Agenda Item 3	Updates from across the Baltic and Belt Seas
Information Document 3	**Estimating a mortality threshold for the Belt Sea population of harbour porpoises**
Action Requested	• Take note
Submitted by	Swedish Museum of Natural History

ASCOBANS

Naturhistoriska riksmuseet

Estimating a mortality threshold for the Belt Sea population of harbour porpoises

Kylie Owen, Matthieu Authier, Mathieu Genu, Martin Sköld, Julia Carlström

Photo: Håkan Aronsson

Report nr 3:2022

Swedish Museum of Natural History
Department of Environmental Research and Monitoring
P.O. Box 50 007
104 05 Stockholm
Sweden

Overview

For small cetaceans bycatch in fishing gear is one of the largest threats towards their conservation. In order to effectively manage this threat, an estimation of the maximum number of animals that can be killed by anthropogenic activities each year is required. Such calculations rely on species or population specific information on population dynamics, and information on the current state of the population relative to carrying capacity. Here, we calculate the mortality limit for the Belt Sea population of harbour porpoises (*Phocoena phocoena*) based on a modified potential biological removal (mPBR) method. We estimate that for the population to reach the conservation objective set by ASCOBANS (the population should reach 80% of carrying capacity (assumed here to be 50,000 animals), with the assumption that this is achieved within 100 years with an 80% probability) a maximum of 29 animals can be removed annually. This removal rate applies a recover factor (F_r) of 0.1 that accounts for many uncertainties in population dynamics, abundance estimates, and the current removal rate and depletion level of the population. However, even using the highest possible F_r value (1.0) (which is not recommended for populations with unknown status and does not allow the population to reach the conservation objective), the mPBR limit of the population is 292, which is still significantly lower than the current estimated levels of bycatch in this population (~700 a year). Therefore, urgent action is required in order to ensure that this population is able to reach the conservation objective and achieve good environmental status under a range of European legislation.

Introduction

The loss of individuals from a population can come from either natural or anthropogenic factors, with bycatch in fisheries being one of the main threats for many species and populations ("units") of small cetaceans (Brownell et al., 2019). There are three populations of harbour porpoises (*Phocoena phocoena*) in the Baltic region; 1) the North Sea population, with a management range from the northern Kattegat, through Skagerrak to the entire North Sea, 2) the Belt Sea population in the western Baltic Sea, Belt Sea, the Sound and southern Kattegat, and 3) the Critically Endangered Baltic Proper population in the inner Baltic Sea. The three populations are morphologically and genetically distinct (Wiemann et al., 2010; Galatius et al., 2012; Lah et al., 2016), and also have limited overlap in distribution during the summer breeding season (Sveegaard et al., 2011; Sveegaard et al., 2015; Carlén et al., 2018). Under the EU Habitats Directive (92/43/EEC), all Member States are required to monitor the abundance of the populations as well as the level of bycatch, and to report results and implement a strict system of protection for the species. The status of the populations and the level of bycatch also needs to be reported under the Marine Strategy Framework Directive (MSFD) (2008/56/EC). Additionally, an estimate of a limit for sustainable mortality is needed for each population under D1C1 of the MSFD, which is implemented as an indicator threshold within the Helsinki Commission (HELCOM) every six years. However, for many species and populations these thresholds are missing. Therefore, as a part of the HELCOM BLUES project (https://blues.helcom.fi/), Task 2.1 aimed to improve the state of indicator assessments for bycatch for a range of species, including for the harbour porpoise.

One of the most common ways to estimate a mortality limit is to calculate the potential biological removal (PBR) for a species or population. This method was developed as a framework within the Marine Mammal Protection Act (MMPA) in the USA, relying on an absolute abundance estimate (and precision) to determine a threshold above which removal would prevent a population from reaching a defined conservation objective (Wade 1998). In the case of the MMPA, the conservation objective is defined based on two criteria; 1) that a population that is at the maximum net productivity level (MNPL) is able to remain there for 20 years, and 2) that a population that is at 30% carrying capacity (K) is able to reached MNPL in 100 years (Wade 1998). This method has been applied to a range of species around the world (Slooten et al. 2006, Stensen et al. 2012, Parra et al. 2021), however, in many cases, regions have a different conservation objective than that set by the MMPA.

In the Baltic Region, the Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) has set a conservation objective for harbour porpoises that "populations should be kept at or restored to 80% of their carrying capacity" (Resolution 3.3 on Incidental Take of Small Cetaceans); however, no time frame or indication of certainty has yet been specified. Estimates of mortality limits have previously been calculated for harbour porpoises in the

Baltic region based on this conservation objective (Berggren et al. 2002). However, these calculations were based on hypothetical population structures at the time that are now known to vary from the assumptions made. ASCOBANS have also passed two resolutions (Resolution 3.3 and Resolution 5.5 on Incidental Take of Small Cetaceans) which state that for harbour porpoises, bycatch should be reduced to less than 1% of the best available population estimate as an "intermediate precautionary objective", with bycatch of above 1.7% of the population being an "unacceptable interaction". Based on this, a threshold limit on bycatch for the Belt Sea population has previously been set as <1% of population size within the HELCOM "Number of drowned mammals and waterbirds in fishing gear" indicator (HELCOM 2018). However, limits based on a percentage of the population do not take population dynamics and demographic differences between species and populations into account (Genu et al. 2021). Additionally, factoring in potential sources of biases when assessing mortality limits is essential when evaluating the best management strategy (Moore et al. 2013, Genu et al. 2021).

