

Harbour porpoise distribution in the Western Baltic

A comparison of existing models

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Data sheet

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Technical brief – update of harbour porpoise summer distribution in the Belt Sea. - Technical brief – update of harbour porpoise summer distribution in the North Sea from University of Veterinary Medicine Hannover, Foundation. Both available [here](#).

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1 Preface and introduction

This report contributes to the project “Environmental mapping and screening of areas for offshore wind in Denmark” initiated in 2022 by the Danish Energy Agency. The project aims to support the long-term planning of offshore wind farms by providing a comprehensive overview of the combined offshore wind in Denmark. It is funded under the Finance Act 2022 through the programme “Investeringer i et fortsat grønnere Danmark” (Investing in the continuing greening of Denmark). The project is carried out by NIRAS, DCE (Aarhus University, Department of Ecoscience) and DTU Wind.

The overall project consists of four tasks defined by the Danish Energy Agency (<https://ens.dk/ansvarsomraader/vindmoeller-paa-hav/planlaegning-af-fremtidens-havvindmoelleparker>):

1. Sensitivity mapping of nature, environmental, wind and hydrodynamic conditions.
2. Technical fine-screening of areas for offshore wind based on the sensitivity mapping and relevant technical parameters.
3. Assessment of potential cumulative effects from large-scale offshore wind development in Denmark and neighbouring countries.
4. Assessment of barriers and potentials in relation to coexistence.

This scientific note addresses one component of Task 1: sensitivity mapping of harbour porpoises. Specifically, it provides additional information on the distribution of harbour porpoises in the Western Baltic. This was previously addressed in this project by Stokholm et al. (2025) where sensitive areas for harbour porpoises in the Western Baltic were identified based on a MaxEnt habitat suitability model for harbour porpoises. Habitat suitability models (= species distribution models) are often used to assess the relative abundance (or relative densities) of populations in different parts of the landscape (e.g. Charre-Medellín et al. 2023). The MaxEnt modelling approach used summer location data from satellite tracked harbour porpoises from the period 2013–2022 to determine the relative density of harbour porpoises in different areas.

In this note, we present the results of an alternative approach, where the relative densities are calculated based on data from visual surveys (mainly aerial, but also ship-based surveys) from the period 2005–2024. The relative densities are calculated using generalized additive models (GAMs) in the exact same way as done for the North Sea harbour porpoises in Stokholm et al. (2025).

This scientific note aims to present and compare the results of the two different modelling approaches that are used to assess the distribution of harbour porpoises in the Western Baltic. The note and the comparison of the results are solely the responsibility of the authors.

2 Existing data and models

The distribution of harbour porpoises in Danish waters has been studied since the 1990's by aerial and ship-based surveys, passive acoustic monitoring and satellite tracking. Each method has its strengths and weaknesses, and it is not the aim of this note to provide a comprehensive comparison of the different methods, but instead to discuss to what extent predictions based on different types of data align and what that means for management of harbour porpoises.

2.1 Telemetry-based model

Aarhus University has collected Argos satellite telemetry data from over 150 harbour porpoises since 1997 as part of a long-term monitoring program in Denmark (Teilmann et al., 2007; Sveegaard et al., 2011; Stalder et al., 2020). The individual harbour porpoises are incidentally trapped in pound nets, which are used in near-shore commercial fisheries in the Belt seas, Kattegat and near Skagen. The entrapped animals are subsequently fitted with Argos satellite tags that can transmit location data for up to 1.5 years.

These data (1997–2022) were used to produce several habitat suitability models (divided in summer/winter and into three periods: 1997-2004, 2005-2012 and 2013-2022; van Beest et al. 2025) using the maximum entropy (MaxEnt) machine learning algorithm (Phillips et al., 2006, Figure 1). This method is suitable for modelling distributions for species that are observed in some areas, but when it is not known where they do not occur (i.e. with missing absence-data), such as is the case when presences are determined based on satellite tagging data. The output of MaxEnt models can be interpreted as a spatially explicit probability that the habitat that occurs in a specific area is suitable for harbour porpoises. It should be emphasized that the predictions of a MaxEnt model are not illustrating the distribution of the tagged harbour porpoises. Instead, they show the distribution of habitats that resemble those where the tagged harbour porpoises were transmitting locations.

