ORCA Looking out for Whales and Dolphins

THE STATE OF EUROPEAN CETACEANS 2017

This report has been produced by ORCA, based on marine survey data collected by its volunteer network of Marine Mammal Surveyors

WITH PLYMOUTH UNIVERSITY

FOREWORD

ORCA continues to play a critical role – quietly and unassumingly – in efforts to care for whales, dolphins and porpoises in European waters. I still marvel at the way it so successfully relies on an outstanding and tireless army of trained volunteers: people, from all walks of life and of all ages, who give their time to make a real difference. Quite simply, they get the job done. The world would certainly be a poorer place without them.

'The State of European Cetaceans' report is testament to over a decade of research undertaken by these volunteers. Painstakingly and methodically, they have been creating a much clearer picture of the cetaceans in our seas: which species live where, what threats they face and, most importantly, what needs to be done to protect them. This long-term monitoring is absolutely essential to securing a better future for them. It is essential for the creation of Marine Protected Areas, for example, but is also important in enabling us to identify and tackle marine issues in real time.

This highly valuable and impressive report builds on ORCA's inaugural effort from last year. More than anything I hope that it results in better protection for cetaceans, but I also want it to inspire even more people to help with ORCA's important work. After all, if we can't look after animals as awe-inspiring, enigmatic and downright remarkable as whales, dolphins and porpoises, what can we do?

Mark Carwardine
Marine wildlife expert, photographer and ORCA patron

Humpback whale

EXECUTIVE SUMMARY

The State of European Cetaceans (SOEC) 2017 report is the latest landmark in ORCA's ongoing mission to use citizen science to better understand the status of cetaceans (whales, dolphins and porpoises) within UK and European waters. The charity has been utilising its volunteer network of Marine Mammal Surveyors on board platforms of opportunity (ferries and cruise ships) since 2001, and this report builds and expands on the inaugural 2016 edition of the SOEC.

This SOEC has made unprecedented progress in moving towards ORCA's vision of oceans alive with whales and dolphins. In particular it provides common dolphin population density estimates to try and address the current bycatch issue in the Celtic Seas and Bay of Biscay. This is a huge step forward for the use of citizen science in marine conservation. The report also expands on the analysis of the range and distribution of cetaceans over the last decade across the nine European sea regions in which ORCA operates.

Another critical expansion to this report is ORCA's examination of threats to cetaceans, highlighting the wide-ranging and cumulative issues that whales, dolphins and porpoises are facing on both a local and global scale.

ORCA's *The State of European Cetaceans* reports continue to demonstrate why ongoing monitoring of cetaceans in the field is so vital. The compilation and analysis of real-time, long-term data is essential in being able to make effective and informed decisions about the protection our whales and dolphins so urgently need. ORCA's work has conclusively shown that the utilisation of ferry and cruise platforms for observation is a highly effective tool in establishing density estimates, as well as understanding the distribution and range of these animals. But whilst ORCA can provide an army of watchful eyes thanks to our dedicated volunteer surveyors, we also need a commitment from governments to take swift and decisive action when evidence shows the growing threats to these animals and the habitats in which they live.


Blue Whale *Credit: Mark Carwardine*

KEY HIGHLIGHTS of 2016

Over 7,500 cetaceans sighted during the 2016 survey season

- In 2016, ORCA surveyors recorded a record number of cetacean encounters – an incredible 1,780 encounters across both ferry and cruise surveys, consisting of 7,572 animals. Of these, 1,168 encounters were of identified cetacean species amounting to 5,931 individuals.
- Overall, the common dolphin was the most commonly sighted cetacean in 2016 with 376 encounters, closely followed by the harbour porpoise (370 encounters).
- Over the 11 years (2006-2016) the highest number of individuals recorded was the harbour porpoise with a total of 1,913 animals. Other frequently sighted species included the common dolphin, fin whale, minke whale, white-beaked dolphin and striped dolphin.

Bryde's whale: an ORCA first

Bryde's whale *Credit: Jolene Bertoldi/ A Bryde's whale in False Bay, South Africa/CC-BY-2.0*

- Twenty different cetacean species were identified in 2016, including ORCA's first ever recorded Bryde's whale, sighted during a cruise survey in the Wider Atlantic.
- The addition of a Bryde's whale means that between 2006-2016 ORCA surveyors have now sighted an amazing 23 different cetacean species.
- Record numbers of sperm whales and fin whales, as well as four brand new species were seen in the Wider Atlantic during 2016. These included the aforementioned Bryde's whale, as well as short-finned pilot whales, Risso's dolphins and white-beaked dolphins. One possible explanation for this higher species diversity is that ORCA increased their effort in this region, conducting their first survey to the Cape Verde Islands.

White-beaked dolphins – common in the Celtic Seas

White-beaked dolphin

- A record eight species were seen in the Celtic Seas in 2016. This included three species never before recorded by ORCA in the region. A humpback whale and orca were seen on the Isles of Scilly route in March and June respectively, whilst white-beaked dolphins were seen on 10 separate occasions during July. White-beaked dolphins were common in 2016; it was the first time that ORCA have recorded white-beaked dolphins in the Irish Sea, and there were also frequent sightings of this species in the Minches and West Scotland.

Record breaking Mediterranean season

- 2016 was a hallmark year for ORCA surveys in the Mediterranean Sea, with an unprecedented number of sightings and surveys. There were almost three times as many sightings compared to 2015, with 116 encounters of a record nine cetacean species.
- Another first in a year of landmarks was the recording of both sei and sperm whales in this sea region.

Ferry Survey Top Three

- There have been 450 encounters with cetaceans on ferry surveys, with 1,784 individuals sighted. The harbour porpoise was the most common with 219 encounters, followed by the common dolphin at 159 encounters. The fin whale came in third with 25 encounters recorded.

Harbour porpoise

- 2016 signalled the first ever sighting of bottlenose dolphins on the Portsmouth to Caen route.
- Despite reduced effort in the North Sea, there were still a greater number of harbour porpoise, minke whale and common dolphin sightings than in previous years.

