Marine mammal seasonal maps: sperm and sei whales

A proof-of-concept output, which should not be used for spatial planning or environmental impact assessment

UNEP WCMC

Marine mammal seasonal maps: sperm and sei whales

A proof-of-concept output, which should not be used for spatial planning or environmental impact assessment

In collaboration with

Kristin Kaschner (Aquamaps; Albert-Ludwigs-University of Freiburg, Germany)

Published May 2014

Acknowledgements

The authors are grateful to the Proteus Partnership who part-financed this work.

Suggested citation

Kaschner K, UNEP-WCMC (2014). Marine mammal seasonal maps: sperm and sei whales. A proof-of-concept output, which should not be used for spatial planning or environmental impact assessment. Cambridge (UK): UNEP World Conservation Monitoring Centre. 14 pp.

The United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) is the specialist biodiversity assessment centre of the United Nations Environment Programme (UNEP), the world's foremost intergovernmental environmental organisation. The Centre has been in operation for over 30 years, combining scientific research with practical policy advice.

Contents

Marine mammal seasonal maps

Introduction

IUCN's Red List Spatial Data[1] (IUCN 2013) are expert-derived range maps where the underlying geographic dataset has a 'seasonality' information field (where '1' = resident, '2' = breeding season, '3' = non-breeding season, '4' = passage, and '5' = seasonal occurrence uncertain). For some species showing seasonal distribution patterns (e.g. the sperm and sei whales), the whole range is however coded '1', meaning that seasonality patterns cannot be mapped directly from the spatial data provided (Figure 1).

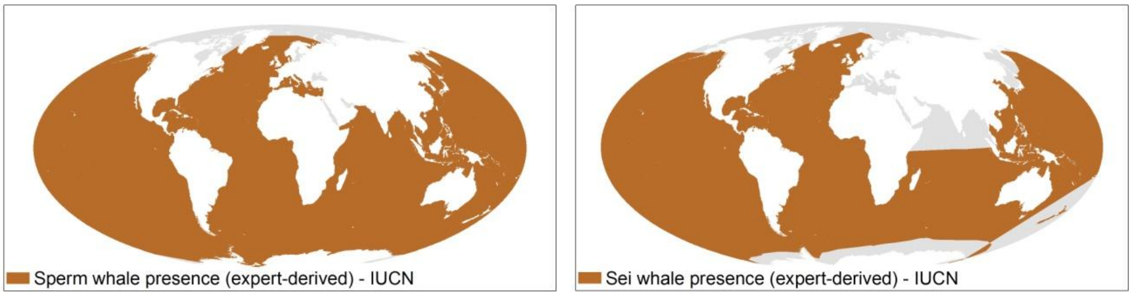


Figure 1[2]. Expert-derived range maps for the sperm (left) and sei (right) whales. Data from IUCN (2013).

The information presented in this document results from a collaboration between UNEP-WCMC and marine mammal expert Dr. Kristin Kaschner (Aquamaps; Albert-Ludwigs-University of Freiburg, Germany). A species distribution modelling approach was used to (i) map spatial distributions for four seasons, and (ii) provide information on the relative probability of occurrence. Maps are provided for two marine mammal species showing seasonal distribution patterns: the sei (*Balaenoptera borealis*) and sperm (*Physeter macrocephalus*) whales (Table 1). This document should be read in conjunction with annex 4 of the '*Manual of marine and coastal datasets of biodiversity importance'* (Martin et al. 2014), which provides additional methodological information.

The seasonal predictions presented here should be considered a proof-of-concept type output, included here to demonstrate the **potential** benefits of incorporating seasonality into the AquaMaps approach in the future. **Therefore, the maps should not be used for spatial planning or environmental impact assessment.**

[1] 2013 Red List Spatial Data; http://www.iucnredlist.org/technical-documents/spatial-data.
[2] Sources: http://maps.iucnredlist.org/map.html?id=41755 (sperm whale); http://maps.iucnredlist.org/map.html?id=2475 (sei whale).

Table 1. Cetacean species for which spatial data layers were obtained from Dr. Kristin Kaschner. The conservation status is according to IUCN (2013): EN – endangered; VU – vulnerable).

