with two independent platforms, aerial surveys, small boat surveys with one platform, and drone data) for estimating abundance in fjord waters. Adding abundances from fjord waters has the potential to increase the total abundance by approximately 15%.

The by-catch estimate is based on data from two gillnet fisheries, bottom set gillnets for cod and monkfish. These fisheries are assumed to be the most important for by-catch of harbour porpoises in Norway. However, the current estimate should be regarded as a minimum estimate of by-catch as there are other gillnet fisheries with potential for harbour porpoise by-catch, such as the fishery for saithe, lunpsucker and halibut. We are currently exploring the possibility to obtain by-catch data from these fisheries.

There are several assumptions associated with using landings of target species as a proxy for effort when estimating fleet-wide by-catch from reported numbers, and some of these assumptions are violated in the current estimates from Norwegian waters. Effort reporting is not mandatory for vessels less than 15 m overall length, and an estimate of effort is therefore lacking for this smaller category of fishing vessels. The Directorate of Fisheries is currently exploring automated, electronic means for effort reporting from small vessels. If direct effort data become available, the accuracy and precision of the by-catch estimates will improve.

8. MONITORING REQUIREMENTS, RESEARCH PRIORITIES AND OPPORTUNITIES FOR COOPERATION

The current monitoring of by-catch in cod and monkfish fisheries is required to continue and be expanded to cover also other commercial fisheries with large mesh gillnets. A restricted number of gillnets are also allowed in leisure fisheries in Norway and there is a demand to develop methods for monitoring by-catch in these fisheries.

Research on developing methodology to combine data from different sources (ship-based surveys with two independent platforms, aerial surveys, small boat surveys with one platform, and drone data) for estimating abundance of harbour porpoises in the complex Norwegian fjord waters should be prioritized. Cooperation between IMR, the Norwegian Computing Centre, Universities of Bergen, Tromsø and St Andrews is adviced.

Initial experiments with acoustic alarms (pingers) on gillnets show a 70% decrease of porpoise by-catches. The simulation for estimating the effect of deployment of pingers on different proportions of the Norwegian gillnet fisheries should be continued and actual experiments carried out.

9. ASSESSMENT UNIT STATUS

The PBR for Norwegian waters north of 62°N is about 700 and current estimates of by-catch exceed this level. This means that the population is expected to decline under the current regime. The population status in 2016 is 84% of the initial population size in 2006 when by-catch monitoring started. If the by-catch in the period 2016-2025 is equal to the average of the three last years of annual estimates, the decline will continue. The population status in 2025 will then be 79% of the initial abundance in 2006.

However, abundance estimates from Norwegian fjord waters are still not available. A few surveys report higher densities of porpoises in fjords than observed in the open waters of the North and Bartens Seas. Abundance estimates from fjord waters have the potential to increase the total abundance and therefore also the PBR by about 15%.

Initial experiments with acoustic alarms (pingers) on gillnets have demonstrated a 70% reduction of harbour porpoise by-catch. The pinger experiments will be continued with more pingers and more vessels included. The use of pingers has the potential to bring Norwegian by-catch within the limits of PBR.

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JOINT IMR/NAMMCO INTERNATIONAL WORKSHOP ON THE STATUS OF HARBOUR PORPOISES IN THE NORTH ATLANTIC

Area Status Report

West Scotland/Ireland & Celtic and Irish Seas

Compiled by S. Murphy[1], F. Caurant[2], P.G.H. Evans[3], J. Tougaard[4], and P.S. Hammond[5]

[1] *Galway-Mayo Institute of Technology, Ireland*
[2] *Centre d'Etudes Biologiques de Chizé, France*
[3] *Sea Watch Foundation/Bangor University, UK*
[4] *Aarhus University, Denmark*
[5] *University of St. Andrews, UK*

1. IDENTIFICATION OF ASSESSMENT UNITS WITHIN EACH SUB-AREA

One continuous harbour porpoise population has been reported to exist ranging from waters off Norway to the northern Bay of Biscay based on genetic analysis of 10 microsatellite loci and 752 individuals (Fontaine et al. 2007). Fontaine et al. (2014, 2017) reported significant isolation by distance within the region, i.e. increasing genetic differentiation with geographic distance that was more apparent in the southern extent of their range. A distinct sub-species *Phocoena phocoena meridionalis* of a larger-sized morphotype has been proposed, with two genetically distinct populations inhabiting Iberian and Mauritian waters (Fontaine et al. 2014).

The ASCOBANS/HELCOM small cetacean population structure workshop considered "*a few generations (equivalent to low tens of years) as the appropriate time frame for defining a management unit, and we identify a MU as a group of individuals for which there are different lines of complementary evidence suggesting reduced exchange (migration/dispersal) rates*", i.e. a maximum of 10% migration per generation (Evans and Teilmann 2009). Within the North-east Atlantic, the ICES WGMME (2013, 2014) delineated five management units (MU) (or assessment units (AU) under the MSFD), including the (1) Kattegat and Belt Seas, (2) North Sea, (3) West Scotland, (4) Celtic and Irish Seas (including French Atlantic waters), and (5) Iberian Peninsula (see Figure 1a). Delineations of the five MUs/AUs were based partially on genetic analysis as well as measurements of time-integrated ecological tracers and morphological differences – though limited data were available from porpoises inhabiting waters off the west of Scotland and delineation was based more on the extent of anthropogenic activities (IAMMWG 2015). More recent genetic analysis further supported separation of porpoises in the Celtic Sea and French Atlantic waters, with the Irish Sea as a transition zone between admixed and non-admixed North Sea porpoises. However, the genetic analysis did not justify a western Scotland AU based on genetic structure alone (Fontaine et al. 2017). Both Fontaine et al (2014) and Fontaine et al (2017) showed no genetic distinction between the porpoises from the Atlantic coasts of Ireland and North-Western Scotland.

Abundance and occurrence of harbour porpoises have fluctuated over the last 100 years within the North-east Atlantic. A decline in both strandings and observations occurred in the southern North Sea, English Channel and French Atlantic coasts from the 1950s onwards (Smeenk 1987, Evans 1992, Addink and Smeenk 1999, Camphuysen 2004, Evans et al. 2008, Jung et al. 2009). Within the last two decades porpoises started to return again to these waters, which included a re-distribution of animals from the northern to the southern North Sea, as well as the re-population of central English Channel and waters off the French Atlantic coast (Camphuysen 2004, Hammond et al. 2013, Hammond et al. 2017, Laran et al. 2017). Alfonsi et al. (2012) and Fontaine et al. (2014, 2017) analysed samples from 'French' porpoises using both mtDNA and microsatellite markers from animals that stranded between 2000 and 2010 and results suggested that porpoises from the French Atlantic, Celtic and Irish Seas were an admixture of individuals from waters further north (northern ecotype), as well as the Iberian-Mauritian sub-species (southern ecotype). The extent of this contact zone for admixed individuals extends into waters off the southwest coast of the UK, where porpoises were found to be genetically admixed and of a larger body size compared to other regions around the UK - using samples collected between 1990 and 2002 (Fontaine et al. 2017). More recent unpublished analyses undertaken by Murphy et al. in prep. assessing variations in life history parameters among AUs in English and Welsh waters using data collected between 1990 and 2013 reported that harbour porpoises in the Celtic and Irish Seas were significantly larger in asymptotic length compared to animals inhabiting the North Sea. Porpoises in the Celtic and Irish Seas also were a significantly larger size at attainment of sexual maturity (L50) compared to the North Sea, and this was evident in both sexes. Whereas no significant variation in the age at attainment of sexual maturity (A50) was observed among AUs.

Based on the newly available genetic and biological data, a re-delineation of the boundaries of the Celtic and Irish Seas AU and the Western Scotland AU is proposed, with the former now confined to the region of the admixed individuals, including waters of the Celtic Sea and Western France, and the latter now including waters west of Ireland. The Irish Sea is defined as a zone of uncertainty pending further analysis. For the purposes of the assessment (see section 9), the Irish Sea was combined with the Celtic Sea, western English Channel and French Atlantic waters. The two proposed AUs are therefore: (1) Celtic & Irish Seas, and (2) West Scotland/Ireland (Figure 1b).

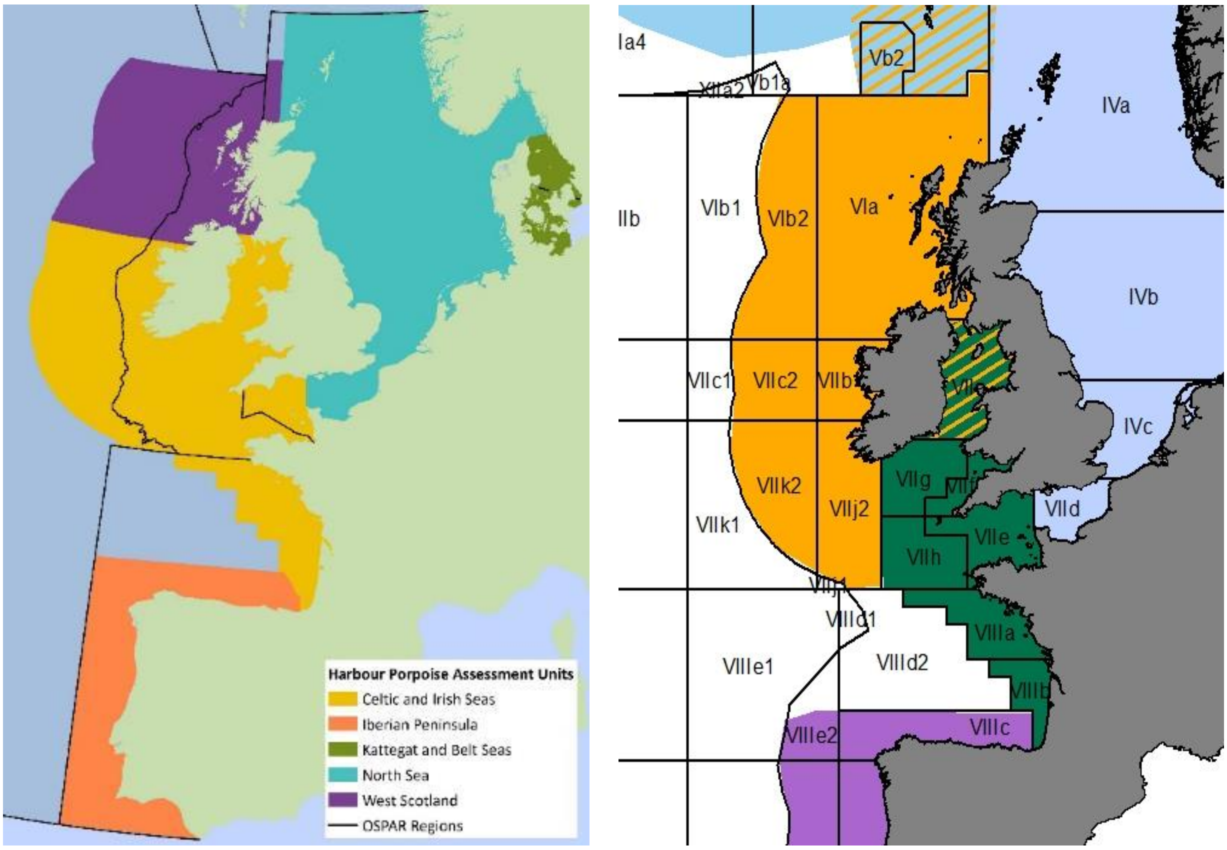


Figure 1. (a) Assessment units used within the OSPAR Intermediate Assessment (IA 2017). Taken from ASCOBANS (2018). (b) Revised boundaries for the AUs including West Scotland/Ireland (yellow), the Celtic Sea and western France (green) and the zone of uncertainty of the Irish Sea (green and yellow stripes).

2. DISTRIBUTION, ABUNDANCE AND TRENDS

Data

Data that have been used to provide robust information on distribution and abundance of harbour porpoise at the scale of the West Scotland, and the Celtic and Irish Seas Assessment Units in European Atlantic waters (as defined by OSPAR IA 2017) come from a relatively limited number of sources.

The approximately decadal series of multinational SCANS surveys were systematically designed to generate estimates of cetacean abundance and provide information on distribution in summer at a large spatial scale (Hammond et al. 2002, CODA 2009, Hammond et al. 2013, Hammond et al. 2017). The focus of the original 1994 SCANS survey was to estimate the abundance of harbour porpoise and other small cetaceans in the North Sea and adjacent waters (English Channel and Celtic Sea). In 2005, SCANS-II extended the survey area to all European Atlantic shelf waters and, in 2007, CODA extended coverage to all species of cetacean in offshore waters (as much of the EEZs of the UK, Ireland, France and Spain as possible). The most recent SCANS-III survey in 2016 covered effectively the same area as SCANS-II/CODA combined, except (a) coverage was extended for the first time to Norwegian coastal waters and (b) waters around western and southern Ireland were not covered because these were the focus of the Irish ObSERVE aerial surveys in 2015 and 2016 (Rogan et al. 2018).

Surveys conducted as part of the SAMM project covered French Atlantic national waters (English Channel and Bay of Biscay) in winter 2011/2012 and summer 2012 (Lambert et al. 2017, Laran et al. 2017). Surveys of the west Scotland area conducted between 1993 and 2010 have been analysed to investigate distribution (Marubini et al. 2009, Booth et al. 2013).

Data from many small-scale studies have been used to estimate harbour porpoise abundance in various sectors of European Atlantic waters. Although these are of regional value, they do not provide useful information at the larger scale of West Scotland/Ireland, and the Celtic and Irish Seas assessment areas and are not considered explicitly here.

However, some of these data have been used, in addition to data from larger scale surveys, in three analytical studies of distribution and abundance at a large scale (Heinänen and Skov 2015, Paxton et al. 2016, Waggitt et al. in prep.). These studies included data from small scale and/or opportunistic studies from various sources including European Seabirds at Sea surveys, regional NGO surveys, surveys conducted on platforms of opportunity such as ferries, and surveys conducted on behalf of energy companies.

Estimates of abundance

The most complete estimates of abundance for West Scotland/Ireland and the Celtic and Irish Seas assessment areas come from the SCANS surveys in 1994, 2005 and 2016 and the ObSERVE surveys in 2016 (Irish waters) (Table 1). The estimates of abundance for the revised AUs were used in the assessment.

No difference was observed in the estimated abundance of harbour porpoises within the West Scotland or West Scotland/Ireland areas between the SCANS II and III surveys, undertaken in 2005 and 2016, respectively. However, estimated abundance in the ICES/OSPAR Irish and Celtic Seas AU and the newly proposed Celtic and Irish Seas AU differed markedly between 2005 and 2016. Estimates in 2016 were 50% and 40% of the 2005 estimates in the original ICES AU and newly proposed revised AU, respectively, with CVs in the range 0.19 - 0.34. The reasons for this difference are unknown but could include a re-distribution of animals with the wider NE Atlantic population and/or increased mortality due to by-catch.

Table 1. Estimates of harbour porpoise abundance in the Greater North Sea, West Scotland, and the Celtic and Irish Seas areas in summer. Estimates in italics are for part of the area.

Year	Area	Survey	Abundance	CV
1994	ICES *West Scotland (part)* AU	*SCANS*	*9,151*	*0.24*
2005	ICES West Scotland AU	SCANS-II	26,300	0.37
2016	ICES West Scotland AU	SCANS-III	24,370	0.23
1994	ICES *Irish & Celtic Seas (part)* AU	*SCANS*	*57,217*	*0.52*
2005	ICES Irish & Celtic Seas AU	SCANS-II	107,344	0.30
2016	ICES Irish & Celtic Seas AU	SCANS-III + ObSERVE	53,336	0.24
2005	Revised AU West Scotland/Ireland	SCANS-II	44,976	0.317
2016	Revised AU West Scotland/Ireland	SCANS-III + ObSERVE	42,920	0.151
2005	Revised AU Celtic & Irish Seas	SCANS-II	88,696	0.339
2016	Revised AU Celtic & Irish Seas	SCANS-III + ObSERVE	35,232	0.192

The French SAMM project estimated the abundance of harbour porpoise in the English Channel (partly in the North Sea and partly in the Celtic and Irish Seas areas) to be 17,829 (CV=0.30) and 18,429 (CV=0.30) in winter and summer, respectively.

Some information on changes in relative abundance is available from strandings data. An increase in observed strandings of harbour porpoises along French coastlines was observed from the late 1990's onwards, reaching a peak in the year 2013 (Figure 2) (Dars et al. 2018). In 2017, the harbour porpoise was the second most frequently reported stranded cetacean species on the French Atlantic coast (Bay of Biscay) (6.7% of (1211) stranded individuals) and the most frequently reported species on the French Channel coast (74.1% of (307) stranded individuals) (Dars et al. 2018).

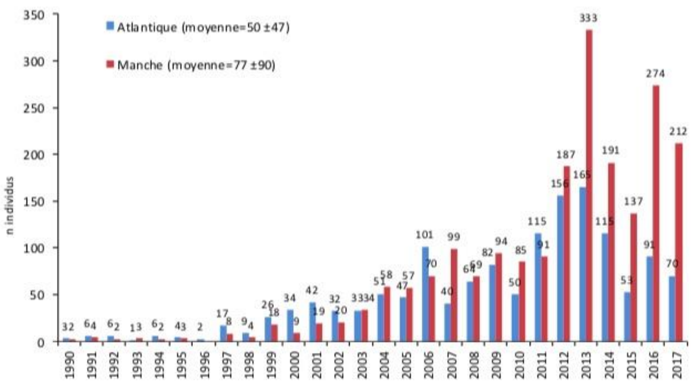


Figure 2. Annual strandings of harbour porpoises along the French Atlantic coast (Bay of Biscay, in blue) and French Channel coast (in red) from 1990 to 2017. From Dars et al. (2018).

Distribution

In the West Scotland area, Booth et al. (2013) modelled visual and acoustic data from 2003-2010 (Figure 3). The analysis found consistent preferences for water depths between 50 and 150 m and highly sloped regions. Presence was predicted inshore throughout the west of Scotland and the authors concluded that the results could help inform the establishment of Special Areas of Conservation (SACs) under the EU Habitats Directive for this species. A fuller analysis conducted more recently led to the proposal of an SAC for harbour porpoise over much of this area.

The distribution of harbour porpoise has been modelled in Irish waters using data from 2015-2017 collected as part of the ObSERVE project (Rogan et al. 2018). These waters make up a substantial part of the Celtic and Irish Seas area and predicted distributions for summer 2015 and 2016 are shown in Figures 4-5. The modelled distributions highlight the importance of the Irish Sea, waters to the SW of Ireland and the northern Porcupine Basin.

Results from modelling the distribution of harbour porpoise in 2016 in other parts of the West Scotland/Ireland and Celtic and Irish Seas areas based on SCANS-III data (Hammond et al. 2017) are not yet available.

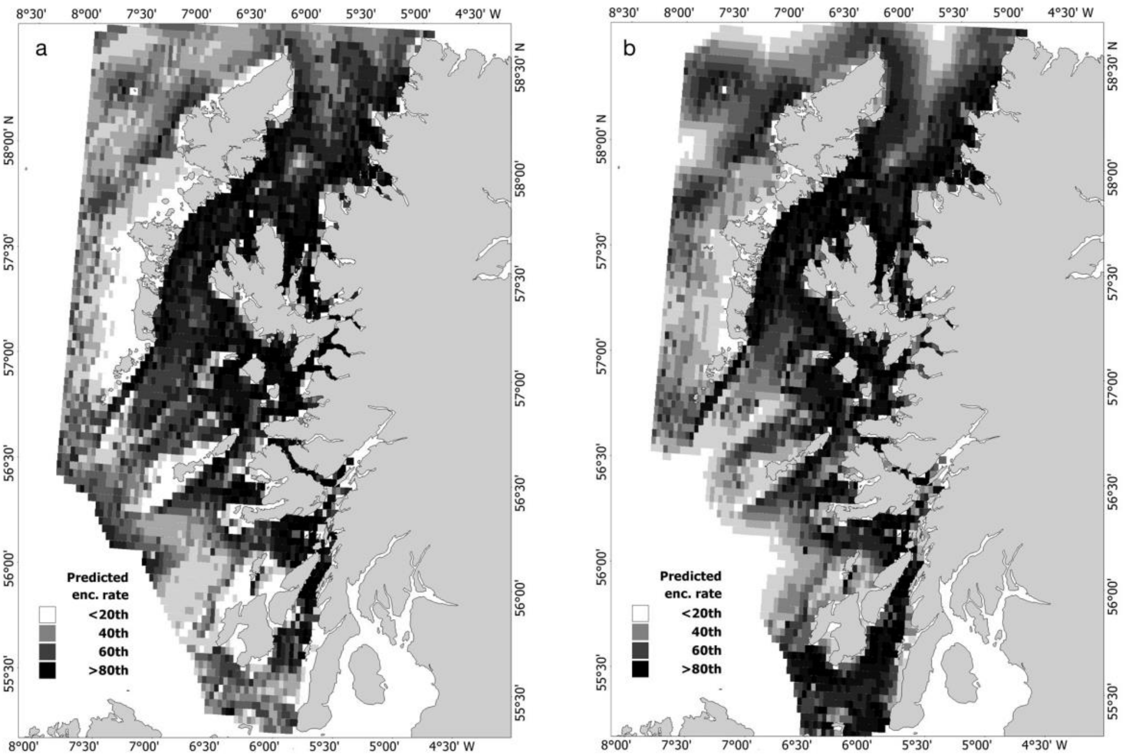


Figure 3. Predicted relative spatial patterns for the models constructed using (a) visual and (b) acoustic data displayed in percentiles. Enc.: encounter (Taken from (Booth et al. 2013)).

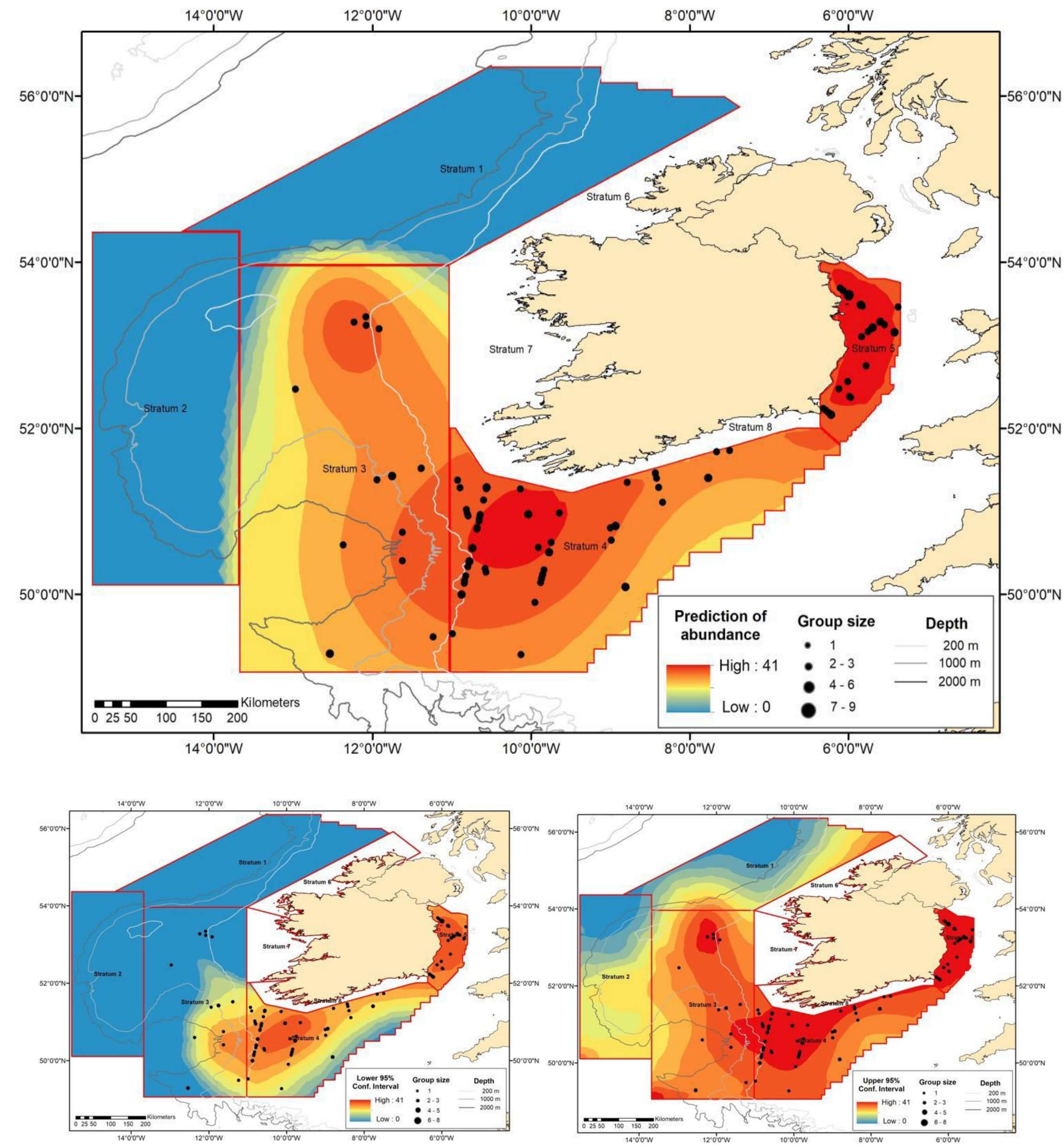


Figure 4. Predicted summer distribution of harbour porpoise in Irish waters in 2015. Figures below indicate predictions of the lower (left) and upper (right) 95% confidence intervals around predictions. Note that the density (abundance) scale is relative. Taken from Rogan et al. (2018).

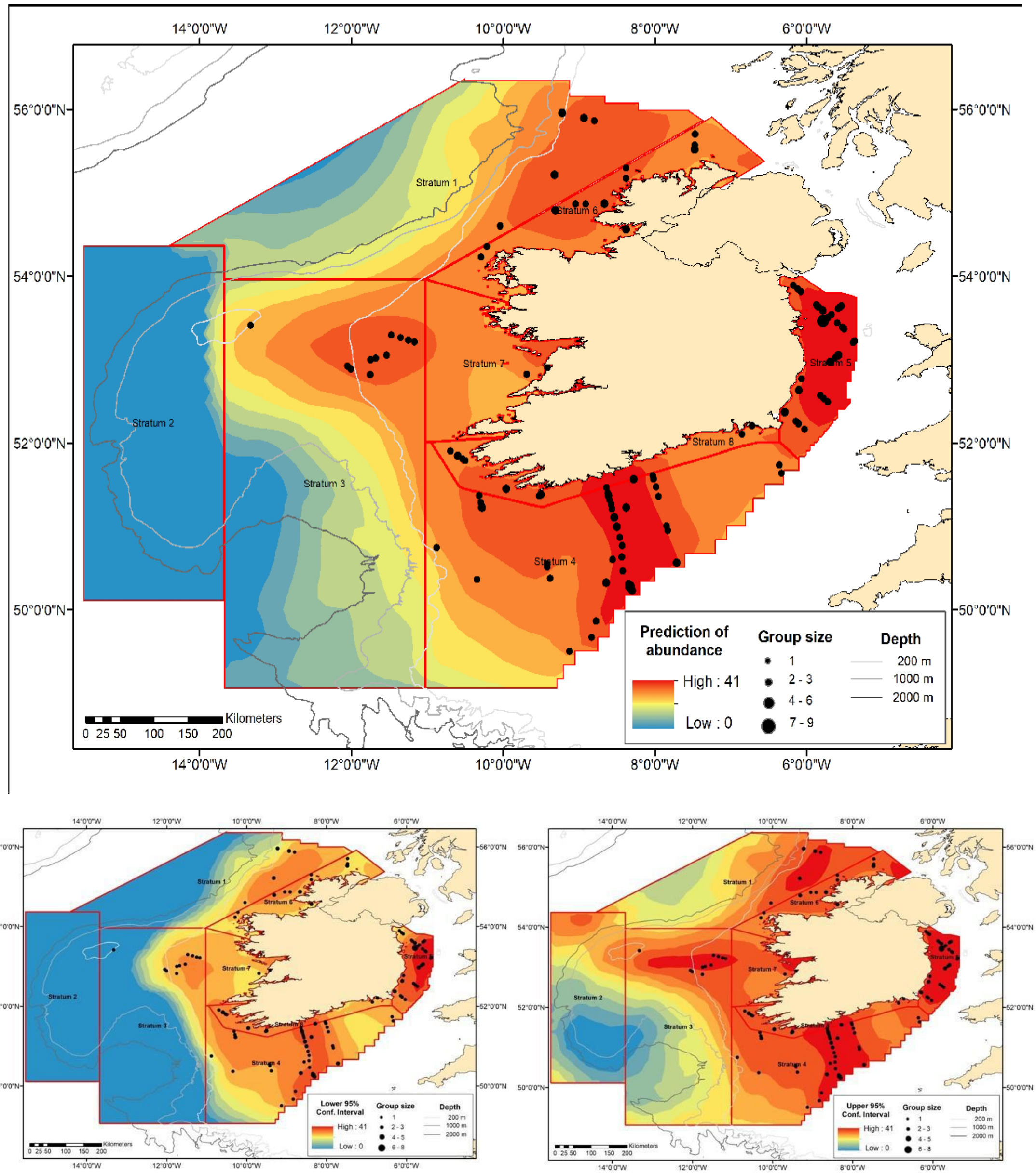


Figure 5. Predicted summer distribution of harbour porpoise in Irish waters in 2016. Figures below indicate predictions of the lower (left) and upper (right) 95% confidence intervals around predictions. Note that the density (abundance) scale is relative. Taken from Rogan et al. (2018).

3. Anthropogenic removals in time and space

A number of studies have investigated interactions between fisheries and harbour porpoises in the Celtic and Irish Seas areas (Berrow and Rogan 1998, Northridge et al. 2000, Cosgrove 2010, Brown et al. 2015, Breen et al. 2017). Of these, only Tregenza et al. (1997) estimated by-catch at a scale relevant to the assessment area. In this study, volunteer observers observed greater than 2,500 km of net in the Irish and UK set gillnet fisheries in the Celtic Sea between August 1992 and March 1994, in which 43 harbour porpoises were by-caught. The by-catch rate was 7.7 porpoises per 10,000 km-hours of net immersion. Total annual by-catch was estimated to be 2,200 (95% CI = 900-3,500), which was around 6% of the estimated number of porpoises in the Celtic Sea at that time.

In 2018, the ICES Working Group on By-catch (WGBYC) undertook a by-catch risk assessment for harbour porpoise by-caught in static nets in the Celtic Sea (ICES divisions 7 a–c, g–h, j–k) (ICES WGBYC 2018). The assessment used data from 2015 and 2016 combined. The estimated by-catch rate was 0.035 - 0.079 (95% CI) porpoises per day at sea, which, when multiplied by the reported fishing effort, resulted in estimates of total annual by-catch of 619 - 1,391 animals.

ICES WGBYC (2018) noted that these estimates are subject to unquantifiable biases. Underestimation may result from smaller vessels not being fully represented in the effort data, the use of non-dedicated observers and, depending on the observer programme, by-caught animals falling out of the net during hauling. However, the focus of by-catch monitoring on larger vessels may result in overestimation of by-catch rate. ICES WGBYC (2018) concluded that the magnitude of potential bias in fishing effort and by-catch is unknown.

By-catch estimation from strandings data

Peltier et al. (2018) present a case study using harbour porpoise to illustrate the use of cause of death data and drift models to estimate by-catch from strandings and ‘mortality areas’ associated with fisheries interactions, focussing on the English Channel and the Bay of Biscay. In total, 895 stranded animals with evidence of by-catch were recovered between 1990 and 2015 along both the French Channel (n = 533) and Bay of Biscay (n = 362) coastlines. The models estimated that in the early years ‘mortality areas’ were almost exclusively located within the Celtic Sea and western Channel followed by an increase in the Bay of Biscay from the early 2000s onwards. The study suggested that from 2012 onwards, a yearly average of 1,300 harbour porpoises died from fisheries interactions in the English Channel and the Bay of Biscay combined (Peltier et al. 2018).

The IWC Scientific Committee’s Sub-Committee on Non-Deliberate Human-Induced Mortality of Cetaceans reviewed this work and recommended ‘further work to address uncertainties in the analysis arising from parameters that either don’t appear to have been quantified directly in the analysis to date, or that have been assessed directly but with either very limited sample size or samples obtained in potentially unrepresentative contexts’ (IWC 2018). Estimates of by-catch from this case study were therefore not used in the assessment.

Lassalle et al. (2012) undertook an ecosystem approach through employing an ecosystem model to assess the impact of fisheries on marine top predators in the Bay of Biscay. Harbour porpoises (and common dolphins) were most impacted by their incidental capture in fishing gears, whereas bottlenose dolphins were more susceptible to resource depletion (Lassalle et al. 2012). The study further highlighted that the Bay of Biscay was not far from overexploitation at the current fishing rate. The Pianka index value for resource overlap with fisheries was intermediate for harbour porpoises inhabiting neritic waters of the Bay.

Within the Irish and Celtic Seas and western English Channel, a peak in mortality of one-year olds was observed in stranded animals diagnosed as by-catch (Figure 6).

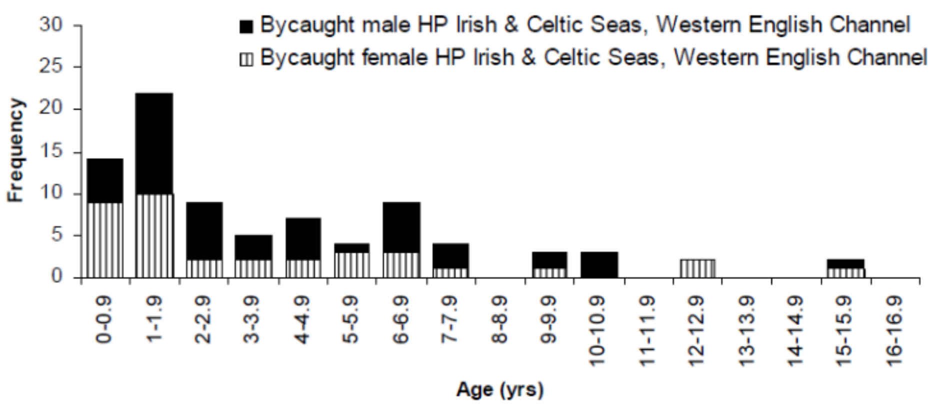


Figure 6. Age distribution of stranded harbour porpoises diagnosed as by-catch by the UK Cetacean Strandings Investigation Programme (1990-2006). Taken from Murphy et al. (2008).

By-catch data used in the assessment

By-catch rate was estimated for each assessment area from data collated by the ICES Working Group on By-catch (WGBYC) from monitoring of set net fisheries conducted between 2006-2016 and reported under EU

Commission Regulation 812/2004 (ICES WGBYC 2018). Table 2 summarises these data for the two assessment areas. An "uninformed multiplier" (x2) was introduced in an attempt to compensate for any potential sources of negative bias for which there is no information, for example animals dropping out of the net underwater. However, it is unknown whether or not such a value is at all realistic (or even justified) and not all workshop participants agreed with the use of the multiplier.

To generate time series of days at sea to calculate estimates of annual by-catch, days at sea data from the ICES Regional database (RDB) were collated for ICES divisions within the assessment areas: ICES divisions VIa, b, VIIb, c, j, k for the West Scotland/Ireland assessment area; and ICES divisions VIIa, e, f, g, h, VIIIa, b, d) for the revised Celtic & Irish Seas assessment area. These data were provided by ICES for the years 2009-2017 only. During collation of these data, problems were identified with the days at sea for ICES divisions VIIIa, b, d so these data were not included in the assessment. The time series of days at sea used in the assessments are given in Table 3.

Total annual by-catch was estimated using the estimated upper 95% confidence limits of by-catch rates from Table 2 (0.1162 and 0.2073 for the West Scotland/Ireland assessment area; 0.0312 and 0.0595 for the revised Celtic & Irish Seas assessment area). Time series of by-catch for 2009-2017 considered in the assessments are given in Table 3. By-catch occurred in these areas in earlier years (e.g. (Tregenza et al. 1997)) but it was not possible at the meeting to generate time series of by-catch prior to 2009.

Table 2. Estimates of harbour porpoise by-catch rate from monitoring collated by ICES WGBYC in the two assessment areas. The upper 95% confidence limit (CL) of by-catch rate was calculated assuming the data are binomially distributed and that each by-catch event is of a single animal. The "uninformed multiplier" is intended to compensate for any potential sources of negative bias for which there is no information.

Assessment area	**Revised West Scotland/Ireland**	**Revised Celtic & Irish Seas**
ICES divisions included	VIa, b, VIIb, c, j, k	VIIa, e, f, g, h, VIIIa, b, d
Days at Sea Observed	342	5700
By-catch observed	28	152
By-catch rate (per day at sea)	0.0819	0.0267
Upper 95% CL of by-catch rate	0.1162	0.0312
Days per by-catch	9	32
Uninformed multiplier	2	2
Multiplied by-catch observed	56	304
Multiplied by-catch rate (per day at sea)	0.1637	0.0533
Upper 95% CL of multiplied by-catch rate	0.2073	0.0595
Days per multiplied by-catch	5	17

Although there was disagreement about whether or not the "uninformed multiplier" was appropriate, in the spirit of a precautionary approach, the assessments were run using the upper 95% confidence limit of the multiplied by-catch rate, which generated the time series of total by-catch given as "Multiplied by-catch" in Table . The assessment thus aimed to account for both uncertainty and any negative bias in the data used. The assessment ran from 2005 to incorporate the earlier abundance estimate; in the absence of information, by-catch was set to zero for 2005-2008. For prediction in the future period 2018-2025 the annual by-catch was assumed to be equal to the mean of the previous five years (2013-2017): 720 for West Scotland/Ireland and 852 for the Celtic & Irish Seas.

Table 3. Days at sea collated from the ICES Regional Database (RDB) provided by ICES for 2009-2017, and estimates of by-catch using the estimated upper 95% confidence limits of by-catch rates from Table 2.

	West Scotland/Ireland (revised)			Celtic & Irish Seas (revised)		
Year	**Days at sea**	**By-catch**	**Multiplied by-catch**	**Days at sea**	**By-catch**	**Multiplied by-catch**
2009	784	91	163	1,114	35	66
2010	7,417	862	1,538	24,802	773	1,475
2011	7,261	844	1,505	24,801	773	1,475
2012	6,507	756	1,349	28,866	900	1,717
2013	1,753	204	363	14,102	440	839
2014	1,755	204	364	13,891	433	826
2015	4,879	567	1,011	10,078	314	600
2016	4,596	534	953	14,330	447	852
2017	4,376	508	907	19,215	599	1,143

Data limitations

The robustness of the estimates of by-catch is questionable. The method of incorporating uncertainty in by-catch rate is believed to be appropriate but the estimates of by-catch rate are likely to be subject to both positive and negative biases and the use of the "uninformed multiplier" is very crude, and may not be an appropriate way to try to capture the potential biases. In addition, some problems were identified with the days at sea data provided by ICES from its Regional database raising questions about the usefulness of these data for creating time series of by-catch estimates. An important limitation is that the time series of by-catch estimates only goes back until 2009 and therefore does not cover earlier years when there was substantial by-catch.

4. Impacts from other indirect (sub-lethal) pressures

Pollution

Within the UK, the harbour porpoise is used as a sentinel species for monitoring long-term trends in chemical contaminant exposure in the marine environment, namely organochlorine pesticides, brominated flame retardants, and hexabromocyclododecane (HBCD). Accumulating levels of brominated flame retardants observed in UK-stranded porpoise blubber in the 1990s was partially responsible for the EU-wide ban of the commercial penta- and octa-mix polybrominated diphenyl ether (PBDE) products in 2004 (Law et al. 2012a). Following which, a significant (and consistent) decline was observed in concentrations of brominated diphenyl ethers (BDEs) in the marine sentinel species during the period 2008 to 2012 (Law et al. 2012a). A decline was also observed in HBCD, as well as organochlorine pesticides such as DDTs and dieldrin concentrations as well as TBT in UK-stranded porpoise blubber for the same period (Law et al. 2012a, Law et al. 2012b). However, although levels of these pollutants are declining, combined toxic effects of multiple exposures to pollutants at low dose levels cannot be ruled out.

In contrast, and although they have been banned for over three decades, concentrations of polychlorinated biphenyls (PCBs) in harbour porpoise blubber have remained rather stable since 1998, with mean ∑PCBs concentrations in adult male and female porpoises (sampled between 1990 and 2012) exceeding an established mammalian toxicity threshold of 9 mg/kg ∑PCBs for onset of physiological (immunological and reproductive) endpoints in marine mammals (Kannan et al. 2000, Law et al. 2012a, Jepson et al. 2016). Individual porpoises exceeded established thresholds particularly in the Irish Sea, Celtic Sea, English Channel and southern North Sea (see Figure 7) - including the 41 mg/kg ∑PCBs threshold that has been associated with profound reproductive impairment in Baltic ringed seals (*Pusa hispida*) (Helle et al. 1976, Jepson et al. 2016). This suggests a continued environmental input of PCBs into the marine environment (Law et al. 2012a, Jepson et al. 2016). As observed in Figure 8, regional differences in ∑PCB burdens exist, with stable levels in both the east of the UK and Scotland (declined until 1998, followed by an increase which reversed around 2005), although levels are falling in the west of the UK where they were historically high – mean concentrations dropped from c27 mg/kg lipid weight in the early 1990s to about 15 mg/kg lipid weight in the mid-2000s. Mean concentrations for animals sampled between 1991 to 2006 includes Scotland, 11.5 mg/kg lipid weight; East (England and Wales), 16.0 mg/kg lipid weight and; West (England and Wales), 20.5 mg/kg lipid weight.