Citizen science supports pivotal cetacean research

- In 2017 there were reports of high common dolphin mortalities as a result of bycatch. ORCA's common dolphin dataset (2006-2016) has been analysed in conjunction with Plymouth University to establish if there have been any significant changes in common dolphin population densities around the UK. The assessment establishes an important baseline dataset that will allow ORCA to explore whether future survey sightings show a decrease in common dolphin density estimates as a result of the reported bycatch deaths.
- 61,887km of effort and 862 encounters (1-1,000 individuals) from three sea regions (Bay of Biscay, English Channel and Celtic Seas) was used for analysis.
- ORCA's data was compared to the Small Cetaceans in European Atlantic waters and the North Sea (SCANS) III survey during July 2016. SCANS plays a pivotal role in informing UK and European marine protection policy.
- Both ORCA and SCANS III datasets have shown that the common dolphin population across the three sea regions are relatively stable.
- This is a landmark finding for ORCA and reinforces the substantial role that citizen science has to play in informing policy and augmenting the established cetacean research taking place in Europe. It also highlights how platforms of opportunity used with citizen scientists can gather longer term data within smaller areas, and thus help to display spatial and temporal trends that may not be apparent from single surveys that focus on one single month every decade.

ORCA team photo

Threats to European cetaceans

Although some may interpret ORCA's 2006-2016 findings as an indication of a diverse and thriving population of cetaceans in European waters, significant and emerging threats continue to adversely impact their environment. Bycatch, ship strike, commercial whaling, pollutants and strandings are all threats that, if ignored, will continue to have devastating effects on cetacean habitats and populations.

- Bycatch is responsible for an unprecedented number of harbour porpoise and common dolphin deaths in UK and European waters. The most recent UK report to the EU estimated that 1,500 porpoises were bycaught in UK fishing nets in 2015 alone and latest research indicates there is a real possibility of bycatch negatively impacting common dolphin populations.

Striped dolphin *Credit: Greenpeace*

Blue whale - ship strike *Credit: Craig Hayslip/ Researchers examine a dead blue whale killed from a collision by a ship/CC-BY-2.0*

- Ship strike has already led to the decimation of North Atlantic right whale populations. And with the Bay of Biscay recognised as a ship strike hotspot and an important habitat for fin whales, there is serious concern for fin whale populations. ORCA have been working with corporate partners to identify and help mitigate the risk of collisions in the Bay of Biscay and is committed to continuing to advance understanding in this area, helping to protect important whale populations.

- Despite a global ban on commercial whaling coming into force in 1986, there are European nations that still conduct these practices, slaughtering hundreds of animals each year. Our fin whales and minke whales are at serious risk of commercial whaling by Norway and Iceland and each individual animal that falls victim to this activity is subjected to unnecessary, prolonged suffering.

Icelandic whaling ships
Credit: Dirk Heldmaier/CC-BY-2.0

- Significant public awareness of the impact of pollutants, such as plastics and PCBs, on marine life has been a defining feature of environmental coverage recently, but the issue still poses a deadly threat to whales and dolphins. Only this year, a Cuvier's beaked whale washed ashore in Norway with 30 plastic carrier bags in its stomach. In 2016 the UK's only resident pod of orca lost a member. The dead female was found to have one of the highest PCB levels ever recorded in an animal, resulting in reproductive failure. This would explain why the pod has not reproduced for over 20 years and at a mere eight members, is likely to become extinct.

Plastic bag pollution *Credit: NOAA*

Stranded beaked whale *Credit: Avenue/CC-BY-SA-3.0*

- In recent years, the number of cetacean strandings in some species appears to be on the rise in the UK, with common dolphins amongst those increasingly at threat. However, evidence as to the reasons for such events remains poorly understood. For example, theories to explain the causes and mechanisms leading to the mass stranding of 29 sperm whales in the North Sea in 2016 continues to be debated.

It is the culmination of such threats that put our whales and dolphins at an unprecedented risk and without meaningful action to address the increasing pressures facing cetaceans today, they may not survive into tomorrow. Real-time, long-term monitoring programmes, such as those conducted by ORCA are essential to shed further light on the level of impact human activities are having on our oceans. We call on governments, policymakers, industry and the public alike, to all take responsibility and urgent action to ensure the safeguarding of our whales, dolphins and porpoises for the future.

Contents


Common dolphin

Acknowledgements

Shipping partners

We would like to extend our overwhelming gratitude to our shipping partners* without whom the survey data collection could not be possible.

*correct as of 2016

Contributors

This report could not have been written without the help and support of other non-governmental organisations such as; Whale and Dolphin Conservation (WDC), British Divers Marine Life Rescue (BDMLR), International Fund for Animal Welfare (IFAW) and Environmental Investigation Agency (EIA),

Common dolphin population analyses were conducted by The School of Engineering and Marine Science at Plymouth University.

ORCA volunteers

ORCA's offshore monitoring programme is entirely reliant on our network of volunteer Marine Mammal Surveyors. Each one has played a role in this vital monitoring work, which can only take place thanks to their contribution – whether in the past, present or future.

These annual reports are a testament to their skill, time, effort and dedication.

False killer whales *Credit: Jim McLean*

About ORCA

ORCA is a UK whale and dolphin conservation charity dedicated to the long-term protection of whales, dolphins and porpoises (collectively known as cetaceans) and their habitats in UK & European waters. Founded in 2001, ORCA works to monitor vulnerable cetacean populations and helps to protect threatened marine habitats. Working with governments, research institutions and other conservation charities, ORCA's aim is to create safer places for cetaceans, ultimately promoting the health and well-being of the wider marine ecosystem.

Alongside its dedication to cetaceans, ORCA is passionate about people; in fact, the charity's work is as much about people as it is about whales and dolphins. What makes ORCA unique is the way we combine accessible marine education with our conservation activities, allowing us to give people from all walks of life the opportunity to take an active role in marine science and conservation. We are making science less exclusive and more accessible and tangible. We train volunteers to join our survey teams, to become Wildlife Officers and to support our educational programmes. ORCA's projects reach over 40,000 people of all ages each year, providing memorable educational activities and remarkable local wildlife experiences both on and offshore. By doing so, we are empowering local communities to become stewards of local whales and dolphins and the marine environment in which they live.

The report and its purpose

The *State of European Cetaceans* report is the second in a series of annual reports published by ORCA. It summarises the distribution and range of cetacean populations in and around Europe's waters using data collected on platforms of opportunity (namely cruise ships and ferries). This edition also reports on the growing and cumulative threats that our cetacean populations face today. These include the global impact of whales being hit by ships, the devastating impact to both small and large cetaceans when they become victims of bycatch, and the growing impact of marine litter, particularly plastics, on our marine species.

With ever-increasing commercial pressures impacting our oceans, justifiable concern is developing about the health of our marine ecosystems. ORCA's cetacean monitoring programme helps to provide the necessary year-round supporting evidence needed to assess the health of our whale and dolphin populations in the face of these threats. ORCA's research highlights areas within our seas that are consistently utilised by a range of cetacean species. It is these hotspot areas that must be given more protection as a matter of urgency.