Dataset title	Contact organisation	ID	Metadata	IUCN status	Spatial data
Global Seasonal Distribution of Sperm Whales (2013)	Albert-Ludwigs-University of Freiburg	Kaschner-007	Annex 1	VU	Seasonal maps
Global Seasonal Distribution of Sei Whales (2013)	Albert-Ludwigs-University of Freiburg	Kaschner-010	Annex 1	EN	Seasonal maps

Specific methodology for generating seasonal predictions

AquaMaps (Kaschner et al. 2014) currently does not support the generation of seasonal predictions of species' distribution. Current predictions represent the annual average distribution of a given species, based on long-term annual means of environmental and species occurrence/habitat usage information. However, environmental conditions vary seasonally and therefore species' occurrence, ultimately determined by these parameters, can be expected to shift intra-annually as well as inter-annually. In addition, many marine mammal species are highly migratory and habitat usages may differ in different seasons and may also vary for different populations in different geographic areas.

Annual average predictions are particularly problematic for cosmopolitan species, where different populations in different hemisphere may have opposing patterns in habitat usage during the same time period. For instance, humpback whales' winter breeding is in shallow coastal waters during the northern hemisphere winter months. This time period actually corresponds to the Austral summer during which the same species will be foraging in its much deeper offshore summer feeding grounds. **Therefore, the incorporation of seasonality into the AquaMaps approach would likely to further improve predictions of relative species occurrence and decrease areas of false predicted presence and absences.**

Seasonal predictions included in the present document were originally produced in 2006 using a seasonal version of the 'RES[3] model' (Kaschner et al. 2006), the predecessor of AquaMaps. The RES approach relies a maximum of only four environmental variables (depth, sea surface temperature, sea ice concentration and – for a few otariid species – distance to land) while AquaMaps uses an additional two predictors (primary production and salinity). RES also uses a slightly different environmental data set as well as outdated species information. The seasonal version of the RES approach, however, allows habitat usage in different ocean basins to be modelled independently, with final outputs for different ocean basins being "pasted" together into a global map covering a three month season:

- December to February,
- March to May,
- June to August, and
- September to November.

[3] Relative environmental suitability

All of these factors will result in some differences between RES-based and AquaMaps-based predictions, even if the exact same input parameter settings would be used. The extent of these differences that have to be attributed to differences in modelling approach and data used rather than the incorporation of seasonality is illustrated for both species in additional metadata documentation (available on request), through a comparison of annual average predictions from both RES and AquaMaps using identical envelope settings.

It should be noted that the necessary but somewhat arbitrary latitudinal split used to model both hemisphere independently can result in artefacts along the equator visible as abrupt changes in predicted relative habitat suitability between northern and southern hemispheres. The extent of this artefact will likely be much reduced in outputs generated by a seasonal version of AquaMaps.

Mapped seasonal predictions

The selected species, sei and sperm whales were chosen to show different aspects. For the sei whale (Figure 2), a cosmopolitan species with an almost global range, predicted core areas of occurrence based on seasonal input would be much smaller than based on annual averages, and the fit with observed records is much improved.

For sperm whale (Figure 3), also a cosmopolitan but comparatively rare species, predicted core areas based on seasonal RES predictions are still quite large. These, however, could probably be reduced if the two extra predictor variables used by AquaMaps (salinity and primary production) would be incorporated in the seasonal model.

Please refer to the dataset-specific metadata (annex 1) for further details on these maps. The two sets of maps can also be viewed in an 'interactive PDF' (also annex 1).