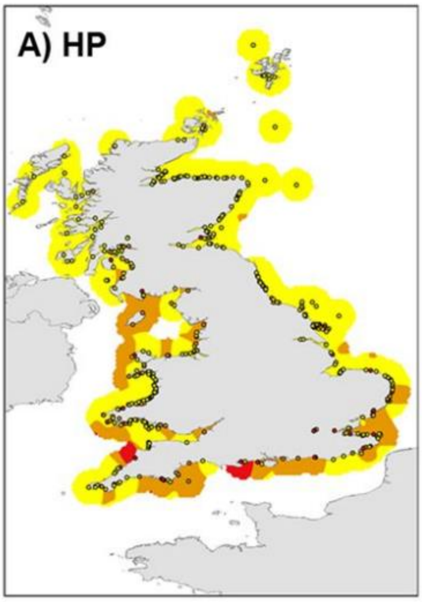


Figure 7. A spatial distribution map of ∑PCB lipid concentrations in harbour porpoises and includes data points along with local averages. Both the data points and the local averages are displayed in three colours: yellow (∑PCB concentration = < 20 mg/kg); orange (∑PCB concentration = 20–40 mg/kg lw); and red (∑PCB concentration = > 40 mg/kg lw). Data obtained between 1990 and 2012 (n = 548). Taken from Jepson et al. (2016).

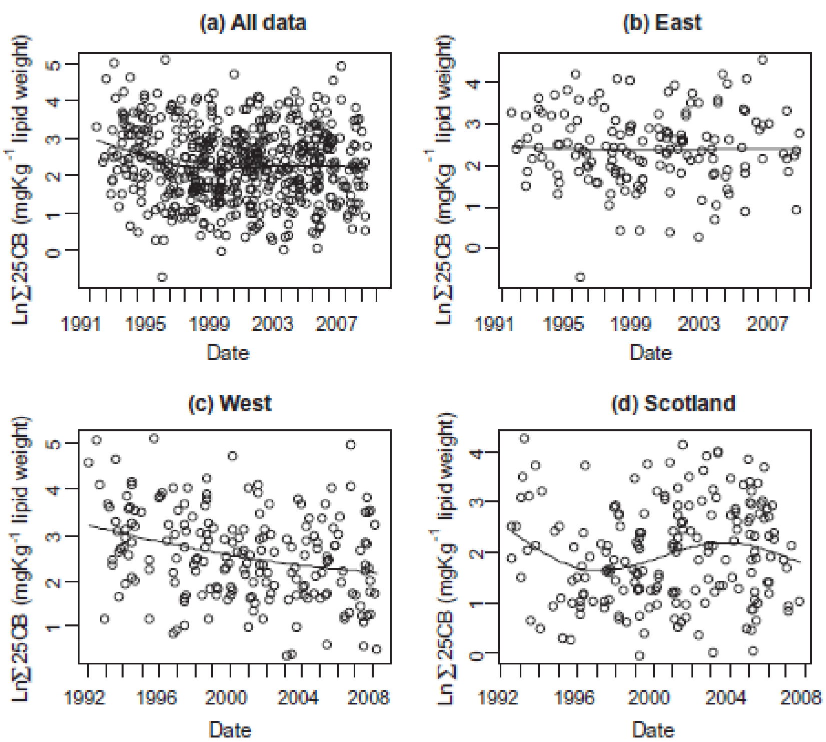


Figure 8. Ln ∑PCB concentrations in porpoise blubber against date for all data, presented for individual areas (East, West and Scotland) as well as for all areas. Taken from Law et al. (2012a).

Studies focusing on a wider geographical area included an assessment of trace elements in porpoises inhabiting the Celtic shelf (NW Scotland, S Ireland and Irish Sea) as well as French waters (Channel and Bay of Biscay). Cadmium concentrations in the kidney of individuals were relatively low, with the highest concentrations found in Scottish porpoises and presumably linked to their diet (Lahaye et al. 2007). Mercury concentrations varied extensively in liver samples and were mainly influenced by the age of the individual. Most of the European porpoises from this study (95 out of 102 individuals) exhibited a Hg:Se ratio lower than 1:1, indicating the efficiency of the detoxification process. Trace metals in porpoises in French waters are being used as a national pollutant indicator under Descriptor 8 within the Marine Strategy Framework Directive. Temporal trends of mercury concentrations in liver and cadmium concentrations in kidney have both shown increased concentrations since 2010, with large individual variation observed (Figure 9).

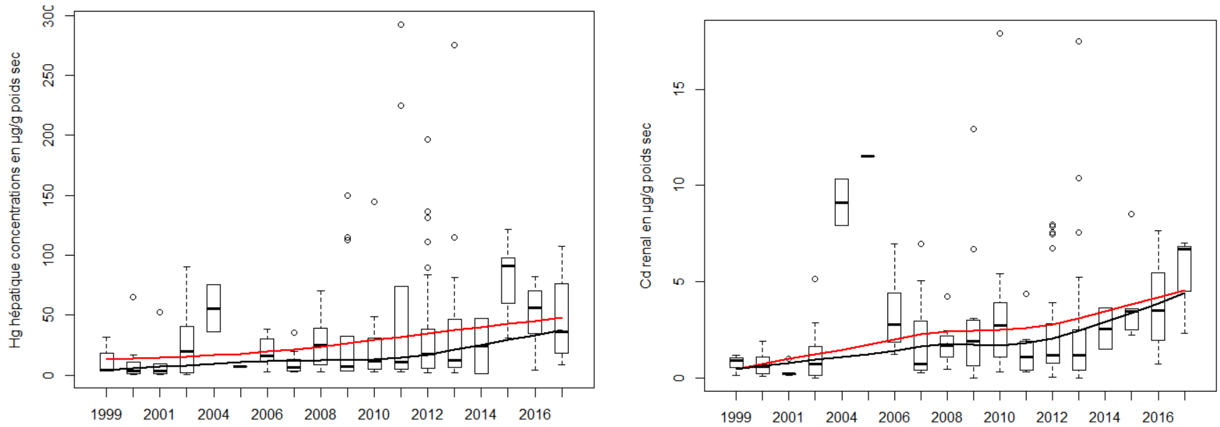


Figure 9. Temporal trends of Hg concentrations in liver (µg.g^{-1} dry weight, left) and Cd concentrations (kidney µg.g^{-1} dry weight, right) in harbour porpoises stranded along the coasts of France between 1999 and 2017.

Mahfouz et al. (2014) summarised mean concentrations of ΣICES7PCBs, CB153 and DDX (mg/kg) in blubber of harbour porpoises from different regions of the North-east Atlantic and the Black Sea for the years 1985 to 2013 (see Appendix I**Error! Reference source not found.Error! Reference source not found.**). Significant between-region differences in concentrations of PCBs, PBDE and HBCD were found in porpoise blubber ((Pierce et al. 2008), see Appendix I**Error! Reference source not found.Error! Reference source not found.**). Significantly higher ΣPCB levels were observed in porpoises in the southern North Sea compared to Scotland for the period 2001 to 2003 – although ΣPCB concentrations still exceeded the threshold for the onset of physiological endpoints in over one-third of the Scottish sample. Within the same study, PBDE levels were higher in Scottish samples than porpoises off Ireland and Galicia, while HBCD concentrations were highest in porpoises off Scotland and Ireland, particularly animals sampled in the Irish Sea (Pierce et al. 2008).

Noise and Disturbance

Sound sources will be divided into a) Continuous noise; and b) Impulsive noise.

Continuous noise is derived largely from shipping, and models of noise levels primarily at low frequencies have been developed based upon AIS data of ship tracks. Whereas this has been undertaken in detail within the Baltic (BIAS Project), and there is currently a similar exercise being undertaken for the North Sea (JOMOPANS Project), there is no comparable project being undertaken in the Celtic and Irish Seas nor for West Scotland and Northern Ireland. However, the distribution of shipping in both regions have been mapped using AIS/VMS (Evans 2011). This shows concentrations in the English Channel extending west into the Celtic Sea and south at the western end of the Bay of Biscay but relatively low levels of shipping further north in the Irish Sea, mainly along ferry routes between Wales/NW England and east coast of Ireland and off North Wales into the port of Liverpool, and in West Scotland and Northern Ireland. Thus, one might expect continuous noise levels to be highest in those areas outlined above where shipping is highest. Porpoises are ultra-high frequency sound producers whereas most energy from shipping is at low frequencies less than 500 Hz and therefore less likely to impact porpoises. However, some noise is created in the frequency range overlapping that of porpoise hearing, and studies by Dyndo *et al.* (2015) and Wisniewska *et al.* (2018) suggest disturbance effects from shipping.

Impulsive noise can be sub-divided into those derived from seismic surveys for oil & gas exploration, active sonar used in military exercises, pile driving used in marine construction, and explosions (for clearance of military ordinance). In both West Scotland and Northern Ireland area and the Celtic and Irish Seas, there have been seismic activities, mainly concentrated along the Atlantic Margin but also off the south coast of Ireland and in the Irish Sea (Beck et al. 2011, Evans et al. 2016). There is little information on the effects of seismic upon harbour porpoise, most effects having been demonstrated on baleen whale species whose vocalisations (and likely hearing) show greater overlap. Pile driving activities have occurred in restricted areas in the region, for example associated with construction of wind turbines (mainly in the northern Irish Sea) and gas pipelines (off the Mullet Peninsula). Effects on porpoises have been demonstrated in very many publications in the case of the former (see Teilmann *et al.* (2006), Thomsen (2010) and Mann & Teilmann (2013) for reviews), and by Culloch *et al*. (2016) in the case of the latter. Active sonar and explosions have been used to only a limited extent in this region, and to date no negative effects on porpoises have been reported. Other sources of impulsive noise potentially relevant to porpoises include the deployment of seal scarers by fish farms. The distribution of fish farms has been mapped in West Scotland (Minches & Sea of Hebrides) by the Hebridean Whale & Dolphin Trust, but no record exists as yet of which fish farms are currently using functional scarers. Fish farms in Western Ireland may also deploy seal scarers but an inventory of these has not yet been made. Elsewhere in Northern Ireland, the Irish and Celtic Seas, there are few fish farms. The effects upon porpoises have not been researched in any detail, but potential negative effects have been discussed by Hermannsen *et al.* (2015) and Mikkelsen *et al.* (2017).

Disturbance of porpoises from recreational activities may occur in parts of the Irish Sea where such activities are concentrated, although this has been little investigated in the region.

In summary, shipping and recreational activities could be having negative impacts in a number of areas in the Irish and Celtic Seas where those activities are known to be concentrated, but these have yet to be investigated in the context of the species. Of impulsive noise sources, seismic surveys have introduced the greatest amount of noise in both regions particularly along the Atlantic Margin, but with localised inputs from pile driving, mainly in relation to wind turbine construction. Fish farms commonly deploy seal scarers and these are most concentrated in the West of Scotland and parts of Western Ireland. They may have negative impacts on porpoises in these areas, but this has yet to be investigated.

5. LIFE-HISTORY PARAMETERS AND HEALTH STATUS

Life history

Early studies undertaken assessing the life history of UK harbour porpoises by Lockyer (1995a, b, 2003) sampled stranded and by-caught animals (between 1985 and 1994) from all UK waters, with the majority of animals assessed being from the North Sea. At birth, porpoises ranged between 65 and 70 cm in length (Lockyer 1995b). Maximum lengths of 163 and 189 cm were reported for males and females, respectively, and asymptotic lengths were estimated at approximately 145 cm in males and 160 cm in females – based on regressing age on length (Lockyer 1995a). Porpoises ranged in age from 0 to 24 years, which Lockyer (1995a) noted was in stark contrast to the maximum age reported in North-western Atlantic waters of 13 years (Gaskin et al. 1984, Read 1990), though similar to the maximum age reported in California waters of 24 years (Hohn and Brownell 1990). Females attained sexual maturity between 140 and 145 cm in length, and males between 130 and 135 cm in length (Lockyer 2003).

Life history parameters of porpoises in Scottish waters have not been determined separately for the North Sea AU and west Scotland AU. Learmonth et al. (2014) analysed samples and data collected from 994 stranded and by-caught porpoises obtained from all Scottish waters between 1992 and 2005. Females and males had similar body length ranges, 66–173 cm and 65–170 cm, respectively, though females did attain a larger asymptotic size of 158 cm compared to 147 cm in males. Conception occurred mainly in July and August and reproductively active males (though sample size was small) were recorded between April and July. The gestation period was estimated at 10-11 months, with parturition reported mainly between May and July. Mean size at birth was 76.4 cm (range 65–88 cm). Harbour porpoises tend to start weaning around 8 months of age, though they may not feed entirely independently until approximately 10 months old (Lockyer 2003). Small calves in Scottish waters with solid food in their stomachs were observed during February to May. Maximum age for both sexes in Scottish waters was 20 years, though only 7.5% of porpoises were aged ≥12 years. In contrast to other studies, males attained an average age at sexual maturity (ASM: estimated using a binomial GLM) at an older age of 5.00 years compared to 4.35 years in females. The ASM in both sexes was higher than what was observed in other geographical regions, e.g., Iceland (3.2 and 2.9 yr), Gulf of Maine (3.4 and >3 yr), Denmark (3.6 and 2.9 yr) and West Greenland (3.6 and 2.45 yr for females and males, respectively) (Sørensen and Kinze 1994, Read and Hohn 1995, Lockyer et al. 2001, Lockyer 2003, Ólafsdóttir et al. 2003), and the authors noted this may have been due to the high incidence of deaths resulting from poor health (i.e., pathological conditions). The estimated pregnancy rate ranged from 34 to 40%, depending on the length of the conception period/mating period used, and a sample that was largely composed of mature females of poor health status (approximately two-thirds). Based on all mature female data from Scottish waters (i.e. not excluding the conception/mating period), a pregnancy rate of 28% was determined.

Analysis of biological material by the EU 5th Framework funded BIOCET project obtained from stranded and by-caught harbour porpoises sampled between 1997 and 2003 in Irish waters revealed that, although based on small sample sizes, females ranged in age and length from 0 to 11 years (n= 21) and 91 to 175 cm (n= 27), respectively. While, male harbour porpoises ranged in age and length from 0 to 7.5 years (n= 14) and 81.5 to 157 cm (n= 17), respectively. Female porpoise off the south coast of Ireland attained sexual maturity at body lengths greater than 150 cm and 5 years of age (Learmonth et al. 2004), and males off the south and west coasts of Ireland attained sexual maturity between 134 and 144 cm in length, and 3 and 7 years in age. In the Irish Sea, female porpoises attained sexual maturity at body lengths greater than 140 cm and between 3.5 and 5 years in age. While males attained sexual maturity between 131 and 146 cm in length, and 4 to 8 years in age. Due to small sample sizes, the average ages at attainment of sexual maturity (ASM) could not be determined for either sex in Irish waters (Learmonth et al. 2004). The pregnancy rate of porpoises in Irish waters based on the presence of an embryo/foetus and a sample of only five sexual mature females sampled outside the main mating/calving period for the species in the North-east Atlantic (June to September), was 40% (2001-03) (Learmonth et al. 2004).

Preliminary analysis undertaken by Murphy et al. (2012) on reproductive seasonality and testicular regression in harbour porpoises in all UK waters, reported a more active period in sperm production in June and July, though spermatozoa were observed in seminiferous tubules year-round. This was in contrast to the western North Atlantic population, where complete involution and recrudescence was observed outside the defined breeding period (Neimanis et al. 2000). Interestingly, within the UK sample, spermatozoa and spermatids were not observed in the tubules of 17% of the sampled mature porpoises. These individuals died during the months January to April, ranged in age from 5 to 16 years, and where cause of death was established, the majority of individuals died from infectious and non-infectious diseases ((Murphy et al. 2012); Unpub. Data).

Murphy et al. (2015) assessed reproductive material from stranded and by-caught female harbour porpoises sampled between 1990 and 2012 from all UK waters (n = 329). Based on all available samples, a low pregnancy rate of 34% and an ASM of 4.73 years were estimated, while a slightly higher pregnancy rate of 50% and a higher ASM of 4.92 years were determined for ‘healthy’ females – females that died of traumatic causes of death such as by-catch, boat/ship strike, bottlenose dolphin attacks or dystocia. The pregnancy rate estimated for ‘healthy’ porpoises was almost half that reported in other geographical locations such as the Gulf of Maine and Bay of Fundy in the North-west Atlantic (93%, 3.27 years) (Read and Hohn 1995), and waters off Iceland (98%, 3.2 years) (Ólafsdóttir et al. 2003). Reproductive failure was reported in UK porpoises that may have been related to exposure to endocrine disrupting chemicals (see health status section).

More recent unpublished analysis by Murphy et al. (in prep.) of reproductive material in UK harbour porpoises assessed the life history parameters for the Celtic and Irish Seas (CIS) Management Unit using samples and data collected between 1990 and 2013 (n = 638). Figure 10 presents the age distributions of porpoises in the Celtic and Irish Seas MU and the North Sea MU. For the statistical analysis, the dataset was divided into two time periods (period 1: 1990-1999 and period 2: 2000-2013) to assess temporal variations in life history parameters. A pregnancy rate of 60% was determine for the Celtic and Irish Seas Management Unit, with a slight decline observed between both time periods (68% in period 1 vs 54% in period), although this was non-significant. 60% of the mature female sample that was used to determine the pregnancy rate in the CIS was composed of animals that died as a result of trauma. Using the Gompertz growth model, females attained a larger asymptotic size of 162.9 cm compared to 146.5 cm in males. At a given age, porpoises were of a larger size in the 1990s compared to the 2000s and 2010s. Further, a significant decline in the growth rate parameters was observed during the study period that was more evident in the female data.

Further analysis in the unpublished study observed that females attained a length at 50% sexual maturity (L50), determined using a binomial logistic regression, at a larger size than males, most apparent in period 2. Males significantly declined in their L50 during the study period, from 138.7 cm in period 1 (1990-1999) to 133.5 cm in period 2 (2000-2012). While in females no significant difference was observed between time periods - 146.6 cm in period 1 and 146.9 cm in period 2. Based on the age at 50% maturity (A50) method (estimated using a binomial logistic regression), females attained sexual maturity at an older age compared to males, and again this was more evident in period 2. Males attained sexuality maturity, on average, at a similar age in both time periods in the Celtic and Irish Seas MU - 3.6 years. While, females attained sexual maturity, on average, a year later during the 2000s and 2010s compared to the 1990s, 4.8 years vs 3.8 years, respectively, which was significantly different. Overall health status (proxied by cause of death) did not affect estimates of A50 or L50 as it did not appear in the top ten best fitting models for either parameter. In conclusion, during the study period there was a slight (non-significant) decline in the pregnancy rate and significant increase in the A50 in females suggesting some density dependent limiting factors in operation.

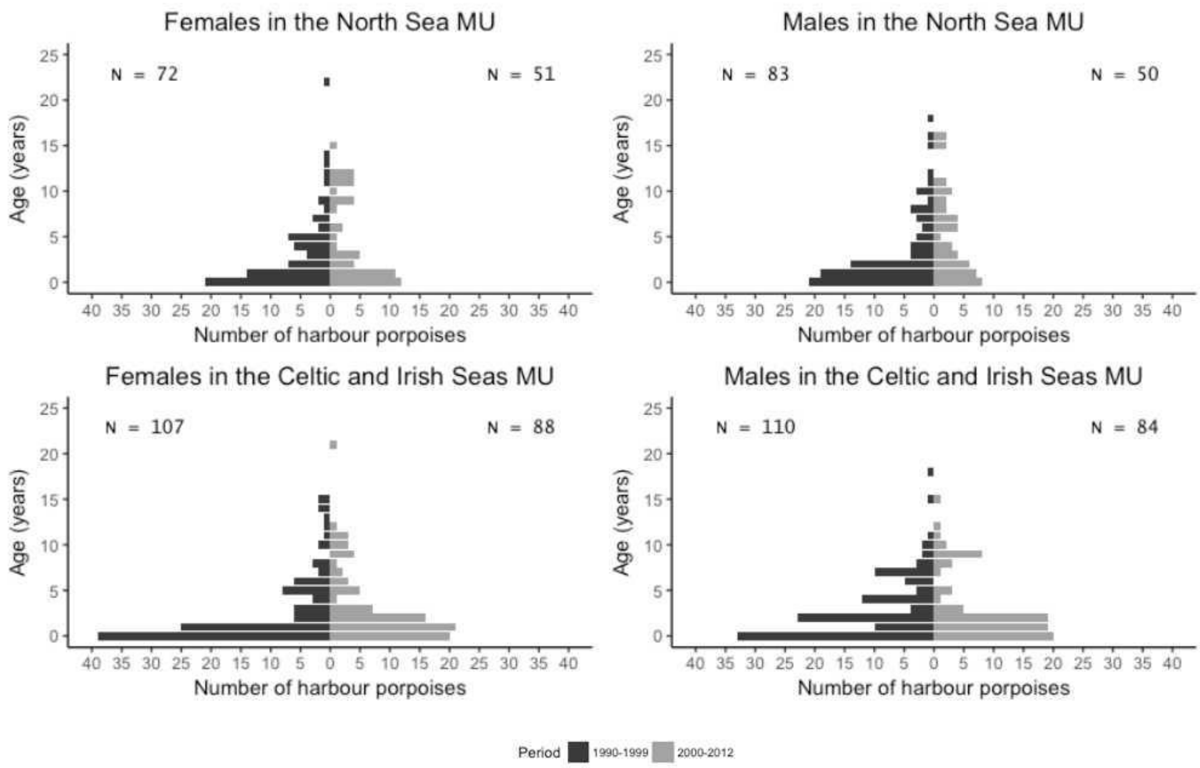


Figure 10. Age-frequency distribution and sample sizes of female and male harbour porpoises sampled in UK waters within the North Sea MU and Celtic and Irish seas MU during the two time periods, 1990-1999 and 2000-2012. Murphy et al. (Unpublished).

Collet (1995) assessed harbour porpoise strandings and by-catch data (n = 93) for the period 1970 to 1994 for porpoises inhabiting waters off the French English Channel coast and the Bay of Biscay. A seasonal peak in strandings was observed in the Channel sample, with 62% of animals reported between February and April. Within this region, females and males ranged in length from 83 to 186 cm and 124 to 168 cm, respectively. Whereas slightly larger animals were observed inhabiting waters off the French Atlantic coast, as females ranged from 124-190 cm in length, and males from 119 to 183 cm in length.

More recent unpublished analysis by Dabin et al. analysed biological samples and data collected from 532 individual porpoises sampled between 1990 to 2015 in French waters; 210 individuals sampled in the Celtic Sea MU and 322 from the North Sea MU, with the boundary of the MUs in the English Channel drawn at Cotentin, France. A higher number of young individuals was evident in the North Sea MU sample, with a significant difference observed in the length distribution between individuals of North Sea and Celtic Seas MUs ($p < 0.0001$), as well as a significant difference in the age distribution of stranded porpoises ($p < 0.0001$) (Figure 11). Using the Laird-Gompertz model, males and females in the North Sea MU attained asymptotic lengths of

141.7 cm and 155.7 cm, respectively. While males and females in the Celtic and Irish Seas MU attained asymptotic lengths of 160.3 cm and 168.9 cm, respectively. A significant difference was also observed in the age attained at sexual maturity between MUs, with individuals (both sexes combined) from the North Sea MU attaining sexual maturity at an older age than the Celtic and Irish Seas MU (5.4 years vs 4 years) ($p < 0.0013$).

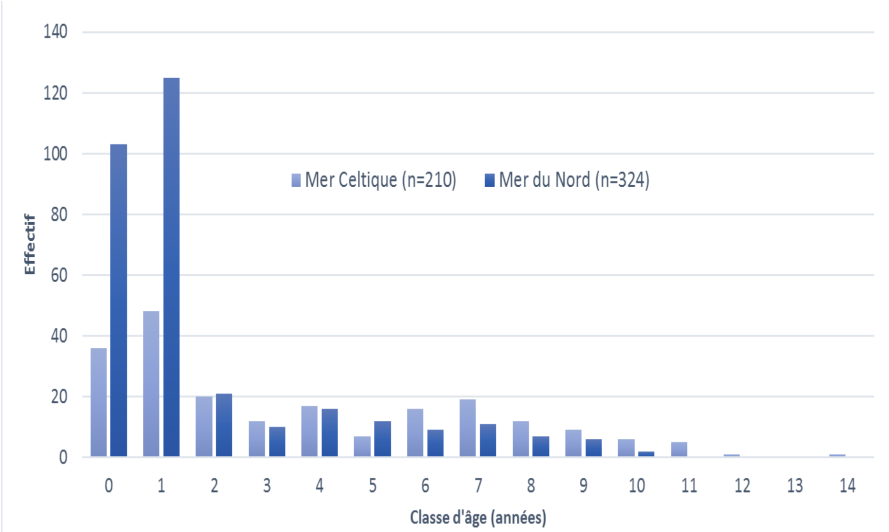


Figure 11. Comparison of age distributions between North Sea (dark blue) and Celtic Seas (light blue) populations (Dabin et al, Unpub. Data).

In the English Channel and the Bay of Biscay, harbour porpoises are exposed to different human pressures such as by-catch. In this context, population dynamics of harbour porpoises were investigated in these two areas on the basis of demographic data (Rouby et al, Unpub. Data). Vital rates were estimated using age and sexual maturity data from 474 stranded and by-caught individuals (Bay of Biscay + west Channel n = 174; east Channel n = 300). Demographic projections showed a growth rate of 0.87 ± 0.03 in the Bay of Biscay and west Channel and a growth rate of 0.78 ± 0.03 in the east Channel. Without immigration from adjacent waters, harbour porpoise groups from the Bay of Biscay and west Channel were predicated to be extinct in ≈ 30 years and those from east Channel to be extinct in ≈ 15 years. The conclusion was that current pressures, including anthropogenic pressures such as by-catch, are most likely too high for harbour porpoises (Rouby et al, Unpub. Data) (Figure 12). However, biases in using strandings and by-catch data for such approaches needs to be accounted for.

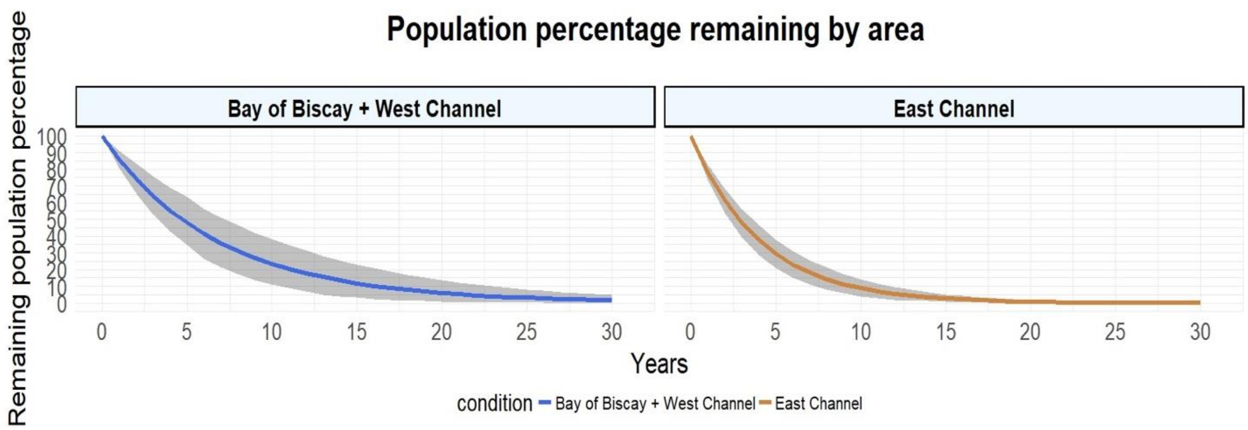


Figure 12. Demographic projections of harbour porpoises in the French two areas (Rouby et al, Unpub. Data).

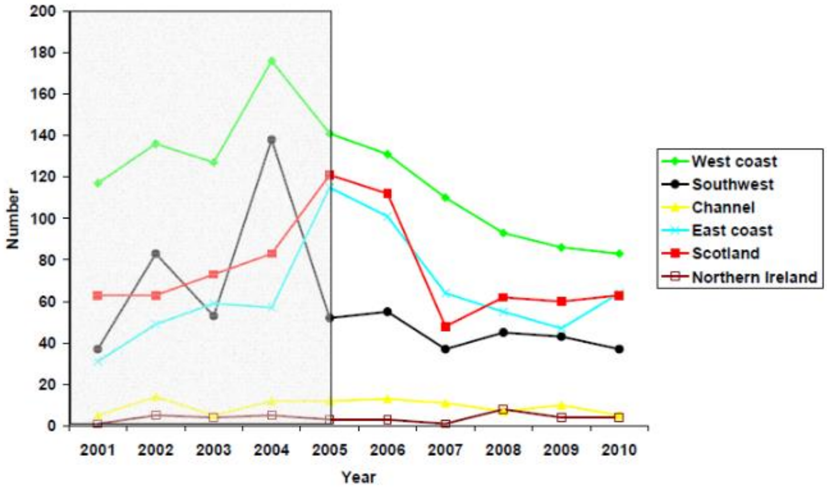
Health Status

The number of harbour porpoises that have been reported as stranded along the Irish coastline has increased since the 1990s, from around six in 1993 to 49 in 2012 (Rogan 2009, McGovern et al. 2018). This may be due to either (a) an increase in recording effort by individuals due to an increased awareness of the stranding scheme, (b) an increase in the abundance of harbour porpoises in the region, (c) increased adverse anthropogenic interactions causing an increase in the stranding of carcasses and/or (d) changes in environmental conditions, such as prevailing winds, causing an increase in carcass strandings (Rogan 2009, McGovern et al. 2018). A significantly higher number of strandings have been reported in the first quarter (January to March) with a second smaller peak observed in June (McGovern et al. 2018). A higher number of strandings were reported on the south-east and east coasts of Ireland though they have been recorded as stranded on all coasts (McGovern et al. 2018). Based on an assessment of causes of death in 123 necropsied harbour porpoises that stranded between 1990 and 2004, 4% of individuals live stranded, and 7% were identified as by-catch - this increased to 11% if only 'fresh' carcasses were assessed. While two porpoises showed traumatic injuries on necropsy consistent with injuries sustained from a bottlenose dolphin (*Tursiops truncatus*) attack (Rogan 2009).

In the UK, harbour porpoises predominately strand along the south-west coast (Cornwall and Devon) between December and April. For the period 2006 to 2010, there was a decline in the number of porpoises reported stranded in all UK waters compared to the previous five year period (2001 to 2005) (see Figure 13) (Deaville and Jepson 2011). The number of porpoise strandings remained low between 2010 and 2015, compared to the early 2000s. However, in Scotland, notably peaks in strandings (>100 individuals) occurred in 2005, 2006, 2013 and 2014. Further, peaks in strandings along the west coast (> 100 individuals) were reported between 2001-2007, 2011, 2013 and 2014 (see Figure 13). More than 170 porpoises were reported as stranded along the west coast in the year 2004.

An analysis of post-mortem examinations conducted between 1991 and 2010 showed a slight decline in the proportion of stranded porpoises along UK coastlines diagnosed as by-catch, along with a relative increase in the proportion of infectious disease and starvation cases. The most recent available report from the UK Cetacean Strandings Investigation Programme is for the year 2015. In 2014, a decrease in harbour porpoise strandings was reported for all regions, and this decline continued in 2015 apart for the south-west coast of the UK (Figure 13) (Deaville 2016). For the 53 stranded harbour porpoises necropsied in 2015, collected throughout the UK, the most common causes of mortality were entanglement in fishing gear (by-catch, 18.9%, n=10), infectious disease (18.9%, n=10, primarily pneumonias due to parasitic infestations or diseases of the gastrointestinal tracts), starvation (17%, n=9) and attack by bottlenose dolphins (15%, n=8). As seen in Figure 14, there were no consistent trends in any cause of death category for UK-stranded harbour porpoises between 2011 and 2015 (Deaville 2016) – though cases of by-catch slightly increased while cases of infectious disease slightly decreased. Cases of starvation increased from 4% for the period 1990 to 2002, to 24% for the period 2005 to 2010 (with 32 out of 117 starvation cases being neonatal starvation) and declined to 17% in 2015 (with the majority being neonatal starvation, 7 out of 9 cases) (Deaville and Jepson 2011). In Scottish waters, the overall estimated mortality rate, and the number of bottlenose dolphin kills, was lower on the west coast than the east coast (Pierce et al. Unpubl. Data).

Case control epidemiological studies reported that the risk of mortality from infectious disease in UK harbour porpoises increased in a dose-dependent manner with increasing blubber PCB concentration, with a 50% increase in relative risk of infectious disease mortality at concentrations of total PCBs >25 mg/kg lipid in the blubber (Jepson et al. 2005, Hall et al. 2006, ICES WGMME 2010). Females with high pollutant burdens were more likely to die from ill health. 93% (14 of 15) of mature females with ΣPCB burdens ≥30 mg/kg died as a result of infectious disease or "other" causes such as starvation, and these cause of death groups also comprised 92% (23 of 25) of the pollutant sample ≥20 mg/kg (Murphy et al. 2015).



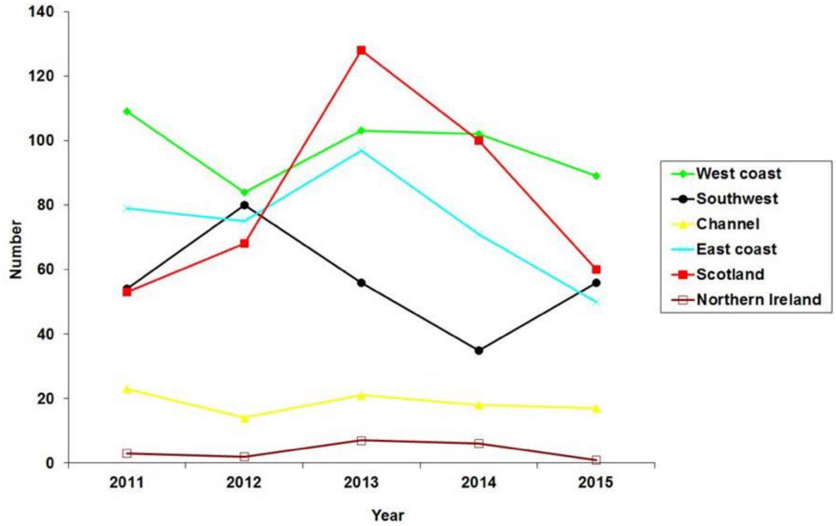


Figure 13. Interannual variation in UK regional reported strandings of harbour porpoises for (a) 1991 to 2010 and (b) 2011-2015. Taken from Deaville and Jepson (2011) and Deaville (2016).

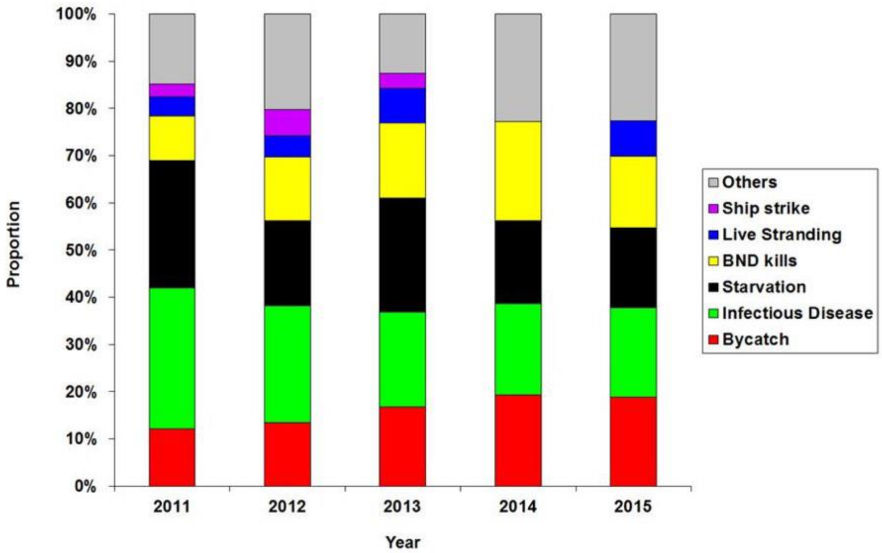


Figure 14. Proportions of major cause of death categories in UK stranded harbour porpoises examined at post mortem 2011-2015. Taken from Deaville (2016).

Reproductive failure was evident in porpoises sampled from all UK waters with 19.7% of sexually mature females showing direct evidence of reproductive failure - such as foetal death, aborting, dystocia or stillbirth (Murphy et al. 2015). Additionally, 16.5% of mature females had infections of the reproductive tract or tumours of reproductive tract tissues that may have attributed to reproductive failure. Murphy et al. (2015) reported that the observed reproductive dysfunction in UK porpoises may have been related to exposure to PCBs, either through endocrine disrupting effects or via immunosuppression and increased disease risk. However, there were difficulties in showing casual relationships between cases of reproductive dysfunction and ΣPCB concentrations due to a females capability to offload their lipophilic pollutants burdens through gestation and lactation transfer (Murphy et al. 2015). Whether or not PCBs were part of the underlying mechanisms of reproductive dysfunction, the authors used individual PCB burdens to show further evidence of reproductive failure in the sample. Based on direct and indirect evidence (individual PCB burdens) of reproductive failure, the authors suggested it could have occurred in around 39% or more of mature females sampled.

6. DIET AND PREY AVAILABILITY

Santos et al. (2004) divided porpoises into east and west Scottish mainland and Shetland. Overall, sandeels and whiting contributed around 75% of prey biomass. The west coast diet included a higher proportion of *Trisopterus minutus* and less haddock and cod than the other areas. In addition, the importance of sandeel, whiting, and herring was higher on the east coast than on the west coast and the reverse was true for saithe.

In Irish waters, porpoises forage primarily on fish (98%), though remains of cephalopods and crustaceans were also identified in the stomachs of necropsied individuals. Analysis of 73 stomachs revealed that although a broad range of fish taxa were consumed, whiting Merlangius merlangus, and Trispoterus sp. (poor cod Trisopterus minutus, norway pout Trisopterus esmarkii) were identified as important in terms of percentage prey by number (i.e. how many of an individual species was present in all the stomachs), whereas data in relation to % occurrence (how often a prey item occurs) reported that herring Clupea harengus was also important (Brown 1999, Rogan 2009) (Figure 15). Analysis of a sub-set of individuals (n=34, sampled between 1993 and 1999) identified that the prey remains between stranded and by-caught animals was largely similar, apart from less Clupidae species being observed in by-caught individuals (Brown 1999). Whereas the majority of poor cod (87%) was observed in the stomachs of by-caught individuals. Overall, fish consumed were predominately < 300 mm in length, with a modal size class of 110-200 mm (Brown 1999).

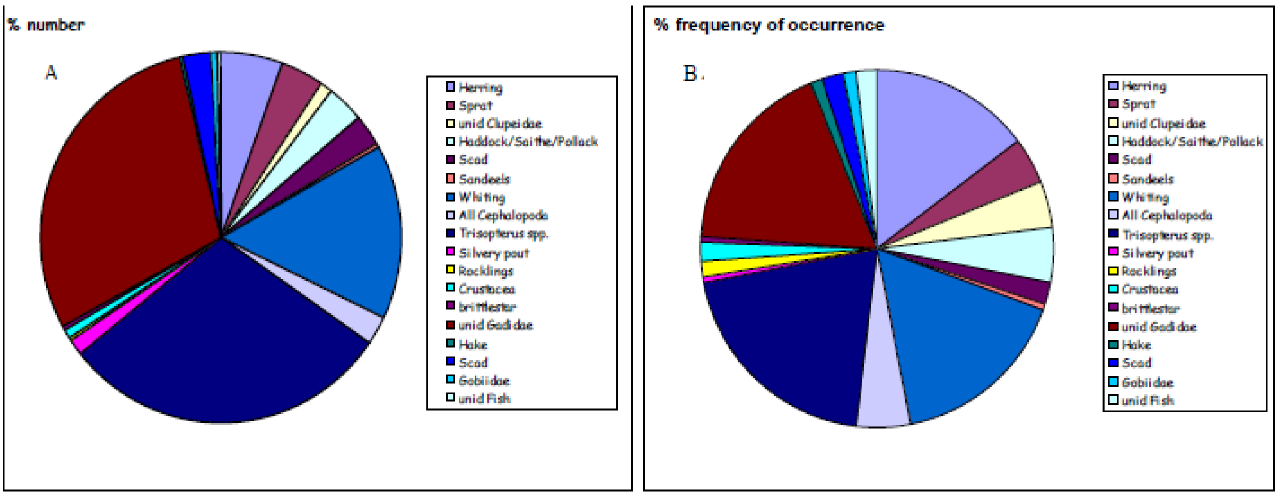


Figure 15. Proportion of different prey items in the diet of harbour porpoises in Irish waters by a) % number and b) % occurrence. Taken from Rogan (2009).

In south-west UK waters, the most important fish species by weight were whiting, Gobiidae sp, herring, sprat (Sprattus sprattus) and scad (Trachurus trachurus) in the stomachs of stranded and by-caught harbour porposies (n= 67 stomach) (Tierney 2002). Comparing cause of death groups, the three most important fish species by weight for by-caught individuals included whiting, Gobiidae sp., and herring, whereas for animals that died from other causes the most important fish species were whiting, sandeel and Gobiidae sp. Tierney (2002) reported that porpoises off the south-west coast of the UK were consuming smaller size prey than porpoises in the North Sea and Outer Hebrides. Further, for all UK waters whiting increased in importance in stomach contents during the study period (n=123; 1995-2002) from 63% to 94%, while herring decrease in importance from 33% to 7% (Tierney 2002).

In French waters, analysis of dietary remains in porpoises that stranding along the North Coast of Normandy between 1998 and 2003 (n=7) reported that their diet mainly consisted of fish, primarily Gobiidae sp. (De Pierrepont et al. 2005). Spitz et al. (2006) assessed the diet of 29 porpoises that stranded along the Northeast Atlantic French coast, Bay of Biscay and western Channel between 1998 and 2003. Again, small schooling fish living close to the sea floor dominated the diet both by number (85%) and mass (98%). Crustaceans and cephalopods accounted for a lower fraction of reconstructed mass, with only one species of crustaceans observed, the northern krill, Meganyctiphanes norvegica (Spitz et al. 2006). Blue whiting, Micromesistius poutassou, comprised 21% of reconstructed mass, followed by sardine, Sardina pilchardus, scads, Trachurus trachurus (or/and T. mediterraneus) and whiting, accounting for 21, 28 and 20% of reconstructed biomass respectively. Although gobies represented 22 % by number, owing to their very small body size (44 ± 11 mm body length), they only contributed to 1% by mass. In the same way, northern krill (29 ± 0 mm) accounted for 13% by number and only 0.2 % by mass. Overall prey size distribution ranged from 8 to 307 mm with the mean at 130 mm.