This report is the culmination of 11 years' worth of sightings and environmental data conducted from 2006-2016 during 447 ORCA surveys. It highlights the sightings and observations recorded during the 2016 survey season and compares them to previous years. In light of the recent reports of high mortalities of common dolphins from bycatch, ORCA's common dolphin dataset has also been analysed to explore if there have been any significant changes over time. The analysis creates a baseline for ORCA to compare the impact of common dolphin bycatch annually, which meets one of the key purposes of these reports - to better inform policy makers by highlighting critical habitats that require urgent protection. Creating and safe-guarding habitats for cetaceans is the only way to achieve long-term protection for our whales, dolphins and porpoises.

Common dolphins

SURVEY OVERVIEW

Striped dolphin *Credit: Kev Barwell*

Survey Methodology

ORCA surveys utilise distance sampling through line-transect surveys, which is a widely employed sampling method for estimating cetacean density and abundance. Surveys are conducted by a fully trained team of three or four volunteer ORCA Marine Mammal Surveyors from the ship's bridge (or other forward-facing platform) aboard ferries and cruise ships. A standardised survey protocol is adhered to, ensuring data collection is rigorous and comparable (Appendix I).

Data analysis

The data was analysed both by region and route. A 20x20nm (nautical mile) grid (Figure 1) with an equal area projection (Albers) was used for the entire dataset in ArcGIS®. The grid was generated for a wide region with a central meridian of 0 degrees. This grid was then cropped to the full extent of the study area and assigned to a study region based on OSPAR shapefiles, using the INTERSECT function in ArcGIS®. Cells were assigned to a region as accurately as possible whilst retaining the whole grid cells. Grid cells were omitted from subsequent analyses if no survey effort was conducted within them. For ferry route analyses, grid cells were selected from the base grid by visual selection based on the specific ferry effort transects. Where certain grid cells were shared between routes, these were analysed separately for route specific statistics. All maps and map layers were projected in World Geodetic System 1984 projection. Once relevant analyses had been conducted, data was attached to each grid cell ID for display and map production.

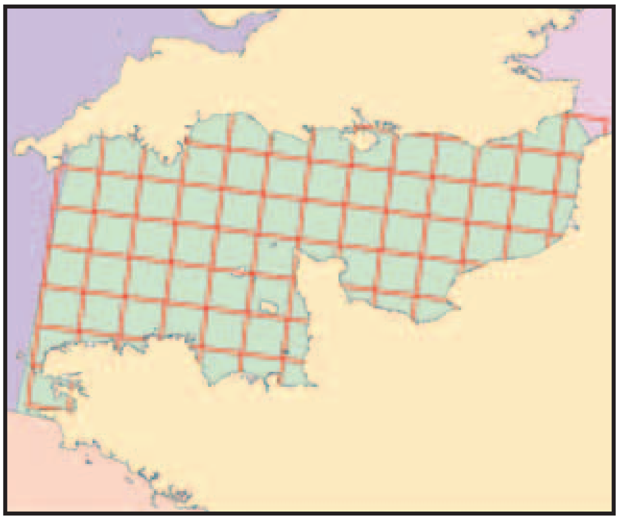


Figure 1 An example of the 20x20nm grid within the English Channel.

ORCA survey areas

ORCA's surveys traverse nine sea regions (Figure 2) within the North-East Atlantic; Arctic Waters, North Sea, English Channel, Celtic Seas, Irish Sea, Minches and West Scotland, Bay of Biscay and Iberian Coast, Wider Atlantic and the Mediterranean Sea.

Since 2006, ORCA have conducted 397 dedicated distance sampling surveys on 14 ferry routes in partnership with seven ferry companies, as well as 50 observation surveys in partnership with two cruise companies. Three