The long-term average habitat suitability model for harbour porpoises from the period 1997–2022 (Figure 1, left) clearly shows an uneven distribution of suitable harbour porpoise habitat with the waters from the Cadet Trench through Fehmarn Belt and Great Belt to Samsø Belt, the central Sound as well as the waters in Northern Kattegat having highest suitability.

The analyses revealed that the distribution of harbour porpoises changed over time, and specifically that Skagerrak, Samsø Belt and in the Great Belt have gradually become less important summer habitats for porpoises. In contrast, the northern part of the study area (>56°N, Skagerrak and most of Kattegat) have gradually become more important during the winter months. Litte Belt, Great Belt, the Sound and the western Baltic have become less important harbour porpoise habitat than it was in the beginning of the study period. The sensitivity mapping recently conducted by Stokholm et al. (2025) was based on MaxEnt prediction from the period 2013–2022 (46 animals).

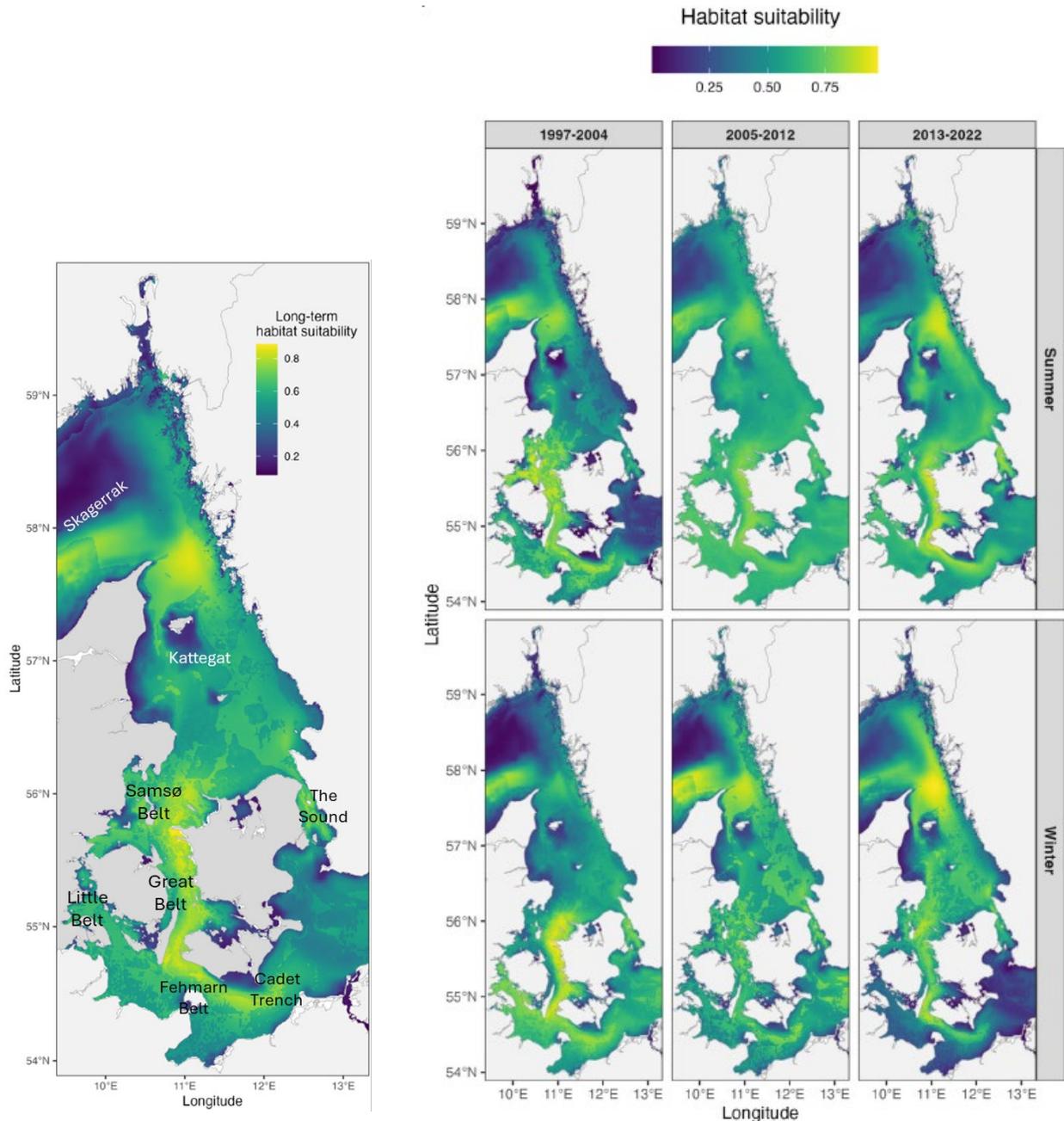


Figure 1. Map of year-round habitat suitability for harbour porpoises from 100 MaxEnt model iterations using Argos-based location data from 111 tagged harbour porpoises collected in the waters between the North Sea and proper Baltic Sea during 1997–2022 (left) and divided into summer and winter and three 8–10 year periods (right). Habitat suitability ranges from 1 (optimal in yellow) to 0 (poor in dark blue). From Van Beest et al. 2025. The map uses the EPSG:3035 ETRS89 projection.

2.2 Aerial and ship-based visual surveys

Harbour porpoises and other cetaceans have been surveyed from ships and airplanes across European waters since 1994 with the aim of estimating the abundance, trend in abundance and distribution. Surveys have been conducted in 1994 (SCANS), 2005 (SCANS-II), 2016 (SCANS-III) and 2022 (SCANS-IV) (Gilles et al. 2023) in the North Sea and most of the adjacent waters. Further, two surveys covering the Western Baltic have been carried out in a trilateral effort by Denmark, Germany and Sweden in 2012 (MiniSCANS) and 2020 (MiniSCANS-II), and additional aerial surveys were carried out in the Western Baltic by Germany in the south-western Baltic in the years 2005–2024 in the frame of their