7. Knowledge gaps and uncertainties in assessment parameters

Genetic structure and ecological stocks

Genetic stock structure within the region still needs to be fully elucidated, examining more closely whether the current northern and southern boundaries of the Assessment Units are located appropriately, as well as formally allocating the ‘Irish Sea’ to an Assessment Unit. Investigations on possible ‘ecological stocks’ based on ecological tracers (such as cadmium, stable isotopes, tagging data) is required.

Abundance and distribution

The SCANS-type surveys, including the Irish ObSERVE project (Rogan et al. 2018), provide robust (i.e. they are believed to be unbiased) and fairly precise estimates of harbour porpoise abundance across all European Atlantic shelf waters, including west Scotland/Ireland and the Celtic and Irish Seas. However, these surveys occur infrequently (hitherto approximately decadal). For a species in which the large majority of animals die before age 10 years, such a frequency provides only a very coarse resolution to monitor changes in abundance. These large-scale surveys also only occur in summer – little is known about distribution and abundance of harbour porpoise in these assessment areas in spring, autumn and winter.

By-catch

As outlined above in Section 3, and detailed in reports of the ICES Working Group on By-catch (e.g. ICES WGBYC 2018), there are a number of knowledge gaps and uncertainties in the data used to estimate by-catch. These include inconsistent and incomplete reporting of fishing effort data, and unquantifiable biases in data used to estimate by-catch rate. These problems are not unique to the west Scotland/Ireland and the Celtic and Irish Seas assessment areas.

Other parameters not included in the model

Contaminants

There is a lack of information on emerging contaminants of concern, both in terms of their potential bio-accumulative properties and potential adverse effects is required. The majority of research on pollutants undertaken to date has assessed legacy pollutants, and effects thereof. The development of new synthetic chemicals, and the emergence and use of some of those chemical substance on the market, has been increasing at a rapid rate in recent years (Bernhardt et al. 2017). It is unknown as to the number and variety of synthetic chemicals that harbour porpoises are exposed to, and if those chemicals are having an adverse health effect. Little attention has been paid to the raft of new emerging pollutants on wildlife in general (Bernhardt et al. 2017). Particularly the additive and synergetic effects in the presence of other pollutants at low dose levels.

Noise and Disturbance

The largest knowledge gaps relate to establishing links between behavioural reactions to noise and vital parameters relevant for population development (adult survival, fecundity etc.).

Additional knowledge gaps relate to the long-term consequences of smaller or larger noise-inflicted hearing losses in porpoises, as well as the natural and noise-induced hearing loss in wild porpoises.

Sound maps do not exist for the region as a whole but the distribution of noise-producing activities has been mapped for shipping, seismic, and wind farm construction. The effects of noise upon porpoises in both regions from all the major sources have yet to be investigated.

Life history

Region-wide estimates of life history parameters and temporal changes in those parameters that may have resulted from anthropogenic activities are not available at the AU level.

Health Status

Within Ireland, a cetacean necropsy programme was re-established in 2017, funded by the EMFF through the Marine Institute. However, the area of coverage for the stranding programme is limited to the west and south coasts of Ireland, and does not cover the east coast where porpoises strand in higher numbers (Levesque et al. 2018). Within France, assessments of causes of death, health and nutritional status monitoring are not currently being undertaken, apart from reporting incidences of by-catch in stranded animals.

Diet

The majority of studies that have assessed the diet of stranded and by-caught harbour porpoises in the region used samples collected prior to 2005.

8. MONITORING REQUIREMENTS, RESEARCH PRIORITIES AND OPPORTUNITIES FOR COOPERATION

Multifarious dimensions of the ecology and evolution of the European populations of harbour porpoises

Genetic structure revealed by mtDNA and microsatellites analysis revealed a strong structure in harbour porpoise within the North East Atlantic waters. Beside the Black Sea subspecies (P. p. relicta), two other distinct evolutionary units are present in the NE Atlantic, each occupying different habitats: one (P. p. phocoena) is distributed on continental shelf habitats of northern European waters and the other one (P. p. meridionalis) is distributed in upwelling waters and includes Mauritania and Iberia. This large area shares a dynamic structure, with the Bay of Biscay being an admixture zone between the two sub-species. Studying this hybrid zone and the neighbouring populations is crucial to understand the population dynamic, local adaptive processes, and the effects of climate change. By combining relevant approaches, such as ecological tracers (POPs, trace elements and stable isotopes), life-history trends, and population genetic, would provide a comprehensive picture of the multifarious dimensions of the ecology and evolution of the European populations of harbour porpoises.

Abundance and distribution

Estimates of abundance from SCANS-type surveys should be available more frequently than every 10 years. A logical period would be every 6 years to tie in with reporting requirements under the EU Habitats Directive and MSFD. Estimates of abundance from surveys in seasons other than summer could be useful to help assess impacts of by-catch that does not occur in summer.

By-catch

By-catch estimates are uncertain and subject to a number of biases. The ICES Working Group on By-catch has been working for some time to improve the quality of data available for by-catch risk assessments (e.g. ICES WGBYC 2018). Progress on solving these problems is needed to improve the quality of future assessments and the inferences that can be drawn from the results. Time series of reliable data in earlier years are also needed.

Pollutants

A European-based risk list of priority pollutants for monitoring in the harbour porpoise should be devised, and research should continue into monitoring effects from exposure to pollution on health and reproductive status in both female and male harbour porpoises as required by Commission Decision (EU) 2017/848 on the Marine Strategy Framework Directive. This list should include those contaminants on the EU watchlist for emerging pollutants (EC decision 495, 20th March 2015), particularly those pollutants identified as endocrine disrupting chemicals (Murphy et al. accepted).

Within the UK, the harbour porpoise is used as a sentinel species for monitoring long-term trends in chemical contaminant exposure in the marine environment. Pollutant assessment monitoring akin to the long-term monitoring strategy employed by the UK should be implemented by Ireland and France. A 'common' mammal indicator using the harbour porpoise for assessing pollutant effects under Descriptor 8 "Concentrations of contaminants are at levels not giving rise to pollution effects" of the Marine Strategy Framework Directive should be devised.

While inorganic compounds (trace elements) are likely not to induce direct effects in harbour porpoises, they need to be considered as factors of susceptibility that may increase the effects of, for example, persistent organic pollutants. Thus, when modelling the cumulative impacts of pollutants, inorganic compounds should also be included.

Noise and Disturbance

It appears unlikely that links between behavioural reactions to noise and vital parameters relevant for population development can be established directly through observation, and currently the best option appears to be individual based modelling schemes, such as the iPCoD (New et al. 2014) and DEPONS (Nabe-Nielsen et al. 2018) frameworks. However, considerable effort is required in obtaining accurate and relevant input data for these models. The required information includes, but is not limited to, better description of reaction thresholds and distances for different sound sources and metabolic consequences of different types of behavioural disturbances. Equally important for the quality of the output from the models is reliable information about source characteristics, their duration, and abundance of the different sound sources in the region.

Substantial monitoring and reporting of activities are required as part of implementation of the Marine Strategy Framework Directive. Current effort is limited to loud impulsive sounds and ship noise, however. Effort should be directed at increasing coverage of noise sources included in the monitoring, in particular smaller vessels, which tend not to carry AIS-transmitters and to the ubiquitous echosounders. Effort is also required to ensure that data entered into the monitoring database are as complete as possible (in particular an issue for military sonar) and with sufficient level of detail to allow for subsequent meaningful use of the data in the database.

Related to the low-frequency ship noise is a need to ensure that monitoring programmes quantify this noise in a way that is meaningful to high-frequency specialists, such as the harbour porpoise. More specifically this means that monitoring effort should be extended above the currently implemented 63 Hz and 125 Hz frequency bands.

The mapping of distribution of both continuous and impulsive noise sources with emphasis on the duration of exposure for each source on an annual basis. Noise maps for the former should derive from the INTERREG funded JOMOPANS project.

Other pressures

Work should continue and expand on assessing the cumulative impacts of multiple stressors, through integrating sub-lethal effects, on physiological and behavioural changes (e.g. (King et al. 2015)). Stressors should include, but are not limited to, disturbance, anthropogenic pollutants, changes in prey availability (that may result from the indirect effects of fishing), and the potential effects of climate change. Attempts should be made to estimate exposure rates to key pressures, and the dose-response relationship of each.

Monitoring programmes for health status, life history and diet

Continued monitoring population condition and trends in cause of death, health and nutritional status in dead specimens through funding national stranding and by-catch observer programmes for collection of carcasses. The development of coordinated sampling strategies for dead carcasses within the region is required for assessment of health and nutritional status, causes of death, life history parameters and dietary analysis of individuals. This would enable more detailed analyses and coordinated research at the Assessment Unit level if appropriate funding was available.

Cases of starvation have been on the increase in the UK in the last two decades, though such information is lacking from other countries in both AUs. New studies incorporating stomach content and stable isotope analyses are required on contemporary samples to monitor dietary requirements and possible fishery interactions through, for example, targeting similar prey (sizes). Results of which should be incorporated within ecosystem models in the region that include data on food web interactions as well as other impacts of fisheries (i.e. both direct and indirect) on the harbour porpoise. An updated analysis examining temporal trends in the diet of harbour porpoises could inform possible causes for the observed southern range shift in the region.

Region-wide estimates of life history parameters and temporal changes in those parameters that may have resulted from anthropogenic activities is required and needs to be undertaken at an AU level. An assessment such as this requires funding for collaboration between UK, Irish and French stranding and life history programmes. Information on life history should be incorporated within future assessment modelling approaches.

9. Assessment unit status

The status of harbour porpoise in the West Scotland/Ireland and the Celtic & Irish Seas assessment areas is unknown. The assessments conducted for these areas are a step forward but cannot be taken as realistic assessments of the impact of by-catch on harbour porpoises in these areas and the results should not be used. The main problems are that by-catch that occurred prior to the available time series (2009-2017) of days at sea (e.g. Tregenza et al., 1997 for the Celtic Sea in 1993) has not been included in the assessments, and problems identified with the days at sea data in the ICES Regional database need be investigated and resolved. Further, it would be informative to run the assessments using the by-catch time series without the “uninformative multiplier” to illustrate the effect of using this. Until this can be done, assessments for these areas will not provide useful information. Notwithstanding these uncertainties, it is clear that by-catch is one of the main anthropogenic pressures in these assessment areas.

The abundance of harbour porpoise in the west Scotland/Ireland AU was estimated as 44,976 (CV= 0.317) in 2005, and 42,920 (CV=0.151) in 2016, suggesting a stable population. In the Celtic & Irish Seas AU, however, estimated abundance was 88,696 (CV=0.339) in 2005 and 35,232 (CV=0.192) in 2016. There is insufficient power in these two estimates to detect a trend. If a decline has occurred within the Celtic and Irish Seas AU area, possible reasons could be increased mortality due to anthropogenic activities, such as incidental capture in fishing gear, increased mortality due to a decline in individual health or nutritional status and/or a decline in reproductive output. In UK waters as a whole, an increase since the 1990s in the proportion of necropsied harbour porpoise displaying evidence of starvation/nutritional stress has been observed and reproductive failure and dysfunction has been reported, associated with poor health status and possibly exposure to PCBs. A decline in observed pregnancy rate (68% in the 1990s vs 54% in the 2000s and 2010s) and an overall decline in size at age of harbour porpoises from UK waters of the Celtic and Irish Seas AU area has been documented.

It is also possible that individuals may have re-distributed within the wider North-east Atlantic region. During this time-period there is evidence of a southern movement of animals into French waters (Figure 2), which form southerly waters of the Celtic & Irish Seas AU area, and individuals could also have moved into the eastern channel and southern North Sea (waters of the North Sea AU). Porpoises in the Celtic & Irish Seas AU are ‘admixed’ individuals from the northern and southern ecotypes (Fontaine et al. 2017); genetic analysis of porpoises that stranded or were by-caught in recent years in the eastern channel and southern North Sea region could provide insight into the change in estimated abundance in the Celtic & Irish Seas AU.

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APPENDIX I TO ANNEX 7

Table 1. Mean concentrations of the sum of PCBs, CB 153 and DDXs (µg.g^{-1} lipids) in blubber of harbour porpoises from different regions of the North East Atlantic Ocean and the Black Sea. Years in brackets refer to the date of stranding. A: Adults; J: Juveniles; AM: Adult males; AF: Adult females; JM: Juvenile males; JF: Juvenile females; n: number of samples. * median; ** Σ7CBs. Provided by Mahfouz et al. (2014).

		∑PCBs			CB 153			∑DDXs			
Area	Age/Gender	Mean ± SD	(min - max)	n	Mean ± SD	(min - max)	n	Mean ± SD	(min - max)	n	References
Dansih and Norwegian waters (1987-1991)	M	23.3	(3.7-65)	34				16.39	(3.2 - 45.1)	34	(Kleivane et al. 1995)
Baltic sea (1985 - 1993)	JM	16 ± 8	(2.9 - 32)	13	6.6 ± 3.6	(1.1 - 13)	13	15 ± 18	(1.5 - 59)	11	(Berggren et al. 1999)
Baltic sea (1988 - 1989)	AM	46 ± 29	(14 - 78)	4	20 ± 13	(5.9 - 33)	4	116 ± 134	(20 - 308)	4	
Kattegat-Skagerrak Seas (1989-1990)	JM	11 ± 5.0	(2.2 - 20)	10	4.8 ± 2.5	(1.0 - 10)	10	20 ± 13	(5.7 - 36)	8	
Kattegat-Skagerrak Seas (1988-1990)	AM	13 ± 5.2	(6.7 - 22)	7	5.7 ± 2.3	(3.0 - 9.5)	7	25 ± 20	(2.8 - 61)	7	
Kattegat-Skagerrak Seas (1978-1981)	AM	40 ± 22	(17 - 67)	5	19 ± 12	(6.0 - 33)	5	98 ± 43	(35 - 154)	5	
West coast of Norway (1988-1990)	AM	15 ± 11	(7.2 - 33)	8	5.6 ± 4.6	(2.5 - 14)	8	9.1 ± 7.4	(3.1 - 22)	6	
Southern North Sea (2001-2003)	F	15 ± 8.6		19							(Pierce et al. 2008)
Scotland (2001-2003)	F	10.5 ± 13.2		31							
Ireland (2001-2003)	F	53.5 ± 48		12							
France (2001-2003)	F	13.8 ± 11		2							
Galicia (2001-2003)	F	53 ± 42		3							
Southern North Sea (1999-2004)	JF	12.9 ± 11.9	(1.3 - 39.3)	9	3.7 ± 4.1	(0.2 - 13.4)	9				(Weijs et al. 2009)
	JM	15.4 ± 10.7	(5.3 - 39.8)	12	3.9 ± 3.0	(1.2 - 11.5)	12				
	AF	7.3 ± 2.0	(4.4 - 8.9)	5	1.7 ± 0.6	(1.0 - 2.3)	5				
	AM	82.9 ± 31.8	(38.7 - 125.5)	8	28.7 ± 12.0	(11.6 - 46.0)	8				
East England (1991-2005)	M	11.6 ± 9.7		23							(Law et al. 2010)
Southern North Sea (1991-2005)	M	46.4 ± 30.7		21							

		∑PCBs			CB 153			∑DDXs			
Area	Age/Gender	Mean ± SD	(min - max)	n	Mean ± SD	(min - max)	n	Mean ± SD	(min - max)	n	References
Black Sea (1998)	A	13.2*	(8.8 – 24.9)	11				77.3*	(55 – 157)	11	(Weijs et al. 2010a)
	J	7.0*	(4.9 – 13.7)	9				40.9*	(27.4 – 82)	9	
North Sea (1990-1999)	A	81.5		1				22.9		1	(Weijs et al. 2010b)
North Sea (2000-2008)	A	24.9	(15.3-34.5)	2				3.4	(1.2-1.4)	2	
North Sea (1990-1999)	J	19.1		1				4.5		1	
North Sea (2000-2008)	J	9.9	(1.1-68.2)	5				1.7	(0.4-6.4)	5	
North West Iberian Peninsula	JF	10.8 ± 2.8		5	2.9 ± 0.8		5				(Méndez-Fernandez et al. 2014)
(2004-2008)	JM	9.4 ± 3		3	2.8 ± 1		3				
	AF	37.5 ± 30.8		3	12.0 ± 9.7		3				
	AM	50.8		1	16.6		1				
Southern North Sea (2010-2013)	JF	32 ± 21**	(7.4 - 48)	3	14 ± 10	(3 - 22)	3	16 ± 10	(8 - 27)	3	(Mahfouz et al. 2014)
	JM	20 ± 31**	(0.6 - 110)	12	9 ± 15	(0.3 - 54)	12	19 ± 25	(2.4 - 96)	12	
	AF	4 ± 1,8**	(2.5 - 7)	4	1.8 ± 0.9	(1 - 3)	4	1.9 ± 1.3	(0.7 – 3.5)	4	
	AM	22**	-	1	10	-	1	13	-	1	

JOINT IMR/NAMMCO INTERNATIONAL WORKSHOP ON THE STATUS OF HARBOUR PORPOISES IN THE NORTH ATLANTIC

Area Status Report

North Sea

Compiled by S. Murphy[1], J. Tougaard[2], P.G.H. Evans[3], F. Caurant[4] and P.S. Hammond[5]

[1] *Galway-Mayo Institute of Technology, Ireland*
[2] *Aarhus University, Denmark*
[3] *Sea Watch Foundation/Bangor University, UK*
[4] *Centre d'Etudes Biologiques de Chizé, France*
[5] *University of St. Andrews, UK*

1. IDENTIFICATION OF ASSESSMENT UNITS WITHIN EACH SUB-AREA

One continuous harbour porpoise population has been reported to exist ranging from waters off Norway to the northern Bay of Biscay based on genetic analysis of 10 microsatellite loci and 752 individuals (Fontaine et al. 2007). Fontaine et al. (2014, 2017) reported significant isolation by distance within the region, i.e. increasing genetic differentiation with geographic distance that was more apparent in the southern extent of their range. A distinct sub-species *Phocoena phocoena meridionalis* of a larger-sized morphotype has been proposed, with two genetically distinct populations inhabiting Iberian and Mauritian waters (Fontaine et al. 2014).

The ASCOBANS/HELCOM small cetacean population structure workshop considered "*a few generations (equivalent to low tens of years) as the appropriate time frame for defining a management unit, and we identify a MU as a group of individuals for which there are different lines of complementary evidence suggesting reduced exchange (migration/dispersal) rates*", i.e. a maximum of 10% migration per generation (Evans and Teilmann 2009). Within the North-east Atlantic, the ICES WGMME (2013, 2014) delineated five management units (MU) (or assessment units (AU) under the MSFD), including the (1) Kattegat and Belt Seas, (2) North Sea, (3) West Scotland, (4) Celtic and Irish Seas (including French Atlantic waters), and (5) Iberian Peninsula (see Figure 1a). Delineations of the five MUs/AUs were based partially on genetic analysis as well as measurements of time-integrated ecological tracers and morphological differences – though limited data were available from porpoises inhabiting waters off the west of Scotland and delineation was based more on the extent of anthropogenic activities (IAMMWG 2015). More recent genetic analysis further supported separation of porpoises in the Celtic Sea and French Atlantic waters, with the Irish Sea as a transition zone between admixed and non-admixed North Sea porpoises. However, it did not justify a western Scotland AU based on genetic structure alone (Fontaine et al. 2017). Both Fontaine et al (2014) and Fontaine et al (2017) showed no genetic distinction between the porpoises from the Atlantic coasts of Ireland and north-western Scotland.

There have been numerous discussions with regard to the merits of defining more than one assessment/management unit in the North Sea (Evans and Teilmann 2009, ASCOBANS 2018)). Based on the current level of information and further work that is required to resolve this issue, the current status assessment will report at the North Sea level; i.e. the MU area previously defined by the ICES WGMME (2013; 2014). However, a change in the position of the boundary between the North Sea MU and the Kattegat and Belt Seas MU was proposed by Sveegard et al. (2015) based on genetic, morphological, acoustics and satellite tracking data. This information was reviewed at the workshop and those adjustments to the boundary with the Kattegat and Belt Seas MU were endorsed by the attendees (see Figure 1b).

Abundance and occurrence of harbour porpoises have fluctuated over the last 100 years within the North-east Atlantic. A decline in both strandings and observations occurred in the southern North Sea, English Channel and French Atlantic coasts from the 1950s onwards (Smeenk 1987, Evans 1992, Addink and Smeenk 1999, Camphuysen 2004, Evans et al. 2008, Jung et al. 2009). Within the last two decades porpoises started to return again to these waters, which included a re-distribution of animals from the northern to the southern North Sea, as well as the re-population of central English Channel and waters off the French Atlantic coast (Camphuysen 2004, Hammond et al. 2013, Hammond et al. 2017, Laran et al. 2017). Alfonsi et al. (2012) and Fontaine et al.

(2014, 2017) analysed samples from 'French' porpoises using both mtDNA and microsatellite markers from animals that stranded between 2000 and 2010 and results suggested that porpoises from the French Atlantic and Celtic Sea were an admixture of individuals from waters further north (northern ecotype) and the Iberian-Mauritian sub-species (southern ecotype). The extent of this contact zone for admixed individuals extends into waters off the southwest coast of the UK, where porpoises were found to be genetically admixed and of a larger body size compared to other regions around the UK - using samples collected between 1990-2002 (Fontaine et al. 2017). More recent unpublished analyses undertaken by Murphy et al. (Unpublished data) assessing variations in life history parameters among AUs in English and Welsh waters using data collected between 1990 and 2012 reported that harbour porpoises in the Celtic and Irish Seas were significantly larger in asymptotic length compared to animals inhabiting the North Sea. Porpoises in the Celtic and Irish Seas also attained a significantly larger size at sexual maturity (L50) compared to the North Sea, and this was evident in both sexes whereas no significant variation in the age at attainment of sexual maturity (A50) was observed among AUs.

In 2009, ASCOBANS produced a conservation plan for the harbour porpoise in the North Sea and reports from the North Sea group overseeing the implementation of the conservation plan can be found at https://www.ascobans.org. The plan contains 12 specific actions including reviewing stock structure, monitoring of trends in distribution and abundance, evaluation of fisheries with respect to the extent of by-catch, development of alternative pingers and gear modifications, finalisation of a management procedure approach for determining maximum allowable by-catch limits in the region as well as investigations of health, nutritional status, diet and effects of anthropogenic sounds on harbour porpoises. For further information see ASCOBANS (2018).

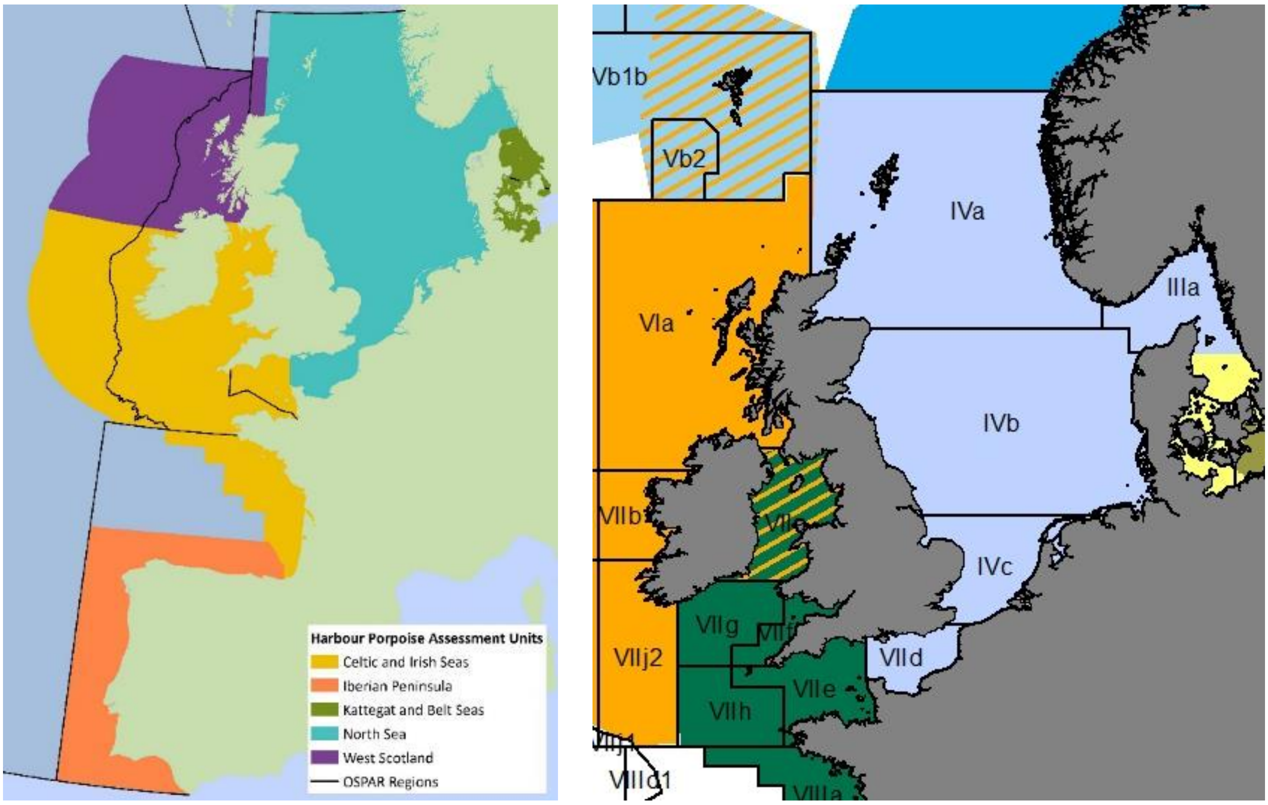

Figure 1. (a) Assessment units used within the OSPAR Intermediate Assessment (IA 2017); (b) Revised boundary of the North Sea and the Kattegat and Belt Seas AUs (proposed by Sveegaard et al. (2015)). Light blue shading indicates the range of the North Sea AU.

2. DISTRIBUTION, ABUNDANCE AND TRENDS

Data

Data that have been used to provide robust information on distribution and abundance of harbour porpoise at the scale of the North Sea come from a relatively limited number of sources.

The approximately decadal series of multinational SCANS surveys were systematically designed to generate estimates of cetacean abundance and provide information on distribution in summer at a large spatial scale (Hammond et al. 2002, CODA 2009, Hammond et al. 2013, Hammond et al. 2017). The focus of the original 1994 SCANS survey was to estimate the abundance of harbour porpoise and other small cetaceans in the North Sea and adjacent waters (English Channel and Celtic Sea). In 2005, SCANS-II extended the survey area to all European Atlantic shelf waters and, in 2007, CODA extended coverage to all species of cetacean in offshore waters (as much of the EEZs of the UK, Ireland, France and Spain as possible). The most recent SCANS-III survey in 2016 covered effectively the same area as SCANS-II/CODA combined, except (a) coverage was extended for the first time to Norwegian coastal waters and (b) waters around western and southern Ireland were not covered because these were the focus of the Irish ObSERVE aerial surveys in 2015 and 2016 (Rogan et al. 2018).

At a smaller but still reasonably large scale, German, Dutch, Danish and Belgian national waters have been surveyed as part of national harbour porpoise monitoring programmes (e.g. (Gilles et al. 2009, Haelters et al. 2011, Scheidat et al. 2012). In addition, two surveys of UK, German, Danish and Dutch waters of the Dogger Bank took place in summer 2011 and 2013 (Gilles et al. 2012, Geelhoed et al. 2013). These data from 2005-2013, combined with SCANS-II data from 2005, have been analysed to predict the seasonal distribution of harbour porpoise over the majority of the North Sea (Gilles et al. 2016).

Surveys conducted as part of the SAMM project covered French Atlantic national waters (English Channel and Bay of Biscay) in winter 2011/2012 and summer 2012 (Lambert et al. 2017, Laran et al. 2017).

Data from many small-scale studies have been used to estimate harbour porpoise abundance in various sectors of European Atlantic waters. Although these are of regional value, they do not provide useful information at the larger scale of the North Sea area and are not considered explicitly here.

However, some of these data have been used, in addition to data from larger scale surveys, in three analytical studies of distribution and abundance at a large scale (Heinänen and Skov 2015, Paxton et al. 2016, Waggitt et al. in prep.). These studies included data from small scale and/or opportunistic studies from various sources including European Seabirds at Sea surveys, regional NGO surveys, surveys conducted on platforms of opportunity such as ferries, and surveys conducted on behalf of energy companies.

Estimates of abundance

The most complete estimates of abundance for the North Sea area come from the SCANS surveys in 1994, 2005 and 2016 (Table 1). These estimates were used in the assessment.

Table 1. Estimates of abundance for the North Sea assessment area in 1994, 2005 and 2016 from SCANS, SCANS-II and SCANS-III surveys. Some survey blocks covered waters in more than one assessment area; estimated abundance within these blocks was prorated by area.

Year	Assessment area	Abundance	CV
1994	North Sea	289,150	0.145
2005	North Sea	355,408	0.225
2016	North Sea	345,306	0.180

The French SAMM project estimated the abundance of harbour porpoise in the English Channel (partly in the North Sea and partly in the Celtic and Irish Seas areas) to be 17,829 (CV=0.30) and 18,429 (CV=0.30) in winter and summer, respectively.

Using data from German, Dutch, Danish and Belgian surveys in national waters, the two Dogger Bank surveys and SCANS over the period 2005-2013, Gilles et al. (2016) generated model-based estimates for the majority of the North Sea in spring, summer and autumn of 372,167 (CV=0.18), 361,146 (CV=0.20) and 228,913 (CV=0.19), respectively. These estimates excluded the eastern English Channel.

Some information on changes in relative abundance is available from strandings data. An increase in observed strandings of harbour porpoises along French coastlines was observed from the late 1990’s onwards, reaching a peak in the year 2013 (Figure 2) (Dars et al. 2018). In 2017, the harbour porpoise was the second most frequently reported stranded cetacean species on the French Atlantic coast (Bay of Biscay) (6.7% of (1211) stranded individuals) and the most frequently reported species on the French Channel coast (74.1% of (307) stranded individuals) (Dars et al. 2018).

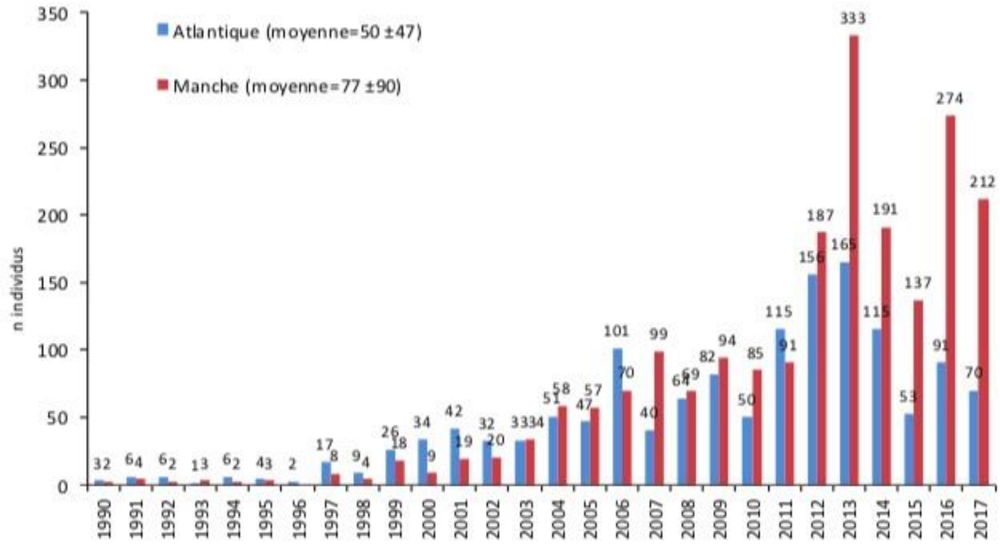

Figure 2. Annual strandings of harbour porpoises along the French Atlantic coast (Bay of Biscay, in blue) and French Channel coast (in red) from 1990 to 2017. Taken from Dars et al. (2018).

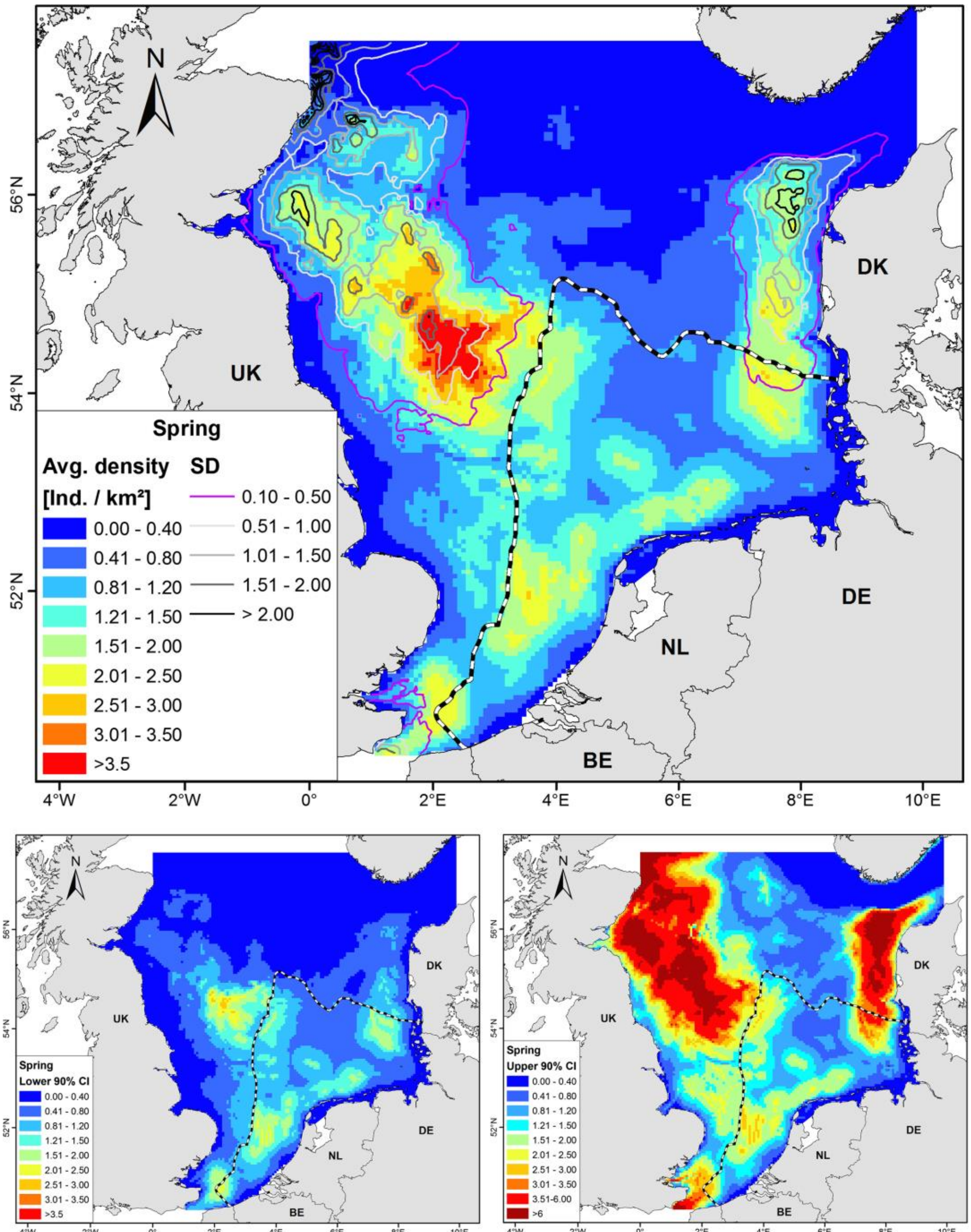

Figure 3. Predicted harbour porpoise densities in the North Sea in spring (March-May) 2005-2013. Upper panel: The overlaid contours are associated jackknife standard deviations (SD). The black and white dashed boundary depicts the sampling coverage in spring. Lower panel: Lower and upper lognormal 90% confidence intervals of predicted density. From Gilles et al. (2016).

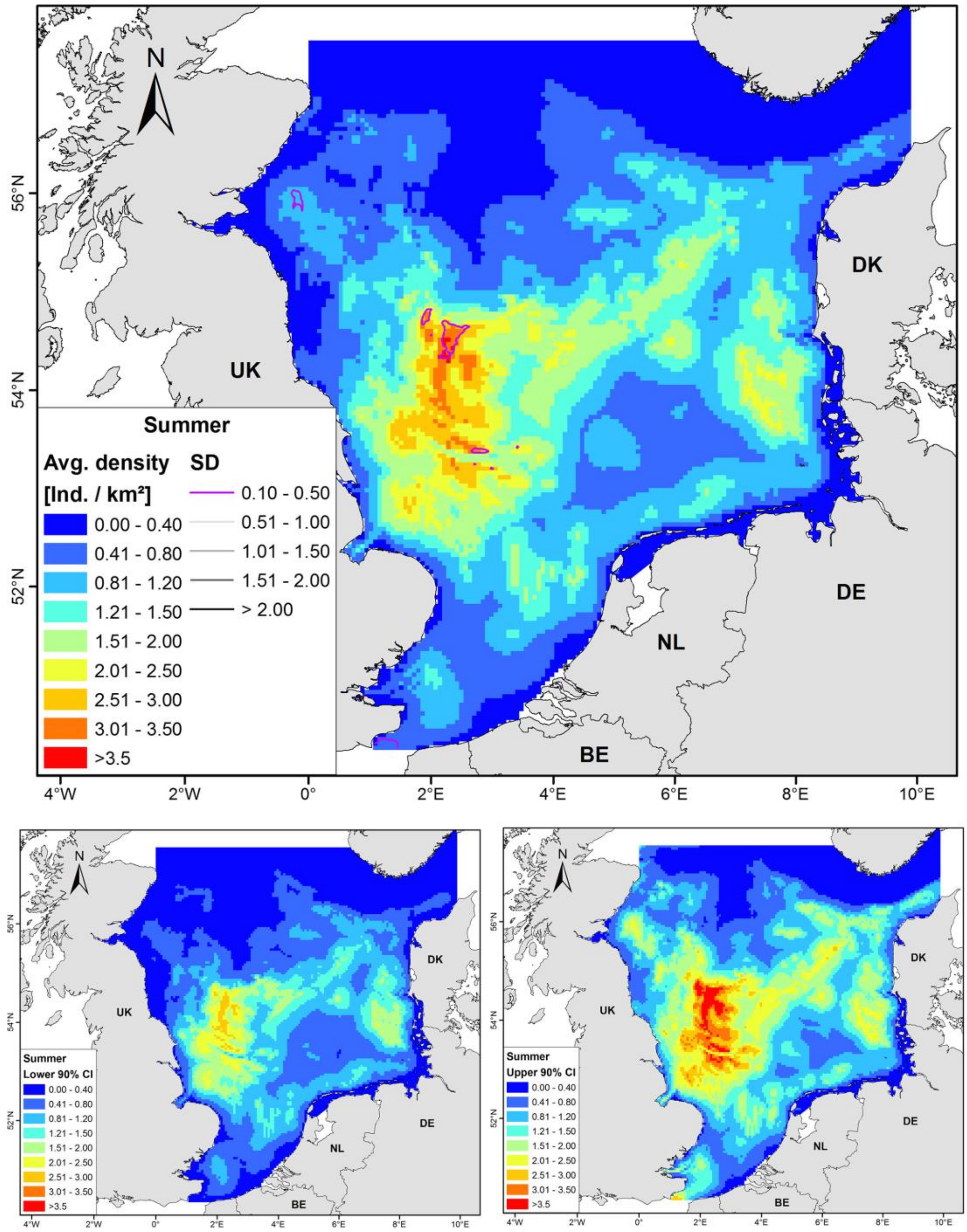

Figure 4. Predicted harbour porpoise densities in the North Sea in summer (June-August) 2005-2013. Upper panel: The overlaid contours are associated jackknife standard deviations (SD). Lower panel: Lower and upper lognormal 90% confidence intervals of predicted density. From Gilles et al. (2016).

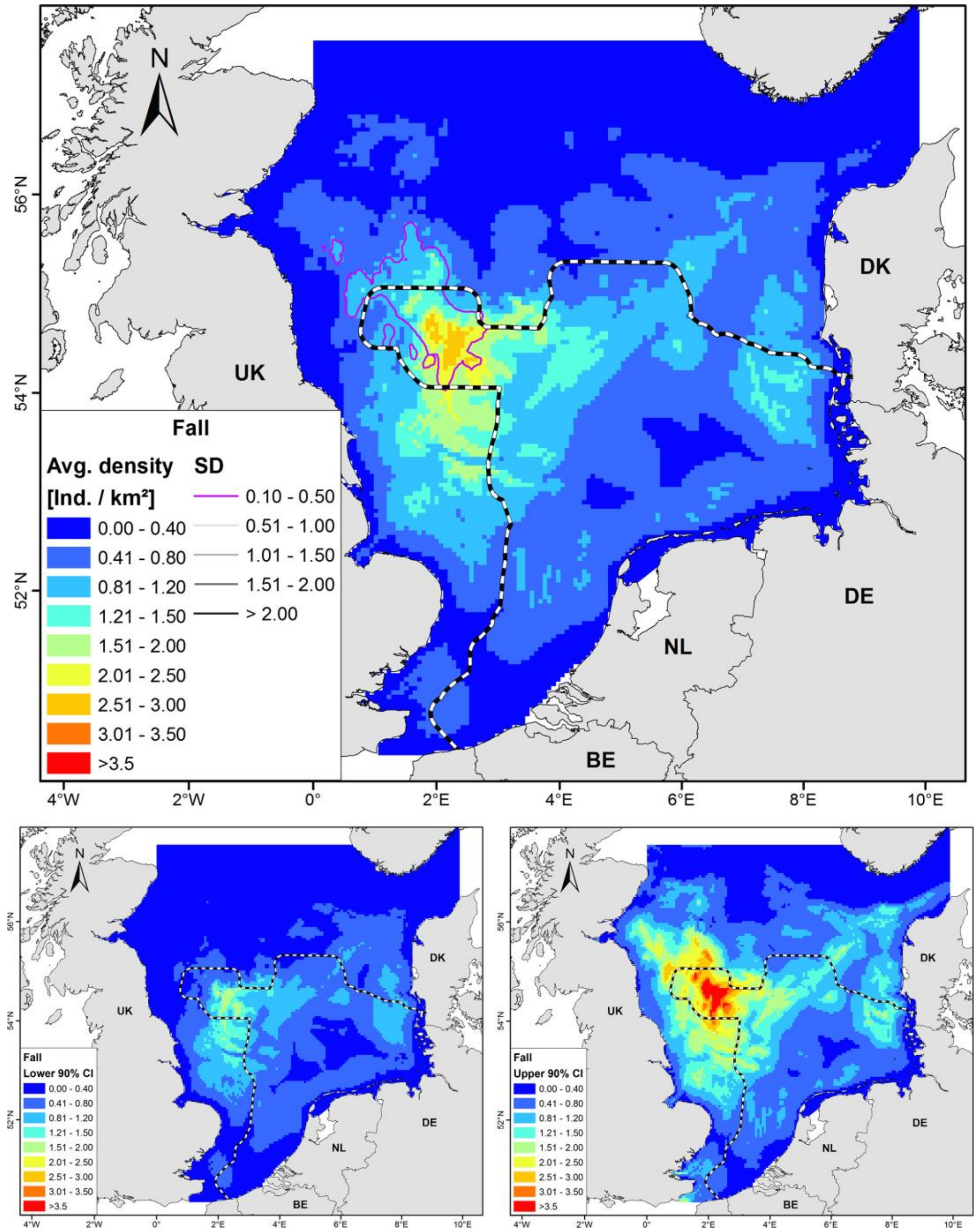

Figure 5. Predicted harbour porpoise densities in the North Sea in autumn (September-November) 2005-2013. Upper panel: The overlaid contours are associated jackknife standard deviations (SD). The black and white dashed boundary depicts the sampling coverage in spring. Lower panel: Lower and upper lognormal 90% confidence intervals of predicted density. From Gilles et al. (2016).