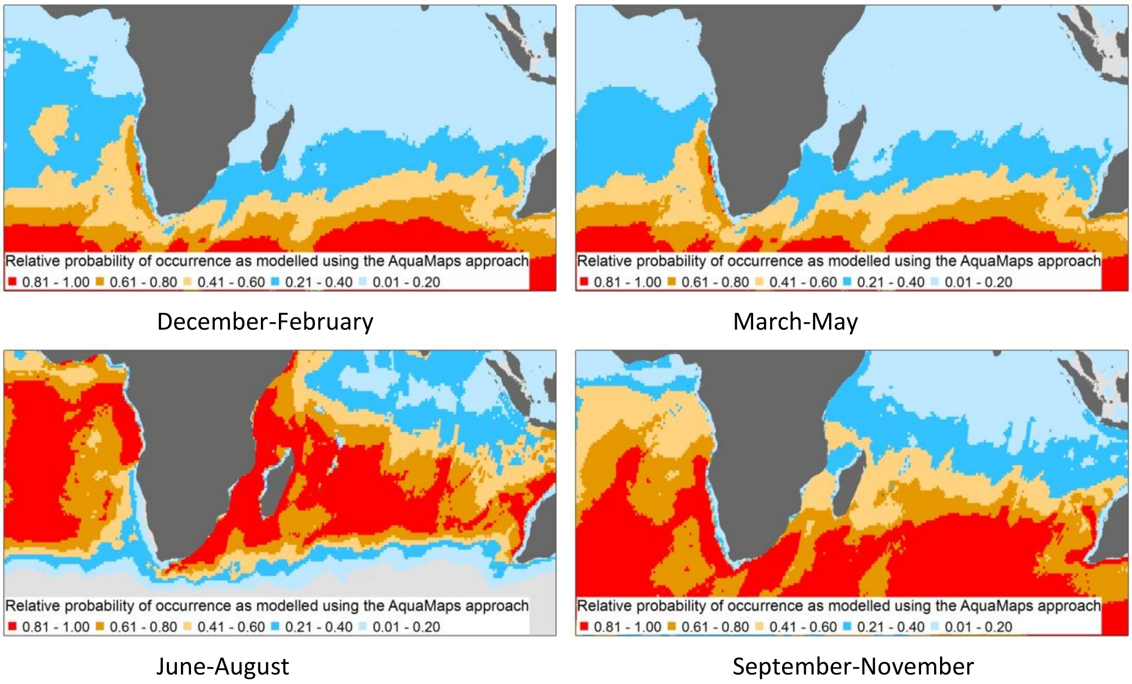


Figure 2. Seasonal distributions of sei whale in the southeastern Atlantic and southern Indian Ocean. The maps show modelled relative probabilities of occurrence.

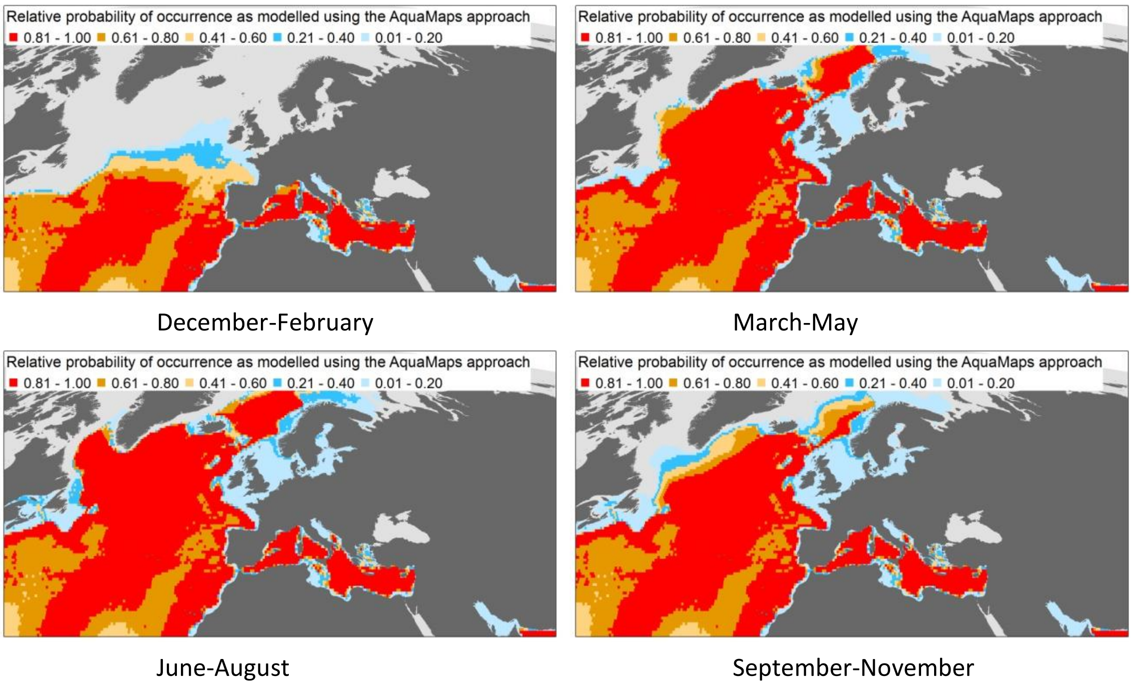


Figure 3. Seasonal distributions of sperm whale in the northeast Atlantic. The maps show modelled relative probabilities of occurrence.

References

IUCN (2013) The IUCN Red List of Threatened Species. Version 2013.2.

Kaschner K, Rius-Barile J, Kesner-Reyes K, Garilao C, Kullander SO, Rees T, Froese R (2014) AquaMaps: Predicted range maps for aquatic species. Version 08/2013.