Recent work on the North Sea population has resulted in a modified PBR method (mPBR) that is tuned to the ASCOBANS conservation objective (Genu et al. 2021), allowing this method to also be applied to the Belt Sea population for the first time. While the PBR approach is not as robust as the Removal Limits Algorithm (RLA) method for calculating mortality limits (used for example for the North Sea population of harbour porpoises, Genu et al. 2021), a lack of reliable data on bycatch rates over time for the Belt Sea population makes the use of the RLA method impossible. Therefore, mPBR is currently the best method available to calculate a mortality limit for the Belt Sea population. The aim of this study was to calculate the mPBR mortality limit of the Belt Sea population of harbour porpoises. The results will be presented to the HELCOM Expert Group on Marine Mammals (EG MAMA) and HELCOM State and Conservation (S&C) as a new proposed threshold value for potential approval and inclusion in the third Holistic Assessment of the Ecosystem Health of the Baltic Sea (HOLAS III).

Methods

Population demographics modelling

The first step to determine an mPBR mortality threshold is to complete a population dynamics model. The RLA package (Genu at al. 2021) in R (R Core Team, 2021) was used to simulate a generalized logistic (Pella-Tomlinson), density-dependent, and age-disaggregated model using the function "pellatomlinson_rla" (Genu et al. 2021). This model allowed population-specific demographic parameters to be utilised to simulate population growth towards carrying capacity (K). Carrying capacity was set to 50,000 based on an abundance estimate of 51,660 (CV=0.30) for an area with major overlap with the management range of this population (SCANS 1994, Hammond et al., 2002, revised in Hammond et al. 2021). The female:male sex bias in relative vulnerabilities to bycatch was defined as 1.0:1.2 (Lockyer and Kinze, 2003), and the proportion of females that are mature for each age was defined based on the results of Kesselring et al. (2017). Additionally, the female:male sex ratio at birth was assumed to be 1.0:1.1 (Lockyer and Kinze, 2003). All other required demographic parameters were assumed to be consistent with those used for the North Sea population of harbour porpoises (see Genu et al. 2021).

The "pellatomlison_rla" function then simulated the impact of randomised removals as a result of unregulated bycatch to deplete the population to likely current day levels. Bycatch was assumed to occur over a 60 year period from 1960, when fishing effort largely increased in the Belt Sea region due to modernisation of fishing methods, up until the most recent abundance estimate from a dedicated survey in 2020 (MiniSCANS II, Unger et al. 2021). Randomised bycatch was assumed to be between 0.1% and 5% of K. A total of 100,000 simulations were completed, and the scenarios that resulted in final population depletion levels at the end of the 60 year period of between 30% and 70% of K were selected to be utilised in the mPBR management scenarios.

Modified Potential Biological Removal calculation

Potential biological removal (PBR) is a method for estimating the maximum number of animals, excluding natural mortalities, that can be removed and still allow a population to reach a particular conservation objective (Wade 1998). PBR is typically calculated as:

$$PBR = N_{min} \times 0.5R_{max} \times F_r$$

Where R_{max} is the highest possible population growth rate of the population, and N_{min} is the 20th percentile of the most recent abundance estimate, calculated as the lower percentile of a log-normal distribution:

$$N_{min} = \frac{\hat{N}}{exp\left(Z\sqrt{l_n\left(1 + CV(\hat{N})^2\right)}\right)}$$

Where $\hat{N}$ is the most recent abundance estimate for the population, CV is the coefficient of variation from the abundance survey, and Z is the standard normal deviate for the 20th percentile (0.842) (Wade 1998). For the management area of the Belt Sea population, the most recent unbiased abundance estimate from MiniSCANS II is 17,301 (95% CI = 11,695-25,688; CV = 0.20) (Unger et al. 2021), resulting in an N_{min} of 14,644 animals.

When calculating PBR, F_r is a recovery factor that is set between 0.1 and 1.0, with the value used influencing the rate at which a population can recover and the populations ability to reach a pre-determined conservation objective. In the EU region, the conservation objective defined by ASCOBANS, that "populations should be kept at or restored to 80% of their carrying capacity (K)" (Resolution 3.3), is the most relevant. In this study, a modified PBR (mPBR) method (Genu et al. 2021) was used to tune the results of the PBR model to the ASCOBANS conservation objective, under the assumption that this objective needed to be achieved with a probability of 80% within 100 years.