Distribution

The most robust modelling of the distribution of harbour porpoise in the North Sea is by Gilles et al. (2016), who generated modelled distributions for the period 2005-2013 for spring, summer and autumn (Figures 3, 4 & 5). Variables retained in the best model included depth, distance to shore, distance to sandeel (*Ammodytes* spp.) grounds, sea surface temperature, proxies for fronts and day length. The predicted distributions for all seasons show higher density in the western North Sea off the coast of the UK and lower densities in the eastern North Sea closer to Denmark and Germany. In summer, the predicted higher density area appears to extend slightly further south in summer than in autumn and spring (Gilles et al. 2016).

3. Anthropogenic removals in time and space

By-catch of harbour porpoise in the North Sea has previously been considered or estimated in a number of studies (e.g. Northridge and Hammond 1998, Northridge and Hammond 1999, Vinther 1999, Northridge and Hammond 2001a, Northridge and Hammond 2001b, Northridge et al. 2003, Vinther and Larsen 2004). Of particular note are the estimates from Vinther & Larsen (2004) of by-catch in Danish gillnet fisheries between 1987 and 2001. Depending on the method of estimation, mean annual by-catch over this period was estimated to be 5,600-5,800 with a significant reduction in by-catch towards the end of the time series as a result of a decrease in fishing effort and landings. Estimates of by-catch from UK fisheries are considered below.

By-catch estimation from strandings data

Peltier et al. (2018) present a case study using harbour porpoise to illustrate the use of cause of death data and drift models to estimate by-catch from strandings and 'mortality areas' associated with fisheries interactions, focussing on the English Channel and the Bay of Biscay. The eastern English Channel is part of the North Sea AU.

In total, 895 stranded animals with evidence of by-catch were recovered between 1990 and 2015 along both the French Channel (n = 533) and Bay of Biscay (n = 362) coastlines. The models estimated that in the early years 'mortality areas' were almost exclusively located within the Celtic Sea and western Channel followed by an increase in the Bay of Biscay from the early 2000s onwards. The study suggested that from 2012 onwards, a yearly average of 1,300 harbour porpoises died from fisheries interactions in the English Channel and the Bay of Biscay combined (Peltier et al. 2018).

The IWC Scientific Committee's Sub-Committee on Non-Deliberate Human-Induced Mortality of Cetaceans reviewed this work and recommended 'further work to address uncertainties in the analysis arising from parameters that either don't appear to have been quantified directly in the analysis to date, or that have been assessed directly but with either very limited sample size or samples obtained in potentially unrepresentative contexts' (IWC 2018). Estimates of by-catch from this case study were therefore not used in the assessment.

Examination of stranded harbour porpoises in the North Sea showed that the large majority of animals diagnosed as by-catch were less than 3 years old (Figure 6) (Murphy 2008).

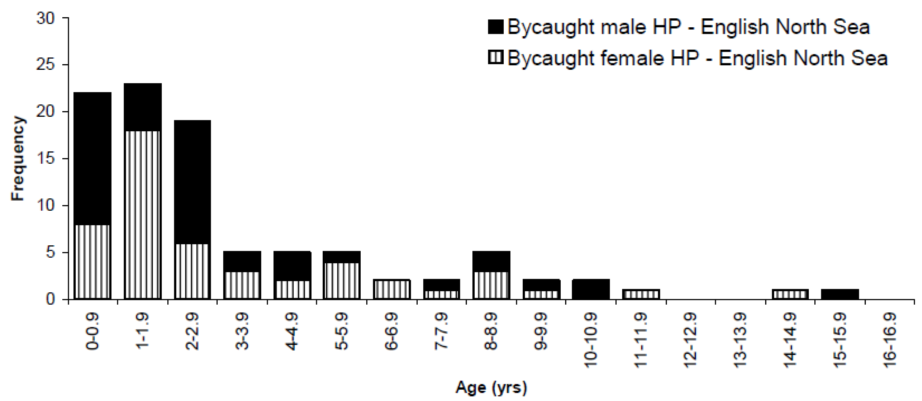

Figure 6. Age distribution of stranded harbour porpoises diagnosed as by-catch by the UK Cetacean Strandings Investigation Programme (1990-2006). Taken from Murphy (2008).

By-catch data used in the assessment

The majority of the time series of by-catch estimates used in the assessment was taken from Hammond, Paradinas & Smout (2018). This report is currently unpublished so the description of how this time series was created is repeated below.

> "The by-catch series … was created from available information on fishing effort and by-catch rates from a number of sources. The aim was first to create a time series of fishing effort (days at sea) for the fleets of the main countries fishing gear that could entangle harbour porpoise (gillnets, drift nets, tangle nets) operating in the North Sea (Belgium, Denmark, England, France, Germany, Netherlands and Scotland), and then to use typical levels of estimated harbour porpoise by-catch rate to estimate the number of porpoises that were by-caught in each year.
>
> The primary source of fishing effort data was a time series from 1966 to 2015 of estimated days at sea by English vessels fishing gear that could entangle harbour porpoise - gillnets, drift nets, tangle nets (S.P. Northridge pers. comm.). Equivalent data were available for Denmark from 1990 to 2000 (S.P. Northridge pers. comm.).
>
> Estimates of days at sea for 2003-2015 for fleets operating in the North Sea other than the English fleet were obtained using data from the STECF database (https://stecf.jrc.ec.europa.eu/dd/effort). For each of the non-English fleets, in the absence of other information, a multiplier relative to the English fleet was calculated for each year and applied to the English days at sea.
>
> For 1966-2002 for non-English fleets other than Denmark, days at sea were estimated using the mean multiplier from the STECF data for 2003-2015. For 1966-1989 for the Danish fleet, days at sea were assumed equal to the English fleet (the average multiplier in the early 1990s was approximately 1). Multipliers for the Danish fleet for 2001 and 2002 were interpolated between 2000 and 2003.
>
> Three overall estimated by-catch rates were used to calculate a plausible range of estimated total annual by-catch from total annual estimated days at sea: 1 porpoise every 5 days at sea (high); 1 porpoise every 10 days at sea (medium); and 1 porpoise every 20 days at sea (low). These overall by-catch rates were based on data from S.P. Northridge (pers. comm.)."

The time series of by-catch generated for 1966-2015, taken from Hammond, Paradinas & Smout (2018) is given in Table 2. In the spirit of a precautionary approach, the assessments were run using the time series of annual by-catch estimated using the "high" by-catch rate. Note that this rate (0.2 porpoises per day at sea or 1 porpoise every 5 days at sea) is approximately double the upper 95% confidence limit of the multiplied by-catch rate (0.1108) used for 2009-2017 (Table 3).

Table 2. Time series of by-catch estimates for the North Sea based on days at sea data for the English and Danish fleets and days at sea for other fleets derived from the STECF database (https://stecf.jrc.ec.europa.eu/dd/effort) from Hammond, Paradinas & Smout (2018), The high, medium and low time series were calculated using a by-catch rate of 1 harbour porpoise per 5, 10 and 20 days at sea, respectively. The high values for 1966-2008 were used in the assessment. Values for 2009-2015 (*in italics*) were replaced by values in Table 4.

Year	High	Medium	Low
1966	2004	1002	501
1967	1639	820	410
1968	1199	599	300
1969	788	394	197
1970	998	499	249
1971	791	395	198
1972	524	262	131
1973	797	398	199
1974	922	461	231
1975	1337	668	334
1976	2370	1185	592
1977	2952	1476	738
1978	4746	2373	1186
1979	3792	1896	948

Year	High	Medium	Low
1980	4126	2063	1032
1981	5175	2587	1294
1982	6246	3123	1562
1983	6147	3073	1537
1984	6352	3176	1588
1985	6005	3002	1501
1986	6824	3412	1706
1987	9960	4980	2490
1988	10023	5011	2506
1989	10152	5076	2538
1990	8336	4168	2084
1991	9749	4874	2437
1992	11062	5531	2765
1993	11356	5678	2839
1994	12363	6182	3091
1995	11887	5944	2972
1996	11060	5530	2765
1997	11370	5685	2843
1998	9905	4952	2476
1999	8512	4256	2128
2000	7360	3680	1840
2001	7471	3735	1868
2002	7632	3816	1908
2003	7462	3731	1865
2004	5239	2619	1310
2005	4435	2217	1109
2006	4094	2047	1023
2007	2616	1308	654
2008	3013	1507	753
2009	*2882*	*1441*	*720*
2010	*3109*	*1554*	*777*
2011	*3505*	*1752*	*876*
2012	*3207*	*1603*	*802*
2013	*2733*	*1366*	*683*
2014	*2804*	*1402*	*701*
2015	*2552*	*1276*	*638*

For the years 2009-2017, annual by-catch was estimated using (a) by-catch rate estimated from data collated by the ICES Working Group on Bycatch (WGBYC) from monitoring conducted 2006-2016 and reported under EU Commission Regulation 812/2004, and (b) a time series of days at sea generated from the ICES Regional database (RDB) for ICES divisions IIIa, IVa, b, c and VIId.

For (a) by-catch rate calculations, as for the West Scotland/Ireland and Celtic & Irish Seas areas, an “uninformed multiplier” was introduced in an attempt to compensate for any potential sources of negative bias for which there is no information, for example animals dropping out of the net underwater. However, it is unknown whether or not such a value is at all realistic (or even justified) and not all participants agreed with the use of the multiplier. Table 3 summarises the data on by-catch rate.

For (b) generation of the time series of days at sea, problems of consistency were identified with the days at sea data provided by Germany so these data were not included in the assessment. The time series of days at sea used in the assessments for 2009-2017 are given in Table 4.

Total annual by-catch for 2009-2017 was estimated using the estimated upper 95% confidence limits of by-catch rates from Table 3 (0.0592 and 0.1108). The time series of by-catch for 2009-2017 considered in the assessment for 2009-2017 are given in Table 4. Although there was disagreement about whether or not the “uninformed multiplier” was appropriate, in the spirit of a precautionary approach, the assessments were run using the upper 95% confidence limit of the multiplied by-catch rate. Note that the upper 95% CL of the multiplied by-catch rate of 0.1108 is approximately equivalent to the by-catch rate of 1 porpoise per 10 days used in the medium time series in Table 2.

For prediction in the future period 2018-2025 the annual by-catch was assumed to be equal to the mean of the previous five years (2013-2017): a value of 4,421.

Data limitations

The method of incorporating uncertainty in by-catch rate is believed to be appropriate. However, the estimates of by-catch rate are likely to be subject to both positive and negative biases and the use of “low”, “medium” and “high” values for most of the time series (1966-2008) and of the “uninformed multiplier” for recent years (2009-2017) is a crude way to try to capture the potential biases.

Table 3. Estimates of harbour porpoise by-catch rate from monitoring collated by ICES WGBYC for the North Sea. The upper 95% confidence limit (CL) of by-catch rate was calculated assuming the data are binomially distributed and that each by-catch event is of a single animal. The “uninformed multiplier” is intended to compensate for any potential sources of negative bias for which there is no information.

Assessment area	North Sea
ICES divisions included	IVa, b, c, VIId
Days at Sea Observed	1,673
By-catch observed	80
By-catch rate (per day at sea)	0.0478
Upper 95% CL of by-catch rate	0.0592
Days per by-catch	17
Uninformed multiplier	2
Multiplied by-catch observed	160
Multiplied by-catch rate (per day at sea)	0.0956
Upper 95% CL of multiplied by-catch rate	0.1108
Days per multiplied by-catch	9

Table 4. Days at sea collated from the ICES Regional Database (RDB) provided by ICES for 2009-2017 for ICES divisions IIIa, IVa, b, c and VIId, and estimates of by-catch using the estimated upper 95% confidence limits of by-catch rates from Table 3.

Year	Days at sea	Estimated by-catch	Multiplied estimated by-catch
2009	22,849	1,353	2,530
2010	58,897	3,487	6,523
2011	60,493	3,581	6,699
2012	57,510	3,405	6,369
2013	34,808	2,061	3,855
2014	35,112	2,079	3,889
2015	53,288	3,155	5,901
2016	36,895	2,184	4,086
2017	39,485	2,338	4,373

There are also limitations with the days at sea data used to create time series of annual by-catch. The information generated for non-English/Danish days at sea using relative values calculated from the STECF database (https://stecf.jrc.ec.europa.eu/dd/effort) is undesirable because of apparent inconsistencies within this database. Problems also exist with the days at sea data provided by ICES from its Regional database raising questions about the usefulness of these data for creating time series of by-catch estimates. In particular, the days at sea data provided by Germany were inconsistent and were not used in the assessment.

4. Impacts from other indirect (sub-lethal) pressures

Pollution

Within the UK, the harbour porpoise is used as a sentinel species for monitoring long-term trends in chemical contaminant exposure in the marine environment, namely organochlorine pesticides, brominated flame retardants, and hexabromocyclododecane (HBCD). Accumulating levels of brominated flame retardants observed in UK-stranded porpoise blubber in the 1990s was partially responsible for the EU-wide ban of the commercial penta- and octa-mix polybrominated diphenyl ether (PBDE) products in 2004 (Law et al. 2012a). Following which, a significant (and consistent) decline was observed in concentrations of brominated diphenyl ethers (BDEs) in the marine sentinel species during the period 2008 to 2012 (Law et al. 2012a). A decline was also observed in HBCD, as well as organochlorine pesticides such as DDTs and dieldrin concentrations as well as TBT in UK-stranded porpoise blubber for the same period (Law et al. 2012a, Law et al. 2012b). However, although levels of these pollutants are declining, combined toxic effects of multiple exposures to pollutants at low dose levels cannot be ruled out.

In contrast, and although they have been banned for over three decades, concentrations of polychlorinated biphenyls (PCBs) in harbour porpoise blubber have remained rather stable since 1998, with mean ∑PCBs concentrations in adult male and female porpoises (sampled between 1990 and 2012) exceeding an established mammalian toxicity threshold of 9 mg/kg ∑PCBs for onset of physiological (immunological and reproductive) endpoints in marine mammals (Kannan et al. 2000, Law et al. 2012a, Jepson et al. 2016). Individual porpoises exceeded established thresholds particularly in the Irish Sea, Celtic Sea, English Channel and southern North Sea (see Figure 7) - including the 41 mg/kg ∑PCBs threshold that has been associated with profound reproductive impairment in Baltic ringed seals (*Pusa hispida*) (Helle et al. 1976, Jepson et al. 2016). This suggests a continued environmental input of PCBs into the marine environment (Law et al. 2012a, Jepson et al. 2016). As observed in Figure 8 regional differences in ∑PCB burdens exist, with stable levels in both the east of the UK and Scotland (declined until 1998, followed by an increase which reversed around 2005), although levels are falling in the west of the UK where they were historically high – mean concentrations dropped from c27 mg/kg lipid weight in the early 1990s to about 15 mg/kg lipid weight in the mid-2000s. Mean concentrations for animals sampled between 1991 to 2006 includes Scotland, 11.5 mg/kg lipid weight; East (England and Wales), 16.0 mg/kg lipid weight and; West (England and Wales), 20.5 mg/kg lipid weight.

Murphy et al. (2018) assessed the influence of metabolism and the degree of offloading of PCBs in female harbour porpoises in UK waters (n = 278). Seven PCB congeners (PCB118, -138, -149, -153, -170, -180, and -187) contributed to 79% of the ΣPCB content in blubber samples. PCB118, PCB170, and PCB180 are dioxin-like PCBs, whereas PCB138 and PCB153 are non-dioxin-like, with the latter having estrogen-like activities. The top PCB congeners in the blubber of females were PCBs 153>138>149>180>187, and accounted for 54% of the ΣPCB concentration. PCB153, -138 and -149 are SAG 1, 2 and 5 congeners, respectively and are considered non-biotransformable in cetaceans, whereas SAG 3 congeners (PCB28, -31, -66, -105, -118, and -156) that are metabolized by CYP1A1 mediated enzymes in cetaceans were observed at relatively low concentrations within the blubber tissue of all maturity groups ((Murphy et al. 2018) and references therein).

Weijs et al. (2009) analysed blubber samples from stranded and by-caught harbour porpoises sampled between 1999 and 2004 in the southern North Sea. Median values for Σ21 PCB congeners and Σ10 PBDEs congeners were 12.4 mg/g lw and 0.76 mg/g lw (n= 35), respectively. Highest PCB concentrations were observed in adult males indicating bioaccumulation, whereas highest PBDE concentrations were measured in juveniles, likely due to better-developed metabolic capacities with age in adults. A higher contribution of lower chlorinated and non-persistent congeners (e.g. CB52, CB95, CB101, and CB149), together with higher contributions of other PBDE congeners than BDE 47, indicated that harbour porpoises are unable to metabolize these compounds – in contrast to harbour seals which exhibited a higher ability to metabolize PCBs and PBDEs (Weijs et al. 2009).

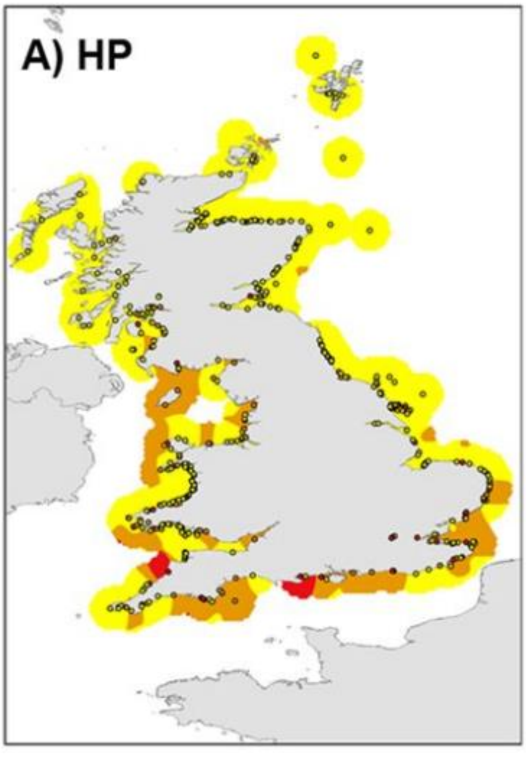

Figure 7. A spatial distribution map of ∑PCB lipid concentrations in harbour porpoises and includes data points along with local averages. Both the data points and the local averages are displayed in three colours: yellow (∑PCB concentration ≤20 mg/kg); orange (∑PCB concentration = 20–40 mg/kg lw); and red (∑PCB concentration ≥ 40 mg/kg lw). Data obtained between 1990 and 2012 (n = 548). Taken from Jepson et al. (2016).

While a decline in the levels of persistent organic pollutants was observed in adults and juveniles harbour porpoises in the southern North Sea between 1990 and 2008, this was not observed in calves – where an increase over time was observed for some contaminant types including PCBs (Weijs et al. 2010b). Harbour porpoise calves were the most vulnerable age class in the study, possibly due to foetal and newborn exposure to these lipophilic pollutants during gestational and lactational transfer, and calves may also have a lower ability to eliminate these compounds as their enzyme and metabolic pathways may be underdeveloped ((Weijs et al. 2010b) and references therein). Further, Weijs et al. (2010) suggested that calves may be feeding at a higher trophic position than their mothers, essentially ‘consuming the tissues of their mothers’. A decline was observed in PBDEs over time in calves.

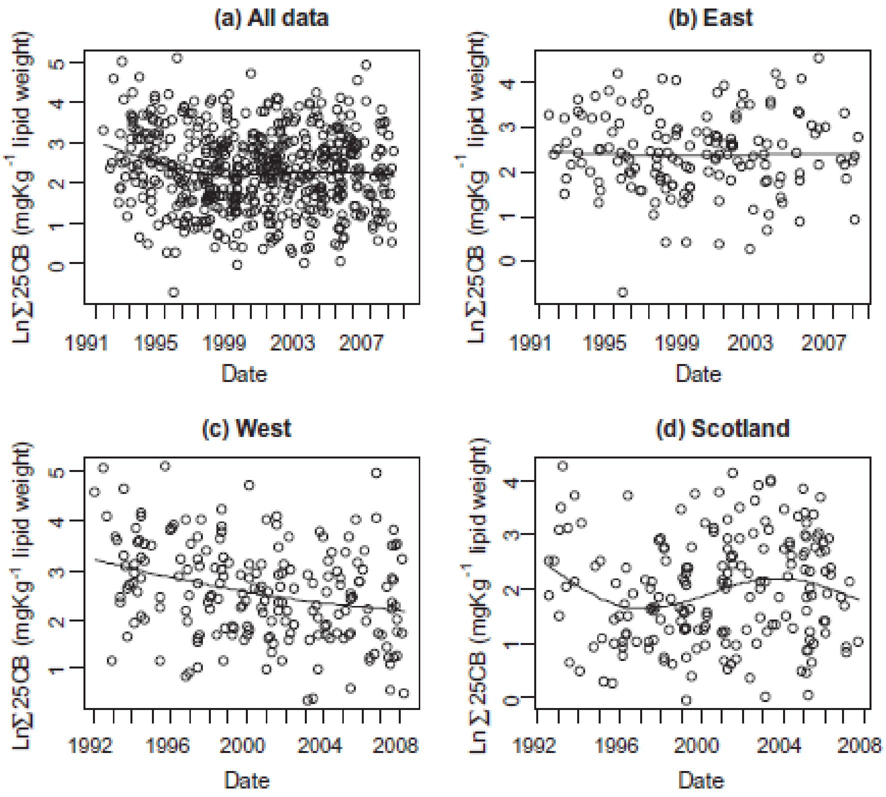

Figure 8. Ln ∑PCB concentrations in porpoise blubber against date for all data, presented for individual areas (East, West and Scotland) as well as for all areas. Taken from Law et al. (2012a).

For the sampling period 2001-2003, significant between-region differences in blubber concentrations of PCBs, PBDE and HBCD were reported in the North-east Atlantic – included samples from porpoises off Ireland, Scotland, the Netherlands, Belgium, France and Galicia, NW Spain (Pierce et al. 2008). ΣPCB levels were significantly higher in porpoises in the southern North Sea compared to Scotland. However, concentrations still exceeded the threshold for the onset of physiological effects (9 mg/kg) in over one-third of the Scottish sample – and in three-quarters of the southern North Sea sample. PBDE levels were higher in Scottish samples than porpoises off Ireland and Galicia, while HBCD concentrations were highest in porpoises off Scotland and Ireland, particularly animals sampled in the Irish Sea (Pierce et al. 2008).

Mahfouz et al. (2014) summarised mean concentrations of Σ7PCBs, CB153 and DDX (mg/kg) in blubber of harbour porpoises from different regions of the North-east Atlantic (including data from Weijs and colleagues from the southern North Sea and data from Pierce and colleagues) and the Black Sea for the years 1985 to 2013 (see Appendix I). What is apparent, and similar to that reported in UK waters, is that mean concentrations of organochlorine pollutants in porpoises in the North Sea have declined. Though mean concentrations of Σ7 PCBs in adult male porpoises in the southern North Sea (northern French and Belgium water) for the period 2010-2013 were still at 22 mg/kg lipid – though much lower than the average ΣPCB concentrations of 82.9 mg/kg reported in mature males in the southern North Sea for the sampling period 1999-2005 (see Appendix I).

For Dutch waters, recent analysis reported Σ17 PCBs in harbour porpoise blubber sampled between 2006-2016 ranging from 0.2 – 80 mg/kg lw (lipid weight), which is within the range previously published for the UK (0.4 – 160 mg/kg lw) and adjacent North Sea waters ((van den Heuvel-Greve et al. 2017); see Appendix I). Within the Dutch sample, 60% of the neonates, 62% of the juveniles and 27% of the adults had ΣPCB concentrations higher than the 9 mg/kg threshold level, and the highest concentrations were observed in adult males, akin to other studies (see Figure 9) (van den Heuvel-Greve et al. 2017). Σ6 dioxin-like (dl) PCBs ranged from 0.05 – 1.64 mg/kg lw. When based on TEQ, Σ6 dl-PCB levels were 1 - 86 ng/kg TEQ ww and 3 - 97 ng/kg TEQ lw. Σ6 PBDE levels in blubber tissue ranged between 0.002 – 2.170 mg/kg lw, and HCB levels ranged from 0.015 - 0.586 mg/kg lw. Whereas, HCBD was not found at levels above detection limits. PFCs concentrations in liver samples were expressed as wet weight (ww) or dry weight (dw) due to their protein-binding characteristics. ΣPFC levels ranged from 0.05 – 3.0 mg/kg ww and 0.17 – 10.6 mg/kg dw.

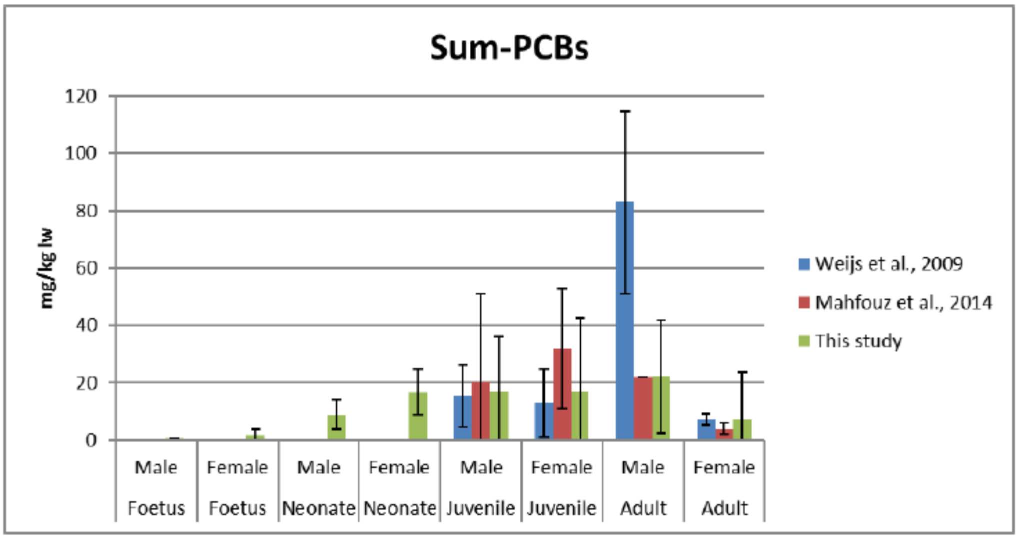

Figure 9. ΣPCB concentrations (in mg/kg lw) in blubber samples of different age groups of harbour porpoises of the North Sea. Taken from van den Heuvel-Greve (2017).

Analysis of perfluorochemicals in the liver of stranded and by-caught harbour porpoises sampled between 1980 and 2005 in the Danish North Sea reported that PFOS was the predominant compound, making up on average 88.9% of the ΣPFC (n= 85). While lower levels of PFOSA (7.8%), and PFUnA (1.9%) and PFDA (1.2%) were detected, and PFHxS, PFNA and PFOA were only found in a small fraction of the samples. Figure 10 presents information on trends in perfluorochemicals in porpoises sampled for the study, and what is apparent is that levels of PFOS and PFOSA were somewhat stable over the 25-year period. In contrast, for two PFCAs consistently detected (PFDA and PFUnA), increasing trends were observed during this time-period – with PFUnA showing a significant increase. Differences among life history groups was reported with highest levels observed in neonates, suckling juveniles and lactating females. Potential reasons for higher levels in lactating females was discussed in the paper (Galatius et al. 2011).

Further work undertaken assessing seven compounds of perfluoro-alkyl substances (PFASs) in three marine mammal species in Danish North Sea waters reported that pinnipeds have a much higher capacity of transforming PFOSA to perfluorooctane sulfonic acid (PFOS) than the harbour porpoise (Galatius et al. 2013). Further, porpoises, possibly due to their higher metabolic rate, had lower concentrations of the perfluorinated carboxylic acids, which are generally more easily excreted than perfluorinated sulfonamides. Total burdens for PFASs in harbour porpoises were 355.8 ng g^{-1} ww (n=11; 1999-2002).

Further information on the adverse health effects in the species from exposure to pollutants is included in the health status section.

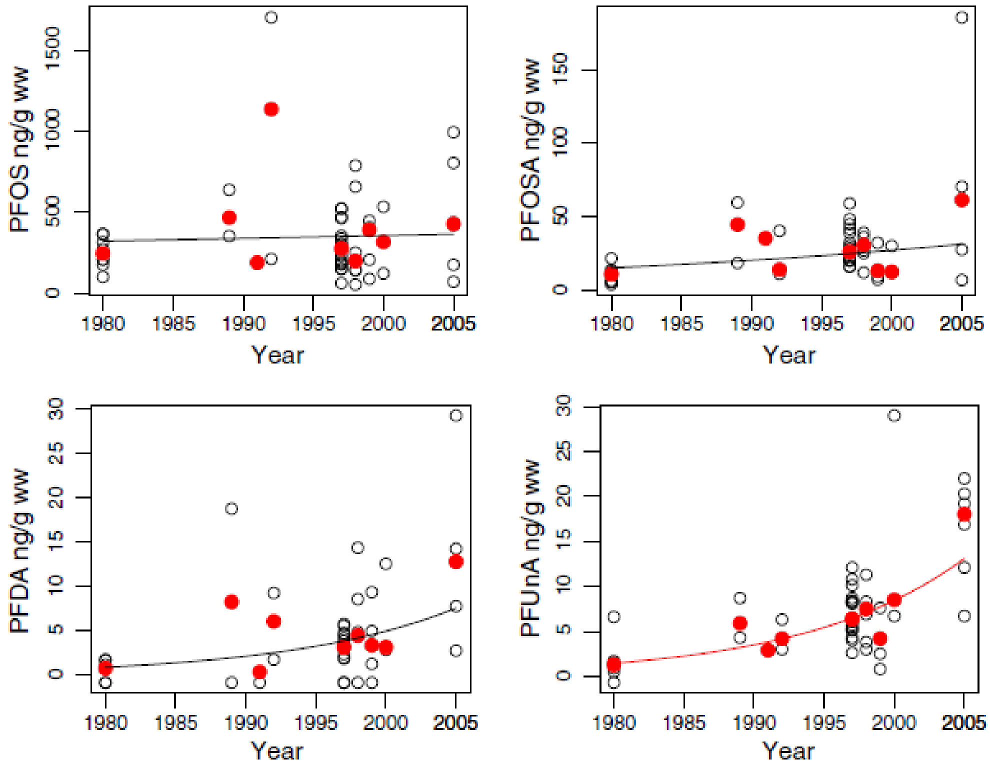

Figure 10. Scatter plots of concentrations of PFOS, PFOSA, PFDA and PFUnA in harbour porpoises in Danish waters against sampling year. Regression lines are shown, with significant regression lines in red. Taken from Galiatus et al. (2011).

Noise and Disturbance:

Underwater noise

A wide range of noise producing activities occur in the North Sea, some of which are relatively well known in terms of occurrence and effects, whereas for others, very limited knowledge is available. Noise sources are commonly divided into impulsive sources and continuous sources and although the division is somewhat arbitrary, the distinction is often useful. This distinction is also mirrored in the requirements for implementation of the EU Marine Strategy Framework Directive, where two separate criteria for Good Environmental Status with respect to underwater noise have been defined: loud, impulsive sounds below 10 kHz and continuous low frequency noise in the 63Hz and 125Hz third-octave bands (European Commission 2008).

Impulsive noise sources

Impulsive noise is somewhat loosely characterised as sound pulses of short duration (seconds or less), occurring with a low duty cycle. The loudest sources are (in no particular order): underwater explosions, seismic surveys, percussive pile driving and certain types of powerful low- and mid-frequency military sonars (see for example Hildebrand 2009), but other impulsive sources of interest include seal scarers (AHDs), net pingers (ADDs), and less powerful fish-finding and navigational sonars, echosounders etc. The four loud sources, as well as other loud sources with significant energy below 10 kHz, are reported by EU member states to the ICES' impulsive noise register (http://ices.dk/marine-data/data-portals/Pages/underwater-noise.aspx), which serves as a source of information about the extent of these sources.

Explosions. By their very nature, underwater explosions generate extremely high sound pressures, which can be lethal at shorter distances and inflict injury to tissue and hearing at considerable distance (many kilometers for large charges; Yelverton et al. 1973, Lance et al. 2015). In the North Sea, the main source of explosive shock waves is detonation of unexploded ordnance (UXOs), primarily from WWII, confined largely to the southern part of the North Sea.

Seismic surveys. Known to have effects on larger whales (e.g. bowhead whales) at distances of several km (Blackwell et al. 2015), but experience with porpoises is lacking (however, see Stone and Tasker 2006, Pirotta et al. 2014). The few data available suggest that behavioural reactions could extend out to distances of several km. Seismic surveys in the North Sea are most common in the southern and central parts, as well as in certain areas around the Scottish east coast, e.g. Moray Firth. There is currently a declining trend in the activity.

Pile driving. Porpoises are known to react to large pile drivings, such as in connection to construction of offshore wind farms, out to distances of at least 20 km (e.g. Tougaard et al. 2009a, Dähne et al. 2013). The level of activity has increased gradually since the early 2000's and shows no sign of levelling off. Areas with highest activity include the German Bight, along Dutch and Belgian coasts, and UK east coast, but activities are expected to move towards the central North Sea, including the Dogger Bank. Efficient mitigation measures, in the form of bubble curtains and insulation sleeves, are available and required for large pile drivings in some countries.

Sonars. Many different types are used, from small fish-finding sonars, which operate at frequencies above the hearing range of porpoises, to very powerful low-frequency military sonars. The low- and mid-frequency anti-submarine sonars are known to have pervasive behavioural effects on odontocetes (Harris et al. 2015, Southall et al. 2016), but experience is lacking for porpoises in the wild. Experiments in captivity (Kastelein et al. 2011, Kastelein et al. 2013, Kastelein et al. 2015, Kok et al. 2017) are consistent with distances of tens of kilometres. Limited information is available about where and how extensively the navies of the North Sea countries as well as foreign nations may use these sonars. Other types of side-scan, fish-finding and navigational sonars, operating at frequencies below 100 kHz, could be of relevance as well, but limited information is available.

Seal scarers. Powerful pingers designed to deter seals from fish farms and fishing gear. Known to deter porpoises at distances of many kilometres, likely more than 10 km (Johnston 2002, Olesiuk et al. 2002, Mikkelsen et al. 2017). Seal scarers are not known to be used in connection with fisheries in the North Sea, however, but are used routinely as deterrent devices in connection with other loud and potentially damaging sounds, such as pile drivings. In some cases, the seal scarer may constitute a larger impact than the original impact it is intended to mitigate (Dähne et al. 2017).

Pingers. Mandatory in some gill net fisheries and some areas to prevent by-catch of porpoises. Deterrence ranges are small, some hundred metres (Culik et al. 2001, Carlström et al. 2009, Kyhn et al. 2015).

Other impulsive sources, including seabed surveys and echosounders. Covers a wide range of techniques for sub-bottom profiling, ranging from side-scan sonars, to various types of boomers, sparkers, pingers and all sorts of echosounders. Experience is very limited and direct measurements lacking, but various impact assessments suggest that reaction distances of up to several kilometres could be expected for the more powerful sources (sparkers and pingers), whereas limited impact is predicted from individual echosounders due to their narrow and vertical beam. The magnitude of the combined impact of the thousands of echosounders active at any one time in the North Sea is unknown, however.

Continuous noise sources

Ships. Considerable information has become available in recent years about noise from individual ships and the combined ship noise in highly trafficked areas. Information is not yet available from the wider North Sea, but will become so during 2019, through deliverables of the joint monitoring project JOMOPANS. Direct evidence of reactions of porpoises to ship noise is scarce, but visual observations and recordings from tagged animals suggest reaction distances in the range of hundreds of metres to a few km (Evans et al. 1994, Evans 1996, Palka and Hammond 2001, Bas et al. 2017, Wisniewska et al. 2018).

Offshore renewables. Available measurements of noise from offshore renewable installations in operation (offshore wind turbines, wave energy converters and tidal turbines) indicate that noise levels are low and exclusively at low frequencies (Tougaard et al. 2009b, Robinson and lepper 2013, Tougaard 2015). Reaction distances are thus expected to be very small, within some hundred metres. Direct studies of porpoise presence in and around offshore wind farms are scarce but a study from the Dutch North Sea coast demonstrated no negative effect of the wind farm, and possibly even a positive effect on porpoise activity (Scheidat et al. 2011). The area covered by offshore wind farms has expanded very fast since the early 2000s and is likely to increase even further in coming years. Most offshore wind farms are located relatively close to shore in the southern North Sea and east coast of Scotland, but they are expected to expand into the central North Sea, including the

Dogger Bank. Impacts from service ships, rather than noise from the turbines themselves, could be the most significant source of disturbance from such installations.

Small boats. Although very abundant in coastal waters and known to be a substantial source of high-frequency noise, very little direct evidence is available on reactions of porpoises to smaller pleasure boats (Evans et al. 1994, Evans 1996). Experience from dolphins suggests that reaction distances are in the range of kilometres, with a correlation between engine size/boat speed and reaction (Nowacek et al. 2001, Mattson et al. 2005). Possible impact in the North Sea is naturally limited to coastal waters but could be substantial in such waters around the southern North Sea coasts.

Dredging and offshore construction. Limited direct evidence of reactions, but noise levels are comparable to ships sailing at cruise speed (Todd et al. 2015). This suggests that reaction distances could be comparable, i.e. hundreds of metres to a few km.

Pipelines. The few measurements and modelling available suggest that the noise from oil and gas pipelines in operation (caused by oil and gas flowing through the pipeline) is very low, in most cases below the natural ambient levels, and at very low frequencies, and inaudible to porpoises (Birch et al. 2000, Glaholt et al. 2008).

Oil rigs. Limited direct measurements are available (Wyatt 2008, Erbe et al. 2013). Noise levels suggest that disturbance comparable to that of larger ships could occur. However, other studies appear to indicate high levels of porpoise activity (presumably foraging) close to and even directly below platforms (Todd et al. 2009), suggesting a strong habituation to the noise.

5. LIFE-HISTORY PARAMETERS AND HEALTH STATUS

Life history

UK

Early studies undertaken assessing the life history of UK harbour porpoises by Lockyer (1995a, b, 2003) sampled stranded and by-caught animals (between 1985 and 1994) from all UK waters, with the majority of animals assessed being from the North Sea. At birth, porpoises ranged between 65 and 70 cm in length (Lockyer 1995b). Maximum lengths of 163 and 189 cm were reported for males and females, respectively, and asymptotic lengths were estimated at approximately 145 cm in males and 160 cm in females – based on regressing age on length (Lockyer 1995a). Porpoises ranged in age from 0 to 24 years, which Lockyer (1995a) noted was in stark contrast to the maximum age reported in North-western Atlantic waters of 13 years (Gaskin et al. 1984, Read 1990), though similar to the maximum age reported in California waters of 24 years (Hohn and Brownell 1990). Females attained sexual maturity between 140 and 145 cm in length, and males between 130 and 135 cm in length (Lockyer 2003).

Life history parameters of porpoises in Scottish waters have not been determined separately for the North Sea AU and west Scotland AU. Learmonth et al. (2014) analysed samples and data collected from 994 stranded and by-caught porpoises obtained from all Scottish waters between 1992 and 2005. Females and males had similar body length ranges, 66–173 cm and 65–170 cm, respectively, though females did attain a larger asymptotic size of 158 cm compared to 147 cm in males. Conception occurred mainly in July and August and reproductively active males (though sample size was small) were recorded between April and July. The gestation period was estimated at 10-11 months, with parturition reported mainly between May and July. Mean size at birth was 76.4 cm (range 65–88 cm). Harbour porpoises tend to start weaning around 8 months of age, though they may not feed entirely independently until approximately 10 months old (Lockyer 2003). Small calves in Scottish waters with solid food in their stomachs were observed during February to May. Maximum age for both sexes in Scottish waters was 20 years, though only 7.5% of porpoises were aged ≥12 years. In contrast to other studies, males attained an average age at sexual maturity (ASM: estimated using a binomial GLM) at an older age of 5.00 years compared to 4.35 years in females. The ASM in both sexes was higher than what was observed in other geographical regions, e.g., Iceland (3.2 and 2.9 yr), Gulf of Maine (3.4 and >3 yr), Denmark (3.6 and 2.9 yr) and West Greenland (3.6 and 2.45 yr for females and males, respectively) (Sørensen and Kinze 1994, Read and Hohn 1995, Lockyer et al. 2001, Lockyer 2003, Ólafsdóttir et al. 2003), and the authors noted this may have been due to the high incidence of deaths resulting from poor health (i.e., pathological conditions). The estimated pregnancy rate ranged from 34 to 40%, depending on the length of the conception period/mating period used, and a sample that was largely composed of mature females of poor health status (approximately two-thirds).

Based on all mature female data from Scottish waters (i.e. not excluding the conception/mating period), a pregnancy rate of 28% was determined.