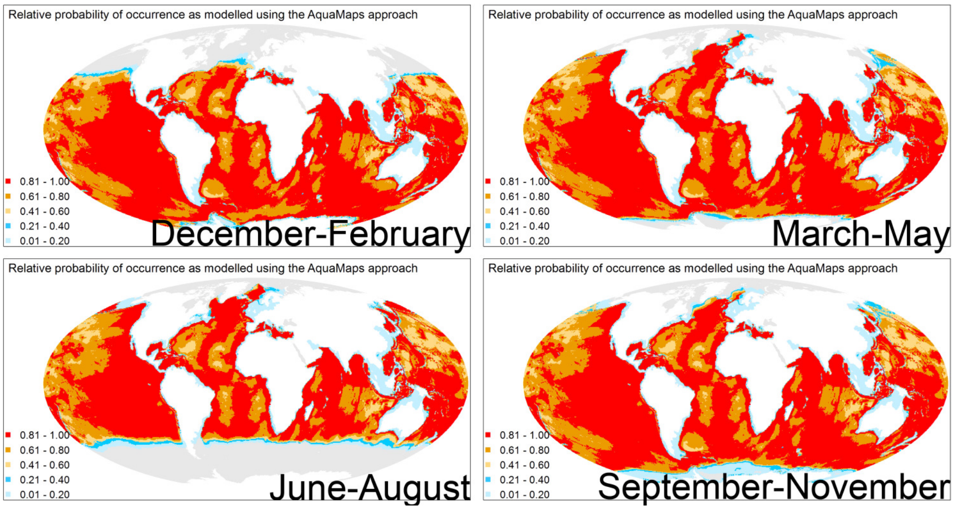
Kaschner K, Watson R, Trites A, Pauly D (2006) Mapping world-wide distributions of marine mammal species using a relative environmental suitability (RES) model. Mar Ecol progess Ser 316:285–310

Martin C, Fletcher R, Jones M, Kaschner K, Sullivan E, Tittensor D, Mcowen C, Geffert J, Bochove J van, Thomas H, Blyth S, Ravillious C, Tolley M, Stanwell-Smith D (2014) Manual of marine and coastal datasets of biodiversity importance. May 2014 release. UNEP World Conservation Monitoring Centre, Cambridge (UK)

Annex 1. Dataset-specific metadata and ‘interactive PDF’

Dataset ID: Kaschner-007

Global Seasonal Distribution of Sperm Whales (2013)



Description: This dataset shows the modelled distribution of sperm whales (Physeter macrocephalus) for four seasons (December-February, March-May, June-August, September-November) using a seasonal version of the 'RES model' (Kaschner et al. 2006). IUCN status: Vulnerable (Red List of Threatened Species).

Citation(s): Kaschner K,Watson R, Trites AW, Pauly D (2006). Mapping worldwide distributions of marine mammals using a Relative Environmental Suitability (RES) model. Marine Ecology Progress Series 316: 285-310

Temporal range: 2006

Geographical range: Global

Supplementary information (eg attribute table): The dataset contains continuous probabilities of occurrence as a global grid of 0.5 dd resolution. Field information: scientific name (Species_ID); area code (AreaCode); Latitude; Longitude; Time Period; predicted Relative Environmental Suitability (RES). Detailed dataset-specific information (provided by K. Kaschner) is also available, and includes a comparison between the methodology used here and the current AquaMaps approach.

Purpose of creation: To gain insights in seasonal patterns of spatial distribution for this highly migratory species with different habitat usage during summer feeding and winter breeding seasons in different hemispheres. To demonstrate the potential benefits of incorporating seasonality into the AquaMaps approach in the future.

Creation methodology: The seasonal distributions were created using a modified version of the RES approach (Kaschner et al. 2006) that incorporates seasonality. Seasonal predictions are generated by matching available information about seasonal habitat usage for four seasons (Dec-Feb, Mar-May, Jun-Aug, Sep-Nov) to mean seasonal environmental conditions. As seasonal habitat usage for species with global distributions may be opposing in different hemispheres, predictions were generated separately for each hemisphere. Table 3 in Kaschner et al. (2006) lists data sources which include the Global Biodiversity Information Facility (GBIF; www.gbif.org) and the International Whaling Commission (IWC), as well as published information on species-specific habitat usage and expert knowledge. Methodological notes (provided by K. Kaschner) are also available. The distribution model was based on three environmental variables (depth, temperature, and sea ice concentration), and details of the species envelope are in the dataset-specific information (provided by K. Kaschner).