The function “pbr_nouveau” (Genu et al. 2021) was then used to complete robustness trials, to determine the value for F_r required for the population to achieve the conservation objective of ASCOBANS, under different scenarios of biases in data inputs (Table 1). The scenarios tested mirrored that of previous studies (Wade et al. 1998, Genu et al. 2021), and all scenarios were completed for two different CV values (0.2 and 0.4) that were based on the minimum and maximum CVs obtained during the five abundance surveys that have been completed for this population (Hammond et al., 2002, Hammond et al., 2013, Viquerat et al., 2014, Hammond et al., 2021, Unger et al. 2021). The output from the “pellatomlison_rla” was further reduced prior to running each robustness trial, by selecting population scenarios that met the required CV, Maximum Net Productivity Level (MNPL), population growth rate (R_{max}) for each trial. The lowest F_r value required for the population to achieve the conservation objective across all robustness trials at the CV of the most recent abundance survey (MiniSCANS II, CV = 0.2) was then used in the calculation of mPBR in the PBR calculation equation shown above.

Results and discussion

Population demographics modelling

A total of 5,370 simulations resulting in a population with depletion levels between 30% and 70% of carrying capacity (50,000 animals) were randomly selected. In comparison, the current level of depletion of the population (17,301 animals) with the carrying capacity assumed in this study is 34.6%. The simulations were further reduced to model population trajectories under different scenarios, resulting in approximately 300 simulations to complete each robustness trial (specific numbers for each trial are given in Table 1).

Table 2: Calculated potential biological removal (PBR) mortality limit values for the Belt Sea population of harbour porpoise (*Phocoena phocoena*) based on the most recent abundance estimate and associated CV from MiniSCANS II (17,301 (95% CI = 11,695-25,688; CV = 0.20) (Unger et al. 2021)). In order to meet the conservation objective of ASCOBANS under potential scenarios of bias in the available data, a recovery factor (F_r) of 0.1 and PBR of 29 animals is required (grey line).

Fr	PBR mortality limit
0.1	**29**
0.2	58
0.3	87
0.4	117
0.5	146
0.6	175
0.7	205
0.8	234
0.9	263
1	292

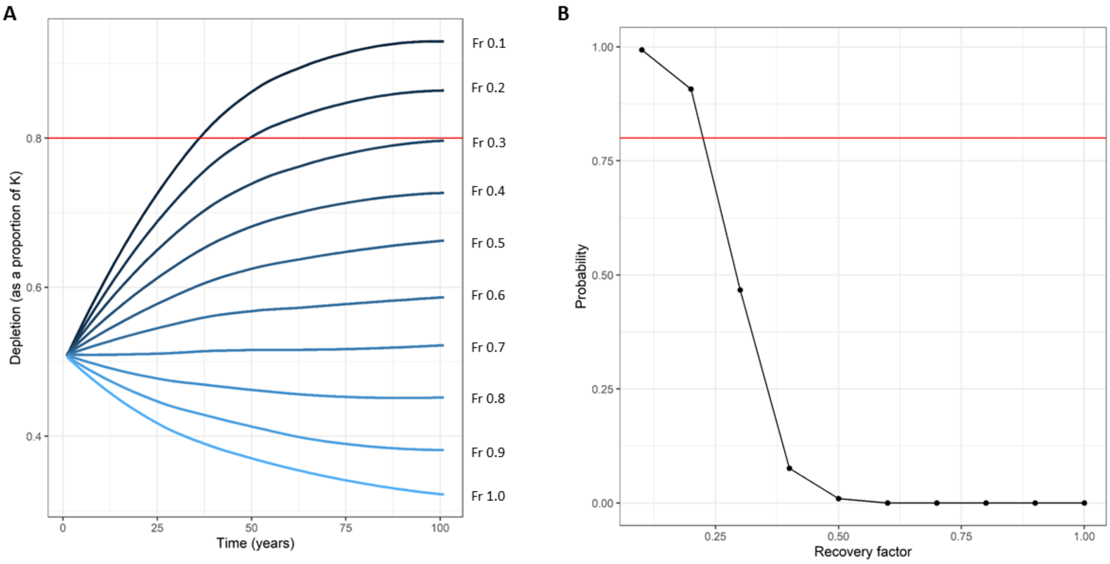

Figure 1: Mean trajectories of depletion level for the Belt Sea population of harbour porpoises (*Phocoena phocoena*) over 100 years of management with various levels of recovery factors (F_r) (A). The probability that the population will achieve the conservation objective of reaching 80% of carrying capacity (red line panel A) within 100 years is shown (B). Values are shown for the base case scenario that assumes a Maximum Net Productivity Level (MNPL) of 0.5, a population growth rate (R_{max}) of 4%, coefficient of variation of the abundance estimate of 0.2, and no bias in any of the factors that could influence the calculation of potential biological removal. Each F_r tested is shown, and only F_r values of 0.1 and 0.2 allow the population to have a >80% probability (red line panel B) of reaching the conservation objective (80% of K within 100 years).