national monitoring (e.g. Ramirez-Martinez et al. 2025a). During these surveys, sightings of harbour porpoise groups were recorded using standardized line-transect survey methods that incorporated correction factors for missed animals on the transect line. This makes it possible to determine where the animals do not occur, which is not possible using telemetry data. Abundance and distributions of cetaceans are predominately assessed based on visual line-transects surveys following a representative survey design along pre-defined transect lines in a study area, such as implemented in aerial and ship-based surveys. This method contrasts with models based on tagging data in that it can be used for deriving an unbiased estimate of absolute abundances, since it also allows for estimating the fraction missed on the transect.

As part of the Screening project, density surface maps were updated for both the Belt Sea (Figure 2: data from 2005-2024 and 3: data from 2020-2024, from Gilles et al. 2026a) and the North Sea (Figure 4, from Gilles et al. 2025b) applying habitat-based density modelling. Each figure also displays the associated estimated coefficient of variation (CV). The maps of CVs provide a measure of variability in predicted densities across the survey area. It is important to note that for the actual sensitivity mapping in Stokholm et al. (2025), the habitat-based density model was only used in the North Sea, while the MaxEnt model was used for the Belt Sea area. The North Sea model in Figure 4 is also shown in this note so that the prediction for northern Kattegat and eastern Skagerrak can be compared between the two predictions for the two modelling approaches.

Figures 2-4 only present the summer distribution of harbour porpoises because this season is where most data have been collected. In January to March 2024, the first winter-SCANS survey was carried out in the southern North Sea (Figure 5), but Danish waters were only poorly covered, and no distribution model have been made so far (Ramirez-Martinez et al. 2025b). It would require a dedicated effort to survey Danish waters during winter, before a distribution model would be representative of harbour porpoise winter density distribution.