Lineage (versioning):	
Category:	Species distribution
Keywords:	marine, coastal, model, pelagic, high seas, deep sea
Similar datasets:	Kaschner-006
Quality, limitation(s), fitness for use:	Excluded from the models: species misidentifications, fossil records and outliers. The modelled distribution has been expert-reviewed by Kristin Kaschner (15 December 2013), and the quality of predictions ranks 3 out of 5 (see www.aquamaps.org/rating.html for further details). Expert comment: "This is a highly migratory species with different habitat usage during summer feeding and winter breeding seasons in different hemispheres, which cannot be captured adequately using an generic annual average model. Hence, predictions are improved by the incorporation of seasonality, including both seasonal environmental dataset and seasonally specified habitat use of the species for four seasons (Dec-Feb, Mar-May, Jun-Aug, Sep-Nov). As seasonal habitat usage for species with global distributions may be opposing in different hemispheres, predictions were generated by modelling northern and southern hemispheres separately. Please note that the necessary but somewhat arbitrary latitudinal split used to model both hemisphere independently can result in artefacts along the equator visible as abrupt changes in relative habitat suitability between northern and southern hemispheres. The extent of this artefact will likely be much reduced in outputs generated by a seasonal version of AquaMaps. Envelope settings are exclusively based on expert knowledge obtained from the sources summarised in Table 3 of Kaschner et al. (2006). It should be noted that annual AquaMaps predictions are not directly comparable with seasonal RES predictions, as there are some small methodological differences between the two approaches, including the use of two additional predictors by AquaMaps. December-February: Good fit with known maximum range extent of species, but it should be noted that predicted distribution includes northern and southern known maximum range extents of migration of large males. Females and immature animals mostly remain below about 40°N and above 40°S. Occurrence in the Red Sea is not supported by published data. Depth preference of species may be less oceanic in some areas (e.g. Gulf of Mexico). Good match of known relative occurrence in most areas and predictions have been successfully validated in Antarctic waters using independent effort corrected sightings data (Kaschner et al. 2006). However, large areas of potentially false predicted presence remain. Predictions would probably be improved if a seasonal AquaMaps approach would be used, as the incorporation of salinity and primary production envelope may further help to narrow down predicted species occurrence. March-May: Good fit with known maximum range extent of species, but it should be noted that predicted distribution includes northern and southern known maximum range extents of migration of large males. Females and immature animals mostly remain below about 40°N and above 40°S. Occurrence in the Red Sea is not supported by published data. Depth preference of species may be less

oceanic in some areas (e.g. Gulf of Mexico). Good match of known relative occurrence in most areas, however, large areas of potentially false predicted presence remain. Predictions would probably be improved if a seasonal AquaMaps approach would be used, as the incorporation of salinity and primary production envelope may further help to narrow down predicted species occurrence.

June-August: Good fit with known maximum range extent of species, but it should be noted that predicted distribution includes northern and southern known range extents of migration of large males. Females and immature animals mostly remain below about 40°N and above 40°S. Occurrence in the Red Sea is not supported by published data. Depth preference of species may be less oceanic in some areas (e.g. Gulf of Mexico). Good match of known relative occurrence in most areas, however, large areas of potentially false predicted presence remain. Predictions would probably be improved if a seasonal AquaMaps approach would be used, as the incorporation of salinity and primary production envelope may further help to narrow down predicted species occurrence.

September-November: Good fit with known maximum range extent of species, but it should be noted that predicted distribution includes northern and southern known range extents of migration of large males. Females and immature animals mostly remain below about 40°N and above 40°S. Occurrence in the Red Sea is not supported by published data. Depth preference of species may be less oceanic in some areas (e.g. Gulf of Mexico). Good match of known relative occurrence in most areas, however, large areas of potentially false predicted presence remain. Predictions would probably be improved if a seasonal AquaMaps approach would be used, as the incorporation of salinity and primary production envelope may further help to narrow down predicted species occurrence".

Maintenance frequency:	Data are not being updated.
Main access/use constraint:	See 'Other access/use constraint(s)'.
Other access/use constraints:	Seasonal maps should be considered a proof-of-concept type output; included here to demonstrate the potential benefits of incorporating seasonality into the AquaMaps approach in the future.