Modified Potential Biological Removal calculation

The PBR calculated for each possible F_r value based on the most recent abundance estimate and associated CV (17,301 (95% CI = 11,695-25,688); CV = 0.20, Unger et al. 2021) is shown in Table 2. The F_r required for the population to reach the conservation objective (80% of K within 100 years, with an 80% probability) for the base case scenario (0A) was 0.2 (for both a CV of 0.2 and 0.4) (Table 1, Figure 1). However, the base case scenario assumes no bias in the data available. In order to achieve all scenarios tested (with a CV of 0.2), an F_r of 0.1 is required in order for the Belt Sea population of harbour porpoises to meet the conservation objective (Table 1). Simulated trajectories of the base case scenario (0A, n = 302) with an F_r value of 0.1 are shown in Figure 2. The scenario where bycatch is underestimated (scenario 1A) requires an F_r of 0.1 for the conservation objective to be reached (Table 1).

Using an F_r of 0.1, the calculated mPBR mortality limit was 29 animals (Table 2). If using the highest F_r possible (1.0) the calculated PBR was 292 (Table 2). However, with a CV of 0.2, no scenario allowed the population to reach the conservation objective with an F_r of 1.0. The highest F_r that allowed the population to reach the conservation objective with a CV of 0.2 was 0.4 in scenario 3A (R_{max} underestimation), scenario 8A (higher MNPL, and bycatch underestimation), and scenario 10A (carrying capacity degradation). All seven other scenarios (with a CV of 0.2) required an F_r of 0.2 or 0.1 to achieve the conservation objective (Table 1).

Table 1: Robustness trials to determine under which scenarios and recovery factor (F_r) value the Belt Sea population of harbour porpoise (*Phocoena phocoena*) is able to reach the conservation objective of ASCOBANS, that the population reaches 80% of carrying capacity (here assumed to be 50,000 animals), within 100 years with 80% certainty. The scenarios tested (and numbers given for the scenario) reflect that of Genu et al. 2021, except that scenario 4A and 4B (higher CV of the abundance estimate) were excluded in this study and instead the likely range of CVs obtained for abundance estimates in this population (0.2-0.4) were tested for every scenario.

Robustness trial	Scenario	n	q	MNPL	K_{trend}	Frequency	R_{max}	CV	b.byc	b.abund	b.R_{max}	byc.CV	cata.	F_r
Base case scenario	0A	302	0.2	0.5	1	6	0.04	0.2	1	1	1	0.3	0	0.2
	0B	298	0.2	0.5	1	6	0.04	0.4	1	1	1	0.3	0	0.3
Bycatch underestimation	1A	302	0.2	0.5	1	6	0.04	0.2	**2**	1	1	0.3	0	0.1
	1B	298	0.2	0.5	1	6	0.04	0.4	**2**	1	1	0.3	0	0.1
Abundance overestimation	2A	302	0.2	0.5	1	6	0.04	0.2	1	**2**	1	0.3	0	0.1
	2B	298	0.2	0.5	1	6	0.04	0.4	1	**2**	1	0.3	0	0.1
Maximum Productivity rate underestimation	3A	302	0.2	0.5	1	6	0.04	0.2	1	1	**0.5**	0.3	0	0.4
	3B	298	0.2	0.5	1	6	0.04	0.4	1	1	**0.5**	0.3	0	0.6
Higher bycatch coefficient of variation	5A	302	0.2	0.5	1	6	0.04	0.2	1	1	1	**1.2**	0	0.2
	5B	298	0.2	0.5	1	6	0.04	0.4	1	1	1	**1.2**	0	0.2
Lower survey frequency	6A	302	0.2	0.5	1	**10**	0.04	0.2	1	1	1	0.3	0	0.2
	6B	298	0.2	0.5	1	**10**	0.04	0.4	1	1	1	0.3	0	0.2
Lower MNPL	7A	289	0.2	**0.45**	1	6	0.04	0.2	1	1	1	0.3	0	NA
	7B	311	0.2	**0.45**	1	6	0.04	0.4	1	1	1	0.3	0	0.1
Higher MNPL + bycatch underestimation	8A	298	0.2	**0.7**	1	6	0.04	0.2	**2**	1	1	0.3	0	0.4
	8B	302	0.2	**0.7**	1	6	0.04	0.4	**2**	1	1	0.3	0	0.4
Catastrophic events happening	9A	302	0.2	0.5	1	6	0.04	0.2	1	1	1	0.3	**0.1**	0.2
	9B	298	0.2	0.5	1	6	0.04	0.4	1	1	1	0.3	**0.1**	0.2
Carrying capacity degradation	10A	302	0.2	0.5	**0.5**	6	0.04	0.2	1	1	1	0.3	0	0.4
	10B	298	0.2	0.5	**0.5**	6	0.04	0.4	1	1	1	0.3	0	0.5