Preliminary analysis undertaken by Murphy et al. (2012) on reproductive seasonality and testicular regression in harbour porpoises in all UK waters, reported a more active period in sperm production in June and July, though spermatozoa were observed in seminiferous tubules year-round. This was in contrast to the western North Atlantic population, where complete involution and recrudescence was observed outside the defined breeding period (Neimanis et al. 2000). Interestingly, within the UK sample, spermatozoa and spermatids were not observed in the tubules of 17% of the sampled mature porpoises. These individuals died during the months January to April, ranged in age from 5 to 16 years, and where cause of death was established, the majority of individuals died from infectious and non-infectious diseases ((Murphy et al. 2012); Unpub. Data).

Murphy et al. (2015) assessed reproductive material from stranded and by-caught female harbour porpoises sampled between 1990 and 2012 from all UK waters (n = 329). Based on all available samples, a low pregnancy rate of 34% and an ASM of 4.73 years were estimated, while a slightly higher pregnancy rate of 50% and a higher ASM of 4.92 years were determined for 'healthy' females – females that died of traumatic causes of death such as by-catch, boat/ship strike, bottlenose dolphin attacks or dystocia. The pregnancy rate estimated for 'healthy' porpoises was almost half that reported in other geographical locations such as the Gulf of Maine and Bay of Fundy in the North-west Atlantic (93%, 3.27 years) (Read and Hohn 1995), and waters off Iceland (98%, 3.2 years) (Ólafsdóttir et al. 2003). Reproductive failure was reported in UK porpoises that may have been related to exposure to endocrine disrupting chemicals (see Health Status section).

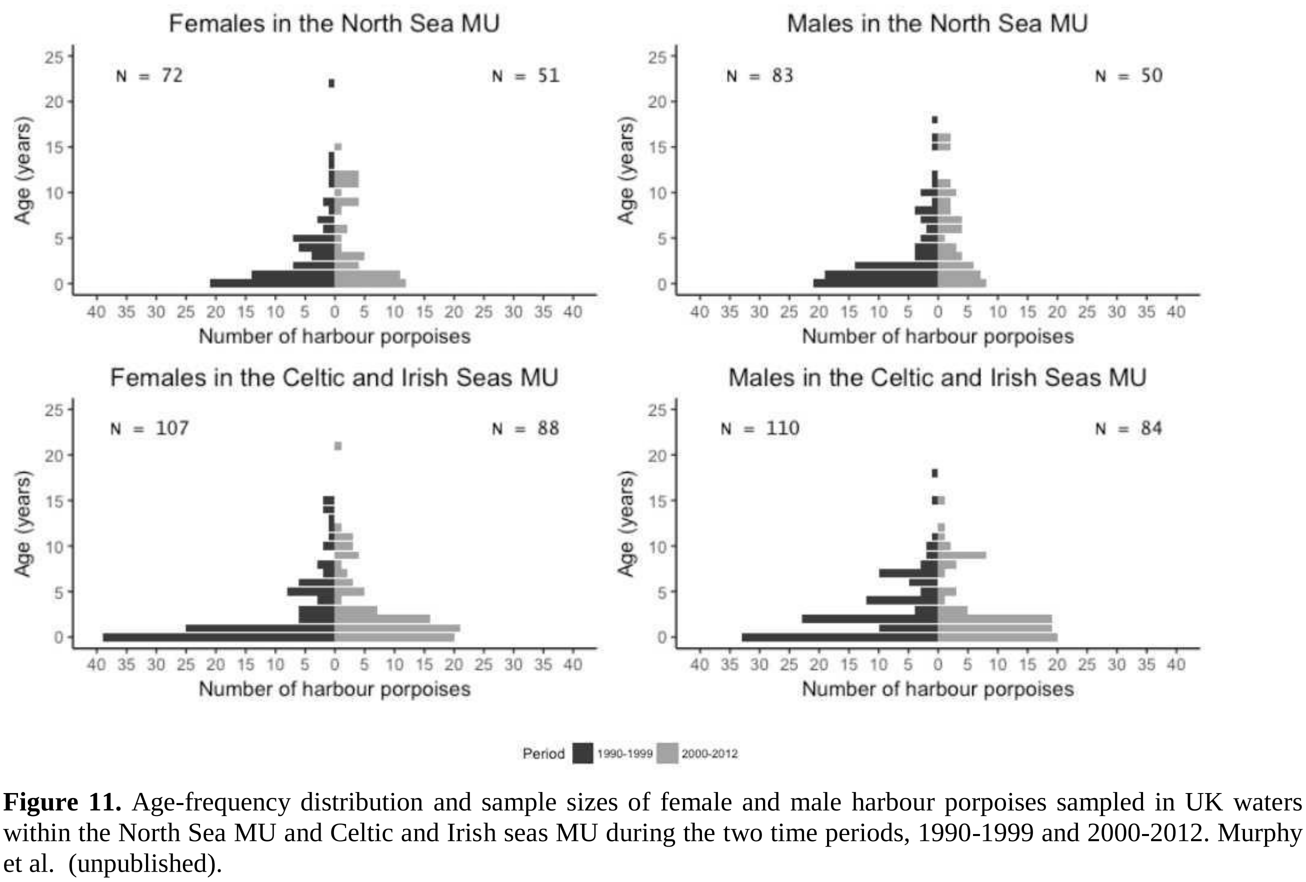

Figure 11. Age-frequency distribution and sample sizes of female and male harbour porpoises sampled in UK waters within the North Sea MU and Celtic and Irish seas MU during the two time periods, 1990-1999 and 2000-2012. Murphy et al. (unpublished).

More recent unpublished analysis by Murphy et al. of reproductive material in UK stranded and by-caught harbour porpoises assessed the life history parameters for the North Sea (NS) Management Unit using samples and data collected between 1990 and 2013 (n = 358). Figure 11 presents the age distributions of porpoises in the North Sea MU and the Celtic and Irish Seas MU. For the statistical analysis, the dataset was divided into two time periods (period 1: 1990-1999 and period 2: 2000-2013) to assess temporal variations in life history parameters. A pregnancy rate of 29% was determine for the North Sea MU, with a slight increase observed between both time periods (26% in period 1 vs 30% in period 2), though this was non-significant. 78% of the mature female sample that was used to determine the pregnancy rate in the NS was composed of animals that died from either infectious disease or other causes such as starvation, live stranding, neoplasia or where cause of death was not established. Using the Gompertz growth model with a period effect on the parameters in the model, females attained a larger asymptotic size of 155.37 cm compared to 140.94 cm in males. No significant temporal variation was observed in the asymptotic size in either sex, although a significant decline in the growth rate parameters was observed during the study period that was more evident in the female data.

Females attained a length at 50% sexual maturity (L50), determined using a binomial logistic regression, at a larger size than males, most apparent in period 2. Males significantly declined in their L50 during the study period, from 133.27 cm in period 1 (1990-1999) to 129.47 cm in period 2 (2000-2012). While in females no significant difference was observed between time periods – 138.90 cm in period 1 and 139.18 cm in period 2. Based on the age at 50% maturity (A50) method (estimated using a binomial logistic regression), females attained sexual maturity at an older age compared to males, and again this was more evident in period 2. Males attained sexual maturity, on average, at a similar age in both time periods in the Celtic and Irish Seas MU - 3.6 years. While, females attained sexual maturity, on average, a year later during the 2000s and 2010s compared to the 1990s – 4.8 years vs 3.8 years, respectively, which was significantly different. Overall health status (proxied by cause of death) did not affect estimates of A50 or L50 as it did not appear in the top ten best fitting models for either parameter.

France

Collet (1995) assessed harbour porpoise strandings and by-catch data (n = 93) for the period 1970 to 1994 for porpoises inhabiting waters off the French English Channel coast and the Bay of Biscay. A seasonal peak in strandings was observed in the Channel sample, with 62% of animals reported between February and April. Within this region, females and males ranged in length from 83 to 186 cm and 124 to 168 cm, respectively. Whereas slightly larger animals were observed inhabiting waters off the French Atlantic coast, as females ranged from 124-190 cm in length, and males from 119 to 183 cm in length.

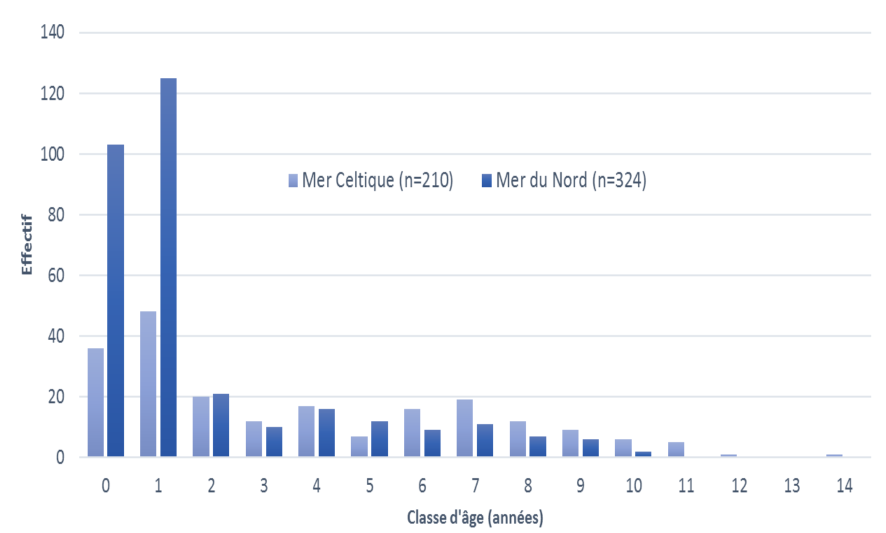

Figure 12. Comparison of age distributions between North Sea (dark blue) and Celtic & Irish Seas (light blue) AUs. Dabin et al. (unpublished data).

More recent unpublished analysis by Dabin et al. analysed biological samples and data collected from 532 individual porpoises sampled between 1990 to 2015 in French waters; 210 individuals sampled in the Celtic & Irish Seas AU and 322 from the North SeaAU , with the boundary between these areas in the English Channel drawn at Cotentin, France. A higher number of young individuals was evident in the North Sea sample, with a significant difference observed in the length distribution between individuals of North Sea and Celtic Sea ($p < 0.0001$), as well as a significant difference in the age distribution of stranded porpoises ($p < 0.0001$) (Figure 12). Using the Laird-Gompertz model, males and females in the North Sea AU attained asymptotic lengths of

141.7 cm and 155.7 cm, respectively, while males and females in the Celtic and Irish Sea AU attained asymptotic lengths of 160.3 cm and 168.9 cm, respectively.

Rouby et al. (Unpub. Data) modelled the population dynamics of harbour porpoises in the Bay of Biscay and English Channel using age and sexual maturity data from 474 stranded and by-caught individuals (Bay of Biscay + west Channel n = 174; east Channel n = 300). Demographic projections showed a growth rate of 0.87 ± 0.03 in the Bay of Biscay and west Channel and a growth rate of 0.78 ± 0.03 in the east Channel. Without immigration from adjacent waters, harbour porpoise in the Bay of Biscay and west Channel were predicted to be extinct in ≈ 30 years and those from east Channel to be extinct in ≈ 15 years (Figure 13). The authors concluded that current pressures, including anthropogenic pressures such as by-catch, are most likely too high for harbour porpoises (Rouby et al, Unpub. Data). However, biases in using strandings and by-catch data for such approaches mean that these results need to be interpreted with caution.

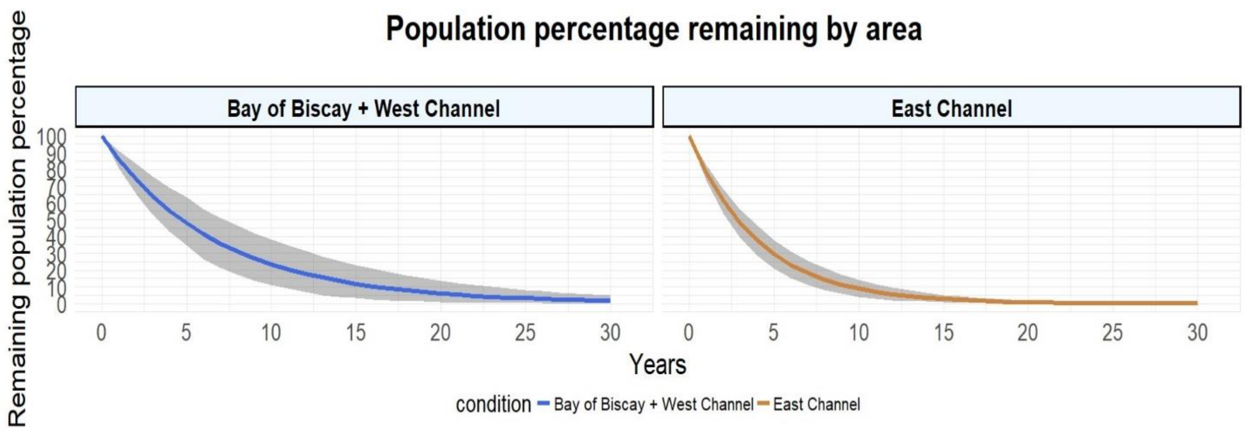

Figure 13. Demographic projections 30 years into the future from a population model of harbour porpoises in French water (Rouby et al, unpublished).

The Netherlands

The majority of information on the life history of Dutch porpoises is based on samples obtained prior to the re-distribution of animals into the southern North Sea. Van Utrecht (1978) reported that sexual maturity was attained around 5 years in males (n=20) and 6 years in age in females (n = 34) using samples collected from 1955 onwards. The maximum length recorded in the study was 151 cm for males and 186 cm for females and the maximum age reported was 12 years. Neonates with umbilical cord attached ranged from 67-90 cm in length, with June being the peak month for births.

Addink et al. (1995) estimated the average length at birth for porpoises in Dutch waters at 74.3 cm (n=27) for animals sampled in the early 1990s. The calving period extended from April to August, with a pronounced peak in July. Based on analysis undertaken by the EU funded BIOCET project, sexually immature female porpoises (n=8) from the southern North Sea (Dutch and Belgium waters sampled between 2001 and 2003) ranged in length and age from 92-130 cm and <1 to 2.5 years, respectively, whereas sexually mature females (n=11) ranged from 132 to 160 cm in length and 5-12 years in age (Learmonth et al. 2004). A pregnancy rate of 11% (1 of the 9 mature females was pregnant with an embryo or foetus) was determined for mature female harbour porpoises sampled in Dutch waters between 2001 and 2003 (sampled outside the mating period). Although the sample size for the 2001-2003 period was small, the pregnancy rate estimate was much lower than the estimate of 58% determined for the time period 1988 to 1995 – based on the presence of an embryo or foetus (Learmonth et al. 2004). The age of sexual maturity of female harbour porpoises in Dutch waters decreased over time from 4.48 years between 1988 and 1995 to 4.00 years for the time period 2001 to 2003 (Learmonth et al. 2004).

Germany

A comparison of the average ages attained at sexual maturity in porpoises inhabiting German North Sea and Baltic Sea waters reported no significant difference in the age at 50% maturity, 4.95 (± 0.6) years in both regions. However, Kesselring et al. (2017) did note that Baltic porpoises died, on average, at a younger age than North Sea porpoises; 3.67 (± 0.30) years vs 5.70 (± 0.27) years, respectively. Using the ASM of 4.95 years, the authors estimated that a total of 54.66% of female harbour porpoises in the North Sea and 27.44% in the Baltic Sea would participate in reproduction (Kesselring et al. 2017).

Denmark

Sørensen and Kinze (1994) assessed 365 stranded and by-caught harbour porpoises sampled between 1985 and 1991 from all Danish waters - including individuals from the North Sea AU and Kattegat and Belt Seas AU. Within Danish waters, conception was noted to occur in late July to early August, and testicular mass peaked in activity in July. Gestation was estimated to last for approximately 10.5 months with parturition noted to occur from mid-June to early July. The ASM (estimated by the sum of fraction immature method) for females and males was 3.64 years and 2.93 years, respectively. The estimated pregnancy rates (excluding females sampled during the mating period) was 73%. This was lower than previous estimates for Danish waters of 84% (Mohl-Hansen 1954) and 79% (Clausen and Andersen 1988). Further, Mohl-Hansen (1954) estimated a larger length at birth of 75 cm compared to 71.3 cm determined by Sørensen and Kinze (1994). A follow-up study by Lockyer and Kinze (2003) using data and samples from direct catches, incidental captures and stranded animals sampled between 1838 and 1998, and again based on samples and data collected from all Danish waters, reported a maximum age of 23 years in both sexes, though only 5% lived beyond 12 years of age. Sexual maturity occurred at slightly over age 3 years in both females and males, with corresponding lengths of about 135 cm in males and 143 cm in females. A peak in activity of testicular tissue was noted in August, and conception most likely occurred in August, with a peak in births noted in June – 10 months later. Data indicated a birth size of between 65 and 75 cm (weight 4.5 – 6.7 kg).

Winship (2008) estimated demographic parameters using data on porpoises sampled in Danish and English North Sea waters between 1987 and 2005. A pregnancy rate of 60% (n = 17) was determined for 'healthy' porpoises (i.e. died as a result of trauma) that died outside the months June to August (Winship 2008).

Health Status and causes of death

This review of the health status and causes of death of harbour porpoises in the North Sea AU area is not all-encompassing and does not include all literature undertaken within this field to date. Publications are extensive, namely as harbour porpoises in the North (and Baltic) Sea present with a higher prevalence of disease, including parasitic and bacterial infections, than other small cetaceans within the North-east Atlantic (Jepson et al. 2000, Siebert et al. 2001, Jauniaux et al. 2002, Jepson et al. 2005, Jauniaux et al. 2010). Porpoises can be heavily parasitised, with endoparasites reported in several organs (ten Doeschate et al. 2017). Analysis of the inner ear has shown the effect of parasites on hearing, which together with other pathological changes might impair appropriate processing of acoustic information (Seibel et al. 2010, Morell et al. 2017). Further work on Dutch porpoises revealed that there was a higher probability of the presence of inner ear parasites in individuals in a poorer nutritive condition (ten Doeschate et al. 2017).

Compared to porpoises in Icelandic and Greenlandic waters, animals in the North Sea have been assessed to be in a poor general health status, with a higher incidence of severe lesions, especially of the respiratory tract (Siebert et al. 2006). For the period 1991 to 1996, pneumonia was considered as the primary cause of death in 46% of stranded (sub-adult and adult) porpoises in the German North and Baltic Seas (Siebert et al. 2001). Research assessing the regional differences in bacterial flora in harbour porpoises (sampling by-caught, hunted and stranded animals over an 18-year period) reported significantly less bacterial growth and fewer associated pathological lesions in porpoises from Icelandic and Greenlandic waters, compared to animals inhabiting the North Sea, Baltic Sea and Norwegian waters (Siebert et al. 2009). These observed differences were attributed to possible impacts from stressors resulting from anthropogenic activities, such as exposure to chemical pollutants, in North and Baltic Sea porpoises. Work concurrently undertaken on pollutants reported that PCB concentrations in adult harbour porpoises were ten times lower in the Arctic than in the North and Baltic Seas (Kleivane et al. 1995, Bruhn et al. 1999, Siebert et al. 2006). Concentrations of PCBs and PBDEs in Icelandic porpoises were on average five times lower than in those from Norwegian and German waters; though with toxaphene concentrations, this situation was reversed (Siebert et al. 2002, Thron et al. 2004, Siebert et al. 2006).

Among other things, exposure to pollutants, namely organochlorines such as PCBs, has been suggested to induce immune-suppression (Hall et al. 2006, Yap et al. 2012), as well as impact thyroid function (Schnitzler et al. 2008) and foetal and newborn survival (Murphy et al. 2015) in North Sea porpoises. Case-control epidemiological studies reported that the risk of mortality from infectious disease in UK harbour porpoises increased in a dose-dependent manner with increasing blubber PCB concentration, with a 50% increase in relative risk of infectious disease mortality at concentrations of total PCBs >25 mg/kg lipid in the blubber (Jepson et al. 2005, Hall et al. 2006, ICES WGMME 2010). Females with high pollutant burdens were more likely to die from ill health. 93% (14 of 15) of mature females with ΣPCB burdens ≥30 mg/kg died as a result of infectious disease or "other" causes such as starvation, and these cause of death groups also comprised 92% (23 of 25) of the pollutant sample ≥20 mg/kg (Murphy et al. 2015).

For the period 2006 to 2010, there was a decline in the number of porpoises reported stranded in all UK waters compared to the previous five year period (2001 to 2005) (see Figure 14) (Deaville and Jepson 2011). The number of porpoise strandings remained low between 2010 and 2015, compared to the early 2000s. However, in Scotland, notable peaks in strandings (>100 individuals) occurred in 2005, 2006, 2013 and 2014. Further peaks in strandings along the English North Sea coast (> 90 individuals) were reported in 2005, 2006 and 2013 (see Figure 14).

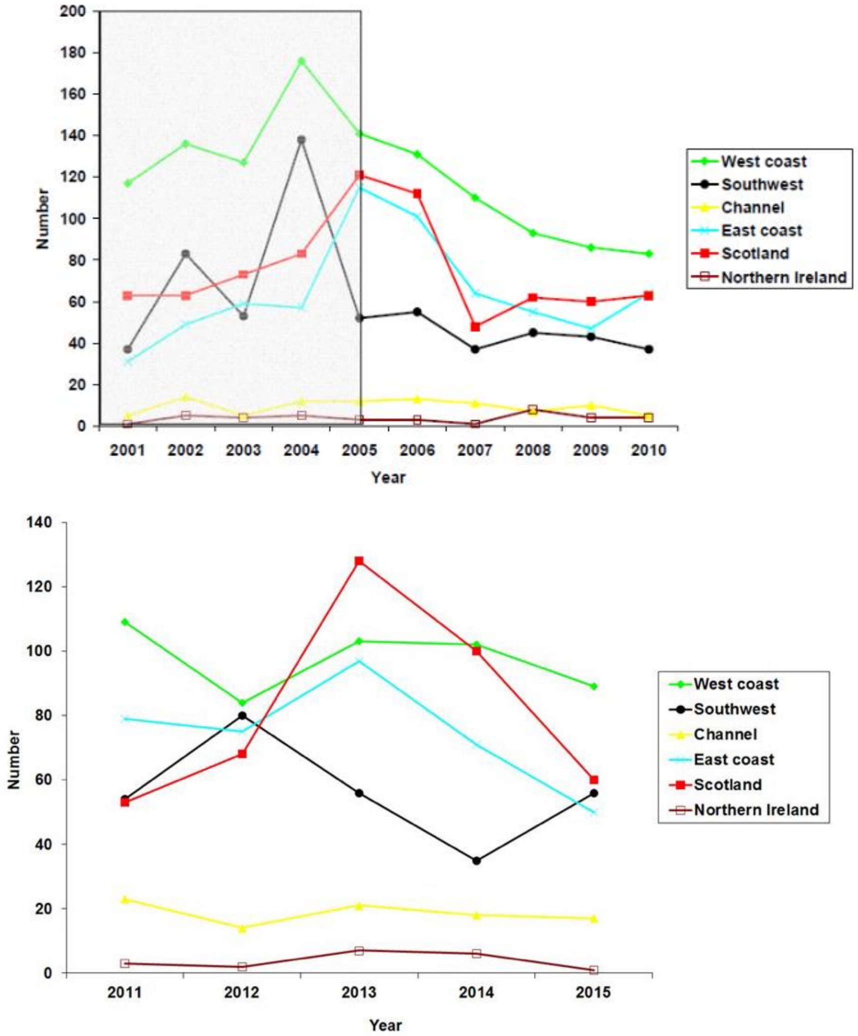

Figure 14. Inter annual variation in UK regional reported strandings of harbour porpoises for (a) 1991 to 2010 and (b) 2011-2015. Taken from Deaville and Jepson (2011) and Deaville (2016).

An analysis of post-mortem examinations conducted between 1991 and 2010 showed a slight decline in the proportion of stranded porpoises along UK coastlines diagnosed as by-catch, along with a relative increase in the proportion of infectious disease and starvation cases. The most recent available report from the UK Cetacean Strandings Investigation Programme is for the year 2015. In 2014, a decrease in harbour porpoise strandings was reported for all regions, and this decline continued in 2015 apart for the south-west coast of the UK (Figure 14) (Deaville 2016). For the 53 stranded harbour porpoises necropsied in 2015, collected throughout the UK, the most common causes of mortality were entanglement in fishing gear (by-catch, 18.9%, n=10), infectious disease (18.9%, n=10, primarily pneumonias due to parasitic infestations or diseases of the gastrointestinal tracts), starvation (17%, n=9) and attack by bottlenose dolphins (15%, n=8). As seen in Figure 15, there were no consistent trends in any cause of death category for UK-stranded harbour porpoises between 2011 and 2015 (Deaville 2016) – though cases of by-catch slightly increased while cases of infectious disease slightly decreased. Cases of starvation increased from 4% for the period 1990 to 2002, to 24% for the period 2005 to 2010 (with 32 out of 117 starvation cases being neonatal starvation) and declined to 17% in 2015 (with the majority being neonatal starvation, 7 out of 9 cases) (Deaville and Jepson 2011). In Scottish waters, the overall estimated mortality rate, and the number of bottlenose dolphin kills, was lower on the west coast than the east coast (Pierce et al. Unpubl. Data).

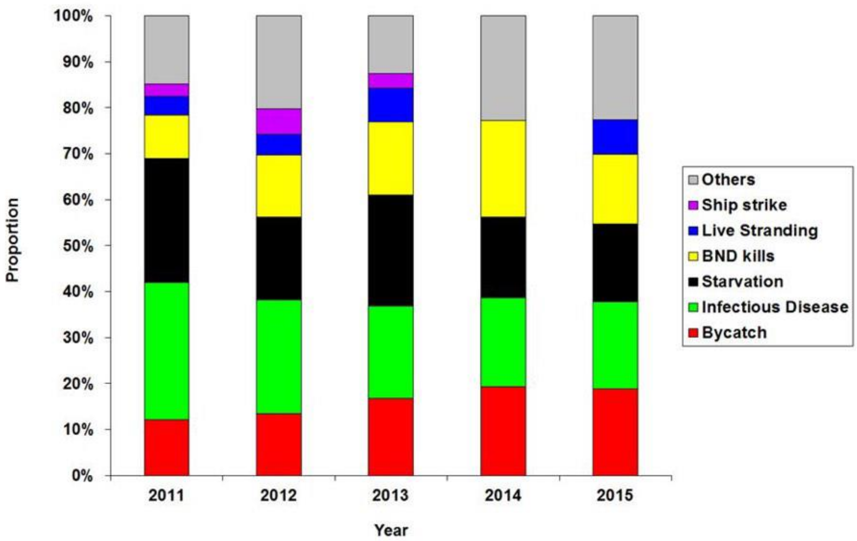

Figure 15. Proportions of major cause of death categories in UK stranded harbour porpoises examined at post mortem 2011-2015. Taken from Deaville (2016).

Reproductive failure was evident in porpoises sampled from all UK waters with 19.7% of sexually mature females showing direct evidence of reproductive failure - such as foetal death, aborting, dystocia or stillbirth (Murphy et al. 2015). Additionally, 16.5% of mature females had infections of the reproductive tract or tumours of reproductive tract tissues that may have attributed to reproductive failure. Murphy et al. (2015) reported that the observed reproductive dysfunction in UK porpoises may have been related to exposure to PCBs, either through endocrine disrupting effects or via immunosuppression and increased disease risk. However, there were difficulties in showing casual relationships between cases of reproductive dysfunction and ΣPCB concentrations due to a females capability to offload their lipophilic pollutants burdens through gestation and lactation transfer (Murphy et al. 2015). Whether or not PCBs were part of the underlying mechanisms of reproductive dysfunction, the authors used individual PCB burdens to show further evidence of reproductive failure in the sample. Based on direct and indirect evidence (individual PCB burdens) of reproductive failure, the authors suggested it could have occurred in around 39% or more of mature females sampled.

An assessment of health status and causes of death in 520 harbour porpoises that stranded along Belgium and Northern French coastlines, or were incidentally captured in fishing gear between 1990 and 2008, revealed that 37% (191 out of 520 animals) presented with severe parasitosis and pneumonia, and 23% died from trauma, (120 out of 520 animals) primarily incidental capture in fishing gear (Jauniaux et al. 2010). The majority of strandings and by-catch events occurred during the wintertime and were biased towards males. Animals that died from infectious disease were emaciated and had marked lymphoid depletion (spleen, thymus and lymph nodes). However, many by-caught individuals also presented with emaciation and infectious diseases. Stranded porpoises that died from infectious disease were more contaminated than by-caught porpoises, similar to what was reported by the UK CSIP (Jepson et al. 2005, Jauniaux et al. 2010).

A change occurred in the profile of stranded porpoises along the Dutch coast in the late 1990s and 2000s, with an increase reported in juvenile males (Camphuysen et al. 2008). Bimodal stranding patterns were observed, with peaks in March-April and August, and approximately one-quarter of all stranded porpoises found along the Dutch coast in July, August and September were neonates or stillborn cases. An assessment of 225 porpoises necropsied between 1990-2000 and in 2006 and 2007 reported that between 50 and 60% of the animals showed signs of definite or probable by-catch in fishing gear (Camphuysen et al. 2008). In recent years, mutilated stranded porpoises have been reported in the southern North Sea, whose causes of death were unknown. Leopold et al. (2015) suggested that the majority of the mutilated cases along the Dutch coast were as a result of grey seal attacks on healthy juveniles (individuals with thick blubber layers that recently fed). Retrospective assessment of necropsy findings and pictures collected between 2003 and 2013 established that predation by grey seals was one of the main causes of death for harbour porpoises in Dutch waters during that time (Leopold et al. 2015). Cases of predation by grey seals have also been observed in Belgium, French and UK waters (Haelters 2012, Bouveroux et al. 2014, Jauniaux et al. 2014, ICES WGPIGS 2017).

In 2005, 85 'freshly dead' harbour porpoises stranded along c.100 km of Danish coastline between 7th to 15th April, which was unprecedented. For the majority of individuals, evidence of by-catch was apparent, with typical lesions of fisheries interactions, such as net markings on the main body and around the flippers, and loss of tail flukes (Wright et al. 2013). As lumpfish catches for 2005 were not unusual in terms of season onset, peak or total catch, the study suggested that naval activity may have been a contributing factor leading to increased incidental capture rates, as military vessels were confirmed in the area from the 7th April onwards (Wright et al. 2013).

6. DIET AND PREY AVAILABILITY

UK

Santos et al. (2004) divided porpoises into east and west Scottish mainland and Shetland. Overall, sandeels and whiting contributed around 75% of prey biomass. The east coast and Shetland diets included a lower proportion of *Trisopterus minutus* and more haddock and cod than the west coast. In addition, the importance of saithe was higher on the west coast than on the east coast and the reverse was true for sandeel, whiting, and herring. More recently, generalised additive models (using individual porpoises as the unit of the response variable and thus accounting for sampling error) indicated significant year to year variation in importance of some prey in porpoises' diet in Scottish waters (Pierce et al. Unpub. Data). Apparent declines in the importance of herring and sandeel in diet of porpoises in Scotland coincided with declines in stocks but, despite stock recovery, herring remains apparently unimportant in porpoise diet in this region. An obvious caveat is that the catchment area of porpoise strandings and areas of high herring abundance may not coincide – however, overwintering herring are found in the Moray Firth where many porpoise strandings occur. Correlation analysis identifies some significant relationships between annual stock abundance and annual importance of some prey species in diets in data from Scotland, Ireland, and the Netherlands. Some of these correlations (negative correlations between abundance of one species and importance of others in the diet) are consistent with preference for certain prey (herring, whiting, sandeel), others (positive correlations between importance in the diet and stock size for a species) are more consistent with opportunistic predation. However, apparently meaningless correlations are also found so these results may not be a reliable indicator of diet selection behaviour (Pierce et al. Unpub. Data).

In English North Sea waters, whiting dominated the diet of harbour porpoises and contributed to 86.4% of the diet for the period 1995 to 2002. The most important fish species by weight in the stomachs of by-caught harbour porpoises in English North Sea waters (n=33 stomachs) were whiting (*Merlangius merlangus*), followed by herring (*Clupea harengus*), sprat (*Sprattus sprattus*) and cod (*Gadus morhua*) (Tierney 2002). The three most important fish species by weight for animals that died from causes other than by-catch (n=9) were whiting, sandeels (Ammodytidae), and Gobiidae sp. Tierney (2002) reported that porpoises off the south-west coast of the UK were consuming smaller sized prey, with more prey per sample, than porpoises in the North Sea and Outer Hebrides. For all UK waters, whiting increased in importance in stomach contents during the study period (n=123; 1995-2002) from 63% to 94%, while herring decrease in importance from 33% to 7% (Tierney 2002).

France

In French waters, analysis of dietary remains in porpoises that stranded along the north coast of Normandy between 1998 and 2003 (n=7) reported that their diet mainly consisted of fish, primarily Gobiidae sp. (De Pierrepont et al. 2005).

Belgium

Analysis of the Belgium strandings database for the period 1970-2011 revealed two stranding peaks for harbour porpoises - spring and summer. Most animals that stranded were juveniles, more males than females, and the spring peak in strandings was partly due to by-caught animals being washed ashore. Assessment of dietary remains of 64 porpoises sampled between 2007 and 2011 revealed that gobies and sandeels were the most important prey in the diet of adults based on reconstructed weight of prey. The most important prey by weight in juveniles were gobies. A similar finding has been obtained in Danish waters in the western Baltic Sea by Andreasen et al. (2017). Surprisingly, clupeids did not contribute much to the diet, even though the re-distribution of porpoises to the southern North Sea has been linked to an increase in herring *Clupea harengus* stocks in the southern North Sea (Haelters et al. 2012).

The Netherlands

In the North Sea, harbour porpoises have re-distributed from northern to southern waters, leaving areas that were previously rich in sandeels to a region where their diet is dominated by leaner gobies and gadoids (Leopold 2015). Although animals are consuming prey of poorer nutritional quality, animals strand in a range of nutritional conditions, from very good to poor, although emaciation is a common cause of death in Dutch waters. Leopold (2015) reported that individual dietary variation depended on age, nutritional condition and season. Juveniles were found to consume small, lean, gobies, and lean gadoids dominated the diet of adults. Within the sample size of 381 individuals, only approximately one third of porpoises (with non-empty stomachs) consumed prey of relatively high energy density. The highest proportion of empty stomachs, the lowest reconstructed prey masses in non-empty stomachs, and the lowest proportion of energy-rich prey were reported for the summertime. Further, lower reconstructed prey masses were observed in porpoises in poorer condition. Analysis of stomach contents collected between 2006 and 2014 showed that there was a significant variation in prey composition between animals in good and poor body nutritional conditions. Starving animals had fewer prey remains in their stomachs, and these prey were, on average, of lower quality which is sometimes referred to as junk food – such as leaner gadoids and gobies. Whereas the stomach contents of 'healthy' good nutritional condition animals contained a mixture of fatty fish (clupeids and sandeels) and leaner prey. Because of the large body surface to volume ratio in the porpoise, individuals need to consume relatively large amounts of food. This work highlighted that periods of decreased quantity or quality of prey can be detrimental for the species.

Germany

Benke et al. (1998) analysed 40 stomachs, collected in the period 1991 to 1993 in German North Sea waters. The authors reported that, according to relative weight, porpoises in the North Sea fed primarily on sandeel (*Ammodytes* spp.) and sole (*Solea solea*), whereas porpoises in the Baltic Sea preyed upon goby (*Pomatoschistus* sp.; *Gobius niger*), herring (*Clupea harengus*) and cod (*Gadus morhua*). Later, 66 stomachs collected in the period 1994 to 2006 at the North Sea coast were analysed, and goby, cod and sandeel were found to be the most important prey species by weight (Gilles et al. 2008, Gilles 2009).

Summary

Table 5 includes a summary of studies assessing the diet of porpoises in the southern North Sea as reviewed by Mahfouz et al. (2017). The authors assessed whether changes in distribution and relative abundance of porpoises in the southern North Sea were linked to the changes in prey availability (Camphuysen 2004). Samples analysed in the study included animals that stranded along the northern French and Belgian coasts and analysis included examination of stomach contents as well as stable isotopes and fatty acid analysis (n=52). Results suggested that the diet of porpoises along the southern North Sea included fish species that are among the most abundant and widely distributed in the area, except for the sardine *Sardina pilchardus* that appeared to be a new potential prey. Results also suggested that the decline in sandeel in the northern North Sea along with the re-invasion of the southern North Sea by sardine species, may have affected the distribution of harbour porpoises in the region.

Table 5. A summary of diet of harbour porpoises in the southern North Sea inferred from stomach content analysis. N = number of stomachs analysed. Taken from Mahfouz et al. (2017).

Area (year of stranding)	n	Main prey	Reference
Southern North Sea (2010–2013)	14	Gobies, whiting, sandeel	Present study
Belgian coast (1997–2011)	64	Gobies, sandeels, whiting, *Trisopterus* sp.	Haelters et al. (2012)
Dutch coast (2006)	64	Gobies, sandeels, sprat, herring, whiting, twait shad	Leopold & Camphuysen (2006)
Northeast Atlantic French coast (1988–2003)	29	Sardine, whiting, blue whiting, scad	Spitz et al. (2006)
English Channel (1998–2003)	7	Pouting, gobies	De pierrepont et al. (2005)
Scotland (1992–2003)	188	Whiting, sandeels, gadids, *Trisopterus* sp.	Santos et al. (2004)
UK (1989–1994)	100	Gadids, sandeels, gobies	Martin (1996)
Germany	34	Sandeels, sole	Benke & Siebert (1996)
Denmark, Sweden, Norway	197	Herring, gadids	Aerefjord et al. (1995)
Germany	36	Sole, cod	Lick (1991)
France	8	Blue whiting, scad, hake	Desportes (1985)
Scotland (1959–1971)	93	Herring, sprat, whiting	Rae (1965, 1973)

7. Knowledge gaps and uncertainties in assessment parameters

Genetic structure and ecological stocks

Genetic stock structure within the region still needs to be fully elucidated, examining more closely whether the current northern and southern boundaries of the North Sea Assessment Unit are located appropriately. Preliminary research suggests some genetic structuring and morphological differences within the North Sea area and thus it may be appropriate to consider more than one Assessment Unit in this area (ASCOBANS 2018). However, these provisional earlier studies utilised samples that were predominately collected prior to the re-distribution of porpoises in the region (Andersen et al. 2001, De Luna et al. 2012) and thus further work is needed. Additionally, investigations on possible ‘ecological stocks’ based on ecological tracers (such as cadmium, stable isotopes, tagging data) is required.

Abundance and distribution

The SCANS surveys provide robust (i.e. they are believed to be unbiased) and fairly precise estimates of harbour porpoise abundance across all European Atlantic shelf waters, including the North Sea. However, these surveys occur infrequently (hitherto approximately decadal). For a species in which the large majority of animals die before age 10 years, such a frequency provides only a very coarse resolution to monitor changes in abundance. These large-scale surveys also only occur in summer. There is some information about distribution and abundance of harbour porpoise in the North Sea in spring and autumn (Gilles et al. 2016) but not in winter.

By-catch

As outlined above in Section 3, and detailed in reports of the ICES Working Group on Bycatch (e.g. (ICES WGBYC 2018)), there are a number of knowledge gaps and uncertainties in the data used to estimate by-catch. These include inconsistent and incomplete reporting of fishing effort data, and unquantifiable biases in data used to estimate by-catch rate. These problems are not unique to the North Sea assessment area.

Other parameters not included in the model

Contaminants

There is a lack of information on emerging contaminants of concern, both in terms of their potential bio-accumulative properties and potential adverse effects is required. The majority of research on pollutants undertaken to date has assessed legacy pollutants, and effects thereof. The development of new synthetic chemicals, and the emergence and use of some of those chemical substance on the market, has been increasing at a rapid rate in recent years (Bernhardt et al. 2017). It is unknown as to the number and variety of synthetic chemicals that harbour porpoises are exposed to, and if those chemicals are having an adverse health effect. Little attention has been paid to the raft of new emerging pollutants on wildlife in general (Bernhardt et al. 2017). Particularly the additive and synergetic effects in the presence of other pollutants at low dose levels.

Noise and Disturbance

The largest knowledge gaps relate to establishing links between behavioural reactions to noise and vital parameters relevant for population development (adult survival, fecundity etc.).

Additional knowledge gaps relate to the long-term consequences of smaller or larger noise-inflicted hearing losses in porpoises, as well as the natural and noise-induced hearing loss in wild porpoises.

Sound maps do not exist for the region as a whole but the distribution of noise-producing activities has been mapped for shipping, seismic, and wind farm construction. The effects of noise on porpoises from all the major sources have yet to be investigated.

Health status, causes of death, diet and life history

Knowledge on causes of death and health status of porpoises at an AU area level is not available for UK waters. Contemporary assessments of the diet of porpoises within English, German, Danish and Norwegian waters (south of 62˚N) are also not available. North Sea-wide estimates of life history parameters and temporal changes in those parameters that may have resulted from anthropogenic activities are lacking.

8. MONITORING REQUIREMENTS, RESEARCH PRIORITIES AND OPPORTUNITIES FOR COOPERATION

Multifarious dimensions of the ecology and evolution of the European populations of harbour porpoises

Genetic structure revealed by mtDNA and microsatellites analysis revealed a strong structure in harbour porpoise within the North East Atlantic waters. Beside the Black Sea subspecies (*P. p. relicta*), two other distinct evolutionary units are present in the NE Atlantic, each occupying different habitats: one (*P. p. phocoena*) is distributed on continental shelf habitats of northern European waters and the other one (*P. p. meridionalis*) is distributed in upwelling waters and includes Mauritania and Iberia. This large area shares a dynamic structure, with the Bay of Biscay being an admixture zone between the two sub-species. Studying this hybrid zone and the neighbouring populations is crucial to understand the population dynamic, local adaptive processes, and the effects of climate change. By combining relevant approaches, such as ecological tracers (POPs, trace elements and stable isotopes), life-history trends, and population genetic, would provide a comprehensive picture of the multifarious dimensions of the ecology and evolution of the European populations of harbour porpoises. Further work is required to assess if ‘admixed’ individuals from the Celtic & Irish Seas AU are moving into North Sea AU via the English Channel (see Celtic and Irish Seas AU report). Additionally, work is required to detect any genetic sub-structure that may exist within the North Sea, as well as the possible existence of ecological stocks in the region.