For the Belt Sea area, which is defined as the population management unit of the Belt Sea population of porpoises (Sveegaard et al. 2015), two maps were produced: One was the selected best model containing all data (Figure 2) and represents the long-term distribution of harbour porpoises while the second model (Figure 3) represents the most recent data and consequently the distribution of harbour porpoises in most recent times. Both models show high density of harbour porpoises in the eastern Kattegat and the northern part of The Sound. The major difference between the two maps is that the harbour porpoise density in the Great Belt and Samsø Belt is considerably lower in the most recent period. This decline in the Great Belt has also been documented based on passive acoustic monitoring data collected under the national monitoring program, NOVANA (Fredshavn & Høgslund 2025), and is assumed to be a consequence of the decline in prey species in the same area.

Figure 2. Predicted harbour porpoise densities in Kattegat, Belt Sea and Western Baltic during summer months (left) and associated coefficient of variation (CV) (right). The model was fitted using survey data collected between 2005–2024 in the management unit of the Belt Sea harbour porpoise population. From Gilles et al. 2025a.

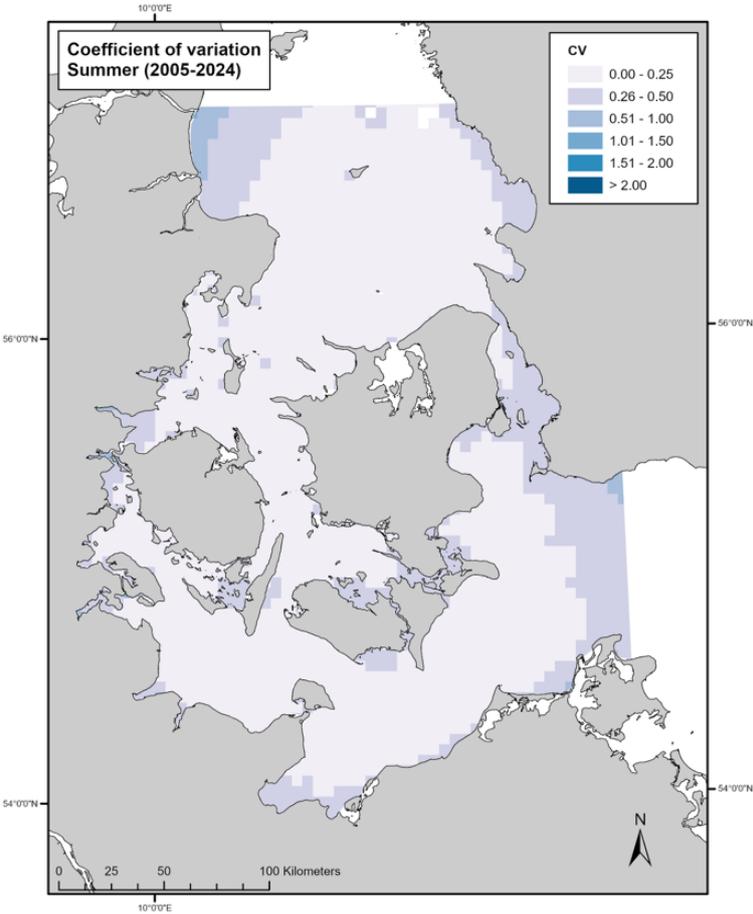
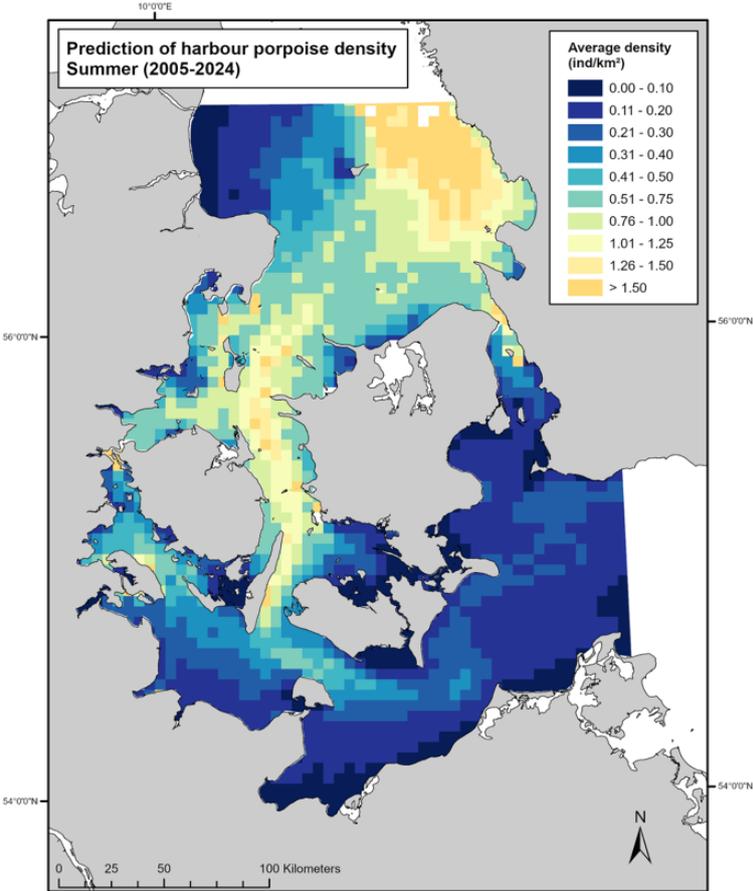