Contact organisation:	Albert-Ludwigs-University of Freiburg		
Organisation type:	Owner	Acronym:	
Name:	Dr. Kristin Kaschner	Position:	Research Affiliate
City:	Freiburg	Country:	Germany
E-mail:	Kristin.Kaschner@biologie.uni-freiburg.de		
Web site:	www.uni-freiburg.de		

Main format:	Tabular (.csv)	Other format(s):	Vector (point; .shp)
Distribution format:	Tabular (.csv)	Dataset size (uncompressed):	20.9 Mb
Webpage and/or download:	http://www.aquamaps.org		
Other webpage:	http://data.unep-wcmc.org		
Web map service:			
Resolution, scale:	0.5 dd	Reference system:	WGS 1984

West bounding:	-180.0	East bounding:	180.0
South bounding:	-90.0	North bounding:	90.0

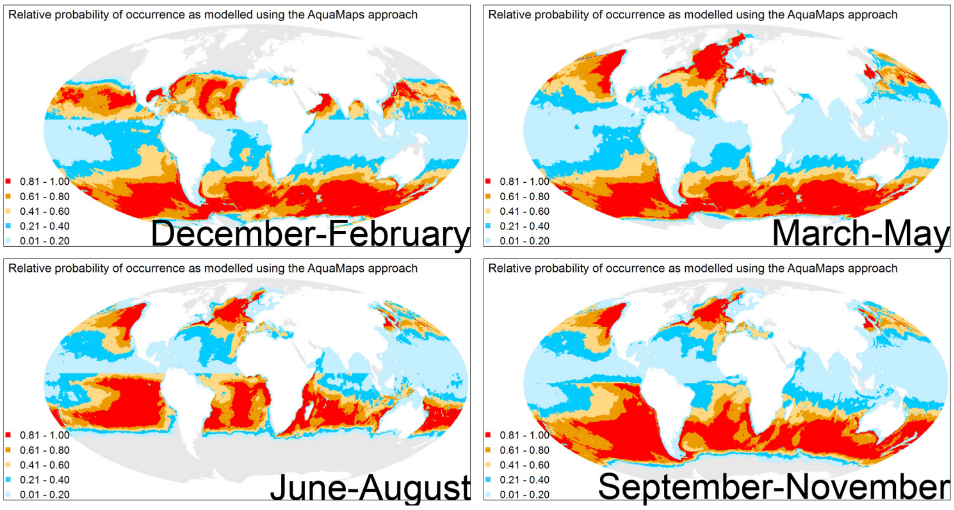
Factsheet: No

Metadata standard: UNEP-WCMC Specific

Date of metadata: 10/03/2014

Dataset ID: Kaschner-010

Global Seasonal Distribution of Sei Whales (2013)



Description: This dataset shows the modelled distribution of sei whales (Balaenoptera borealis) for four seasons (December-February, March-May, June-August, September-November) using a seasonal version of the 'RES model' (Kaschner et al. 2006). IUCN status: Endangered (Red List of Threatened Species).

Citation(s): Kaschner K,Watson R, Trites AW, Pauly D (2006). Mapping worldwide distributions of marine mammals using a Relative Environmental Suitability (RES) model. Marine Ecology Progress Series 316: 285-310

Temporal range: 2006

Geographical range: Global

Supplementary information (eg attribute table): The dataset contains continuous probabilities of occurrence as a global grid of 0.5 dd resolution. Field information: scientific name (Species_ID); area code (AreaCode); Latitude; Longitude; Time Period; predicted Relative Environmental Suitability (RES). Detailed dataset-specific information (provided by K. Kaschner) is also available, and includes a comparison between the methodology used here and the current AquaMaps approach.

Purpose of creation: To gain insights in seasonal patterns of spatial distribution for this highly migratory species with different habitat usage during summer feeding and winter breeding seasons in different hemispheres. To demonstrate the potential benefits of incorporating seasonality into the AquaMaps approach in the future.

Creation methodology: The seasonal distributions were created using a modified version of the RES approach (Kaschner et al. 2006) that incorporates seasonality. Seasonal predictions are generated by matching available information about seasonal habitat usage for four seasons (Dec-Feb, Mar-May, Jun-Aug, Sep-Nov) to mean seasonal environmental conditions. As seasonal habitat usage for species with global distributions may be opposing in different hemispheres, predictions were generated separately for each hemisphere. Table 3 in Kaschner et al. (2006) lists data sources which include the Global Biodiversity Information Facility (GBIF; www.gbif.org) and the International Whaling Commission (IWC), as well as published information on species-specific habitat usage and expert knowledge. Methodological notes (provided by K. Kaschner) are also available. The distribution model was based on three environmental variables (depth, temperature, and sea ice concentration), and details of the species envelope are in the dataset-specific information (provided by K. Kaschner).