Abundance and distribution

Estimates of abundance from SCANS-type surveys should be available more frequently than every 10 years. A logical period would be every 6 years to tie in with reporting requirements under the EU Habitats Directive and MSFD. Estimates of abundance from surveys in seasons other than summer in UK waters could be useful to help assess impacts of by-catch that does not occur in summer.

By-catch

By-catch estimates are uncertain and subject to a number of biases. The ICES Working Group on Bycatch has been working for some time to improve the quality of data available for by-catch risk assessments (e.g. ICES WGBYC 2018). Progress on solving these problems is needed to improve the quality of future assessments and the inferences that can be drawn from the results.

Pollutants

A European-based risk list of priority pollutants for monitoring in the harbour porpoise should be devised, and research should continue into monitoring effects from exposure to pollution on health and reproductive status in both female and male harbour porpoises as required by Commission Decision (EU) 2017/848 on the Marine Strategy Framework Directive. This list should include those contaminants on the EU watchlist for emerging pollutants (EC decision 495, 20th March 2015), particularly those pollutants identified as endocrine disrupting chemicals (Murphy et al. accepted).

Within the UK, the harbour porpoise is used as a sentinel species for monitoring long-term trends in chemical contaminant exposure in the marine environment. Pollutant assessment monitoring akin to the long-term monitoring strategy employed by the UK should be implemented by Ireland and France. A 'common' mammal indicator using the harbour porpoise for assessing pollutant effects under Descriptor 8 "*Concentrations of contaminants are at levels not giving rise to pollution effects*" of the Marine Strategy Framework Directive should be devised.

While inorganic compounds (trace elements) are likely not to induce direct effects in harbour porpoises, they need to be considered as factors of susceptibility that may increase the effects of, for example, persistent organic pollutants. Thus, when modelling the cumulative impacts of pollutants, inorganic compounds should also be included.

Noise and disturbance

It appears unlikely that links between behavioural reactions to noise and vital parameters relevant for population development can be established directly through observation, and currently the best option appears to be individual based modelling schemes, such as the iPCoD (New et al. 2014) and DEPONS (Nabe-Nielsen et al. 2018) frameworks. However, considerable effort is required in obtaining accurate and relevant input data for these models. The required information includes, but is not limited to, better description of reaction thresholds and distances for different sound sources and metabolic consequences of different types of behavioural disturbances. Equally important for the quality of the output from the models is reliable information about source characteristics, their duration, and abundance of the different sound sources in the region.

Substantial monitoring and reporting of activities are required as part of implementation of the Marine Strategy Framework Directive. Current effort is limited to loud impulsive sounds and ship noise, however. Effort should be directed at increasing coverage of noise sources included in the monitoring, in particular smaller vessels, which tend not to carry AIS-transmitters and to the ubiquitous echosounders. Effort is also required to ensure that data entered into the monitoring database are as complete as possible (in particular an issue for military sonar) and with sufficient level of detail to allow for subsequent meaningful use of the data in the database.

Related to the low-frequency ship noise is a need to ensure that monitoring programmes quantify this noise in a way that is meaningful to high-frequency specialists, such as the harbour porpoise. More specifically this means that monitoring effort should be extended above the currently implemented 63 Hz and 125 Hz frequency bands.

The mapping of distribution of both continuous and impulsive noise sources with emphasis on the duration of exposure for each source on an annual basis. Noise maps for the former should derive from the INTERREG funded JOMOPANS project.

Other pressures

Work should continue and expand on assessing the cumulative impacts of multiple stressors, through integrating sub-lethal effects, on physiological and behavioural changes (e.g. (King et al. 2015)). Stressors should include, but are not limited to, disturbance, anthropogenic pollutants, changes in prey availability (that may result from the indirect effects of fishing), and the potential effects of climate change. Attempts should be made to estimate exposure rates to key pressures, and the dose-response relationship of each.

Monitoring programmes for health status, diet and life history

Continued monitoring population condition and trends in cause of death, health and nutritional status in dead specimens through funding national stranding and by-catch observer programmes for collection of carcasses. Within the UK, undertaking health status assessments at the Assessment Unit area level is required. The development of coordinated sampling strategies for dead carcasses within the greater North Sea region is required for assessment of health and nutritional status, causes of death, life history parameters and dietary analysis of individuals. This would enable more detailed analyses and coordinated research at the Assessment Unit level if appropriate funding was available.

Cases of starvation have been on the increase in the UK in the last two decades, though such information is lacking from other countries in both AUs. New studies incorporating stomach content and stable isotope analyses are required on contemporary samples to monitor dietary requirements and possible fishery interactions through, for example, targeting similar prey (sizes). Results of which should be incorporated within ecosystem models in the region that include data on food web interactions as well as other impacts of fisheries (i.e. both direct and indirect) on the harbour porpoise. An updated analysis examining temporal trends in the diet of harbour porpoises as well as the regional impacts of climate change on the species (both direct and indirect effects) could further inform on possible causes for the observed southern range shift in the North Sea.

Effort should be directed at undertaking an assessment of the current status of North Sea harbour porpoises by estimating life history parameters and temporal changes in those parameters' including: (1) production of basin-wide estimates of reproductive parameters (e.g. pregnancy rate, average age and length at sexual maturity) for harbour porpoises inhabiting the North Sea, and (2) assessing evidence of temporal changes in those parameters that may have resulted from anthropogenic activities. Such an assessment requires funding for collaboration between North Sea countries stranding and life history programmes. This information on life history should then be incorporated within future assessment modelling approaches.

9. ASSESSMENT UNIT STATUS

Based on the three SCANS surveys in 1994, 2005 and 2016, there is no evidence for a change in the abundance of harbour porpoises in the North Sea as a whole in the last 20-25 years. The distribution in 2016 was similar to that observed in 2005, following the marked change between 1994 and 2005 but there is some evidence that the distribution now extends further south than previously (Hammond et al. 2017). The re-distribution of harbour porpoises into the southern North Sea during the mid-to-late 1990s may have been linked to the decline in sandeel in the northern North Sea along with the re-invasion of the southern North Sea by sardine (Camphuysen 2004, Mahfouz et al. 2017).

The assessment attempted to account for the impact of by-catch since 1966. There may have been some by-catch before that time, but it is likely that levels were low relative to the peak period of by-catch in the late-1980s and 1990s. The assessment therefore likely provides a reasonable description of the impact of by-catch on harbour porpoise in the North Sea. The assessment model indicates that the population seems able to sustain a by-catch of around 4,500 animals a year, which is around 1.1% of the estimated carrying capacity and around 1.3% of current abundance, while maintaining the population level at close to 90% of carrying capacity. The precautionary approach to use "high" values for by-catch rate was intended to ensure that the assessment has not underestimated the impact of by-catch on harbour porpoises in the North Sea, but the robustness of the assessment also depends on how well the derived days at sea reflect reality. Attempting to obtain an improved time series of these data both by resolving the problems identified with the days at sea data in the ICES Regional database and by extending those data to years prior to 2009 for all fleets to compare with the time series created using English/Danish data and extrapolated to other fleets using the STECF data should be a priority.

Compared to porpoises in more northern waters (Icelandic and Greenlandic waters), animals in the North Sea have been assessed to be in poor general health status, with a higher incidence of severe lesions, especially of the respiratory tract, which may be associated with exposure to anthropogenic pollutants (Siebert et al. 2006). PCBs have been reported to induce immune-suppression (Jepson et al. 2005, Hall et al. 2006, Yap et al. 2012), as well as impact thyroid function in the species (Schnitzler et al. 2008). Reproductive failure and dysfunction has also been reported, associated with poor health status and possibly exposure to PCBs. Further, there has been an increase in some regions in the proportion of necropsied harbour porpoise displaying evidence of starvation/nutritional stress (including neonatal starvation), as well as an increase in documented cases of predation by grey seals.

In summary, a consistent time series of estimates of abundance results in an assessment that harbour porpoise in the North Sea are currently able to sustain an annual by-catch of 4,000 to 5,000 animals and the impacts of other pressures described above. Evidence of a lack of annual reproduction needs to be explored further in the context of the assessment that harbour porpoises in the North Sea are at around 90% of pre-by-catch carrying capacity.

It is also important to improve understanding of the impacts of by-catch and other pressures, and to keep monitoring, because the relatively fast life history of the harbour porpoise means that there is the potential for changes to occur more rapidly than in other cetacean species.

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APPENDIX I TO ANNEX 8

Table 1. Mean concentrations of the sum of PCBs, CB 153 and DDXs (µg.g^{-1} lipids) in blubber of harbour porpoises from different regions of the North East Atlantic Ocean and the Black Sea. Years in brackets refer to the date of stranding. A: Adults; J: Juveniles; AM: Adult males; AF: Adult females; JM: Juvenile males; JF: Juvenile females; n: number of samples. * median; ** Σ7CBs. Provided by Mahfouz et al. (2014).

		∑PCBs			CB 153			∑DDXs			
Area	Age/Gender	Mean ± SD	(min - max)	n	Mean ± SD	(min - max)	n	Mean ± SD	(min - max)	n	References
Dansih and Norwegian waters (1987-1991)	M	23.3	(3.7-65)	34				16.39	(3.2 - 45.1)	34	(Kleivane et al. 1995)
Baltic sea (1985 - 1993)	JM	16 ± 8	(2.9 - 32)	13	6.6 ± 3.6	(1.1 - 13)	13	15 ± 18	(1.5 - 59)	11	(Berggren et al. 1999)
Baltic sea (1988 - 1989)	AM	46 ± 29	(14 - 78)	4	20 ± 13	(5.9 - 33)	4	116 ± 134	(20 - 308)	4	
Kattegat-Skagerrak Seas (1989-1990)	JM	11 ± 5.0	(2.2 - 20)	10	4.8 ± 2.5	(1.0 - 10)	10	20 ± 13	(5.7 - 36)	8	
Kattegat-Skagerrak Seas (1988-1990)	AM	13 ± 5.2	(6.7 - 22)	7	5.7 ± 2.3	(3.0 - 9.5)	7	25 ± 20	(2.8 - 61)	7	
Kattegat-Skagerrak Seas (1978-1981)	AM	40 ± 22	(17 - 67)	5	19 ± 12	(6.0 - 33)	5	98 ± 43	(35 - 154)	5	
West coast of Norway (1988-1990)	AM	15 ± 11	(7.2 - 33)	8	5.6 ± 4.6	(2.5 - 14)	8	9.1 ± 7.4	(3.1 - 22)	6	
Southern North Sea (2001-2003)	F	15 ± 8.6		19							(Pierce et al. 2008)
Scotland (2001-2003)	F	10.5 ± 13.2		31							
Ireland (2001-2003)	F	53.5 ± 48		12							
France (2001-2003)	F	13.8 ± 11		2							
Galicia (2001-2003)	F	53 ± 42		3							
Southern North Sea (1999-2004)	JF	12.9 ± 11.9	(1.3 - 39.3)	9	3.7 ± 4.1	(0.2 - 13.4)	9				(Weijs et al. 2009)
	JM	15.4 ± 10.7	(5.3 - 39.8)	12	3.9 ± 3.0	(1.2 - 11.5)	12				
	AF	7.3 ± 2.0	(4.4 - 8.9)	5	1.7 ± 0.6	(1.0 - 2.3)	5				
	AM	82.9 ± 31.8	(38.7 - 125.5)	8	28.7 ± 12.0	(11.6 - 46.0)	8				
East England (1991-2005)	M	11.6 ± 9.7		23							(Law et al. 2010)
Southern North Sea (1991-2005)	M	46.4 ± 30.7		21							

Area	∑PCBs				CB 153			∑DDXs			References
	Age/Gender	Mean ± SD	(min - max)	n	Mean ± SD	(min - max)	n	Mean ± SD	(min - max)	n	
Black Sea (1998)	A	13.2*	(8.8 – 24.9)	11				77.3*	(55 – 157)	11	(Weijs et al. 2010a)
	J	7.0*	(4.9 – 13.7)	9				40.9*	(27.4 – 82)	9	
North Sea (1990-1999)	A	81.5		1				22.9		1	(Weijs et al. 2010b)
North Sea (2000-2008)	A	24.9	(15.3-34.5)	2				3.4	(1.2-1.4)	2	
North Sea (1990-1999)	J	19.1		1				4.5		1	
North Sea (2000-2008)	J	9.9	(1.1-68.2)	5				1.7	(0.4-6.4)	5	
North West Iberian Peninsula	JF	10.8 ± 2.8		5	2.9 ± 0.8		5				(Méndez-Fernandez et al. 2014)
(2004-2008)	JM	9.4 ± 3		3	2.8 ± 1		3				
	AF	37.5 ± 30.8		3	12.0 ± 9.7		3				
	AM	50.8		1	16.6		1				
Southern North Sea (2010-2013)	JF	32 ± 21**	(7.4 - 48)	3	14 ± 10	(3 - 22)	3	16 ± 10	(8 - 27)	3	(Mahfouz et al. 2014)
	JM	20 ± 31**	(0.6 - 110)	12	9 ± 15	(0.3 - 54)	12	19 ± 25	(2.4 - 96)	12	
	AF	4 ± 1,8**	(2.5 - 7)	4	1.8 ± 0.9	(1 - 3)	4	1.9 ± 1.3	(0.7 – 3.5)	4	
	AM	22**	-	1	10	-	1	13	-	1	

JOINT IMR/NAMMCO INTERNATIONAL WORKSHOP ON THE STATUS OF HARBOUR PORPOISES IN THE NORTH ATLANTIC

Area Status Report

Belt Sea (and adjacent waters)

Compiled by S. Sveegaard[1]

[1] *Aarhus University, Denmark*

1. IDENTIFICATION OF ASSESSMENT UNITS WITHIN EACH SUB-AREA

Population

What is referred to here as the 'Belt Sea' assessment unit covers harbour porpoises that inhabit the Danish, German and Swedish waters of Kattegat, the Belt Seas, the Sound and the Western Baltic. This area is also known as "the Gap area" because of its location in the gap between the North Sea population and the Baltic Proper population of harbour porpoises. In these waters, studies on satellite telemetry, genetics and morphometrics have identified three populations; The 'North Sea population' inhabiting the eastern North Sea including the Skagerrak and the northern part of the Kattegat, the 'Belt Sea population' in the Western Baltic, the Belt Sea and the Kattegat, and the 'Baltic population' in the Baltic Proper (Tiedemann et al. 1996, Andersen et al. 1997, Huggenberger et al. 2002, Galatius et al. 2012, Wiemann et al. 2010). No distinct geographical boundaries have been found between these three populations, as their ranges overlap in transitions zones in the Northern Kattegat (for the North Sea and the Belt sea population) and the western Baltic (for the Belt Sea and the Baltic Proper population).

Geographic range of the assessment unit

Sveegaard et al. 2015 used satellite tracking data, genetics from biopsies of tagged harbour porpoises as well as acoustic data to identify the best management unit during the summer months (defined as the unit with the least overlap between populations and thus the least error when abundance and population status is estimated) for the Belt Sea population of harbour porpoises. They found that the best management border between the Belt Sea and the North Sea populations is an east–west line from Denmark to Sweden at latitude 56.95°N. And further that the border towards the Baltic Proper is at 13.5°E (Figure 1).

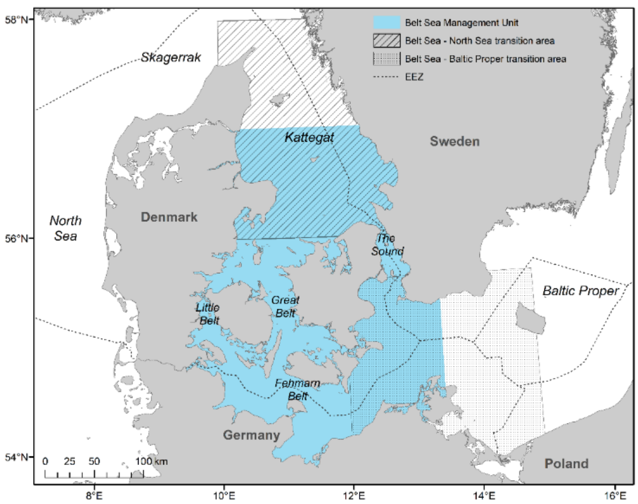

Figure 1. The proposed Summer management unit for the Belt Sea population by Sveegaard et al. (2015). Transition zones between the populations in the North Sea, Belt Sea and the Baltic Proper are indicated (Modified from Sveegaard et al 2015).

2. Distribution, abundance and trends

Distribution

The porpoises within the Belt Sea MU have been studied by means of visual surveys from boats and aircrafts (Heide-Jørgensen et al. 1992, Heide-Jørgensen et al. 1993, Hammond et al. 2002, Siebert et al. 2006, Scheidat et al. 2008, Gilles et al. 2011), detections of incidental sightings and strandings (Kinze et al. 2003, Siebert et al. 2006), passive acoustic monitoring (Verfuss et al. 2007), acoustic surveys (SCANS-II 2008, Sveegaard et al. 2011a) and satellite tracking (Teilmann et al. 2007, Sveegaard et al. 2011b, Sveegaard et al. 2018). From these studies, it is clear that the porpoises are not evenly distributed but concentrate in certain high-density areas. In the most recent study, Sveegaard et al. (2018) analysed satellite tracking data from 1997-2016 to examine changes in distribution over time and seasons (Figure 2). They concluded that the key habitats were relatively stable over time (decades) and that the seasonal changes observed previously observed e.g., few porpoises in the winter in the Sound were still valid.

Distribution and abundance of the Belt Sea population is also studied in part of its range under the national surveillance programs in Denmark and Germany. Germany conduct annual aerial surveys covering the entire German Baltic and also monitor some areas with passive acoustic monitoring (PAM). Denmark monitor the six most important harbour porpoise MPA's (Special Areas of Conservation under the Natura 2000 Network) using PAM. Sweden have not yet begun monitoring harbour porpoises within the Belt Sea MU.

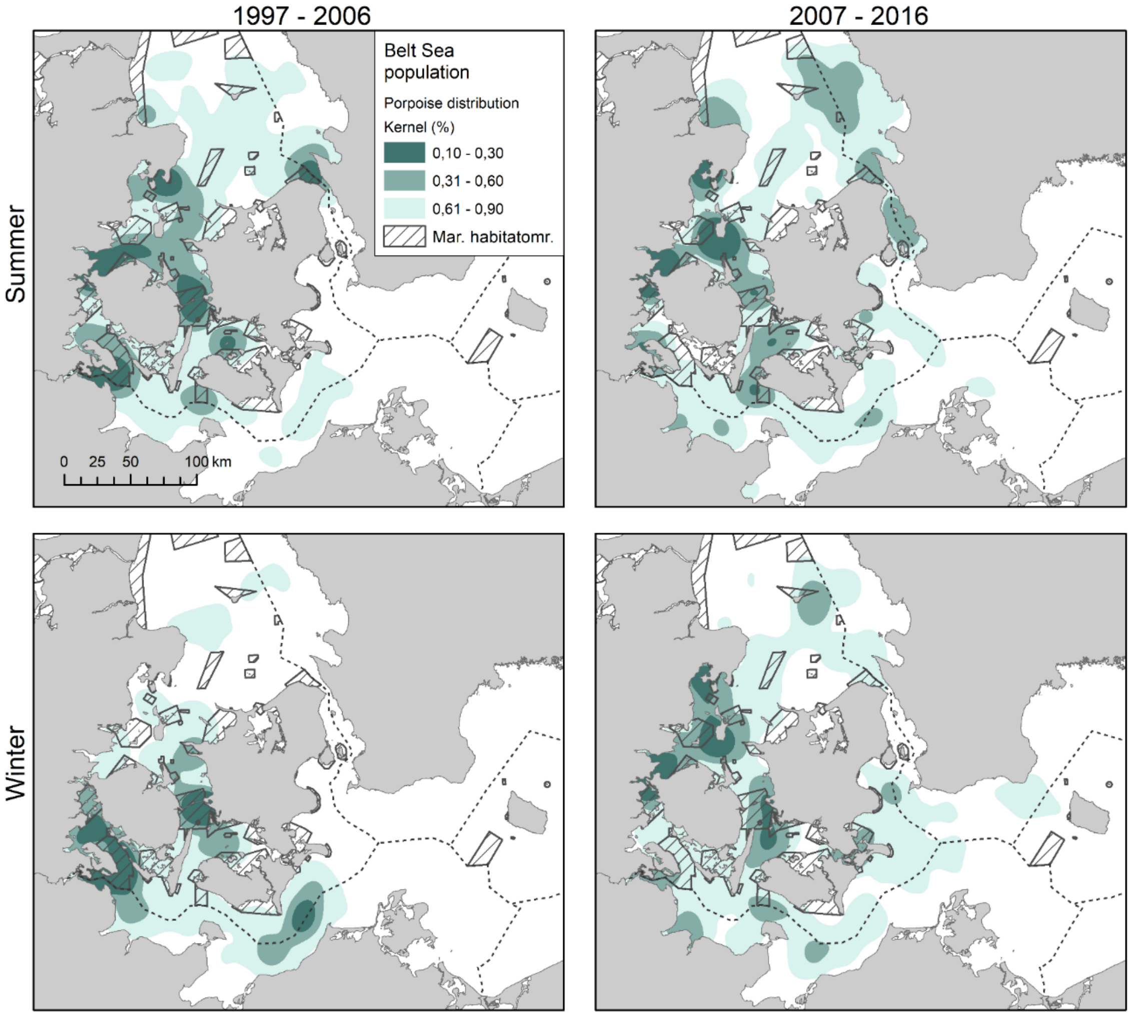

Figure 2. Distribution of satellite tracked harbour porpoises in the Belt Sea MU analysed as Kernel densities (the darker the colour the higher the density) for two decades and two seasons (Summer: April- September, Winter: October-March). The Kernel categories are defined as high (contains 30% of all locations of porpoises on the smallest possible area), medium (31-60%) and low (61-90%). The number of porpoises and location per analysis: 1997-2006, Summer: 39 animals/1958

loc., 1997-2006, Winter: 18 animals/765 loc., 2007-2016, Summer: 43 animals/1540 loc., 2007-2016, Winter: 33 animals/1076 loc.

Trends in abundance

The abundance of the harbour porpoise inhabiting the Belt Sea MU, have been estimated four times; Three times during the major SCANS surveys in 1994, 2005 and 2016, and once in 2012 as a corporation between Denmark, Germany and Sweden as part of their national monitoring programs (This survey is called 'MiniSCANS'). The geographical survey areas have however not been completely comparable, and for the 1994 and 2005 survey, the area cover a large part of the North Sea MU (Figure 3). Only the survey area from 2016 is identical to the Belt Sea MU, but the MiniSCANS-survey area is only slightly bigger and may therefore be comparable to the 2016 estimate. There is no difference between the 2012 and 2016 estimates (Figure 4). Hammond et al. (2017) conducted trend analysis of the abundance estimates within the Skagerrak/Kattegat/Belt Seas area (marked in blue in Figure 4) and concluded that there was no support for changes in abundance since 1994.

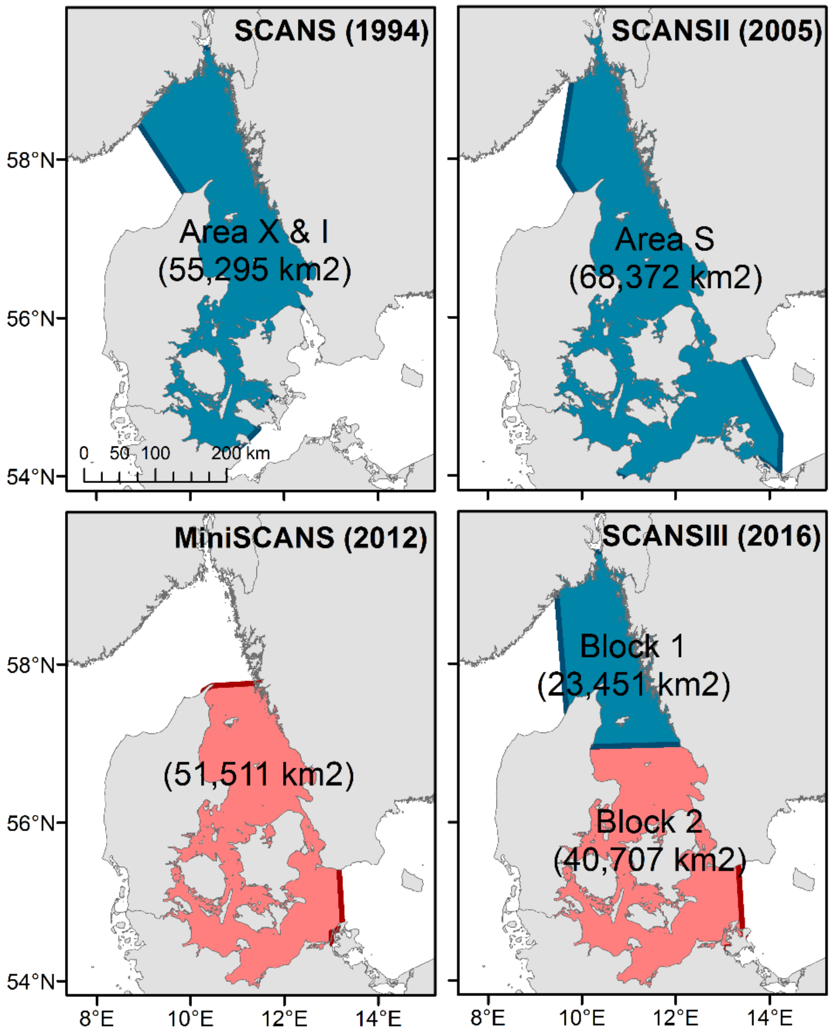

Figure 3. Areas covered during the three SCANS surveys and the "MiniSCANS" survey in 2012 (Viquerat et al. 2014) in the Skagerrak/Kattegat/Belt Seas. Only Block 2 in SCANS III are identical to the proposed MU for the Belt Sea population (Sveegaard et al. 2015).

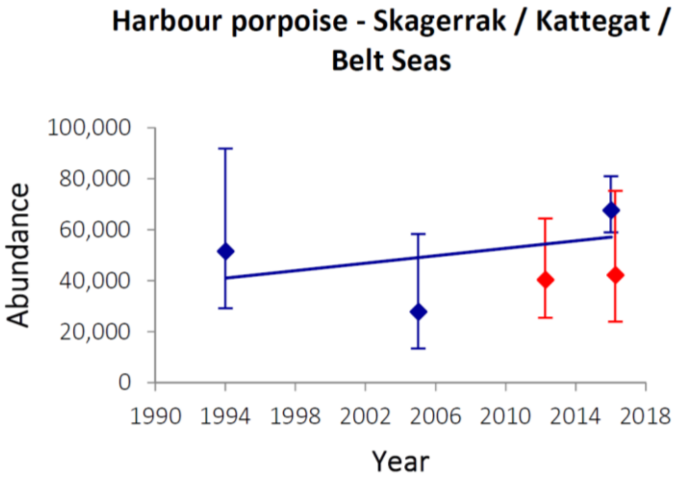

Figure 4. Trendlines fitted to time series of three or more abundance estimates for the harbour porpoise in the Skagerrak/Kattegat/Belt Seas area (blue dots and line). Estimates for the Belt Sea population area are shown as red dots. Error bars are log-normal 95% confidence intervals (From Hammond et al 2017)

Data used in assessment

As shown above, the abundance estimates from 1994-2016 for the Belt Sea harbour porpoise population have not been conducted in directly comparable areas. To adjust for this the estimates from 1994, 2005 and 2012 was recalculated by first calculating the overall density (animals per km2) and then upscaling by multiplying the density with the correct area size for the Belt Sea management unit (Figure 4, data from Hammond et al. 2017). This is not the optimal method but allows for a longer time series than just 2012 and 2016 for the Belt Sea population.

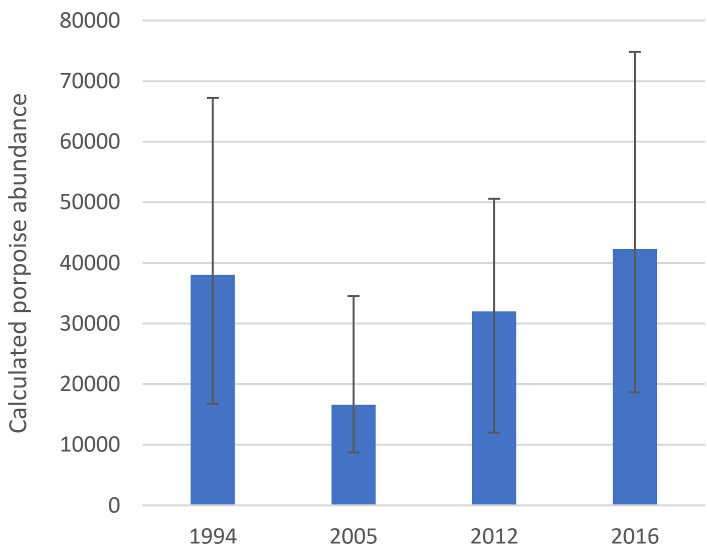

Figure 5. Abundance estimates from 1994-2016 for the Belt Sea harbour porpoise population inhabiting the Kattegat, Belt Seas and western Baltic. The estimates from 1994, 2005 and 2012 have been recalculated by first calculating the overall density (animals per km2) and then upscaling to the correct area size for the Belt Sea management unit (Data from Hammond et al. 2017).

3. ANTHROPOGENIC REMOVALS IN TIME AND SPACE

Hunting statistics (including struck/lost) with uncertainties, where available

No known hunt.

By-catch estimates (information from fisheries monitoring and other methods) with uncertainties, where available

The ICES WGBYC collates the relevant by-catch and fishing effort each year for each country and publish an annual report. The data reported is two years behind, so that data from 2016 is reported in the 2018 report. In 2018, the report describes the by-catch monitoring in Denmark, Germany and Sweden as follows (only porpoise related by-catch are included):

Denmark reported no specific monitoring programs for incidental by-catch of marine mammals during 2016 in the Danish pelagic trawl fishery. The reason for not continuing the monitoring programmes carried out from 2006–2008 was that the observer schemes, with a coverage up to 7%, had no records of incidental by-catch of protected species. Neither was any specific monitoring according to the Reg. 812/2004/2004 carried out in the Danish gillnet fishery. Instead, observer data on incidental catches of marine mammals from gillnets was collected under the Data Collection Regulation scheme (DCR). Monitoring was carried out on vessels <15 m in area 27.3.a (five fishing days; 2.0% coverage; two by-caught harbour porpoises), vessels <15 m in area 27.4 (four days; 2.2% coverage; zero porpoise by-catch), and vessels >15 m in area 27.4 (30 days; 9.4% coverage; zero porpoise by-catch). During the ICES Advice Drafting Group on By-catch (ADGBYC), it was found that the summary of Denmark's Reg. 812/2004 report was incomplete. Their report also documents Remote Electronic Monitoring (REM) trials in <15 m set gillnet fisheries in subareas 27.SD23 and 27.3a. In these areas, ten and 22 harbour porpoises were recorded by-caught, respectively." (WGBYC 2018)

Germany "monitored under the DCF observer programme, trying to follow the requirements of Reg. 812/2004 as much as possible…During monitoring under the DCF observer programme…one by-catch of a harbour porpoise (*Phocoena phocoena*) in gillnets with mesh sizes >=110 mm was reported in the Baltic Sea by a fisherman to DCF observers." (WGBYC 2018)

Sweden has no dedicated marine mammal at-sea observer schemes focusing on the by-catch of marine mammals. The monitoring effort conducted and provided by Sweden is part of the EU DCF where on-board observer data are mainly from trawl fisheries but also pot fisheries for crayfish. The reason for this is due to Reg. 812/2004 article 4 and 5 not effectively serving its purpose to estimate by-catch in waters around Sweden. Harbour porpoises are by-caught in gillnets and by-catch in pelagic trawls are extremely rare. Therefore observing 5% of Swedish pelagic trawl effort in the Baltic cannot provide estimates of total cetacean by-catch with an acceptable level of uncertainty. In the bottom-trawl fisheries, 40 trips were observed out of a total fleet effort of 6161 trips including all areas around Sweden. In the multi-rig otter trawl métier, also 40 trips were observed of a total effort of 5267 trips. In the pot and trap fisheries in Kattegat, 13 trips were observed of a total of 10 777 trips. No by-catch of cetaceans was observed." (WGBYC 2018)

Of the above mentioned reporting data, only the Danish REM trials, have provided sufficient data to calculate a by-catch estimate. This was done in 2016 (with data from 2014) in the Belt Sea MU (Kattegat and the Belt Sea) and resulted in a by-catch rate of 0.41%-0.66% (Table 1). Here both Swedish and Danish fisheries were included. It should be noted that the uncertainty of the abundance estimate (Abundance: 40,475 porpoises, 95 % CI 25,614–65,041, Viquerat et al. 2014) was not included.

Table 1. By-catch rate of harbour porpoises in Kattegat and the Belt Seas estimated by WGBYC in 2016 (from ICES WGBYC 2016). The best abundance estimates are from the MiniSCANS survey (Viquerat et al. 2014).

Harbour Porpoise Assessment Region	Year	Fishing Effort (days at sea)	Estimate of bycaught porpoises (Low-high)		Best Estimate Of Abundance	% mortality using lower bycatch estimate	% mortality using higher bycatch estimate
KATTEGAT AND BELT SEAS –3a21, 3b23, 3c22	2014	10 625	165	263	40 000	0.41%	0.66%

Age structure removal information, where available

No data.

Description of by-catch data for assessment

Since 2009, the ICES Working Group on By-catch of Protected Species (WGBYC) has developed a database on by-catch of protected species in European waters. The main purpose of ICES WGBYC has been to evaluate the annual EU Council Regulation 812/2004 reports, which among other things, obliges EU Member States to monitor by-catch of cetaceans in commercial fisheries. The ICES WGBYC database is therefore derived from the member states' 812/2004 reports to the EU on observed days at sea (DaS) and number of by-caught cetaceans including harbour porpoises.

By-catch rates were calculated from by-catch numbers reported in gillnet fisheries to ICES WGBYC in ICES areas 21, 22 and 23 in 2007-2016. Monitoring was carried out mainly by Remote Electronic Monitoring (REM) but also by onboard observers. A 95% confidence interval of the by-catch rates was calculated by assuming a Binomial distribution (source excel code: John Pezzullo–Kissimmee Florida USA, Clopper and Pearson, 1934), resulting in an upper limit of estimated number of by-catches per DaS. To estimate annual by-catch, time series of DaS per year and ICES areas in 2009-2017 were collated from the ICES Regional Database. The effort data were then multiplied by the upper limit of estimated number of by-caught porpoises per DaS. From 1994-2009 the annual by-catch was calculated as an average over the years 2009-2011. From 2018-2025 the annual by-catch was assumed to equal the 2017 estimate.

The estimated by-catches are subject to unquantifiable biases both with regards to the estimated by-catch rates and the reported fishing effort. Fishing effort data are likely to be underestimated as effort from smaller vessels is not fully represented. Member states report their effort inconsistently and due to this, the effort data reported by Germany in the area needed to be excluded. In this respect, the by-catch range may be underestimated. By-catch monitoring is often carried out by DCF fisheries observers. WGBYC (2015) have reported on the downward bias in by-catch rates from data collected in non-dedicated vs. dedicated observer schemes. Depending on the observer protocol and procedures, by-caught animals falling out of the net during hauling may be overlooked, which might also produce additional downward bias. However, if REM has been used, such animals will be recorded and there will be no such bias. In the Belt Sea area, a large part of the monitoring is carried out by REM. Monitoring most often focuses on larger vessels, which are assumed to have higher by-catch than smaller vessels due to larger numbers of nets being set and this would cause a positive bias in the estimated by-catch.

4. Impacts from other indirect (sub-lethal) pressures

Environmental pollutants

It is well known that heavy loads of polutants will affect the fittness, reproduction and survival of marine mammals, but there are no recent studies from Belt Sea MU. Aarhus University are working on examining PCB and BFRs in porpoises, but results are not yet available.

Polychlorinated biphenyl (PCB) concentrations in adult harbour porpoises were 10 times lower in the Arctic than in the Baltic and North Seas. In harbour porpoises from Icelandic waters, concentrations of PCBs and polybrominated diphenylethers (PBDEs) were on average five times lower than in those from Norwegian and German waters; with toxaphene concentrations, however, this position was reversed. Also, animals from Iceland and Norway had lower incidence of severe lesions, especially in the respiratory tract, as compared with reports of by-caught animals from the Baltic Sea (Siebert et al. 2006).

Underwater noise

The management of the impact of underwater sound has gained much attention in the last decade and the level of impact as well as the proper thresholds and regulations are being discussed worldwide. In Europe, much of these discussions are related to the Marine Strategy Framework Directive (MSFD) launched in 2008. The Baltic Sea Information on the Acoustic Soundscape (BIAS) project was established to implement Descriptor 11 of the MSFD in the Baltic Sea region including the Belt Sea MU. During BIAS 40 stations were deployed to monitor noise levels for one year and noise maps were produced.

The work of BIAS is now continued in the national monitoring programs.

There are several studies of the effect of noise in the Belt Sea MU. Many of them are based on the tagging of harbour porpoises with D-tags allowing for calculation of measuring the both the receive noise level by the porpoise and acoustic response by the porpoise. For instance, Wisniewska et al (2018a) examined vessel noise exposure to tagged harbour porpoises and found the the animals encountered vessel noise 17–89% of the time and occasionally a high behavioural response leading to interruption of foraging behaviour were detected.

The use of pingers in set nets to avoid by-catch of porpoises have a positive effect on the direct death by drowning but deter porpoises away from the area of the net. In a recent study, Beest et al. (2017) predicted the population-level impact within the Belt Sea MU of mitigating harbour porpoise by-catch with pingers and time-area fishing closures and concluded that the "time-area fishing closures reduced by-catch rates substantially but not completely. In contrast, widespread pinger deployment resulted in total mitigation of by-catch but frequent and recurrent noise avoidance behavior in high-quality foraging habitat negatively affected individual survival and the total population size. When both by-catch mitigation measures were implemented simultaneously, the negative impact of pinger noise induced sub-lethal behavioral effects on the population was largely eliminated with a positive effect on the population size that was larger than when the mitigation measures were used independently".

For more information, see relevant references at the end of this document.

Disturbances

Within the Belt Sea MU, anthropogenic disturbances are mostly related to noise, i.e. vessel traffic and construction of wind farms.

Nabe-Nielsen et al. 2013 used an individual-based model to examine the effects of noise and by-catch on the Belt Sea harbour porpoise population. The model produces plausible patterns of population dynamics and matches well the age distribution of porpoises caught as by-catch and it estimated an effect of existing wind farms as a 10% reduction in population size. They also found that the population was sensitive to variations in mortality resulting from by-catch: Annual by-catch rates ≥10% lead to monotonously decreasing populations and to extinction, and even a by-catch rate of 4.1% had a strong impact on the population. They concluded that their result suggested that conservation efforts should be more focused on reducing by-catch in commercial gillnet fisheries than on limiting the amount of anthropogenic noise.

5. LIFE-HISTORY PARAMETERS AND HEALTH STATUS

There are only few new studies published since the NAMMCO harbour porpoise book from 2003.

Kesselring et al. examined the ovaries from 111 female harbour porpoises from the German North Sea and Baltic Sea collected from 1990 to 2016 and found that the onset of sexual maturity in female harbour porpoises was 4.95 years or higher (95% CI: 4.15–5.83 years). They also found that the average age at death in the German Baltic was 3.67 (± 0.30) years.

The Master thesis of Anna Hedlund (2008) from Stockholm University also provide information based on samples from 1988-1991 on life history parametres from Skagerrak and Kattegat. The results are included in the life history parameter tables available as supplementary files on the NAMMCO website (https://nammco.no/topics/scientific-workshops-symposia-reports/#2018).

Harbour porpoises from the North and Baltic Seas suffer from parasitic and bacterial infections, particularly those of the respiratory tract (Jepson et al., 2000; Siebert et al., 2001; Jauniaux et al., 2002; Lehnert et al. 2005). Specimens from the Baltic Sea showed a significantly higher incidence of severe bacterial infections than those from less polluted waters in Greenland (Wünschmann et al., 2001).

6. DIET AND PREY AVAILABILITY

The average daily food intake per adult harbour porpoise is approx. 1.75 kg consisting mainly of fishes of up to 20-25cm (Börjesson and Berggren, 2003). Several studies on prey preferences have been conducted in or near the Belt Sea MU (Table 2). In general, herring, sprat, codfish and sandeel are the most important prey items.

Table 2. Summary of studies on prey intake from porpoises by-caught or stranded in or near the Belt Sea MU.

Publication	Year of stomachs	#stomachs	main prey species	Area
Börjesson et al. 2003	1989-1996	112	Atlantic herring, atlantic hagfish	Kattegat, Skagerrak
Aarefjord et al. 1995	1985-1990	247	herring and codfish	Scandinavia
Andreasen et al. 2017	1980-2011	339	Adult porpoises: Atlantic herring and cod / juveniles: also sandeel	Western Baltic (all but 1stomach was within the Belt Sea MU)

In recent years, tagging of harbour porpoises have suggested a shift to smaller prey since Wisniewska et al. (2016; 2018b) found that the tagged harbour porpoises on average made 125 (juvenile) and 79 (adults) feeding attempts on small fish (3-10 cm) every hour with a 90% success rate. The sample size was however relatively small and more studies are needed to validate whether this shift is general to other porpoises in the region.

7. Knowledge gaps and uncertainties in assessment parameters

The ASCOBANS lists Action Points at its annual meetings for the Belt Sea and the Baltic Proper populations. These are recommendations for actions that should be undertaken to protect the harbour porpoises. The list from its 14th meeting in 2018 covers a total of 26 Action Points and is available here: https://www.ascobans.org/sites/default/files/document/JG14_ActionPoints.pdf.

Here, however, management actions will not be discussed. Instead, the most important knowledge needed in order for a continuous status assessment of the population is listed:

- Trends in abundance: Population abundance estimates every 6th year following the EU reporting periods.
- By-catch rate: Continuous collection of by-catch data.
- Status of prey consumption both quality and quantity of important species
- Improved knowledge on current levels of environmental pollutants, especially PCBs
- Study the impact of noise on harbour porpoises

8. Monitoring requirements, research priorities and opportunities for cooperation

The most important research priorities and opportunities for cooperation are on the issues listed above as important knowledge gaps.