Figure 3. Predicted harbour porpoise densities in Kattegat, Belt Sea and Western Baltic during summer months (left) and associated coefficient of variation (CV) (right). The model was fitted using survey data collected between 2020–2024 in the management unit of the Belt Sea harbour porpoise population. From Gilles et al. 2025a.

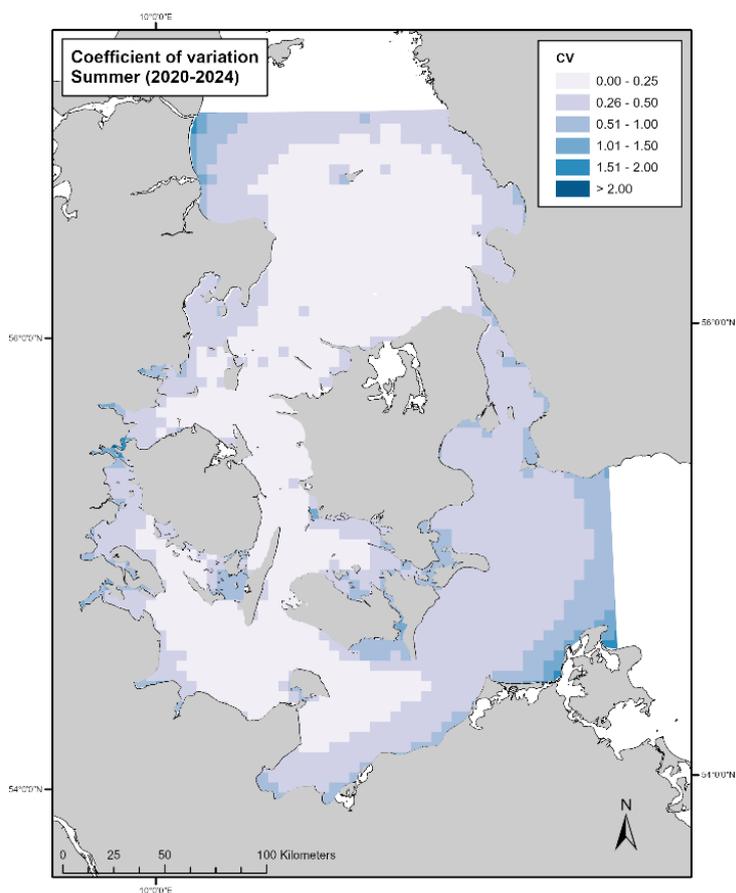
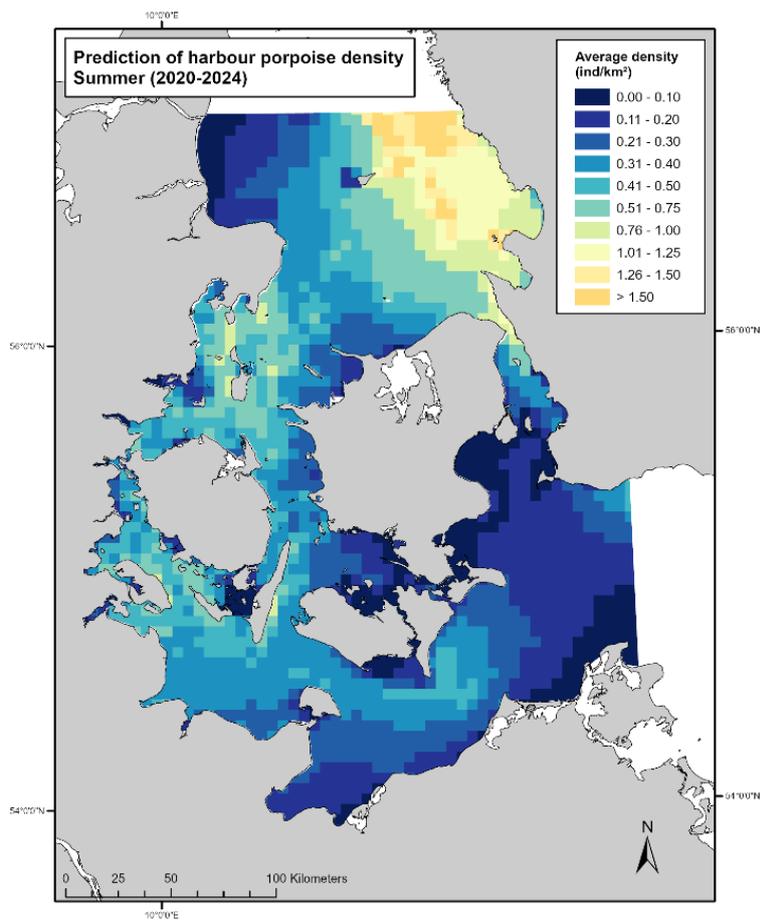