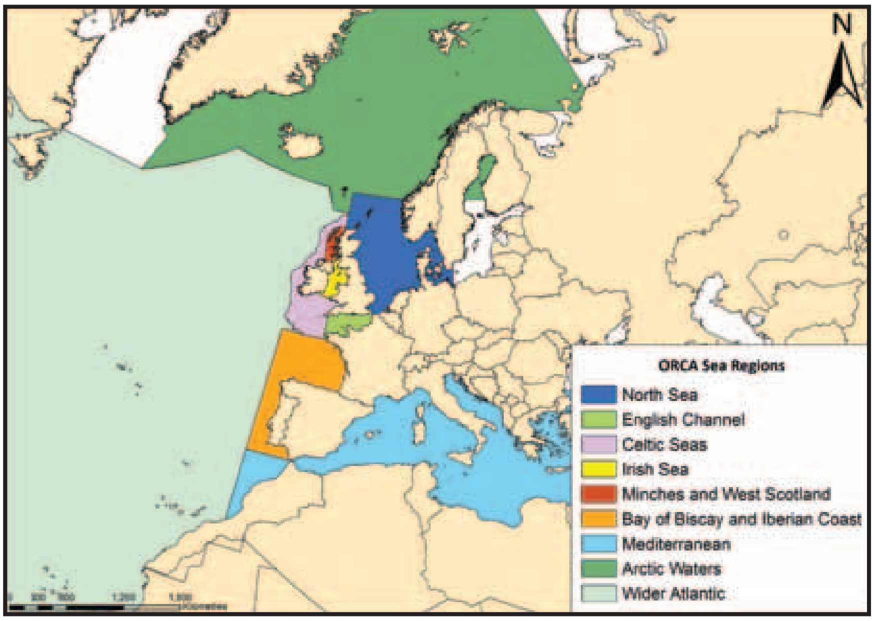


Figure 2 ORCA survey areas/sea regions

Sea Region	Route Code	Route	Years Ran	Company
North Sea	NsId	Newcastle - Amsterdam	2009 & 2011-2016	DFDS
	NcBg	Newcastle - Bergen	2006-2008	DFDS
	HwEb	Harwich - Esbjerg	2008-2014	DFDS
	ImGoBvIm	Immingham - Gothenberg-Brevik	2015	DFDS
	AbLw	Aberdeen - Lerwick	2016	NorthLink
	DvCl**	Dover - Calais	2016	DFDS
	Cruise	*Various cruises*	2006-2016	Saga
Irish Sea	HsPd	Heysham - Douglas	2011-2013 & 2016	Isle of Man Steam Packet Company
	Cruise	*Various cruises*	2008-2016	Saga
Bay of Biscay And Iberian Coast	PlSt*	Plymouth - Santander	2006-2008	Brittany Ferries
	PlStPm*	*Plymouth - Santander - Portsmouth*	2009-2016	Brittany Ferries
	Cruise	*Various cruises*	2006-2016	Saga
English Channel	PlRc	Plymouth - Roscoff	2014-2016	Brittany Ferries
	PmCa	Portsmouth - Caen	2014-2016	Brittany Ferries
	DvCl**	Dover - Calais	2016	DFDS
	PmFi	Portsmouth - Fishbourne	2016	Wightlink
	SoCo	Southampton - Cowes	2016	Red Funnel
	Cruise	*Various cruises*	2006-2016	Saga
Celtic Seas	PzSm	Penzance - St Mary's	2009-2016	Isles of Scilly Travel
	Cruise	*Various cruises*	2009-2016	Saga
Mediterranean Sea	Cruise	*Various cruises*	2009-2016	Saga
Minches and West Scotland	Cruise	*Various cruises*	2009-2016	Saga
Wider Atlantic	Cruise	*Various cruises*	2009-2016	Saga
Arctic Waters	Cruise	*Various cruises*	2009-2016	Saga/Oceanwide Expeditions

Table 1 ORCA survey routes. Routes shown in red are new for 2016.
* PlSt merged into the PlStPm route in 2009, ** shows that the survey route crosses more than one sea region.

of these ferry routes launched in 2016, with ORCA forming new partnerships with Northlink (Aberdeen – Lerwick), Red Funnel (Southampton – East Cowes) and Wightlink (Portsmouth – Fishbourne). ORCA also started surveying from Dover to Calais with one of their long-standing partners, DFDS (Table 1). The addition of these routes has significantly increased ORCA's survey area around the UK, particularly within the English Channel and provides the first survey route in Scotland.

2016 Distance Surveyed (Effort)

In 2016, ORCA conducted 64 ferry surveys and 11 cruise surveys. The ferry surveys took place with seven ferry companies across 10 ferry routes. Two of these routes were in the North Sea (AbLw & NsId), five were within the English Channel (DvCl, PmCa, PmFi, SoCo & PlRc), one was in the Celtic Seas (PzSm), one was in the Irish Sea (HsPd) and one route traversed the English Channel, Celtic Seas and Bay of Biscay (PlStPm) (Table 1 & Figure 3). The 11 cruises were conducted on Saga cruise ships across the North-East Atlantic.

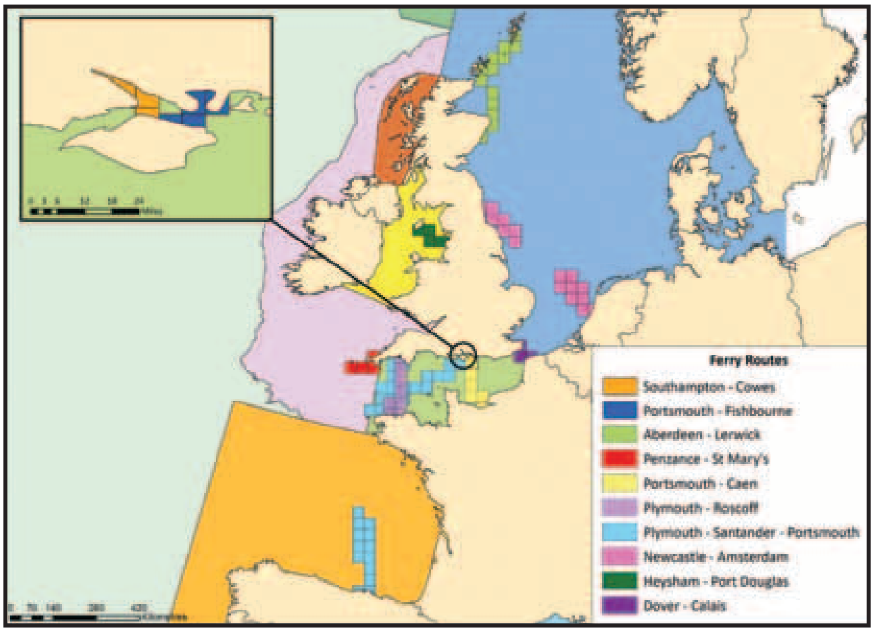


Figure 3 A map to show the location of ferry routes surveyed by ORCA in 2016.

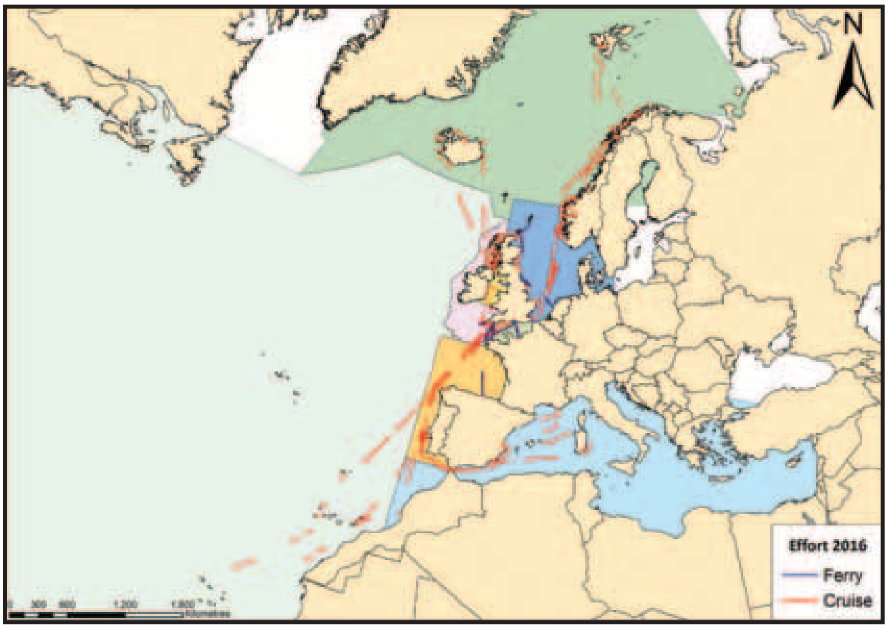


Figure 4 A map to show cruise (red) and ferry (purple) effort across ORCA sea regions in 2016.

The total surveyed distance in 2016 across all regions was 34,643km (Figure 4). The most surveyed region was the North Sea (8,883km), with the least effort recorded in the Minches and West Scotland (659km) (Figure 5). The greatest number of surveys occurred in the English Channel, with 26 undertaken across the six ferry routes that cross this region. Effort for the Mediterranean Sea, Minches and West Scotland, Wider Atlantic and Arctic Waters were confined to cruise surveys.