n = number of simulations used to test the scenario; q = the quantile used to estimate N_{min}, where N_{min} is the 20th percentile of the most recent abundance estimate, calculated as the lower percentile of a log-normal; MNPL = maximum net productivity level of the population. K_{trend} = the trend in carrying capacity over the course of the simulation as a fraction of K at the beginning. Frequency = how often abundance surveys are completed; R_{max} = maximum theoretical or estimated productivity rate of the population; CV = coefficient of variation of the abundance estimate; b.byc = bias in the bycatch estimate as a factor of the true value (i.e. 1 = no bias, 2 = bycatch has been underestimated by a factor of 2); b.abund = bias in abundance estimate as a factor of the true value; b.R_{max} = bias in Rmax as a factor of the true value; byc.CV = coefficient of variation of the bycatch estimate; cata. = strength of a catastrophic event happening (0 = no catastrophic event, 0.1 = 10% of the population are lost at a random stage of the simulation).

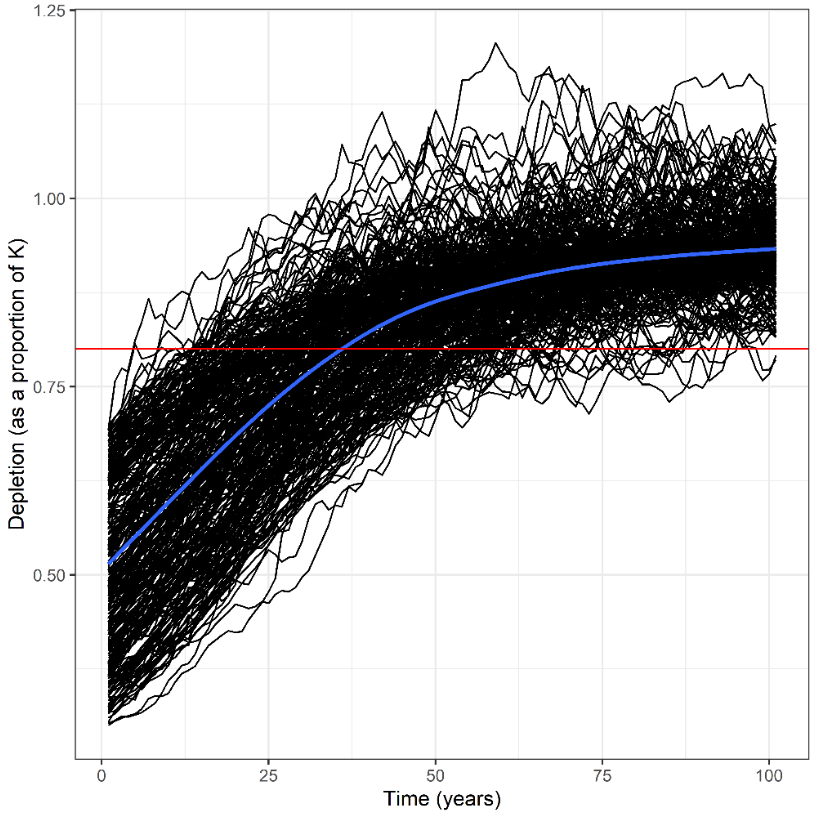

Figure 2: Trajectories of all 302 simulations of the population dynamics of the Belt Sea population under the base case scenario (0A) (assumes a Maximum Net Productivity Level (MNPL) of 0.5, a population growth rate (R_{max}) of 4%, coefficient of variation of the abundance estimate of 0.2, and no bias in any of the factors that could influence the calculation of potential biological removal) with a recovery factor of 0.1. The blue line represents the same mean line presented in Figure 1. The red line shows the 80% depletion level of carrying capacity (K), which is in line with the conservation objective of ASCOBANS.

Discussion

The current threshold used by HELCOM as an indicator for bycatch of harbour porpoise in the Belt Sea population has been set at <1% of the population, which is equal to 173 animals based on the most recent abundance estimate (Unger et al. 2021). This number corresponds to an F_r of approximately 0.6 (Table 2), which did not allow the population to reach the conservation objective in any scenario tested (Table 1). Although population modelling has suggested that the MNPL for this population may be slightly higher than used here (0.6 vs. 0.5) (IMR/NAMMCO 2019), this calculation was only based on the first four abundance estimates for the population, which did not take into account the most recent (and most precise: CV = 0.2) abundance estimate that showed the lowest point estimate for the abundance of this population to date (Unger et al. 2021). Given the likely reduction in population size since the population model suggesting a higher MNPL was completed, the use of 0.5 for MNPL (the same as that used in Wade 1998 and Genu et al. 2021) is possibly more reflective of the actual growth rate of the population. Therefore, the use of the current threshold in the HELCOM indicator is unlikely to allow the population to reach the conservation objective set by ASCOBANS.