9. Assessment unit status

The Belt Sea harbour porpoise is not listed as threatened or endangered and abundance estimates from 1994 to 2916 indicate that the population is stable.

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JOINT IMR/NAMMCO INTERNATIONAL WORKSHOP ON THE STATUS OF HARBOUR PORPOISES IN THE NORTH ATLANTIC

Area Status Report

The Baltic Proper

Compiled by J. Carlström*

* *Swedish Museum of Natural History*

1. IDENTIFICATION OF ASSESSMENT UNITS WITHIN EACH SUB-AREA

Distribution patterns

During May-Oct, the western management border of the Baltic Proper population (here called "SAMBAH summer management border") has been identified to a diagonal line approximately between the island of Hanö in Hanö Bight in southern Sweden, and Jarosławiec near Słupsk in Poland (Carlén et al. 2018). The animals west of this border mainly belong to the Belt Sea population, during this time of year.

During Nov-Apr, there is a continuum of animals from the Baltic Proper in the east, across the summer management border and further SW in the Baltic Sea. This means that animals from the Baltic Proper and the Belt Sea populations mix during this time of year, and it is unknown how far west the Baltic Proper animals move. The influx of Baltic Proper animals to the S Baltic Sea in winter is supported by long-term acoustic monitoring data in the German Pomeranian Bay (Benke et al. 2014), i.e. between the summer management border for the Belt Sea population proposed by (Sveegaard et al. 2015) (13.5°E), and the SAMBAH summer management border for the Baltic Proper population.

There are very few observations of live or dead porpoises north of the Åland and Archipelago Seas during the last decades (see HELCOM Map and Data Service, http://maps.helcom.fi/website/mapservice/).

Genetics

Genetic studies overall show a weak but consistent signal of a separation of harbour porpoises in the inner Baltic Sea in relation to harbour porpoises in the Belt, Kattegat, Skagerrak and North Seas (Andersen et al. 2001; Berggren and Wang 2008; Lah et al. 2016; Palmé et al. 2008; Tiedemann et al. 1996; Wang and Berggren 1997; Wiemann et al. 2010). However, note that most of the borders tested to delineate the Baltic Sea were located west of the SAMBAH summer management border.

Skull morphometrics

Also studies of skull morphometrics indicate a separation between harbour porpoises in the inner Baltic Sea and in the Belt, Kattegat Skagerrak and North Seas (Galatius, Kinze, and Teilmann 2012; Huggenberger, Benke, and Kinze 2002) However note that all borders tested to delineate the Baltic Sea were located west of the SAMBAH summer management border.

Spatio-temporal distribution patterns

Based on monthly detection rates at 304 passive acoustic monitoring stations, the southwestern management border of the Baltic Proper population has been identified to a diagonal line approximately between the island of Hanö in southern Sweden, and Jarosławiec near Słupsk in Poland during May-Oct (Carlén et al. 2018). The animals west of this border mainly belong to the Belt Sea population, during this time of year.

During Nov-Apr, there is a continuum of animals from the Baltic Proper in the east, across the summer management border and further SW in the Baltic Sea. This means that animals from the Baltic Proper and the Belt Sea populations mix during this time of year, and it is unknown how far west the Baltic Proper animals move. The influx of Baltic Proper animals to the S Baltic Sea in winter is supported by long-term acoustic monitoring data in the German Pomeranian Bay (Benke et al. 2014), i.e. between the summer management border for the Belt Sea population proposed by (Sveegaard et al. 2015) (13.5°E), and the SAMBAH summer management border for the Baltic Proper population.

Summary

- The Baltic Proper population should be treated as a separate assessment unit.
- The southwestern border for its distribution range in summer is defined by (Carlén et al. 2018). In winter its distribution range is wider, but it is unknown how far west the animals range in the southern Baltic Sea. In winter animals from the Baltic Proper population are likely to mix with the Belt Sea population in the SW Baltic.
- There is no indication of further sub-structure within the distribution range of the Baltic Proper population.

2. Distribution, abundance and trends

Distribution

The SAMBAH study area covered all waters of 5-80 m depth from the Limhamn/Drogden and Darss underwater sills in the SW Baltic and up to and including the Åland Sea and Archipelago Sea in the north. To the east, all EU waters were included. Within this study area, monthly distribution maps of harbour porpoises were produced (Carlén et al. 2018). The average distribution during May-Oct and Nov-Apr are shown in Figure 1.

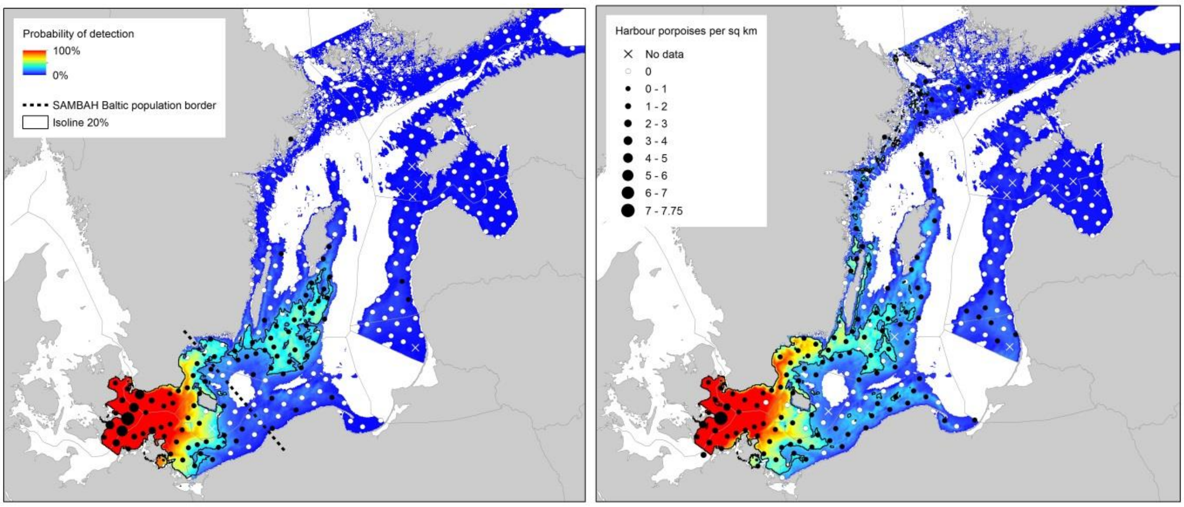

Figure 1. Predicted probability of detection of harbour porpoises per month in the SAMBAH study area during May-Oct (A) and Nov-Apr (B). The black line indicates 20% probability of detection, approximately equivalent to the area encompassing 30% of the population, often used to define high-density areas. The dots or crosses show the probability of detection at the SAMBAH survey stations. The border indicates the proposed management border during May – Oct for the Baltic Proper population *(Carlén et al. 2018)*.

Porpoises are also known to occur in waters deeper than 80m and further to the east and north, however likely not in considerable numbers. This assumption is based on:

- The response curve of probability of detection in relation to depth in (Carlén et al. 2018).
- Low numbers of opportunistic sightings of live animals north of Åland Sea and Archipelago Sea during the last decades (HELCOM Map and Data Service, http://maps.helcom.fi/website/mapservice/, select Biodiversity > Harbour porpoise > Harbour porpoise incidental sightings).
- The absence of detections in Finnish and Estonian waters in the Gulf of Finland in SAMBAH, not indicating any significant numbers in Russian waters further east (ASCOBANS 2016)
- One detection in the Russian waters in the Kaliningrad area in the SE Baltic during a one-year (approximately May 2013-Apr 2014) acoustic survey following the same grid and methodology as in SAMBAH (unpublished data).

Information on the historical distribution of harbour porpoises in the Baltic Sea has been reviewed by (Koschinski 2001). The historical distribution range includes the Bothnian Sea, the Bothnian Bay, the Gulf of Finland and the Gulf of Riga.

Robust estimates of abundance, e.g. from line transect sampling

There is only one abundance estimate for the Baltic Proper population: 497 animals (95% CI 80-1091). This is based on two years (May 2011-Apr 2013) of static acoustic monitoring data collected at 304 survey stations (SAMBAH 2016).

Trends in relative abundance

As there is only one abundance estimate covering most of the distribution range of the population, no robust data on trends in population abundance is available. National monitoring based on selected SAMBAH stations (and in some cases additional stations) is currently carried out by Denmark, Finland, Germany, Poland and Sweden, but these data have not (yet) been evaluated on the population level.

Historic data on catches, by-catches, observations of live porpoises (Lindroth 1962; Skóra and Kuklik 2003), and an interview survey of sighting rates of harbour porpoises (Berggren and Arrhenius 1995) indicate that the population has declined drastically during the 1900's.

Summary

- There is only one abundance estimate for the Baltic Proper harbour porpoise population (497, 95% CI 80-1091).
- The surveyed area covered most of the known current distribution range, and the missing areas are assumed to not have a significant effect on the population abundance estimate.
- Robust trend data are missing, but records of by-caught, stranded and sighted porpoises indicate a drastic decline during the 1900's.

3. ANTHROPOGENIC REMOVALS IN TIME AND SPACE

Hunting statistics (including struck/lost) with uncertainties, where available

Harbour porpoises are not hunted in the Baltic Sea.

By-catch estimates (information from fisheries monitoring and other methods) with uncertainties, including trends

By-catch estimates for assessing the population status

ICES Working Group on By-catch of Protected Species (WGBYC) has since 2009 developed a database on by-catch of protected species in European waters. The main purpose of ICES WGBYC has been to evaluate the 812/2004 regulation which among other things oblige EU Member States to monitor their by-catch of cetaceans in commercial fisheries. The ICES WGBYC database is therefore derived from the member states' 812/2004 regulation reports on observed days at sea (DaS) and number of by-caught harbour porpoises to the EU. Data from the WGBYC database as well as data summarised in the WGBYC reports from 2009 until 2016 resulted in a total 1270 observed DaS and no by-catches of harbour porpoises in ICES sub-areas 25-29 (approximately corresponding to the assessment area of the Baltic Proper harbour porpoise population). This data can be used for assessing an upper limit of the by-catch rate by assuming that a harbour porpoise would have been by-caught if yet one more DaS had been observed. This would yield a by-catch rate of 0.787 per 1000 days at sea. Multiplying this by the total gillnet fishing effort for ICES sub-areas 25-29 gives an upper limit of the observed by-catch numbers. During 2009-2017, the fishing effort in these sub-areas decreased from 82893 to 48976 DaS, resulting in an annual by-catch declining from 65 to 39 by-caught harbour porpoises. As both the by-catch rate and the total number of by-caught harbour porpoises were considered unrealistic, another approach was needed.

Due to the lack of robust by-catch estimates within the summer distribution range of the Baltic Proper population, estimated by-catch numbers were instead derived from a by-catch rate for the Belt Sea population. This was calculated from by-catch numbers obtained mainly by electronic monitoring systems, but also onboard observers, reported to ICES WGBYC in area 21, 22 and 23 during 2007-2016. The fishing effort was obtained from the ICES Regional DataBase (RDB). A 95% confidence interval was calculated by assuming a Binomial distribution (source excel code: John Pezzullo–Kissimmee Florida USA, (Clopper and Pearson 1934)), resulting in an upper limit of 0.0417 by-catches per DaS. The upper limit of the Belt Sea by-catch rate was adjusted for the lower porpoise density within the Baltic Proper assessment unit, using the density estimate for Block 2 in SCANS III (Hammond et al. 2017) and the overall density within the summer distribution range in the SAMBAH survey (SAMBAH 2016). This resulted in an upper Baltic by-catch rate of 0.000148 animals per DaS. By multiplying this with the total gillnet fishing effort in ICES sub-areas 25-29 for the each of the years from 2009 to 2017, the estimated annual number of by-caught harbour porpoises of the Baltic Proper population was obtained. This number declined from 12 in 2009 to 7 in 2017.

In the forecast of the population trajectory to year 2025, it was assumed that the estimated 2017 by-catch numbers would remain unchanged, rather than using the average by-catch rates for the years 2013-2017. As the fishing effort had decreased continually during 2009-2017, it was considered unrealistic that the average annual by-catch number would be higher than in 2017.

Minimum by-catch numbers

For Finnish waters, data on by-caught and caught harbour porpoises during 1900 – 1990 have been verified and compiled by (Pyöriäistyöryhmä, 2006). According to the data reported to HELCOM Map and Data Service (http://maps.helcom.fi/website/mapservice/), the average number of records of by-caught or caught porpoises during 1990 – 1930 was 14 per decennium. During 1950 – 1999, the number was down to an average of 2 animals per decennium.

For Polish waters, catch and by-catch data for 1922-1987 have been compiled by (Skora, Pawliczka, and Klinowska 1988). For the years 1922-1933, a bounty system was in place and catch data are given for most years. For eight years with missing data between 1922 and 1938, catch and by-catch numbers were assumed based on quantitative descriptions and the available data. Based on this, the total take in all Polish waters was approximately 1000 animals during the years 1922-1938. For 1951-1987, date and location are given for most of the recorded by-catches. A total of approximately 10 porpoises were recorded by-caught within the summer distribution range of the Baltic Proper porpoise population. These made up about 2/3 of all recorded by-catches along the Polish coast within this time period. For the period 1990-2009, a total of 66 harbour porpoises were by-caught along the entire Polish coast (Professor Krzysztof Skóra Hel Marine Station database). Further information on minimum observations of harbour porpoises is available in the HELCOM Map and Data Service database (http://maps.helcom.fi/website/mapservice/).

In Swedish waters, 50 harbour porpoises were collected in the Baltic Sea from Nov 1960 to Oct 1961, whereof 46-48 within the summer distribution range of the Baltic Proper population. They had all been by-caught in salmon gear and the aim of the collection was to investigate their stomach contents (Lindroth 1962). In more recent years, minimum by-catch numbers are available from the database of the Swedish Museum of Natural History of necropsied and/or sampled animals. During 1976-2017, a total of 18 by-caught animals were collected that were likely to be from the Baltic Proper population. During May-Oct only animals that were by-caught within the Baltic Proper summer distribution range were included. In Nov-Apr the area was extended to include Hanö Bight and Stenshuvud as the Baltic Proper animals seem to have a wider distribution range during these months (Figure 1).

Attempts were made to estimate the total Swedish by-catches during a longer time period based on the by-catch number in 1960-1961 (Lindroth 1962) and total landings of salmon in the Swedish fishery during 1914-2014 (Hentati-Sundberg 2017). However the results were considered unrealistic and were not used in the modelling.

For Danish waters, reports on marine mammal strandings, necropsies and sightings were published annually during 2006-2012 (L. F. Jensen et al. 2015; Lasse Fast Jensen et al. 2012; L. F. Jensen, Skov, and Baagøe 2008; L. F. Jensen and Thøstesen 2014; Thøstesen, Baagøe, and Jensen 2013; Thøstesen et al. 2011, 2010, 2009). These report on a total of 22 dead harbour porpoises, but very few of them were from geographical locations that are relevant for the Baltic Proper population and for most of them the cause of death was unknown.

Since the year 2000, Latvia has two records of dead porpoises in their national reports to ASCOBANS (2003 and 2004).

No harbour porpoise by-catch was documented in Estonia, Finland or Lithuania during 2000-2016 (ASCOBANS 2016).

Age structure removal information, where available

No data.

4. Impacts from other indirect (sub-lethal) pressures

Environmental pollutants

No data on estimated population impacts are available. However data on measured levels of for example PCBs are available, which can be compared to published data for a guestimate of population impact.

Table 1 gives an overview of ΣPCB levels from harbour porpoises east of the Darss and Limhamn/ Drogden underwater sills. These levels are alarmingly high in comparison to published threshold values for the onset of physiological impacts (9 mg/kg lipid, (Kannan et al. 2000a)), adverse health effects (17 mg/kg, (Jepson et al. 2005b)), and profound reproductive impairment (41 mg/kg, (Helle, Olsson, and Jensen 1976)). The levels can also be compared to those measured for resting mature females (non-lactating or non-pregnant, 18.5 mg/kg), lactating (7.5 mg/kg) and pregnant females (6 mg/kg), and sexually immature females (14.0 mg/kg) in UK waters (Murphy et al. 2015b).

Table 1. Concentrations of ΣPCBs of harbour porpoises in the Baltic Sea. All animals from the German Baltic Sea were collected west of the Darss underwater sill (table from ASCOBANS 2016).

Geographical area	Years	Source	No. of samples of age and sex class	Mean (range) of ΣPCBs (mg/kg lipid)	Reference
East of the Darss and Drogden sills, Sweden	1985-1993	Bycaught	13 immature	16 (2.9-32)	(Berggren et al. 1999)
East of the Darss and Drogden sills, Sweden	1988-1989	Bycaught	4 mature males	46 (14-78)	(Berggren et al. 1999)
Schleswig-Holstein, Mecklenburg-Western Pomerania, Germany	1994-1995	Stranded or by-caught	17 immature, 1 mature female	14.9 (5.6-38.6)	(Bruhn et al. 1999)
Puck Bay, Poland	1989-1990	Bycaught	3 immature	23-42	(Kannan et al. 1993)

Underwater noise

The possible impact of underwater noise on harbour porpoises has not been assessed. However there are spatio-temporal data available on both continuous noise and planned impulsive noise events.

In the BIAS project (www.bias-project.eu), maps of continuous noise have been produced covering all waters from the Skagerrak Sea to the Bothnian Bay (Folegot et al. 2016). Of relevance for harbour porpoises are the 2 kHz maps (1/3 octave band), which are available for three depth ranges (surface to 15 m, 30 m to the bottom, and the full water column) and seven percentiles (5, 10, 25, 50, 75, 90 and 95%). The percentiles describe the proportion of time and space for which the noise exceeds a given level.

Data on planned impulsive noise events are available from ICES impulsive noise events registry in support of OSPAR and HELCOM (http://ices.dk/marine-data/data-portals/Pages/underwater-noise.aspx). Figure 2 shows the total number of days per survey block with a registered impulsive noise event (“pulse block days”) in 2016.

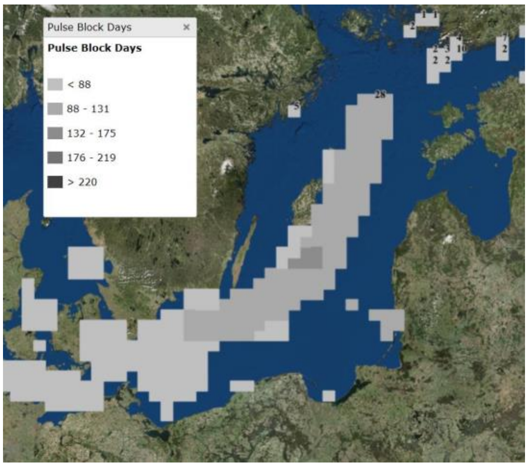

Figure 2. Total number of days per survey block with a registered impulsive noise event in 2016. For definitions, see the ICES Impulsive noise events registry in support of OSPAR and HELCOM (http://underwaternoise.ices.dk/map.aspx). The figure is a screenshot from the registry.

5. Life-history parameters and health status

Due to very limited access to samples, data on life history and health status are only available from a smaller number of animals. Based on the geographic locations of the Baltic animals investigated in (Kesselring et al. 2017), most animals are likely from the Belt Sea population.

6. Diet and prey availability

Lindroth (1962) presents stomach contents of harbour porpoises almost exclusively by-caught within the summer distribution range of the Baltic Proper population. Of the investigated stomachs, four were empty, eight contained few unidentified fish remains, and the content of the remaining 38 are shown in Table 2. (Andreasen et al. 2017) present data on the diet of 339 harbour porpoises in the Belt Sea and the SW Baltic Sea, whereof all were collected in the waters west of the summer distribution range of the Baltic Proper population. (Lindroth 1962) found a higher frequency of occurrence of sprat (*Sprattus sprattus*) than (Andreasen et al. 2017), however in broad terms the results are similar and no conclusions can be drawn due to the limited sample size in (Lindroth 1962).

Table 2. *Stomach contents of 38 harbour porpoises by-caught in salmon fishing gear in Swedish waters during Nov 1960-Oct 1961 (Lindroth 1962).*

Species	Total no. of fish	% of 38 stomachs
Cod (*Gadus morhua*)	62	34
Herring (*Clupea harengus*)	110	55
Sprat (*Sprattus sprattus*)	1400	63
Transparent goby (*Aphia minuta*)	200	18
Sandeel (*Ammodytes* sp.)	4	5

A recent study has investigated the ratio between the number of inter-click intervals (ICIs) below 15 ms and the total number of all within-train ICIs in the acoustic data collected in the SAMBAH project (Kyhn et al. 2018). Foraging events have been characterised by stereotypic echolocation sequences ending with high repetition rates, known as foraging buzzes (Verfuss et al. 2009). Based on (Wisniewska et al. 2012), (Kyhn et al. 2018) used the fixed criterion of 15 ms to identify foraging ICIs in two clusters of acoustic monitoring stations, one SW and one NE of the SAMBAH summer management border. The ratio of foraging ICIs was found to be higher in the NW than in the SE cluster. A possible explanation for this is that the prey quality is lower to the

NE than to the SW, causing the Baltic Proper harbour porpoises to forage more frequently than the Belt Sea population (Kyhn et al. 2018).

A study of herring (*Clupea harengus*) and sprat condition in the Baltic Proper has shown that in 1984-1991, the condition of both species was good across the entire Baltic Proper. In 1992-2008 the condition dropped, and the drop was stronger in the northern parts. The density of sprat was found to be the main driver for both herring and sprat condition, with the condition of both species being negatively correlated to sprat density (Casini et al. 2011). The blubber thickness of Baltic grey seals (*Halichoerus grypus*), which mainly feed on herring, has been found to correlate to herring weight in the Baltic Sea. In parallel to herring and sprat condition, seal blubber thickness has been found to be negatively correlated to herring catch size (a proxy for herring abundance), indicating that prey quality and not quantity is important for the seals' nutritional status. Over the years 2002-2015, seal pup blubber thickness and herring condition decreased from the south (southern Baltic Sea) to the north (Bothnian Bay). Over the years 2002-2010, the blubber thickness of all seal groups (pups, sub-adults and adults) decreased, but has been more fluctuating during 2010-2015 (Kauhala et al. 2017).

Due to the limited access of study material of harbour porpoises in the Baltic Proper, it is not known whether the changes in spat and herring quality have affected the porpoise population. However in a study of 11 species of cetaceans in the North Atlantic, including the harbour porpoise, prey quality was found to be tightly coupled to metabolic costs (Spitz et al. 2012).

7. Knowledge gaps and uncertainties in assessment parameters

The data used for the assessment are one abundance estimate from year 2012, and estimated by-catch numbers from the years 2009-2017. The abundance is estimated in a robust way, but has a quite large CV, which makes the estimated K uncertain and reduces the PBR limit. The by-catch numbers are derived from the upper limit of a by-catch rate originating from the Belt Sea population, and it is unknown how applicable it is to adjust these for the lower harbour porpoise density and possibly different size vessels in the Baltic Proper. The by-catch rate was derived from boats longer than 10 m, which can carry more nets and therefore probably has a higher by-catch rate per DaS than smaller boats. On the other hand does the fishing effort from the Baltic Proper not cover small boats (minimum length varies among countries, often boats < 8 or 10 m length do not have to report their effort), whereby the total fishing effort likely is an underestimate. In addition, there is no consensus among Members States on how to report the fishing effort, wherefore the data are inconsistent. Altogether do the uncertainties prevent a precise interpretation of the model outputs, however it is clear that the population size is small and can barely sustain any by-catch.

8. Monitoring requirements, research priorities and opportunities for cooperation

To improve the assessment of the population's status, the most important action is to obtain an additional abundance estimate with a smaller CV. This would improve the assessment of K and the mortality limit. Second most important is to improve the by-catch assessment. As the monitoring effort required to get reliable data on by-catch rates in the Baltic Sea is enormous, an alternative approach may be to investigate the applicability of adjusting by-catch rates between different areas further, and to improve the estimates of total fishing effort with relevant gear types in the Baltic Proper.

9. Assessment unit status

The modelled population trajectory from 2009 to 2017, and the projection to 2025, show a continual decline of the very small population. The PBR analyses show that the estimated by-catch numbers exceed the mortalily limits for both depleted and/or threatened stocks and stocks of unknown status, as well as for stocks of endangered species. The recovery factor for endangered species resulted in a mortalitly limit of less than one by-catch per year.

In conclusion, the Baltic Proper harbour porpoise population is severely depleted, its abundance is estimated to be declining, and the population is not able to recover given that by-catches occur.

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JOINT IMR/NAMMCO INTERNATIONAL WORKSHOP ON THE STATUS OF HARBOUR PORPOISES IN THE NORTH ATLANTIC

Area Status Report

Iberian Peninsula

Compiled by G. Pierce[1,2,3] and Caroline Weir[4]

[1] *Instituto de Investigaciones Marinas (CSIC), Eduardo Cabello 6, 36208, Vigo, Spain*
[2] *CESAM & Departamento de Biologia, Universidade de Aveiro, 3810-193 Aveiro, Portugal*
[3] *Oceanlab, University of Aberdeen, Main Street, Newburgh, Aberdeenshire, AB41 6AA, UK*
[4] *Ketos Ecology, UK*

Note: *In Spain, the common name for harbour porpoise is marsopa while in Galicia it is the toniña and in the Basque country it is moskotxa. In Portugal it is usually referred to as the boto, although the name toninha (which, confusingly normally refers to common dolphin in Portugal) is sometimes also used for porpoises (Brito & Vieira 2010; López-Fernández & Martínez-Cedeira 2011).*

1. IDENTIFICATION OF ASSESSMENT UNITS WITHIN EACH SUB-AREA

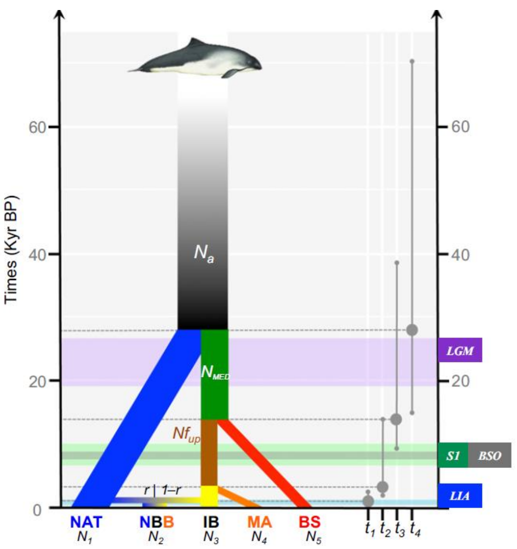

Figure 1. (from Fontaine et al. 2014): Demographic scenario selected by the approximate Bayesian computation (ABC) analysis. The figure also shows the likely timing of divergences in the lineage.

Several genetic studies have suggested a separate Iberian population, potentially extending down the northwest African coast, even a separate subspecies (*P.p. meridionalis*) (Fontaine et al. 2007, 2010, 2014; Fontaine 2016). Fontaine et al. (2014) recognized five lineages (Figure 1), noting the existence of genetic mixing between northern Bay of Biscay and North Atlantic animals, with asymmetric mixing of Iberian and Bay of Biscay animals, i.e. animals have migrated from the Iberian unit but not into it. Mauritanian animals are most closely related to Iberian animals, both being descended from the extinct western Mediterranean population, and diverging from each other around 3000 years ago. Fontaine et al. (2010) estimated Iberian and Bay of Biscay populations to have separated around 300 years ago.

In addition to their presence along the French Atlantic coast (Alfonsi et al. 2012), results in Fontaine et al. (2017) indicate that Iberian animals have also contributed to the gene pool of porpoises in the Celtic Sea area, although again, mixing seems to have been asymmetric. Overall, it seems to make sense to treat the Iberian Peninsula as a unit. Llavona Vallina (2018) found that porpoises from Spain and Portugal had similar mitochondrial nucleotide diversity, though haplotype diversity was lower in Spain. In both cases, mitochondrial DNA diversity measures were lower than in all the other populations except those in the eastern Mediterranean. The most recent data on genetic diversity in Iberian porpoises shows a sharp decline over the last 10 years (Fontaine, Pers. Comm.)

2. Distribution, abundance and trends

The Iberian harbour porpoise population inhabits the cold-water upwelling zone along the Atlantic coasts of Spain and Portugal, from the south Biscay coast to (at least) the Algarve coast of Portugal, bordering the Gulf of Cádiz (Sequeira, 1996; Castro, 2010), with records being most numerous in the Galicia region of Spain and in northern and central Portugal (Donovan and Bjørge 1995; Sequeira 1996; Fontaine 2016; Read 2016; Hammond et al. 2017).

The great majority (86%) of porpoise strandings reported in Spain between 1978 and 1994 occurred along the western Galician coast and comparatively few occur along the Biscay coasts of Galicia, Asturias, Cantabria and the Basque country (Lens 1997; López et al. 2002). Although ocean currents likely favour dead animals being washed ashore on the western coast, this distribution is also supported by recent sightings data. During 1990 to 1999, the porpoise was the third most frequently recorded cetacean species in strandings and there were no clear trends over time in porpoise strandings (Table 1).

Table 1. Numbers on strandings of different marine mammal species in Galicia, 1990-1999 (from López et al. 2002).

	Year											
Species	90	91	92	93	94	95	96	97	98	99	Total	%
Delphinus delphis	24	43	33	61	46	80	141	76	88	81	673	47.0
Tursiops truncatus	12	12	15	18	12	13	15	13	24	20	154	10.7
Unidentified cetacean	12	10	11	10	14	10	9	9	5	12	102	7.1
Unidentified Delphinidae	4	1	1	4	1	—	30	32	13	18	104	7.3
Phocoena phocoena	12	10	3	11	13	6	10	5	14	19	103	7.2
Stenella coeruleoalba	5	6	3	3	12	8	15	9	11	10	82	5.7
Globicephala melas	3	9	7	11	4	3	7	11	9	11	75	5.2
Grampus griseus	—	3	1	4	7	3	10	6	2	6	42	2.9
Cetacean bones	1	1	2	5	3	4	3	1	—	—	20	1.4
Globicephala macrorhynchus	—	—	—	—	—	—	—	—	15	—	15	1.0
Unidentified rorqual	—	—	—	1	3	1	4	—	1	4	14	1.0
Balaenoptera acutorostrata	1	1	—	3	—	1	—	1	1	2	10	0.7
Physeter macrocephalus	1	1	—	2	4	—	—	—	—	—	8	0.6
Pinnipeds	—	—	—	—	—	—	—	4	3	—	7	0.5
Balaenoptera physalus	—	—	—	2	1	2	1	—	—	1	7	0.5
Kogia breviceps	—	—	—	—	—	3	—	2	—	2	7	0.5
Ziphius cavirostris	2	1	—	—	—	1	—	—	1	—	5	0.3
Lagenorhynchus acutus	—	—	—	—	1	1	—	—	—	1	3	0.2
Megaptera novaeangliae	—	—	—	1	—	—	—	—	—	—	1	0.1
Orcinus orca	1	—	—	—	—	—	—	—	—	—	1	0.1
Total	78	98	76	136	121	136	245	169	187	187	1433	

During five years of shore-based monitoring in Galicia, porpoises sightings comprised 9.6% of all coastal cetacean sightings and were distributed all along the Galician coast, with the highest sighting frequencies recorded off Faro Punta Roncadoira on the north coast of Galicia, Faro Cabo Vilán near Cabo Fisterra (the westernmost point of Galicia), and La Guardia (close to the border with Portugal) (Pierce et al. 2010; Llavona Vallina, 2018). An extension of this analysis to 2011 showed that over the whole period porpoises made up 12.3% of cetacean sightings during land-based watches. Average encounter rates varied from year to year with a slight overall upward trend (Figure 2; Llavona Vallina 2018).

Boat transect surveys along the entire northern Spanish coast in 2006/07 did not record any porpoises, and only two sightings were recorded during shore-based monitoring (López et al. 2013). Boat-based surveys of the Galician coast indicate that the south-west region of Galicia is of particular importance for porpoises (López et al. 2004; Spyrakos et al. 2011; Fernández et al. 2013; Llavona Vallina 2018). Opportunistic boat-based surveys during 1998 to 1999 covered approx. 20000 km^2 and recorded five porpoise sightings in shallow waters adjacent to the rías de Pontevedra and Arousa in southern Galicia (López et al. 2004). Despite a wide distribution of multi-faceted survey effort off Galicia between 1998 and 2009, porpoise sightings (N=35) were recorded only between Cabo Fisterra and the Portuguese border (López et al. 2004; Fernández et al. 2013). Surveys in this region (Ría of Arousa) between 2014 and 2017 recorded 70 porpoise encounters (338 animals), with sightings distributed throughout the study area (Díaz López & Methion 2018).

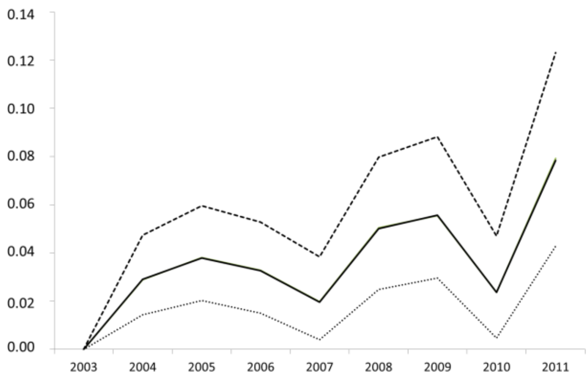

Figure 2. Annual average encounter rates (porpoise sightings per hour) from land-based surveys of the Galician (NW Spanish) coast, across all observation points, with 95% confidence intervals. Taken from Llavona Vallina (2018).

Porpoises appear to be rare off southern Spain in the Gulf of Cádiz (Sociedad Española de Cetáceos, 2006) and are generally absent from the Strait of Gibraltar and the western Mediterranean Sea (Frantzis et al., 2001). In a summary of strandings from the Alboran Sea and Strait of Gibraltar (1991-2008), a single harbour porpoise (in Cadiz in 2008) was recorded among 1198 marine mammal strandings documented by Rojo-Nieto et al. (2011).

Brito & Vieira (2010) summarize historical information on occurrence and distribution of cetaceans in Portugal. Most older information on the distribution of porpoises in Portugal originates from strandings, over 86% of which were located in the upwelling regions along the northern and central zones, especially the area around Aveiro and Figueira da Foz (where 67% of strandings occur) in northern Portugal (Sequeira, 1996; Sequeira et al. 1996, 1997).

A single sighting of 2 porpoises off Figueira da Foz is mentioned by Wise et al. (2007) who recorded the presence of cetaceans in the vicinity of purse seine fishing operations. Aerial surveys between 2008 and 2011 confirmed an important area of occurrence between Porto and Peniche, especially between Figueira da Foz and Nazaré, i.e. immediately to the south of the area of peak strandings (Vingada et al., 2011). The SCANS survey in 2016 recorded porpoise sightings all along the coast from the border with Galicia southwards to Peniche, but no sightings south of Peniche (Hammond et al., 2017).

Brito et al. (2009) compiled information on opportunistic sightings of cetaceans in Portuguese waters. While common dolphins comprised 60% of the total occurrences, harbour porpoises were also reported, although in much smaller numbers and restricted areas.

A year of shore-based monitoring from Cabo Mondego in central Portugal produced 31 porpoise sightings comprising 103 animals (Pereira, 2015). Shore-based surveys at the Douro River mouth (Porto) in northern Portugal during 2017 resulted in 22 porpoise sightings, and included repeated sightings of a leucistic animal that indicated some site-fidelity of the species at that location (Gil et al., In Press).

Strandings of porpoises a relatively frequent along the western coast of Portugal as far south as Lisbon, although there are a number of records from Lisbon to the vicinity of Faro. Numbers of strandings are highest in January to April (Sequeira, 1996). During 2009, 22 porpoise sightings were recorded along the western Algarve coast of southern Portugal (Cape São Vicente to Lagos), indicating that Iberian porpoises do also inhabit that region (Castro, 2010). A recent suite of aerial surveys along the Portuguese coastline produced predicted occurrence maps which suggested that the region of southern Portugal had greater inter-annual fluctuation in porpoise occurrence compared with the other areas (Araújo et al., 2015).

The only surveys to cover (approximately) the whole Iberian coast were SCANS 2 and 3 in 2005 and 2016 respectively, although these surveys did not extend into the interior water of the Galician rías. The 2005 survey was carried out in shelf waters of the combined Iberian Peninsula and the southern and central Bay of Biscay (SCANS II block W), producing abundance and density estimates of 2,357 animals (CV=0.92) and 0.017 animals/km^2 (CV=0.92) respectively (Hammond et al., 2013). During the 2016 SCANS III survey this area was amended to correspond with the Iberian Peninsula Management Unit (IPMU) that was adopted by the ICES WGMME in 2009 (ICES, 2009). The resulting Block A was further divided into three sub-blocks spanning the Atlantic and Bay of Biscay coasts of Portugal and Spain. The survey generated an abundance estimate of 2,715 individuals (CV=0.31) for sub-block AB, from Cabo de São Vicente in Portugal northwards to Cape Finisterre in Galicia, which encompasses the core range of the Iberian population (Table 2). Sub-blocks AA and AC had no or few porpoises (Table 1), resulting in a combined abundance for the IPMU of 2,898 animals (CV=0.32).

The porpoise densities recorded for the Iberian Peninsula SCANS blocks during the 2005 and 2016 surveys were among the lowest over the entire European continental shelf. Final porpoise abundance estimates for the IPMU were very similar, 2880 (CV=0.72) and 2900 (CV=0.32) respectively (Hammond et al. 2017).

Table 2. Harbour porpoise abundance and density (animals/km^2) estimates from the Iberian Peninsula Block A of the SCANS III aerial survey in 2016 (Hammond et al., 2017). CV is the coefficient of variation of abundance and density. CL low and CL high are the estimated lower and upper 95% confidence limits of abundance.

Block	Geographic region	Abundance	Density	CV	CL low	CL high
AA	Straits of Gibraltar to Cabo de São Vicente	0	0	0.00	0	0
AB	Cabo de São Vicente to Cape Finisterre	2,715	0.102	0.31	1,350	4,737
AC	Cape Finisterre to Bayonne (France), including the southern Bay of Biscay	183	0.005	1.02	0	669

National abundance surveys have been carried out in both Portugal and northern Spain and suggest (consistent with SCANS results) that the majority of the population lives in Portuguese waters. Based on data collected in 2003–2011 from multiple sources, López et al. (2013) produced an abundance estimate for harbour porpoises in the Spanish Galician and Bay of Biscay waters of the IPMU of 683 animals (CV=0.63, 95% CI: 345-951, N=40), with a density estimate of 0.0008 animals per km^2. This estimate did not account for availability, perception or responsive movement biases and may therefore have been negatively biased. The Galician population alone was estimated to comprise 386 (CV=0.71) individuals by López et al. (2012; see also CEMMA 2018). According to Santos et al. (2012), an estimate of 2435 animals and a density of 0.0972 animals per km^2 was calculated for porpoises in coastal Portuguese waters up to 20 nm from the coast in 2012. Summed together, the total number of animals for Spain and Portugal is similar to the SCANS abundance estimate. Note however, that in all the national surveys, relatively low numbers of sightings resulted in wide confidence limits, and estimates from Portuguese surveys also varied markedly between years (ICES 2014a). According to ICES (2014a), estimates of harbour porpoise abundance in Portuguese coastal water were 1691 (C.I. 406–7049) and 3593 (C.I. 856–6955), in 2011 and 2012 respectively.

The SCANS surveys indicate similar abundances in 2005 and 2016, suggesting there is no upward or downward trend, although either could be accommodated within the 95% confidence interval.

3. ANTHROPOGENIC REMOVALS IN TIME AND SPACE

Hunting

Sequeira (1996) notes that until 1981 it was legal for porpoises to be caught and sold in Portugal but considers that these were animals captured incidentally rather than deliberately. López et al. (2003) reported that sixty-nine of the fishermen interviewed in Galicia referred to cetaceans being used for human consumption, although the species involved were not identified. While some admitted to eating marine mammals (fillets or the liver), others commented that porpoises were eaten in the Basque country, Portugal and France. The use of cetaceans for bait, animal food and as a source of fat was also mentioned. Again, it seems likely that these would be by-caught animals, but it is not known whether this included porpoises.

Fishery by-catch

Numerous authors have reported that interactions with fisheries are a significant, and unsustainable, cause of mortality for Iberian porpoises (Sequeira 1996; López et al. 2002, 2003; López-Fernández & Martínez-Cedeira 2011; López et al. 2012; Read et al. 2013; Pereira 2015; Read 2016; Llavona Vallina 2018). The North West Iberian Peninsula (NWIP) is one of the most important fishing regions in the world, with an estimated 1.5 million fishing trips per year by 13,000 registered fishing vessels (Read 2016). The most numerous sector is the coastal small boat fishery using gillnets, longlines, traps, beach seines (Portugal only), purse seines, dredges and beam trawls (López et al. 2004; Read 2016). Based on interviews with fishermen at Galician harbours (2008-2010), gillnets comprised 41.5% of the fishing gear used in the region (Goetz et al. 2014). Gillnet fisheries are also prevalent in northern Portugal, with 2320 licences issued in 1991, primarily in areas that overlap with core porpoise habitat (Sequeira 1996). Goetz et al. (2015) reported substantial spatial overlap between fisheries and cetacean foraging areas in the NWIP. Harbour porpoises comprised 8.5% of the cetacean sightings reported by fishers and were primarily seen close to set gillnets in Galicia close while in Portugal they were most frequently seen by fishermen using polyvalent gear, purse seines, and beach seines.

Iberian porpoises are apparently susceptible to by-catch in several different types of fishery, with Lens (1997) reporting 14 porpoise by-catches between 1978 and 1994 in Spanish gillnet, fixed bottom gillnet, purse seine, trawl and longline fisheries. Marçalo et al. (2015) reported the encirclement of a porpoise in a purse-seine operation off Portugal in 2011 (the animal escaped). However, the majority of porpoise by-catch appears to be related to gillnets and Portuguese beach seines (Vingada et al. 2011; Pereira 2015; Read 2016). Beach seine methods continue to be used along the Portuguese coast (despite being illegal in Galicia and most other European countries) and are thought to account for the higher by-catch rates estimated from strandings in Portugal (60%) compared with Galicia (40%; Read et al. 2013). Portuguese beach seine nets can reach up to 5 km length, and captures in this fishery have included mother-calf pairs (Read 2016).