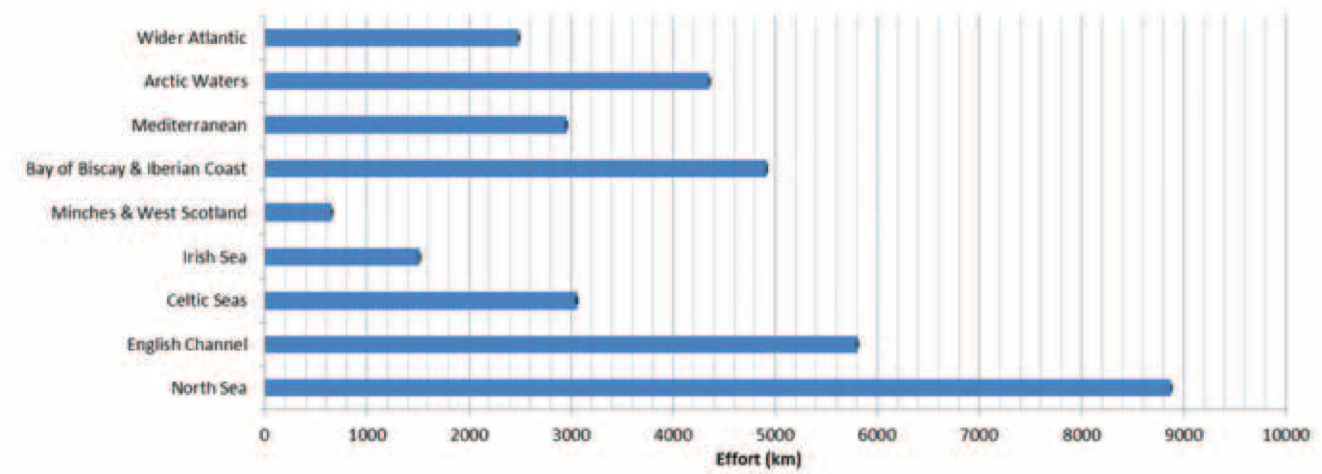


Figure 5 A graph to show the amount of effort (km) undertaken within each sea region in 2016 with error bars.

The greatest amount of effort by ferry route occurred on the Newcastle to Amsterdam route (NsId), with a total of 4,107km surveyed. The least amount of effort on any single route occurred on the Portsmouth to Fishbourne (PmFi) route with 107km (Table 2). This is due to the short distance travelled and only two surveys being conducted during the year.

Year	HsPd	HwEb	ImGoBvIm	NcBg	NsId	PlRc	PlSt	PlStPm	PmCa	PzSm	DvCl	AbLw	PmFi	SoCo	Total
2006				8389			2115								10504
2007				7522			3536								11058
2008		333		7204			4453								11990
2009		1770			704			5459		512					8445
2010		163						4970		1622					6755
2011	588	2544			1855			5692		1364					12043
2012	331	2882			2210			4959		1521					11903
2013	257	2903			4087			4294		1686					13227
2014		6168			7532	1420		5270	212	1878					22480
2015	498		4297		4706	1123		4650	1462	2018					18754
2016	1219				4107	1034		3897	1694	1820	382	916	107	111	16287
Total	2893	16763	4297	23115	25201	3577	10104	39191	3368	12421	382	916	107	111	142446

Table 2 A table to show the yearly amounts of effort (km) undertaken on ferry routes ORCA surveyed in 2016.

2016 Sightings

In 2016 ORCA surveyors recorded a record number of cetacean encounters. A total of 1,780 cetacean encounters across both ferry and cruise surveys, which amounted to 7,572 animals (Figure 6). Of these, 1,168 encounters were of identified cetacean species, which amounted to 5,931 individual animals (Table 3). 20 different species were identified, including a Bryde's whale in the Wider Atlantic, the first time this species has been recorded by ORCA surveyors. The Bryde's whale sighting now means ORCA surveyors have recorded an impressive 23 different cetacean species over the last 11 years. Overall, the common dolphin was the most commonly sighted cetacean with 376 encounters, closely followed by the harbour porpoise (370 encounters). Over 11 years from 2006-2016, the highest number of individuals recorded was the harbour porpoise with a total of 1,913 animals. Other frequently sighted cetacean species included fin whale, minke whale, white-beaked dolphin and striped dolphin.

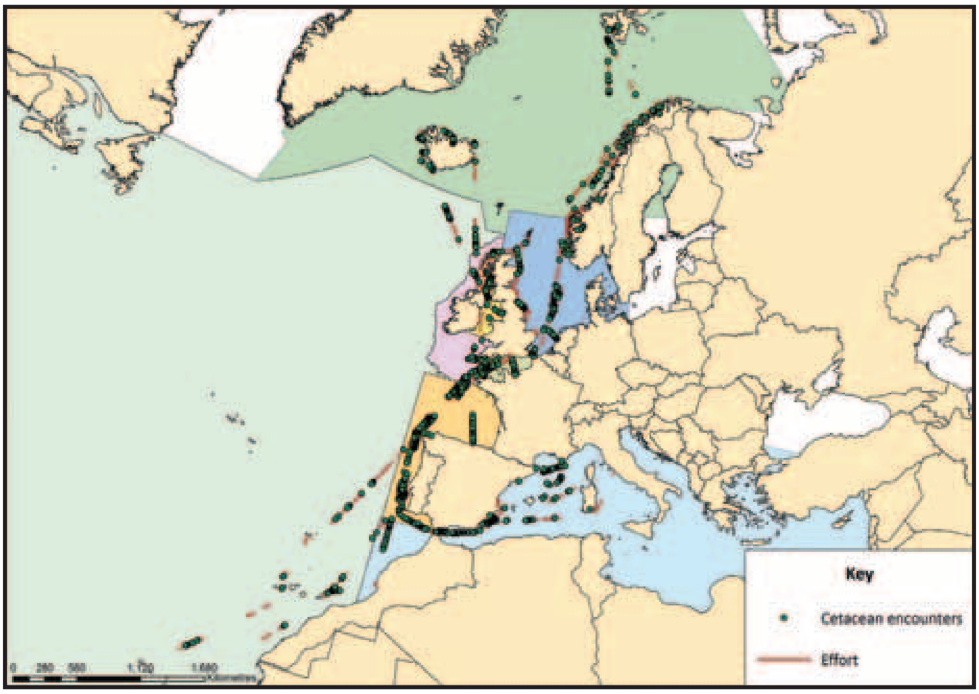


Figure 6 A map to show all sightings on routes where effort was undertaken in all sea regions.