In order to reach the conservation objective of ASCOBANS for all scenarios tested, an F_r value of 0.1 is required, resulting in an mPBR mortality limit, and new proposed threshold for this population, of 29 animals (for comparison to the current threshold setting method for the indicator, this would relate to 0.17% of the population) (Table 1 and 2). The lower the F_r (and level of bycatch) the faster the population will grow towards the conservation objective of 80% of K. In Figure 1 it is possible to see that even in the base case scenario (0A) (i.e., with no biases in the available data), it is only possible for the population to sustain its current level of depletion (current population size) with an F_r of 0.7 or lower, which equates to a mortality limit of 205 animals if the conservation aim is to only maintain the current population size and not allow the population to recover. Any higher level of mortality will likely result in a population decline.

However, it is very difficult to assess exactly how much bycatch currently occurs in this population. The data available to assess bycatch rates are scarce, difficult to interpret, and not comparable across ICES sub-divisions, years and countries (see Table 2 in the report of the HELCOM ACTION project for an example). Additionally, data on fishing effort are not reported by all countries, nor for all fisheries likely to result in bycatch. The low quality of data reported makes reliable estimates of bycatch impossible, resulting in estimates that are biased and likely an underestimate of the actual mortality level. In 2014, a total of 33 porpoises were reported to ICES as bycatch in the Belt Sea population management area (32 in Denmark, 1 in Germany, and 0 in Sweden) (IMR/NAMMCO 2019). These reported numbers alone exceed the mortality threshold proposed here for this population, even before relying on fishing effort data to produce estimates of total bycatch. On top of this, a proportion of stranded animals are also determined to have been killed by bycatch every year that are often not reported to ICES and included in these numbers. For example, in Sweden alone, 31% of the animals collected and necropsied in the period 2006-2020 were considered to have been killed by bycatch or probably bycatch (Neimanis et al. 2022). Over the same period, 348 porpoises were reported dead within the Belt Sea population assessment unit management area to the Swedish Museum of Natural History database (tumlare.nrm.se). Assuming a similar cause of death ratio for all stranded animals to those collected, this results in an extra 107 animals reported dead due to bycatch over this 15 year period in Sweden alone (mean of 7 animals a year in Sweden). This is concerning, given the low mortality limit required in order for the population to reach the conservation objective.

Although there are poor quality data on the rate of bycatch for the Belt Sea population, it has been suggested that the number of bycaught animals (and therefore, likely the bycatch rate) is decreasing over time, likely as there is less commercial fishing in the area (IMR/NAMMCO 2019). In 2019, 16 harbour porpoises were reported to be captured in nets in ICES Subdivisions 22 and 23, and in 2020, only five harbour porpoises were reported to be captured in nets in the same area (ICES 2021). However, 2020 was also the year of the lowest point estimate of abundance for the population to date (Unger et al.

2021). In the OSPAR area, which only encompasses part of the Belt Sea population distribution range, modelling as a part of the Workshop on Estimation of Mortality of Marine Mammals due to Bycatch (WKMOMA) has shown that in recent years (2015-2020) there has actually be a higher rate of bycatch of harbour porpoises (ICES 2021). The bycatch rate for the Swedish Kattegat and Skagerrak in the 1990s was estimated to be ~4% of the population (Nui et al. In review). The most recently available estimate of total bycatch for this population (~700 animals/year, reduced from >1000 animals/year previously; IMR/NAMMCO 2019) from a population of 17,301 individuals is still a bycatch rate ~4% of the population. This implies that it is possible that although the number of animals bycaught and fishing effort is decreasing, the population may also be decreasing, resulting in a similar proportion of the population bycaught over time, and at rates that are still too high for the population to sustain itself.

The mPBR model calculations completed in this study confirm that the most recent estimates of total bycatch of approximately 700 animals a year is unsustainable. On top of this, this estimate of total bycatch is only based on effort in Sweden and Denmark (excluding Germany), and there is a large number of smaller vessels and part time fisheries that likely cause bycatch that do not have their effort included in the estimate (IMR/NAMMCO 2019). This implies that the total bycatch is likely even higher than estimated, supporting the need for the use of an Fr of 0.1 for the population that accounts for an underestimation in the amount of bycatch reported. Even when not considering the ASCOBANS conservation objective, and only completing a traditional PBR calculation with a non-conservative F_r value of 1.0, the total allowed bycatch was calculated to be 292 animals (Table 2), i.e. less than half the amount current estimate of bycatch each year.

Under the MMPA in the USA, for assessment units that are depleted, threatened or have an unknown status it is generally recommended that F_r is set to a maximum of 0.5 (Barlow et al. 1995, Wade 1998), and Fr of 1.0 should only be used if the population is increasing (Protected Resources 2016). Given that no abundance thresholds are yet set for the Belt Sea harbour porpoise population under HELCOM, and the most recent abundance estimate was lower than previous estimates, the status should be considered "unknown" as a default (Protected Resources 2016). However, using an F_r of 0.5 will not allow the population to reach the conservation objective set by ASCOBANS under all scenarios tested (with a CV of 0.2) (Table 1), again supporting the need for a much lower F_r of 0.1 in this population. Therefore, bycatch needs to be reduced significantly in order for this population to be in good environmental status and reach the conservation objective.