Figure 4. Predicted harbour porpoise densities in the North Sea during summer (left) and associated coefficient of variation (CV) (right). Model fitted using survey data collected between 2020-2024. From Gilles et al. 2025b.

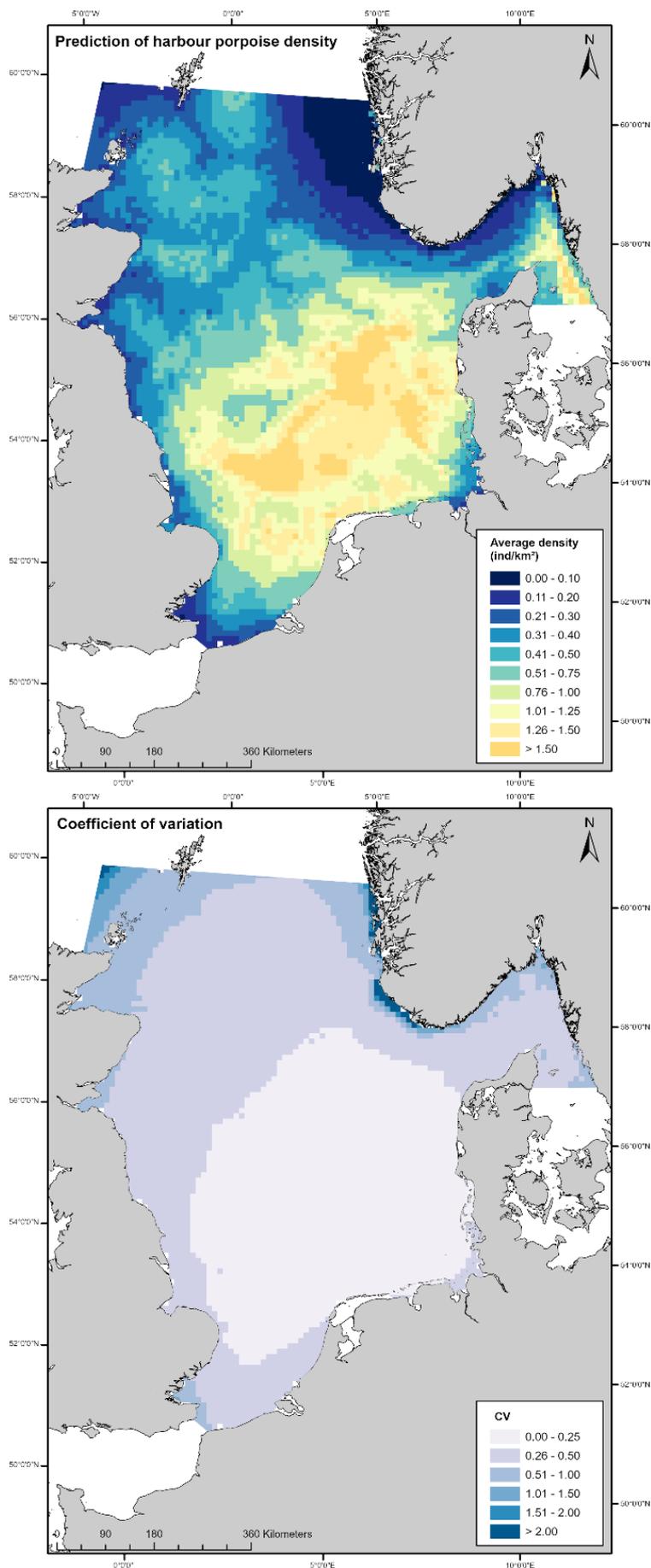