Sightings by sea region

Eight species were seen in the Celtic Seas, the largest number ever seen in this region by ORCA. This included three new species for the region; a humpback whale and orca were seen on the Isles of Scilly route in March and June respectively, and white-beaked dolphins were seen on 10 separate occasions in July. White-beaked dolphins were a common occurrence in 2016. It was the first time that ORCA recorded white-beaked dolphins in the Irish Sea with frequent sightings of this species also seen in the Minches and West Scotland (Figure 7). This could in part be due to the number of cruise surveys traversing these regions in 2016, which was higher than in previous years. Further monitoring by ORCA in these regions would help to determine if the number of sightings recorded were due to survey effort or changes in population numbers or distribution.

Despite half the number of animals having been sighted in the Wider Atlantic compared to previous years, record numbers of sperm whales and fin whales, as well as four new species were seen: Bryde's whale, short-finned pilot whale, Risso's dolphin and white-beaked dolphin. This was the first year that ORCA had surveyed to the Cape Verde Islands, which may account for the additional species being recorded.

2016 also saw record cetacean numbers in the Mediterranean with three surveys undertaken in this region. There were nearly three times as many sightings compared to 2015, with 116 encounters and a record nine species. 2016 also saw the first record of sei whale and sperm whale in this region.

Species	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Harbour porpoise (Phoceona phoceona)	75	61	60	76	83	175	199	271	338	206	369	1913
Common dolphin (Delphinus delphis)	26	64	58	54	108	143	102	220	129	312	373	1589
Minke whale (Balaenoptera acutorostrata)	6	9	9	15	16	36	52	43	79	44	50	359
Fin whale (Balaenoptera physalus)	6	14	74	11	6	42	27	28	49	35	95	387
White-beaked dolphin (Lagenorhynchus albirostris)	4	11	3	3	1	28	19	46	79	21	54	269
Bottlenose dolphin (Tursiops truncatus)	8	9	19	18	8	33	12	24	25	16	30	202
Striped dolphin (Stenella coeruleoalba)	4	6	2	12	13	27	16	28	14	23	87	232
Humpback whale (Megaptera novaeangliae)			1		1	3	7	10	31	25	32	110
Long-finned pilot whale (Globicephala melas)	2	13	7	10		6	20	2	3	8	6	77
Sperm whale (Physeter macrocephalus)	3	3	2	7	5	8	2	14	11	13	15	83
Cuvier's beaked whale (Ziphius cavirostris)	2	2	3	8	3	10	12	6	8	12	9	75
Risso's dolphin (Grampus griseus)	1	2	1	2	1	5	4	6	10	3	9	44
Northern bottlenose whale (Hyperoodon ampullatus)	10	2	3		2	1	1		5	8	1	33
Killer whale (Orcinus orca)	1		1	1		2	4	2	11	9	13	44
Sowerby's beaked whale (Mesoplodon bidens)		1		1	1	6	1	1	1	2	2	16
Atlantic white-sided dolphin (Lagenorhynchus acutus)	1	1				2	1	1	2	6		14
Sei whale (Balaenoptera borealis)		1			1		2	2	6		5	17
Blue whale (Balaenoptera musculus)							3	4	3	1	13	24
Beluga (Delphinapterus leucas)							6			3	2	11
Short-finned pilot whale (Globicephala macroorhynchus)										3	2	5
True's beaked whale (Mesoplodon mirus)		1								1		2
False killer whale (Pseudorca crassidens)	1											1
Bryde's whale (*Balaenoptera brydei*)											1	1
Total no. of encounters/No. of cetacean species	**150** 15	**200** 16	**243** 14	**218** 13	**249** 14	**527** 16	**490** 19	**708** 17	**804** 18	**751** 20	**1168** 20	**5508**
Number of surveys per year	19	25	27	28	25	39	43	46	64	64	71	**451**
Average no. of encounters per survey	8	8	9	8	10	14	11	15	13	12	16	**12**

Table 3 Number of encounters for all cetacean species seen in all sea regions split by year, with the total number of species (green), number of encounters for 2016 (red).