Conclusions

The mPBR mortality limit for the Belt Sea population was calculated to be 29 animals. This is far lower than current estimates of bycatch for the population (~700 animals), which is of great concern given that estimates of bycatch are likely to be an underestimation. The total amount of bycatch should be lowered immediately in order for the population to reach the conservation objective of ASCOBANS. This can be achieved by a) reducing fishing effort with gear in metiers known to cause bycatch, b) introducing spatial or temporal closures, c) making changes to fisheries practices in the area, such as gear modification or the use of pingers, or d) by a combination of tailored measures. The threshold used for the HELCOM indicator "Number of drowned mammals and waterbirds in fishing gear" for the Belt Sea population of harbour porpoises should also be modified to 29 individuals. Future effort should be directed towards improving the reporting of bycatch occurrence and fisheries effort in the region so that reliable bycatch rates can be estimated. These data would assist in correctly assessing this indicator, and also contribute to the building of a time series of data on bycatch rate that would allow a calculation of the mortality limit using the more robust RLA method for the population. Higher accuracy in the data collected and less room for potential bias also results in a higher possible mortality limit as there is less need to factor in uncertainty in the thresholds given.

How to cite

This report can be cited as: Owen K, Authier M, Genu M, Sköld M, Carlström J (2022) Estimating a mortality threshold for the Belt Sea population of harbor porpoises. Report by the Swedish Museum of Natural History. Report number 3:2022. 15 pp.

Acknowledgements

This study was financed by the Swedish Agency for Marine and Water Management. Thank you to Anita Gilles and Signe Sveegaard for their valuable input.

References

Barlow J., Swartz S.L., Eagle T.C., Wade P.R. (1995) U.S. Marine Mammal Stock Assessments: Guidelines for Preparation, Background, and a Summary of the 1995 Assessments. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-6, 73 p.

Berggren P., Wade P.R., Carlström J., Read A. J. (2002) Potential limits to anthropogenic mortality for harbour porpoises in the Baltic region. Biological Conservation 103(3): 313-322.

Brownell R.L., Reeves R.R., Read A.J., Smith B.D., Thomas P.O., Ralls K., … Wang J.W. (2019). Bycatch in gillnet fisheries threatens critically endangered small cetaceans and other aquatic megafauna. Endangered Species Research 40: 285-296.

Genu M., Gilles A., Hammond P.S., Macleod K., Paillé J., Paradinas I., Smout S., Winship A.J., Authier M. (2021) Evaluating Strategies for Managing Anthropogenic Mortality on Marine Mammals: An R Implementation With the Package RLA. Frontiers in Marine Science 8: 795953.

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

Carlén I., Thomas L., Carlström J., Amundin M., Teilmann J., Tregenza N., Tougaard J., Koblitz J.C., Sveegaard S., Wennerberg D., Loisa O., Dähne M., Brundiers K., Kosecka M., Kyhn L.A., Ljungqvist C.T., Pawliczka I., Koza R., Arciszewski B., Galatius A., Jabbusch M., Laaksonlaita J., Niemi J., Lyytinen S., Gallus A., Benke H., Blankett P., Skóra K.E. and Acevedo-Gutiérrez A. (2018) Basin-scale distribution of harbour porpoises in the Baltic Sea provides basis for effective conservation actions. Biological Conservation 226: 42-53.

Hammond P., Berggren P., Benke H., Borchers D., Collet A., Heide-Jørgensen M., Heimlich S., Hiby A., Leopold M.F., Øien N. (2002) Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. Journal of Applied Ecology 39 (2): 361-376.

Hammond P.S., Macleod K., Berggren P., Borchers D.L., Burt L., Cañadas A., Desportes G., Donovan G.P., Gilles A., Gillespie D., Gordon J., Hiby L., Kuklik I., Leaper R., Lehnert K., Leopold M., Lovell P., Øien N., Paxton C.G.M., Ridoux V., Rogan E., Samarra F., Scheidat M., Sequeira M., Siebert U., Skov H., Swift R., Tasker M.L., Teilmann J., Van Canneyt O., Vázquez J.A. (2013) Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. Biological Conservation 164: 107-122.

Hammond P., Lacey C., Gilles A., Viquerat S., Börjesson P., Herr H., Macleod K., Ridoux V., Santos M., Scheidat M. (2021) Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys - Revised version. . https://synergy.st-andrews.ac.uk/scans3/files/2021/06/SCANS-III_design-based_estimates_final_report_revised_June_2021.pdf

HELCOM (2018) Number of drowned mammals and waterbirds in fishing gear. HELCOM core indicator report. Online. [Accessed 16/02/2022], [https://helcom.fi/media/core%20indicators/Number-of-drowned-mammals-and-waterbirds-HELCOM-core-indicator-2018.pdf].