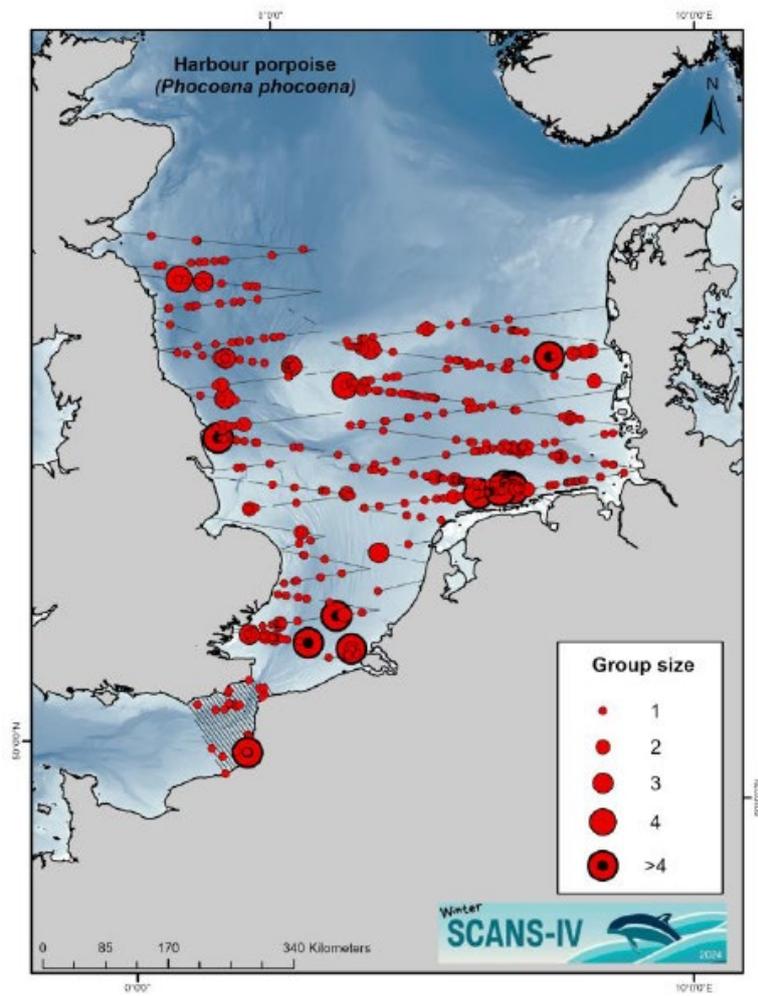


Figure 5. Distribution of sightings of harbour porpoises during winter-SCANS in January to March 2024. Lines show the underlying effort in good and moderate sighting conditions. From Ramirez-Martinez et al. 2025b.