Lineage (versioning):	
Category:	Species distribution
Keywords:	marine, coastal, model, pelagic, high seas, deep sea
Similar datasets:	Kaschner-009
Quality, limitation(s), fitness for use:	Excluded from the models: species misidentifications, fossil records and outliers. The modelled distribution has been expert-reviewed by Kristin Kaschner (15 December 2013), and the quality of predictions ranks 3 out of 5 (see www.aquamaps.org/rating.html for further details). Expert comment: "This is a highly migratory species with different habitat usage during summer feeding and winter breeding seasons in different hemispheres, which cannot be captured adequately using an generic annual average model. Hence, predictions are improved by the incorporation of seasonality, including both seasonal environmental dataset and seasonally specified habitat use of the species for four seasons (Dec-Feb, Mar-May, Jun-Aug, Sep-Nov). As seasonal habitat usage for species with global distributions may be opposing in different hemispheres, predictions were generated by modelling northern and southern hemispheres separately. Please note that the necessary but somewhat arbitrary latitudinal split used to model both hemisphere independently can result in artefacts along the equator visible as abrupt changes in relative habitat suitability between northern and southern hemispheres. The extent of this artefact will likely be much reduced in outputs generated by a seasonal version of AquaMaps. Envelope settings are exclusively based on expert knowledge obtained from the sources summarised in Table 3 of Kaschner et al. (2006). It should be noted that annual AquaMaps predictions are not directly comparable with seasonal RES predictions, as there are some small methodological differences between the two approaches, including the use of two additional predictors by AquaMaps. December-February: Good match with known maximum range extent except for some false predicted seasonal presence in the Mediterranean (this ocean basin was manually excluded in annual average AquaMaps predictions) and the Northern Indian Ocean where the species is not known to occur. Good match of known relative occurrence in most areas, but some artefacts of modelling hemispheres separately can be seen along the equator. Effort corrected sighting rates obtained from IWC surveys support the predominant occurrence of this baleen whale species in less polar waters than minke, fin or blue whale". March-May: Good match with known maximum range extent except for some false predicted presence in Sea of Japan, the Mediterranean (this ocean basin was manually excluded in annual average AquaMaps predictions) and the Northern Indian Ocean where the species is not known to occur. Predicted occurrence in Norwegian Sea probably more representative of historical occurrence before depletion of local population through whaling. Good match of known relative occurrence in most areas, failure to capture all whaling records in high latitudes of southern hemisphere may be due to interannual environmental variability.

June-August: Good match with known maximum range extent except for some false predicted presence in Sea of Japan, the Mediterranean (this ocean basin was manually excluded in annual average AquaMaps predictions) and the Northern Indian Ocean where the species is not known to occur. Predicted occurrence in Norwegian Sea probably more representative of historical occurrence before depletion of local population through whaling. Good match of known relative occurrence in most areas, lack of predicted high environmental suitability in areas of intensive whaling in North Pacific may be related to very high whaling effort in that area which will have produced high catches even if there were comparatively fewer animals. Some artefacts of modelling hemispheres separately can be seen along the equator.

September-November: Good match with known maximum range extent except for some false predicted presence in Sea of Japan, the Mediterranean (this ocean basin was manually excluded in annual average AquaMaps predictions) and the Northern Indian Ocean where the species is not known to occur. Predicted occurrence in Norwegian Sea probably more representative of historical occurrence before depletion of local population through whaling. Some artefacts of modelling hemispheres separately can be seen along the equator".