Strandings

The NWIP has one of the highest rates of marine mammal strandings recorded in Europe. Harbour porpoises comprised 7% of strandings in Galicia (López et al. 2002) and 13% of strandings in central-north Portugal (Ferreira 2007). In Galicia, the proportion of dead porpoises that showed evidence of fisheries interactions was 22.3% between 1990 and 1999 (N=103; López et al. 2002), 24% between 2000 and 2006 (N=64; López et al. 2012), and 15.4% between 1990 and 2013 (N=241; Vázquez et al. 2014). The harbour porpoise was the second most frequently by-caught species on the Asturian coast (12 out of 43 records; Nores et al. 1992). In Portugal, the mortality of 50% of stranded cetaceans between 1981 and 1994 was attributed to fishing activities (Sequeira 1996), and 37.2% of porpoises stranded between 2000 and 2009 showed evidence of by-catch (ICES 2010a).

In a larger dataset of 319 porpoises stranded in the NWIP between 1990 and 2010 (including Portuguese animals from 2000 onwards), approximately 60% of the animals for which cause of mortality could be ascertained had died as the result of fisheries interactions. No sex- or age-related differences in by-catch were detected. Combining results of a life table and necropsies suggest that there is between 4.3 and 11% annual mortality in the Iberian porpoise population due to fisheries interactions (Read et al 2013; Read 2016).

Interview surveys

Two interview-based studies, López et al. (2003) and Goetz et al. (2014) both generated estimates of total annual cetacean by-catch in Galicia of around 1700 animals. Porpoises were not specifically identified in the earlier study. Goetz et al. (2014) reported that Galician fishers operating fixed gillnets caught an average of 2 to 3 porpoises per year, with an estimated total annual by-catch by trawl and set gillnet fleets of approximately 40 porpoises (but almost 1300 of the cetaceans by-caught annually were not identified to species.

On-board observations

The only on-board observer-based by-catch estimates collected under Regulation 812/2004 in area VIII relate to gillnet catches in 2008 and 2009, and pair trawls in 2008. Coverage in 2008 was in only the last quarter of the year and revealed no by-catches of porpoises (one common dolphin by-catch was recorded in the pair trawls and several in gill nets), while a by-catch of around 300 porpoises in gill nets was estimated from 2009 data (see Anon. 2009, Lens & Diaz 2009). No biological data are available for the animals killed. However, breaking the data down by sub-region, the by-catches were all in Bay of Biscay rather than Iberian waters.

An earlier study by Fernández-Contreras et al. (2010) carried out observations onboard pair trawlers in Galicia in 2001 and 2002 estimated an annual by-catch of 394 common dolphins but no harbour porpoises.

A total of 292 beach seine (xávega) hauls monitored in Portugal between 2008 and 2011 resulted in 5 porpoise mortalities, i.e. a mortality rate of 0.017 animals per haul (Vingada et al. 2011). The authors state that they observed 3.3% of national fishing activity for this fleet. Based on broad consistency with annual fishing effort data reported in Oliveira et al. (2015), we assume that 292 hauls represented 3.3% of *annual* fishing effort by this fleet. Thus, the annual number of beach seine hauls would be around 8850, implying a total annual by-catch mortality in this gear of around 152 porpoises. While more recent data exist on by-catches in this fishery, these are not presently in the public domain.

According to reports submitted to SGBYC and WGBYC (ICES 2010b, 2011), in 2007-2009 Portugal had no fisheries covered by regulation 812/2004 and no observer programme. Nevertheless, the tables in ICES (2010b) mention by-catch of several species in gill nets in Portugal (no figures given).

In 2010, Portugal reported on observations of polyvalent and purse seine fisheries in area 9a, reporting an estimated by-catch of 80 porpoises in the polyvalent fishery in ICES area 9a during 2010 (extrapolated from 5 by-caught animals; ICES 2013a). However, according to the figures in the relevant table in ICES (2013a), the estimated number of porpoises by-caught in 2010 should be 150 (and for common dolphins the correct estimate would be 180 animals and not 16). It should be noted that these by-catches are not mentioned in the report text.

In 2011, Portugal reported on observations of purse seine, demersal and polyvalent trawl fisheries, estimating a by-catch of 103 porpoises in the purse seine fishery during 2011 (extrapolated from 1 by-caught animal; ICES, 2013b). Purse seine and trawl by-catches are not mentioned in the report text while results for the polyvalent fleet (which caught only common dolphins – for which no exact figure is given but probably several hundred animals) appear only in the text and not the tables.

Observations on-board purse seiners in Portuguese waters in 2010-2011 (163 days at sea) yielded zero by-catch of porpoises, although a porpoise was observed being encircled and subsequently escaping (Marçalo et al. 2015). These results were reported in a paper and it is not clear whether they were already included within Portugal´s submission to WGBYC.

In 2012, Portugal reported on observations from demersal trawl, purse seine and polyvalent (trammel net) fishing (ICES 2014b). By-catch of one porpoise (also 3 common dolphins and a bottlenose dolphin) was recorded in the polyvalent fleet deploying trammel nets. With 63612 days at sea (possibly the total estimated soak time), of which 71 were observed, the extrapolated by-catch, which ICES 2014b did not report, would have been 896 porpoises.

In 2013 and 2014, Portugal reported on by-catches in polyvalent, seine and bottom trawl fleets, reporting by-catches of common dolphins in both years and bottlenose dolphins in 2013, but no by-catches of porpoise (ICES 2015, 2016). In 2015, only observations from fisheries using “other gears” (presumably the polyvalent fleet based on the number of days at sea reported, with by-catches of 6 porpoise and 2 bottlenose dolphins. Extrapolation gives a porpoise by-catch of 1462 animals (ICES 2017). A small number of trips by boats in the polyvalent fleet and deploying fixed nets was observed in 2016, yielding no by-catches of protected species (ICES 2018b).

Based on the Portuguese data and excluding the 2012 trammel net data, the estimated average annual by-catch across polyvalent, purse seine and beach seine fleets is 906 animals. Again it should be noted that Spanish coastal waters and most fishing vessels <15 were not included here, potentially leading to underestimates. However, drop out of carcases may lead to overestimates.

Year to year trends in by-catch frequency

It is difficult to extract reliable inferences about trends in by-catch over time from the available data. It is however notable that (as reported in the previous section) two interview surveys separated by around a decade (1998-1999 and 2008-2010) resulted in very similar estimates of the total number of cetaceans by-caught in Galician fisheries (around 1700).

The longest time series available derives from strandings (Figure 3, from Read et al 2013), but those data need to be interpreted with caution, not least due to the substantial proportion of undiagnosed deaths among strandings and the fact that the strandings networks do not over the entire Iberian Atlantic coast. A more recent detailed analysis of trends in the number of porpoise strandings in western Galicia identified a seasonal pattern and an effect of the number of days per month with strong southwesterly winds, but no significant year to year variation (Saavedra et al. 2017). Given the small number of strandings recorded each year (totals vary between 3 and 30) and the fact that cause of death is often not diagnosed, annual figures on the proportion of by-catch mortalities are not likely to be useful.

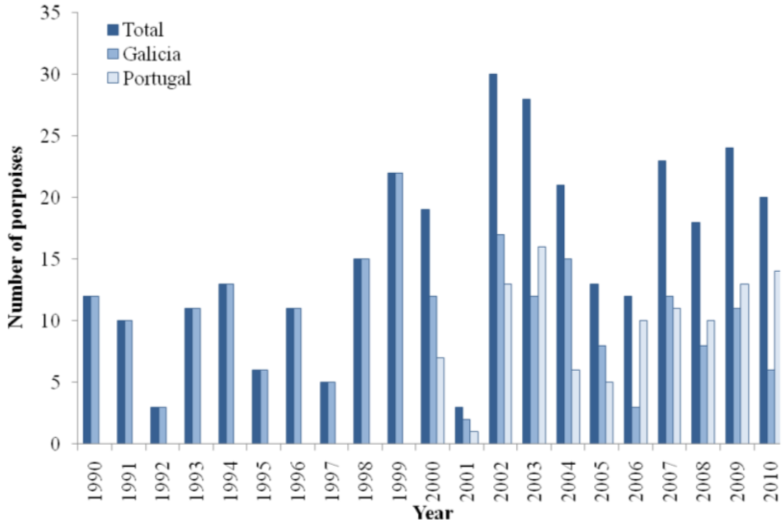

Figure 3. Annual figures on porpoise strandings in Galicia (from 1990) and Portugal (from 2000). Taken from Read et al. (2013).

Iberian harbour porpoises are protected by law in both Spain and Portugal, as well as under EU directives, and no exploitation is permitted. However, interviews with Galician fishers indicated some human consumption of small cetaceans, and their use for bait, animal food and as a source of fat (López et al. 2003). Those reports were assumed to relate to the use of animals initially by-caught in fishing gear.

4. IMPACTS FROM OTHER INDIRECT (SUB-LETHAL) PRESSURES

Pollutants

Of the five cetacean species from the NWIP studied by Mendez-Fernandez et al. (2014a), bottlenose dolphin and harbour porpoise showed the greatest concentrations of PCBs in their blubber. Concentrations in both species exceeded the toxic threshold of 17 µg g^{-1} lipid weight (PCB Aroclor equivalent) for health effects on marine mammals, for 100% and 75% of the individuals tested, respectively. Element concentrations (Hg and Cd) found in Iberian toothed whales indicate that these populations are not especially threatened by Hg and Cd exposure in the area (Mendez-Fernandez et al. 2014b).

Compared with the values reported by Méndez-Fernandez et al. (2014b), 42 harbour porpoises stranded in Portugal from 2005 to 2013 had higher levels of mercury and lower levels of cadmium. The higher mercury levels may reflect anthropogenic sources, with Portuguese animals inhabiting waters closer to the Mediterranean where high levels of mercury occur in the seawater. Nevertheless, the recorded mercury levels did not exceed the level for toxic thresholds in marine mammals (Ferreira et al. 2016).

Previous studies on porpoises in Galicia found low concentrations of mercury and cadmium (Lahaye et al. 2007), PCBs and PBDEs (Pierce et al. 2008) and HBCD (brominated flame retardants, Zegers et al. 2005) but all were based on a very small sample (N=3) of porpoises. One of the three porpoises had a total PCB concentration in blubber higher than the generally accepted threshold for effects on reproduction.

There have been no studies on microplastics in stomach contents of porpoises in the Iberian Peninsula, although a recent study on common dolphin stomach contents in Galicia found microplastics in every stomach (N=35) examined (Hernandez-Gonzalez et al. 2018a). The health implications of the presence of microplastics in dolphin stomachs are presently unknown.

The proximity of Galicia to one of the world's busiest shipping routes, along with the presence of a refinery located in the port of A Coruña, make the NWIP coastline particularly vulnerable to oil pollution. Galicia has experienced five out of the eleven major oil spills in Europe in the last three decades (Loureiro et al. 2006). The 'Prestige' oil spill in November 2002 released 60,000 metric tons of oil into the Atlantic off Galicia, and polluted 1300 km of coastline (Loureiro et al. 2006). In the six months following the spill, 124 cetaceans were stranded along the Galician coast, of which 35% were oiled and 3% were considered to have died as a direct result of oil. This included the mortality of at least one porpoise (López et al., 2005; Loureiro et al., 2006).

Disturbance

The presence of motor boats and fishing vessels was found to negatively affect the presence and density of porpoises recorded off Galicia (Díaz López & Methion, 2018). Similar results were found in central Portugal, where the porpoise sighting rate increased as the number of fishing boats decreased (Pereira, 2015). Further work is needed to understand whether disturbance from vessel traffic represents a population-level threat to Iberian porpoises.

Overfishing and prey depletion

The main prey of porpoises in Galicia (NWIP) include scad, *Trisopterus* and blue whiting, all of which are commercially important, and garfish, which is not (Pierce et al. 2010, Read et al. 2013). Direct and indirect competition with fisheries are likely, and the amount of some commercial fish species fish removed by porpoises has been estimated (Santos et al. 2014), but the impact of competition with fisheries on porpoises is unknown.

Interactions with bottlenose dolphins

Although it is apparently rare (Pierce et al. 2010; López-Fernández & Martínez-Cedeira 2011), mortalities of porpoises due to bottlenose dolphin aggression have been documented in the NWIP (López Rodriguez Folgar 1995; Alonso et al. 2010).

5. LIFE-HISTORY PARAMETERS AND HEALTH STATUS

Life history parameter data for Galician porpoises, based on stranded and by-caught individuals, are reported by Read et al. (2013) and Read (2016), with some information for Portugal in Sequeira (1996). Maximum length and lengths at sexual and physical maturity are larger than in other populations, and age at sexual maturity in females also appears to be higher than in other populations (see Table 3 for a summary and comparison with data for other regions). However, comparisons are difficult due to variation in methodology and an absence of error estimates or confidence limits in many cases. In addition, in the case of estimating age and size at maturity, in order to achieve reasonable accuracy and precision, a good sample size is needed for animals of ages and sizes close to the values at which achievement of maturity is expected to occur.

The large body size of Iberian porpoises is well-known (e.g. Smeenk et al. 1992; Donovan and Bjørge 1995; Sequeira 1996; López 2003). Maximum lengths recorded were 208 cm for females and 189 cm for males (Read et al. 2013). The maximum age recorded for porpoises in the NWIP is 18 years for females and 19 years for males (Read 2016). One animal of undetermined sex reached 21 years of age. Over 85% of animals that stranded or were by-caught in the NWIP were ≤10 years old, and over 60% were ≤3 years old (Read et al. 2013).

Female Iberian porpoises reach sexual maturity at around 5.5 years old, with mature females being 161–202 cm long and pregnant females 176–202 cm long (N=16; Read et al. 2013). Mature male Iberian porpoises ranged from 3–19 years old (N=14) and had body lengths of 154–171 cm (N=17), with an estimated age at sexual maturity of 3.8 years (Read et al. 2012). Growth models indicated that the asymptotic length at physical maturity of males (162 cm) and females (185 cm) was reached at approximately 10 years of age.

The annual pregnancy rate (APR; estimated from the proportion of mature females with a foetus between September and May) for Iberian porpoises was 0.54. The calving interval, during which gestation, lactation and reproductive resting occur, was estimated to be 1.89 years, and females appeared to remain reproductively active until at least 16 to 18 years old (Read et al. 2013; Read 2016). Four neonate porpoises were recovered in May and August, indicating a summer calving period (Read 2016). The sex ratio in the NWIP is apparently close to 1:1 (1.07:1.00: Read et al. 2013; 1.17:1.00: Lens 1997).

Table 3. Life history parameters of harbour porpoise (Read 2016). Data for Atlantic Spain (second row of results) come from Lens (1997) and López (2003) while data for Portugal (row 4) are from Sequeira (1996).

Area	**Females**							**Males**					
	Maximum length (cm)	**Maximum age (yrs)**	**Sexual maturity length (cm)**	**Sexual maturity age (yrs)**	**Physical maturity length (cm)**	**Physical maturity age (yrs)**	**Pregnancy rate (Presence of foetus)**	**Maximum length (cm)**	**Maximum age (yrs)**	**Sexual maturity length (cm)**	**Sexual maturity age (yrs)**	**Physical maturity length (cm)**	**Physical maturity age (yrs)**
NWIP	**202 (N=127)**	**18 (N=71)**	**161-202 (N=60)**	**5.5 (N=60)**	**185 (N=60)**	**10 (N=60)**	**0.54 (N=13)**	**189 (N=136)**	**19 (N=77)**	**154-171 (N=47)**	**3.8 (N=47)**	**162 (N=47)**	**10 (N=47)**
Atlantic Spain	202 (N=31)	n/a	n/a	n/a	n/a	n/a	n/a	176 (N=27)	n/a	n/a	n/a	n/a	n/a
Galicia, north-west Spain	202 (N=38)	9	166	3	n/a	n/a	n/a	n/a	9	155	5	n/a	n/a
Portugal (1981-1994)	208 (N=22)	n/a	n/a	n/a	n/a	n/a	n/a	175 (N=15)	n/a	n/a	n/a	n/a	n/a
Scotland (1992-2004)	173 (N=227)	20 (N=132)	119-148 (N=111)	4.6 (2-5) (N=111)	164 (157-171)	~5	0.42 (N=33)	170 (N=252)	20 (N=138)	116-144 (N=64)	5.7 (3-6) (N=64)	151 (147-155)	~5
British Isles (1985-1994)	189 (N=96)	22 (N=96)	n/a	n/a	160	n/a	n/a	163 (N=114)	24 (N=114)	>130 (N=114)	>3 (N=114)	145	n/a
Ireland (2001-2003)	175 (N=27)	11 (N=21)	n/a	n/a	n/a	n/a	n/a	157 (N=19)	n/a	n/a	n/a	7.5 (N=14)	n/a
Denmark (1938-1998)	189	23	136-151 (N=59)	3.6 (2-5) (N=59)	160	n/a	n/a	167	23	130-135.5 (N=96)	2.93 (2-3) (N=96)	145	n/a
The Netherlands	160 (N=19)	12 (N=14)	n/a	n/a	n/a	n/a	n/a	147 (N=5)	12.5 (N=2)	n/a	n/a	n/a	n/a
France (2001-2003)	192 (N=14)	24 (N=9)	n/a	n/a	n/a	n/a	n/a	165 (N=17)	14 (N=12)	n/a	n/a	n/a	n/a
West Greenland (1988-89, 1995)	166 (N=85)	14 (N=85)	138-142 (N=85)	3.6 (N=84)	154 ± 2.6	n/a	n/a	158 (N=91)	17 (N=91)	127 (123-130)(N=91)	2.45 (N=94)	142 ± 1.7	n/a
Iceland (1991-1997)	174 (N=474)	20 (N=354)	~138-147	~3.2 (2-6) (N=293)	160	n/a	n/a	165 (N=794)	16 (N=615)	~135 (N=526)	~1.9-2.9 (2-5) (N=526)	150	n/a
Gulf of Maine (1989-93)	168	17*	n/a	3.4 (2-4) (N=99)	158 ± 1.56	~7	0.93 (N=14)	157	15*	n/a	>3 (3-4) (N=31)	143 ± 1.25	~5*

Based on age-at-death data from stranded animals, and construction of a life table, Read et al. (2013) estimated an annual mortality rate of 18% of the population, similar to estimates for porpoise in Scotland (Pierce, unpublished data). Evidently such estimates are subject to biases, notably that not all dead animals will strand. The youngest age classes tend to be underrepresented in strandings data (biasing mortality estimates downwards) while coastal mortality (e.g. due to bottlenose dolphins in Scotland) will cause an upward bias. Thus, considering that bottlenose dolphin kills are not known in Galicia, the underlying mortality rate may well be higher than in Scotland. The estimated pregnancy rate (54%) is too low to balance mortality (a value of 82% would be needed). However, the pregnancy rate is based on a very small sample of mature females (N=13) and estimates from strandings tend to be strongly biased downwards unless based only on trauma deaths. The sample size is insufficient to permit a calculation based only on trauma deaths.

Data on the age of stranded animals suggest that mortality rate in 2010 had declined slightly since the mid-2000s, reflecting the occurrence of more 12+ age animals among the strandings (Read et al. 2013).

6. DIET AND PREY AVAILABILITY

Based on analysis of stomach contents of 56 porpoises stranded on the Galician coast during 1991–2010, the most important prey of harbour porpoise in Galician waters in terms of biomass consumed were *Trisopterus* spp. (presumably mainly pouting, *Trisopterus luscus*), blue whiting (*Micromesistius poutassou*) and scad (or horse mackerel, *Trachurus trachurus*). Other prey included sardine (*Sardina pilchardus*), hake (*Merluccius merluccius*), dragonets (Callionymidae), garfish (*Belone belone*), sea breams (Sparidae) and sandeels (Ammodytidae). (Table 4; Santos et al., unpublished data; see also González et al. 1994; Santos 1998; Santos & Pierce 2003; Read et al. 2013). Cephalopods were numerous in the diet, especially Sepiolidae and *Alloteuthis* spp. (Loliginidae) but made up only around 1.3% of prey biomass. Blue whiting is generally found on the continental slope but the other main prey species of porpoises live in shelf waters (Pierce et al. 2010).

Table 4. Fish in the diet of harbour porpoise in Galicia (1990-2010).

PREY SPECIES	% F	N	%N	W	%W
Fish	**96.2**	**1958**	**96.0**	**74338.4**	**98.7**
Sardine (*Sardina pilchardus*)	20.8	156	7.7	4411.2	5.9
All Clupeoids	*20.8*	*156*	*7.7*	*4411.2*	*5.9*
Argentine (*Argentina* sp.)	7.5	11	0.5	269.5	0.4
Blue whiting (*Micromesistius poutassou*)	43.4	493	24.2	15677.1	20.8
Trisopterus spp. (*T. esmarkii*, *T. minutus*, *T. luscus*)	47.2	239	11.7	24267.6	32.2
Silvery pout (*Gadiculus argenteus thori*)	15.1	236	11.6	1186.1	1.6
All Gadidae	*52.8*	*972*	*47.7*	*41394.2*	*54.9*
Hake (*Merluccius merluccius*)	24.5	87	4.3	6454.6	8.6
Snipefish (*Macroramphosus scolopax*)	5.7	108	5.3		
Garfish (*Belone belone*)	9.4	21	1.0	1484.8	2.0
Scad (*Trachurus* sp.)	26.4	142	7.0	13242.9	17.6
Sparidae	13.2	24	1.2	2261.6	3.0
Cottidae	1.9	2	0.1	167.2	0.2
Labridae	3.8	2	0.1	24.1	<0.01
Sandeel (*Ammodytes* spp.)	7.5	71	3.5	1955.9	2.6
Dragonet (Callyonymidae)	13.2	47	2.3	2264.0	3.0
Gobiidae	24.5	219	10.7	217.9	0.3
Atherina sp.	1.9	1	<0.1	7.0	<0.1
Sole (*Solea solea*)	3.8	2	0.1	183.3	0.2
Other flatfish	1.9	*1*	*<0.1*	*0.4*	*<0.1*
Unidentified Fish	*47.2*	*91*	*4.5*	-	-

Scad and blue whiting are assessed by ICES. Two stocks of scad occur in the area, one in the north, which is currently at a historical low and below the stock size producing Maximum Sustainable Yield (ICES 2018b) and one in the south which, while less abundant, appears to be increasing (ICES 2018b). Blue whiting forms a single wide-ranging stock, the distribution of which includes the Iberian Peninsula. The abundance of this stock is currently above MSY but fishing mortality is high (ICES 2018b). The decline of scad in ICES subarea 8 (including the north Spanish coast) is a potential cause for concern. Despite its commercial importance *Trisopterus luscus* is not assessed. A recent update of this work (Hernandez-Gonzalez et al. 2018b) extended the time series through to 2017 (N=66), again finding that *Trisopterus* spp. and blue whiting were the most important prey species.

Stable isotope data from stranded animals suggest that porpoises in Galicia feed more on inshore prey and have a relatively high trophic level, when compared to other common odontocetes in the region, with the exception of coastal bottlenose dolphins (Mendez-Fernandez et al. 2012). Differences in foraging niches between porpoises and other odontocetes are also revealed by studies that include other "ecological tracers" such as cadmium and PCB concentrations in body tissues (Mendez-Fernandez et al. 2013, 2017). Inferences on diet may also be possible from studies on macroparasites but there is so far only one preliminary study for Galicia (Abollo et al. 1998).

7. KNOWLEDGE GAPS AND UNCERTAINTIES IN ASSESSMENT PARAMETERS

There remains a need for more robust and more frequent abundance estimates, and better clarification of the spatio-temporal movements of porpoises within (and out of) the NWIP. The ongoing collection of life history, dietary, health and cause of death data from stranded and by-caught animals is required, in order to obtain better estimates of life history parameters and provide a more complete picture of health status and causes of death in this population. Samples from these animals will feed into ongoing genetic studies.

However, perhaps the most important issue however though is the lack of robust data on by-catch mortality. The problem is particularly acute in the Iberian Peninsula due to the very large number of fishing vessels and the failure to carry out the systematic monitoring required under Regulation 812/2004.

In Spain, to date, a single pilot project has been carried out, during which dedicated observers collected data for slightly over 1 year. Subsequently, in some years, reports on cetacean by-catches from fisheries observers were sent to ICES WGBYC but were not included in the WGBYC reports.

In Portugal, dedicated observers collected data from several fleets (purse seine, polyvalent, beach seine) as part of the MARPRO project, and some reports from fishery observers (also including observations from demersal trawl fleet) were submitted to the ICES WGBYC. However, in most cases the proportion of fishing activity monitored was small (18 by-caught porpoises in Portugal over 7 years resulting in an estimated annual average by-catch of 900-1000 for Portugal alone), so that extrapolated by-catches are of questionable value, and there are some discrepancies in the data presented in the ICES WGBYC reports.

Abundance estimates are available from SCANS 2 and 3 plus some more localized projects but all this activity has depended on project funding. Regular distribution and abundance surveys covering all seasons would be useful, extending into the Galician rías and offshore waters of Portugal.

8. MONITORING REQUIREMENTS, RESEARCH PRIORITIES AND OPPORTUNITIES FOR COOPERATION

Monitoring of strandings is well established in Galicia and in some parts of Portugal but carried out by NGOs which are highly dependent on project funding and other short-term funding. Data for the rest of the NWIP are less readily available. Partly this is a coordination issue – there is a need for coordinated collaboration within and between the countries of the Iberian Peninsula - but adequate and long-term funding of strandings monitoring along all the coast is a priority. It would also be useful to model the drift of carcasses in order to understand the origin of stranded animals, similar to the approach of Peltier et al. (2012), given that dead animals are likely to be transported northwards.

In terms of priorities, the generation of robust by-catch estimates is both a high priority and achievable, given funding and/or sensible use of fishery observers (considering all the caveats about non-dedicated observers). Coordinated strandings monitoring around the whole of the Iberian Peninsula would deliver more comprehensive life history data including better estimates of pregnancy and mortality rate, but this will take time. Further genetic studies may also prove to be a useful way of investigating trends in population size over time.

9. ASSESSMENT UNIT STATUS

It is difficult to make a firm determination of the status of the Iberian porpoise since the indicators produce contradictory signals:

Abundance

The Iberian porpoise population appears to number around 2900 animals: estimates from SCANS II (2005) and SCANS III (2016) were almost identical at 2880 (CV=0.72) and 2900 (CV=0.32) respectively. The highest estimate from national surveys is over 4200 but this within the 95% CI of the SCANS estimates. This is a small population but the best estimates of its size did not change over 11 years. It should be noted however that the wide confidence intervals on the abundance estimates do not preclude upward or downward trends. The population may extend offshore in Portuguese waters beyond the SCANS survey area and also into the Galician rias (which were not surveyed by SCANS), which could have resulted in underestimation of population size.

By-catch: By-catch estimates are available for Spanish gillnet fisheries during 2008-09 but most monitored effort was in the Bay of Biscay outside the Iberian Peninsula and there were no reported by-catches in Spanish Atlantic waters. Over the period 2010-2016, 13 porpoise by-catches were reported (to ICES WGBYC) from Portuguese polyvalent and purse seine fisheries. A further 5 by-catches were recorded from beach seining in Portugal. The extrapolated average annual total by-catch is 530 porpoises, reduced to 411 if the most extreme extrapolation (from 1 porpoise caught in trammel nets in 2012 to 896 by-catches in that gear in that year) is removed from consideration. Low and possibly unrepresentative observer effort is a problem, as is poor quantification of effort by boats <15 m in both countries. Aside from beach seines, the (extremely numerous) <15 m boats are probably not represented in the data. The by-catch results are incompatible with the abundance results since they would result in extinction within a few years. Note that, while estimated by-catch is high, as seen below, the annual number of *known* by-catches (i.e. reported by-catches and diagnosed by-catches in strandings) does not exceed the estimated Potential Biological Removal (PBR, Wade 1998). However, it is extremely unlikely that true by-catch is as low as this minimum figure.

Population model

Due to the incompatibility of population size and by-catch data, the assessment was run using population size data only. Using a Bayesian logistic population growth model (Zerbini et al. 2011) and based on the best estimates of population size, and applying a recovery factor of 0.5, annual PBR is estimated to be 25 animals (D: Palka, Pers. Comm.).

Life history data

The estimated annual total mortality rate based on age data is high (18%), corresponding to an annual by-catch mortality of between 4.3% and 11%. The estimated pregnancy rate (54%) is too low to compensate for 18% mortality. However, mortality rate may be overestimated and pregnancy rate is based on a very small sample. Data on age of stranded animals suggest that mortality rate declined between the mid-2000s and 2010, with more age 12+ animals appearing in strandings in these years. Nevertheless, these data refer to Galicia only and the sample size is small.

Genetic diversity: Genetic (Mt DNA) data indicate a loss of genetic diversity (as well as outward movement of animals into the Bay of Biscay and Celtic Sea) and, although the research is ongoing, the preliminary results support the idea of a declining population (Fontaine, Pers. Comm.).

Conclusion

Fishery by-catch is almost certainly unsustainably high (a by-catch in excess of 25 animals per year would probably lead to a population decline) but the present by-catch mortality estimate, extrapolated from observation on a small proportion of fishing activity, is also unrealistically high. The recent decline in genetic diversity also indicates that the population may be declining.

Recommendations

A robust measure of fishery by-catch mortality is essential. Annual abundance surveys along the Iberian coast would be useful to elucidate population trends. Comprehensive, coordinated and adequately funded strandings monitoring would permit more robust estimates of life history parameters. However, these recommendations do not imply that precautionary management measures should be delayed until more robust data are available.

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Area Status Report

Northwest Africa

Compiled by S. Enoksen[1]

With contributions from W.C. Mullié[2,7,9], O. Ba[3], J.-L. Jung[4], K. Van Waerebeek[5], I. Tai[6], M.M. Wagne[7,8], A.S. Bilal[7,8] & L.W. Keith-Diagne[9]

[1]*NAMMCO Secretariat, Tromsø, Norway*
[2]*Independent Researcher, Ghana*
[3]*Université de Nouakchott, Mauritania*
[4]*Université de Bretagne Occidentale, France*
[5]*COREWAM |Conservation and Research of West African Aquatic Mammals, Dakar-Accra, Senegal*
[6]*Institut National de Recherche Halieutique, Morocco*
[7]*Program Biodiversity, Oil and Gas, GIZ -BP 5217, Nouakchott, Mauritania.*
[8]*Mauritanian Institute for Oceanographic Research and Fisheries (IMROP), BP 22, Nouakchott, Mauritania*
[9]*Senegal Stranding Network, African Aquatic Conservation Fund, BP 449 Ngaparou, 33022 Mbour, Senegal*

1. IDENTIFICATION OF ASSESSMENT UNITS WITHIN EACH SUB-AREA

There is a high degree of reproductive isolation for harbour porpoises (*Phocoena phocoena*) from Northwest Africa (Van Waerebeek & Perrin, 2007). The species appear closely associated with the cool Canary Current, and is probably absent south of the Casamance river, where warmer water predominates (Van Waerebeek et al, 2000).

More than 100 samples of stranded harbour porpoises from Mauritania and Senegal show strong genetic differences with French harbour porpoises (Jean-Luc Jung & Oumar Ba, pers. comm.).

2. DISTRIBUTION, ABUNDANCE AND TRENDS

The available information on surveys, strandings, strandings related to by-catch, by-catch and sightings of harbour porpoises in Northwest Africa have been compiled in Figure 1.

There are no abundance estimates available for harbour porpoises off the Northwest African coast. There have been infrequent reports of sightings and specimens, and harbour porpoises are most common off northern Mauritania (Van Waerebeek & Perrin, 2007). According to Van Waerebeek et al. (2003), Cadenat (1956) reported that harbour porpoises had been taken off Banjul, The Gambia, at 13°27'N.

Boisseau et al. (2010) reported that the northernmost living porpoises from the Atlantic African coasts were seen in Agadir Bay (30 °N), these were also the first confirmed sightings in Morocco. Acoustic surveys performed during the same study also found porpoises between 22 and 24 °N, with high densities around Cap Barbas and Cap Blanc. The core habitat seemed to extend up to Dakhla (24 °N), with some individuals ranging further north. Gaps in the area south of Agadir can be due to a lack of field missions and unsuitable rocky coasts (which disintegrate the carcasses quickly) (Wim Mullié, pers. comm.).

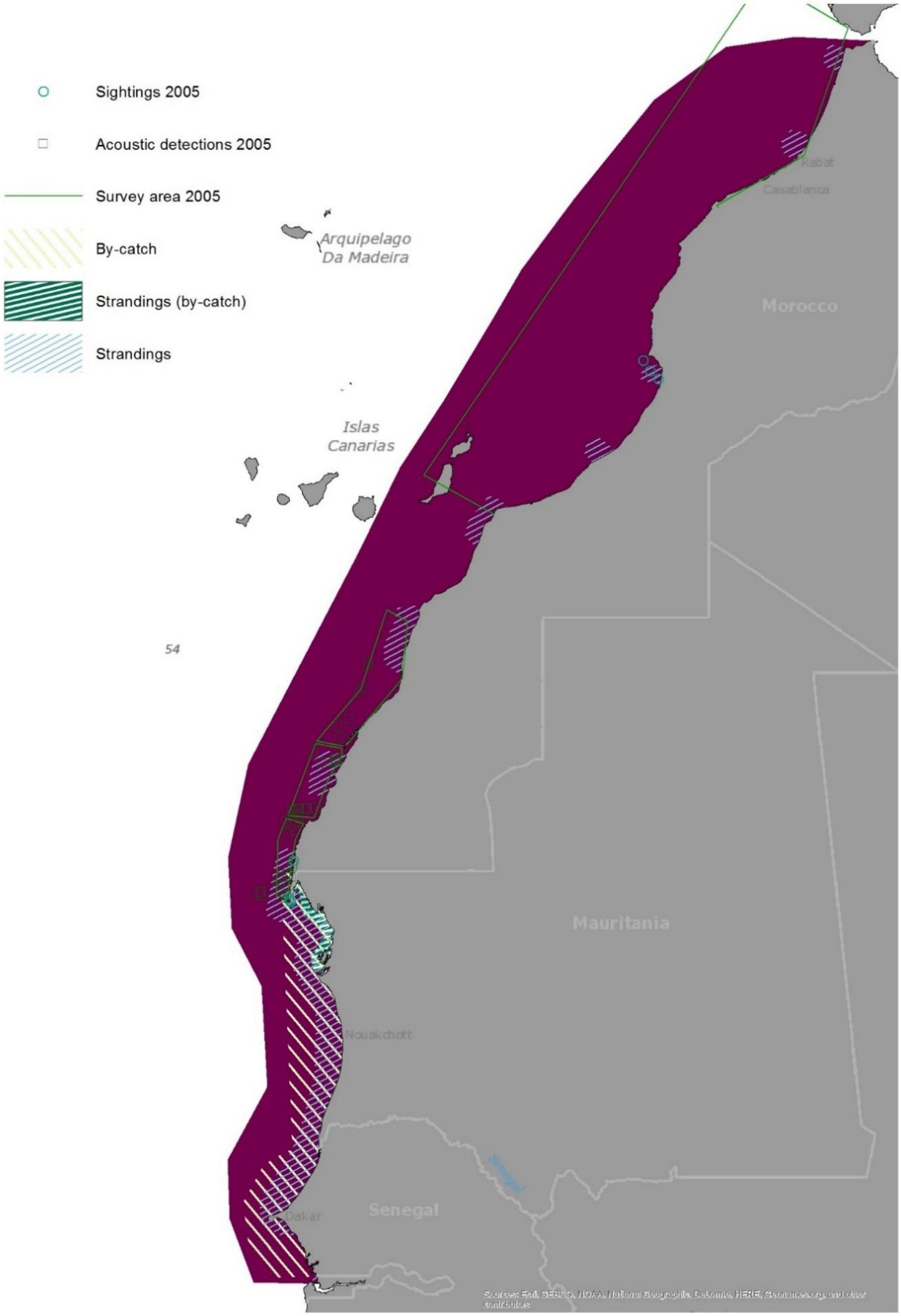

Figure 1: Map of available information on NW African harbour porpoises, with sightings, acoustic detections and the survey area from the Boisseau et al. (2010) survey from 2005, as well as recorded stranding areas, areas with strandings related to by-catch, and areas with reported by-catch.

Three by-caught porpoises landed off Senegal at 14°09’N, 16°49’W were the previous southernmost confirmed records (Van Waerebeek et al., 2000). The newest extant southernmost record is now at 13°37’N, a neonate stranded individual very close to the Gambian border (Wim Mullié, pers. comm.), or only c. 15 km

N from the latitude where Cadenat (1956) reported by-caught individuals in The Gambia, suggesting that the species might also reproduce in Gambian waters.

3. Anthropogenic removals in time and space

By-catch

The principal threat to the Northwest African population of harbour porpoises is thought to be interactions with fisheries, specifically net entanglements (Mullié et al, 2013; Van Waerebeek & Perrin, 2007). There was an increase in marine mammal catches after the introduction of the nylon monofilament nets in the 80s (Maigret, 1994). Annual by-catch mortality cannot be estimated due to poor documentation records, but porpoises have been caught by fishers off Senegal and Mauritania with some regularity for many decades (Maigret, 1994; Van Waerebeek & Perrin, 2007; Boisseau et al, 2010). Much less is known about by-catches in Morocco and Western Sahara (Van Waerebeek & Perrin, 2007).

Boisseau et al (2010) reported that gillnet fisheries appeared to be widespread throughout their study site between the Straits of Gibraltar and northern Mauritania, and porpoises were caught in gillnets as well as in hook-and-line fisheries and driftnets. Harbour porpoises are also caught in the lobster fishery in Mauritania and Morocco (Maigret, 1994). Mullié et al (2013) collected dead porpoises off beaches in Mauritania, where many had signs indicative of by-catch and looked to have been deliberately mutilated to facilitate removal of carcasses from fishing nets. Maigret (1994) also found marine mammal carcasses and skeletons around Kayar, Senegal, some of which could have been related to fishery activities. Between 2013 and 2016, at least 484 cetaceans belonging to more than 20 species were found stranded in Mauritania, more than 284 of which were harbour porpoises. Some of these had obvious evidence of mutilation after being removed from fishing nets, others had traces of regular cuts for use as human consumption (M.M. Wagne & A.S. Bilal, pers. comm.).

4. Impacts from other indirect (sub-lethal) pressures

Strandings

Strandings were observed in Senegal in February, April, May, June and December (Maigret, 1980).

Robineau & Vely (1998) performed surveys for stranded animals over several months in 1994 and 1995. Porpoises were found all along the coast of Mauritania, but seldom in the water of Banc D’Arguin. Stranded porpoises were also observed along the coast of Senegal, especially close to Saint Louis (16 °N) and Dakar (14.30 °N), and along the Moroccan coast. Strandings of harbour porpoises were observed on the Moroccan coast in 1997, 2006, 2008 and 2009 (Masski & De Stéphanis, 2015).

There are more strandings of harbour porpoises in southern Mauritania, which accounts for about 65% of strandings. The stranding record in Mauritania was in June 2014, with 136 stranded animals, 70% of which were harbour porpoises. The harbour porpoise seemed to be the species most frequently found stranded in Mauritania in 2017 (Oumar Ba, pers. comm.).

Between July 2014 and December 2017, 32 stranded harbour porpoises were documented in Senegal. Of these, 13 (41%) were determined to have been by-caught, while the rest were too decomposed to determine by-catch (Keith-Diagne, Mullié, Diagne, Djiba & Diagne, 2017). Strandings of harbour porpoises were also recorded on the Moroccan Coast in 2015, 2016 and 2017 (Imane Tai, pers. comm.). Systematic quarterly stranding surveys along the accessible part of the coast of Mauritania from 2013 till 2016 recorded more than 200 stranded harbour porpoises (Wim Mullié, pers. comm.).

Noise

Frequent seismic surveys are being conducted on the Mauritanian continental shelf (Mullié et al, 2013) and more recently also on the Senegalese continental shelf and beyond where massive gas reserves have been discovered (Wim Mullié, pers. comm., Ndiaye et al. 2016), and noise is also generated by offshore oil installations (M.M. Wagne & A.S. Bilal, pers. comm.). Boisseau et al (2010) recorded relative ambient noise levels along the Moroccan coast, seeing higher noise levels in areas with fewer porpoise sightings.

Overfishing

Overfishing off Northwest Africa is thought to be highly disruptive of the shelf ecosystem, as depleted fish stocks and intense maritime traffic have the potential to reduce foraging efficiency of the porpoise (Van

Waerebeek & Perrin, 2007). In Mauritania, the fishing effort for small pelagic species is drastically increasing, to the detriment of the state of resources (Marti, 2018).

5. Life-history parameters and health status

Two skulls from Mauritania suggest significantly larger animals in West Africa than in Europe (Kompanje & Leuwen, 2009).

Seven by-caught animals in Nouakchott in April/May 1980 were between 57 and 123 cm smaller than stranded animals from Nouadhibou (Maigret, 1980).

6. Diet and prey availability

There is no available information on diet or prey availability, but stable isotope analyses performed by Pinela, Borrell, Cardona & Aguilar (2010) found that the mean δ15N values of Northwest African harbour porpoises were similar to those of *Tursiops truncatus* (bottlenose dolphin), which is consistent with a fish-based diet (Fontaine, Hammill, Barrette & Kingsley, 1994).

7. Knowledge gaps and uncertainties in assessment parameters

There is poor to no documentation of by-catch, no information on diet, and no abundance estimates from Northwest Africa. Surveys are few, and some areas are difficult to reach by boat.

8. Monitoring requirements, research priorities and opportunities for cooperation

Priority should be given to obtaining by-catch data and abundance estimates. There is no established collaboration between the researchers present at the workshop and researchers in France working on a genetic study related to North-West African harbour porpoises. Ideally, this collaboration should be established. M. M. Wagne has also requested help to analyse contaminant levels (trace metals, organic pollutants and plastic contamination) in harbour porpoises, as there are more than 150 stranded animals annually in Mauritania from which samples are collected and stored. These analyses would complement the genetic analyses and would also be necessary for implementing a good conservation policy for harbour porpoises.

9. Assessment unit status

The population of this assessment unit is isolated, and neither abundance, by-catch or other threats are estimated. The status of this population is therefore considered of concern.

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