3 Comparison of models

The two modelling approaches that have been used to study the distribution of harbour porpoises in Danish waters differ in many ways, and both have their advantages and disadvantages. Here, we briefly outline these differences and highlight why results from the two models are often similar.

In short, MaxEnt is a species distribution modelling approach that estimates the relative probability of observing a species in different parts of the landscape based on the environmental conditions in the places where animals were located (i.e. the location data from the tagged animals). Here, it is assumed that animals are also likely to occur in other parts of the landscape with similar environmental conditions. MaxEnt can make predictions using presence-only data and applies the principle of maximum entropy. MaxEnt produces estimates of habitat suitability or relative densities rather than the actual number of animals found in an area. It is useful for identifying areas that are likely to be important for species. In this case, the MaxEnt analysis was based on data from satellite tagged harbour porpoises that provided continuous data throughout the year, year-round estimates can be obtained. Depending on data availability MaxEnt can be divided up into shorter periods when needed, such as summer and winter as done in van Beest et al. (2025).

Habitat-based density models or density surface models (DSMs) are capable of predicting not just occurrences but also the absolute density of animals in different part of the landscape. These models are often fitted using generalized additive models (GAMs), which is a statistical approach that is more flexible than e.g. linear statistical models. For the harbour porpoise models shown here, the models were fitted with presence and absence data available along dedicated transects (rather than data only presence of animals). Predictions from DSMs resemble those of MaxEnt models in that they use observations of animals to make predictions for parts of the landscape that were not included in the survey. If, for example, animals are often observed in areas where sea surface salinity is high, other parts of the landscape where sea surface salinity is similarly high are predicted to be important for the species, all else being equal. The two modelling approaches can use the same set of environmental parameters to characterize the habitats, which builds on the assumption that these parameters influence prey availability (see Stokholm et al. 2025 and van Beest et al. 2024 for a list of environmental parameters for the MaxEnt models and Gilles et al. 2025a, Gilles et al. 2025b for GAMs). One of the reasons why MaxEnt habitat suitability models and GAM-based habitat density models often predict the same areas to be important for a species is therefore that that it is the same environmental variables that are used to characterize the habitats. However, the two modelling approaches also differ in numerous ways, which can cause them to yield slightly different predictions of the distributions of important areas, even when based on the same environmental variables.

A short summary is given in table 1.

Table 1. Summary of comparison of the two models

Feature	Maxent Models	Habitat-based density models
Data Type	Presence-only (e.g. telemetry data)	Abundance/Density (such as dedicated fully corrected surveys)
Output	Relative density by area year-round (or probability of observing animals)	Absolute density by area at the time of the survey
Ecological Focus	Species distribution	Species distribution and absolute density

The predictions presented in previous section of harbour porpoise distribution based on tagging data (fitted with MaxEnt; data from 1997–2022) were generally similar to models based on aerial survey data (GAM models for the period 2005–2024). Population densities were high in the northern and eastern part of the Kattegat and in the Great Belt and Samsø Belt (figure 1, 2 and 4). This strongly suggests that these waters have been important for porpoises for the last 30 years, at least. However, in more recent years, the importance of the southern half of the Belt Seas has decreased dramatically, which is a result that is corroborated by studies based on passive acoustic monitoring (Hansen & Høgslund 2025).

The similarity of predictions based on satellite tracking data and aerial surveys is encouraging, as it makes it possible using both methods to pin-point areas of particular importance for harbour porpoises. However, it should be emphasized that aerial survey data cannot be used to determine seasonal distribution or abundance with the current monitoring program – surveys in other seasons would need to be included. Furthermore, only tagging data can be used to determine the movement patterns of animals, which is required to determine the size of animal home ranges or how individual animals react to disturbances. On the other hand aerial survey data are advantageous in other respects, as they provides an instant overview of abundance and distribution at a specific time.

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