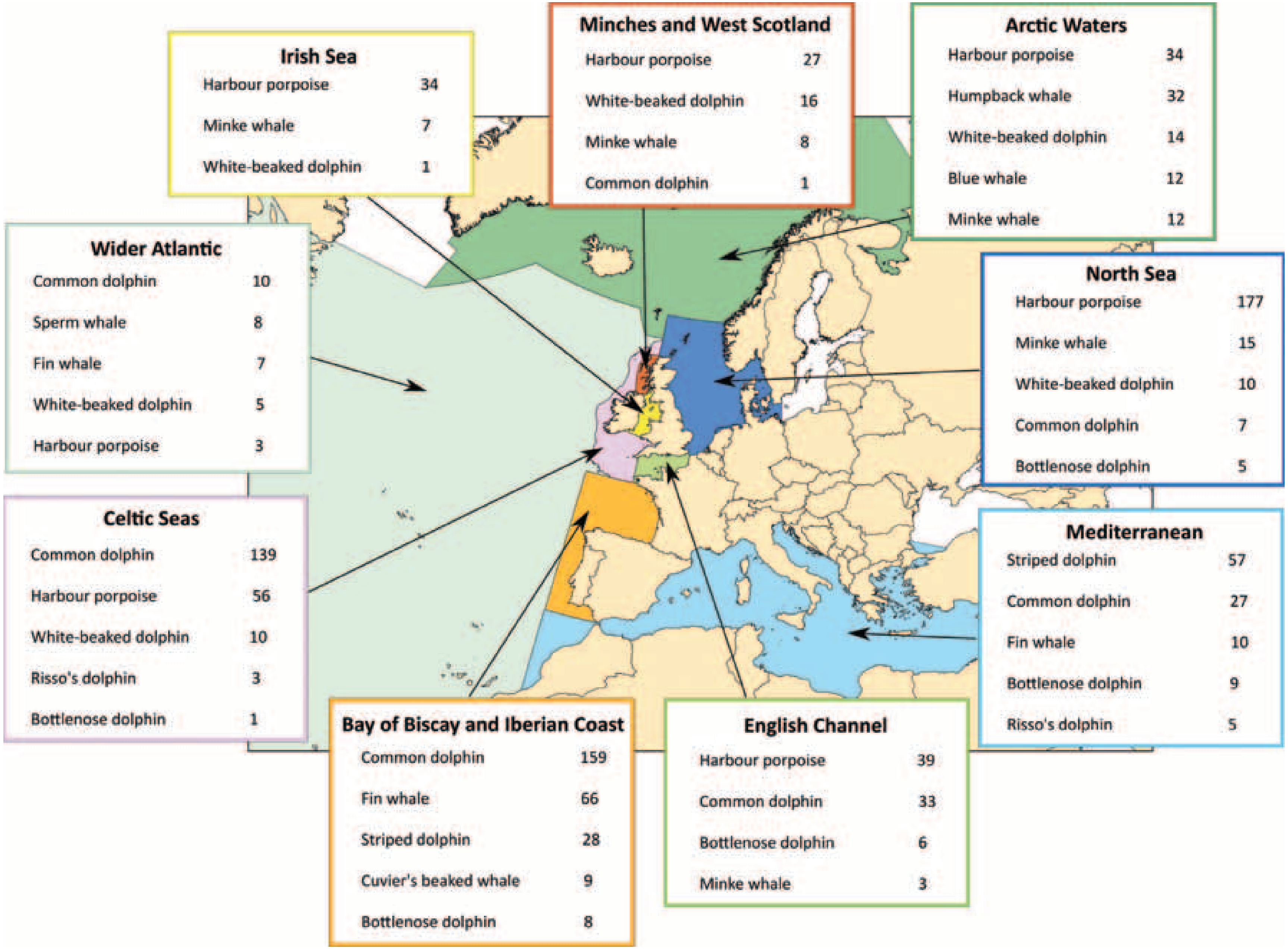


Figure 7 Map of ORCA sea regions with the number of encounters for the most frequently seen cetacean species

Sightings by ferry route

There have been 450 encounters of cetaceans on ferry surveys, consisting of 1,784 individuals (Table 4). The harbour porpoise was the most commonly seen species with 219 encounters followed by the common dolphin (159 encounters). 2016 signalled the first sighting of bottlenose dolphins on the Portsmouth to Caen route (Figure 8) and despite reduced effort in the North Sea there were greater number of harbour porpoise, minke whale and common dolphin sightings than in previous years. Despite 2016 seeing the largest number of surveys ever undertaken on the Heysham to Douglas route, only harbour porpoise and minke whale were seen. The only sightings of Risso's dolphins and humpback whales on ferry routes in 2016 occurred on the Penzance to St Mary's route.

Species	AbLw	DvCl	HwEb	HsPd		ImGoBvIm	NcBg	NsId		PlRc		PlSt	PlStPm		PmCa		PzSm		Total no. of encounters
Harbour porpoise *(Phocoena phocoena)*	[illegible]	[illegible]	169	20	[illegible]	11	142	343	[illegible]	7	[illegible]	50	110	[illegible]	6	[illegible]	198	[illegible]	1275
Common dolphin *(Delphinus delphis)*	[illegible]		2	1			5	8	[illegible]	29	[illegible]	115	545	[illegible]	1	[illegible]	218	[illegible]	1083
Fin whale *(Balaenoptera physalus)*								1				84	94	[illegible]					204
Bottlenose dolphin *(Tursiops truncatus)*	[illegible]		3	1		2	10	9	1	2	[illegible]	23	51	[illegible]		[illegible]	12	1	127
Striped dolphin *(Stenella coeruleoalba)*								1				10	89	[illegible]					105
Minke whale *(Balaenoptera acutorostrata)*			2	1	1	1	15	31	[illegible]	2	[illegible]	5	19				22		104
White-beaked dolphin *(Lagenorhynchus albirostris)*			3			2	16	52	[illegible]										81
Cuvier's beaked whale *(Ziphius cavirostris)*												7	59	[illegible]					75
Long-finned pilot whale *(Globicephala melas)*												22	19				2		43
Sperm whale *(Physeter macrocephalus)*												8	29						37
Risso's dolphin *(Grampus griseus)*								1					10				11	[illegible]	24
Sowerby's beaked whale *(Mesoplodon bidens)*												1	9						10
Northern bottlenose whale *(Hyperoodon ampullatus)*												5	3						8
Killer whale *(Orcinus orca)*			1			1	1						2	1				1	7
Humpback whale *(Megaptera novaeangliae)*							1						4					1	6
Sei whale *(Balaenoptera borealis)*												1	2						3
Atlantic white-sided dolphin *(Lagenorhynchus acutus)*							2	1											3
False killer whale *(Pseudorca crassidens)*												1							1
True's beaked whale *(Mesoplodon mirus)*												1							1
Total no. of encounters 2016	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]		[illegible]		[illegible]		[illegible]
Total no. of encounters 2006-2015	**0***	**0***	**180**	**23**		**17**	**192**	**447**		**40**		**333**	**1045**		**7**		**463**		**2747**
Total no. of encounters 2006-2016	26	10	180	41		17	192	547		58		333	1163		25		605		3197

Table 4 Number of sightings for all cetacean species in split by ferry route. Total number of encounters (green), Number of encounters in 2016 (red).