ICES. (2021) Working Group on Bycatch of Protected Species (WGBYC). ICES Scientific Reports. 3:107. 168 pp. [https://doi.org/10.17895/ices.pub.9256].

Kesselring T., Viquerat S., Brehm R., Siebert U. (2017) Coming of age: - Do female harbour porpoises (*Phocoena phocoena*) from the North Sea and Baltic Sea have sufficient time to reproduce in a human influenced environment? PLoS ONE 12(10): e0186951.
Galatius A., Kinze C.C., Teilmann J. (2012) Population structure of harbour porpoises in the Baltic region: Evidence of separation based on geometric morphometric comparisons. Journal of the Marine Biological Association of the United Kingdom 92: 1669-1676.

Lah L., Trense D., Benke H., Berggren P., Gunnlaugsson P., Lockyer C., … Tiedemann R. (2016) Spatially explicit analysis of genome-wide SNPs detects subtle population structure in a mobile marine mammal, the harbor porpoise. PLoS One 11: e0162792.

Lockyer C., Kinze C. (2003) Status, ecology and life history of harbour porpoise (*Phocoena phocoena*), in Danish waters. NAMMCO Scientific Publications 5: 143-175.

Moore J.E., Curtis K.A., Lewison R.L., Dillingham P.W., Cope J.M., Fordham S.V., Heppell S.S., Pardo S.A., C. A. Simpfendorfer C.A., Tuck G.N., Zhou S. (2013) Evaluating sustainability of fisheries bycatch mortality for marine megafauna: a review of conservation reference points for data-limited populations. Environmental Conservation 40(4): 329-344.

Neimanis A., Stavenow J, Ågren E.O., Wikström-Lassa E., Roos A.M. (2022) Causes of Death and Pathological Findings in Stranded Harbour Porpoises (*Phocoena phocoena*) from Swedish Waters. Animals 12: 369.

Niu J., Berggren P., Sveegaard S., Dietz R., Owen K., Teilmann T., Carlström J. (In review) Disentangling the factors affecting harbor porpoise bycatch in the Swedish Skagerrak and Kattegat Seas. Marine Mammal Science.

North Atlantic Marine Mammal Commission and the Norwegian Institute of Marine Research. (2019). Report of Joint IMR/NAMMCO International Workshop on the Status of Harbour Porpoises in the North Atlantic. Tromsø, Norway. pp 236

Parra G.J., Bilgmann K., Peters K.J., Möller L.M. (2021) Abundance and Potential Biological Removal of Common Dolphins Subject to Fishery Impacts in South Australian Waters. Frontiers in Marine Science 8: 1237.

Protected Resources (2016) Guidelines for Preparing Stock Assessment Reports Pursuant to Section 117 of the Marine Mammal Protection Act. NMFS Procedure 02-204-01, pp. 9. Online. [Accessed 2 March 2022], [https://media.fisheries.noaa.gov/dam-migration/02-204-01.pdf]

R Core Team (2021). R: A Language and Environment for Statistical Computing. Vienna: R Foundation for Statistical Computing.

Slooten E., Dawson S., Rayment W., Childerhouse S. (2006) A new abundance estimate for Maui's dolphin: What does it mean for managing this critically endangered species? Biological Conservation 128: 576-581.

Stenson G., Hammill M., Ferguson S., Stewart R., Doniol-Valcroze T. (2012) Applying the precautionary method to marine mammal harvests in Canada 18. DFO Canadian Science Advisory Secretariat. Research Document 2012/107, p ii+15 [http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2012/2012_107-eng.html]

Sveegaard S., Teilmann J., Tougaard J., Dietz R., Mouritsen K.N., Desportes G., Siebert U. (2011) High-density areas for harbor porpoises (*Phocoena phocoena*) identified by satellite tracking. Marine Mammal Science 27 (1): 230-246.

Sveegaard S., Galatius A., Dietz R., Kyhna L., Koblitz J.C., Amundin M., Nabe-Nielsen J., Sinding M.H.S., Andersen L.W., Teilmann J. (2015) Defining management units for cetaceans by combining genetics, morphology, acoustics and satellite tracking. Global Ecology and Conservation 3: 839-850.

Wade P.R. (1998) Calculating limits to the total allowable human-caused mortality of cetaceans and pinnipeds. Marine Mammal Science 14: 1-37.

Wiemann A., Andersen L.W., Berggren P., Siebert U., Benke H., Teilmann J., … Tiedemann R. (2010). Mitochondrial control region and microsatellite analyses on harbour porpoise (*Phocoena phocoena*) unravel population differentiation in the Baltic Sea and adjacent waters. Conservation Genetics 11: 195-211.

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

Viquerat S., Herr H., Gilles A., Peschko V., Siebert U., Sveegaard S., Teilmann J. (2014) Abundance of harbour porpoises (*Phocoena phocoena*) in the western Baltic, Belt Seas and Kattegat. Marine Biology 161 (4): 745-754.