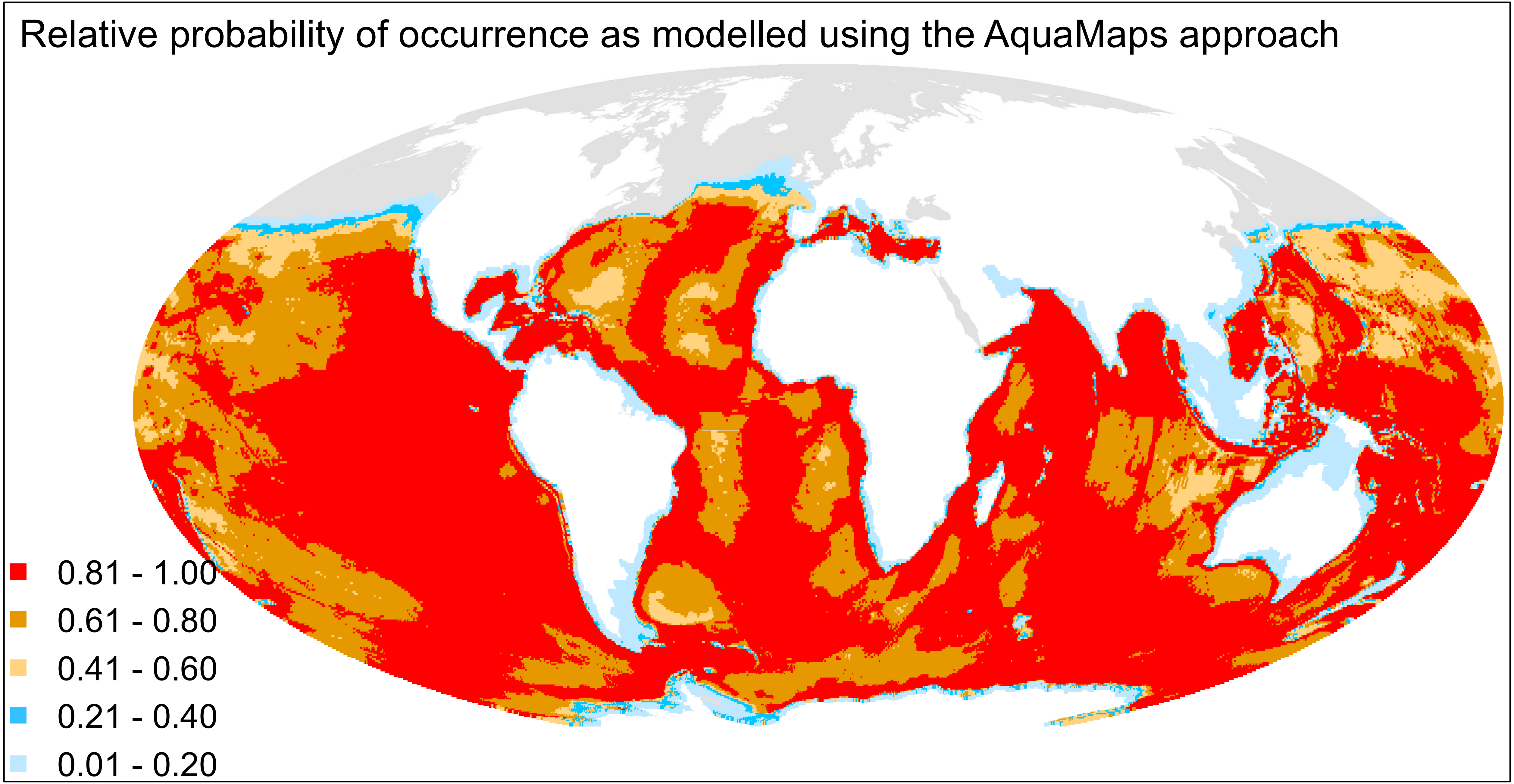
Maintenance frequency:	Data are not being updated.
Main access/use constraint:	See 'Other access/use constraint(s)'.
Other access/use constraints:	Seasonal maps should be considered a proof-of-concept type output; included here to demonstrate the potential benefits of incorporating seasonality into the AquaMaps approach in the future.

Contact organisation:	Albert-Ludwigs-University of Freiburg		
Organisation type:	Owner	Acronym:	
Name:	Dr. Kristin Kaschner	Position:	Research Affiliate
City:	Freiburg	Country:	Germany
E-mail:	Kristin.Kaschner@biologie.uni-freiburg.de		
Web site:	www.uni-freiburg.de		

Main format:	Tabular (.csv)	Other format(s):	Vector (point; .shp)
Distribution format:	Tabular (.csv)	Dataset size (uncompressed):	19.5 Mb
Webpage and/or download:	http://www.aquamaps.org		
Other webpage:	http://data.unep-wcmc.org		
Web map service:			
Resolution, scale:	0.5 dd	Reference system:	WGS 1984
West bounding:	-180.0	East bounding:	180.0
South bounding:	-90.0	North bounding:	90.0

Factsheet: No   Metadata standard: UNEP-WCMC Specific

Date of metadata: 10/03/2014


Relative probability of occurrence as modelled using the AquaMaps approach
0.81 - 1.00
0.61 - 0.80
0.41 - 0.60
0.21 - 0.40
0.01 - 0.20