Humpback whale

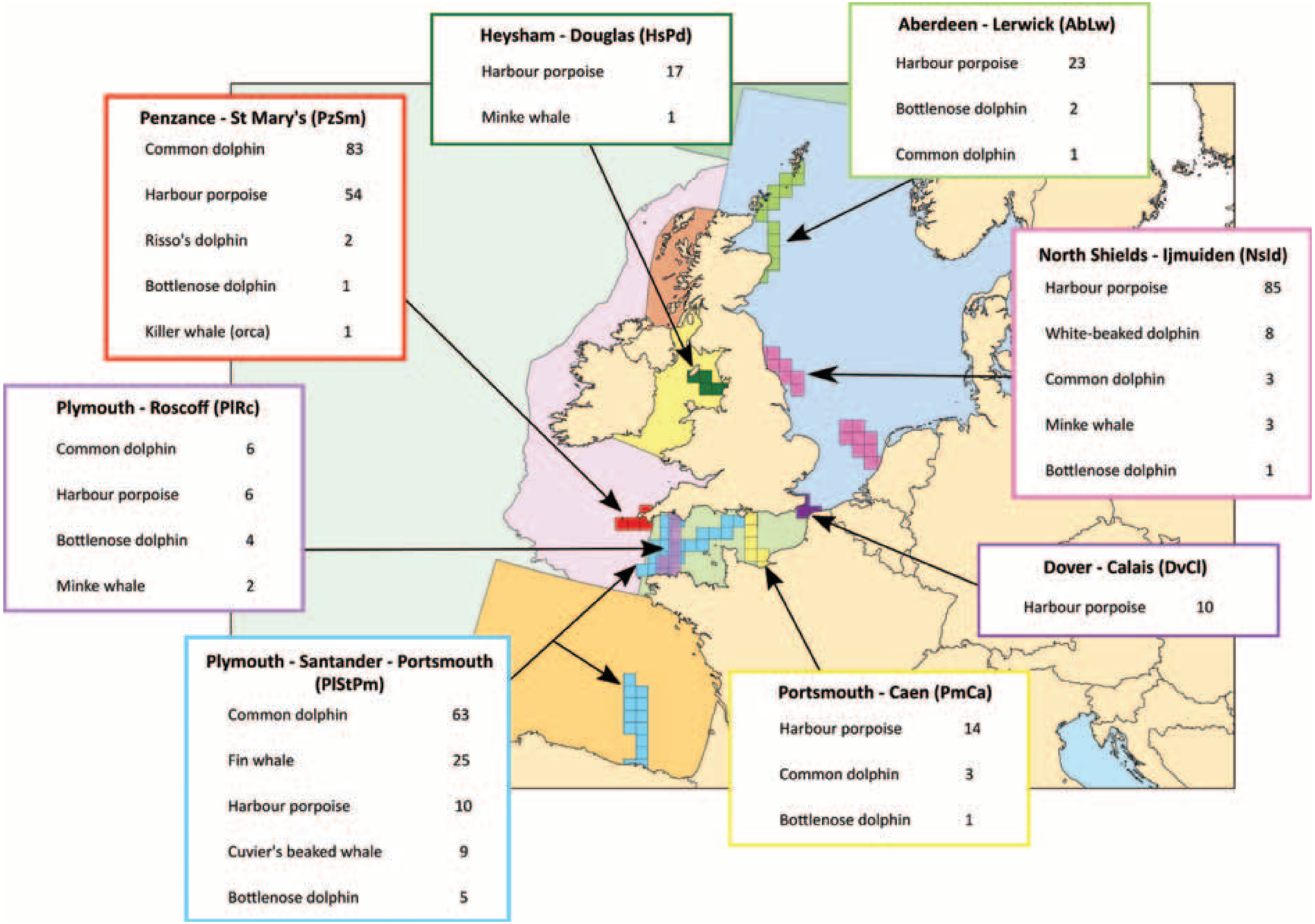


Figure 8 Map of ferry routes surveyed with the number of encounters for the most frequently seen cetacean species.

ORCA cetacean sightings 2016
(whales, dolphins and porpoises)

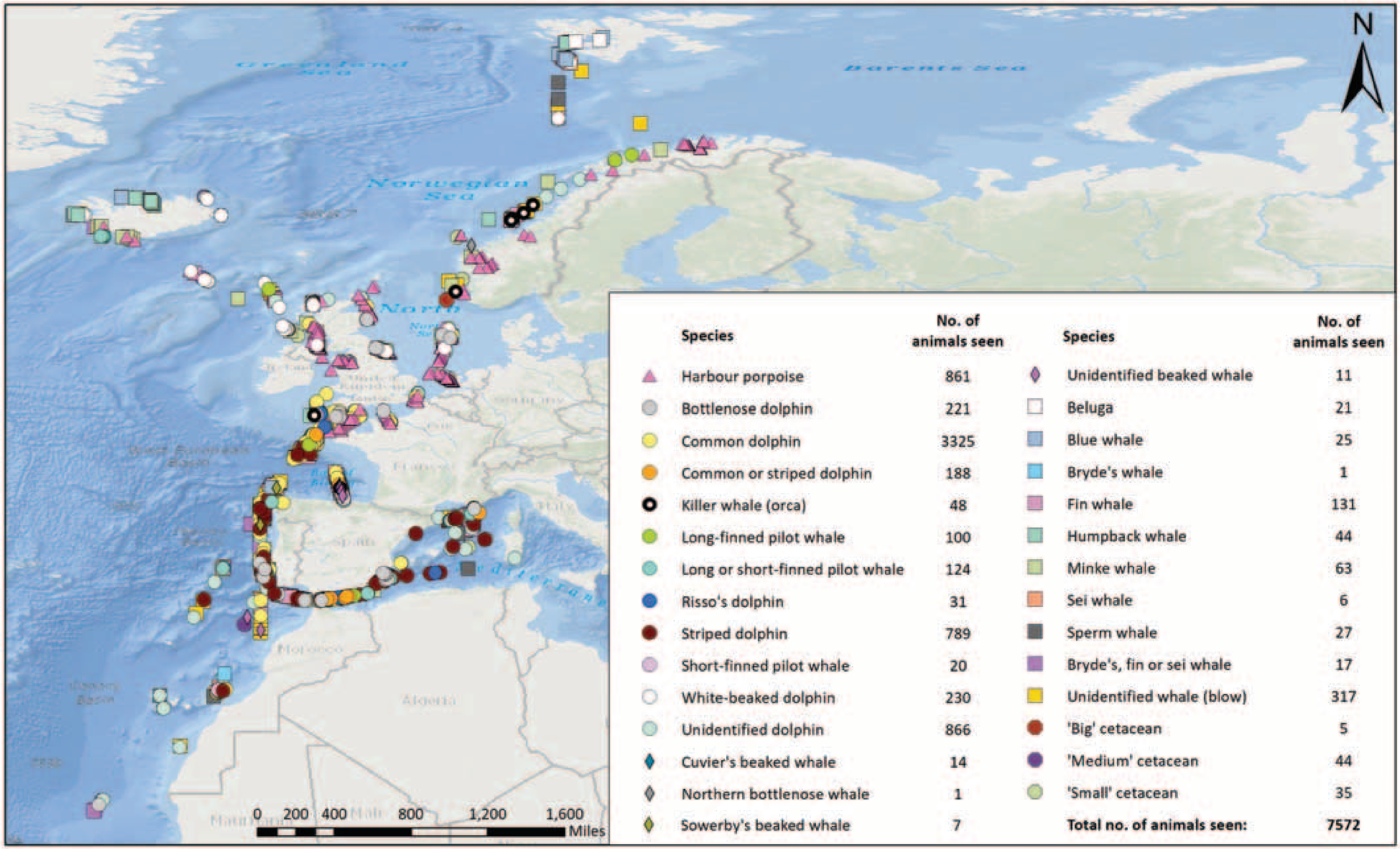


Figure 9 Cetacean species map of all ferry and cruise routes undertaken in 2016.

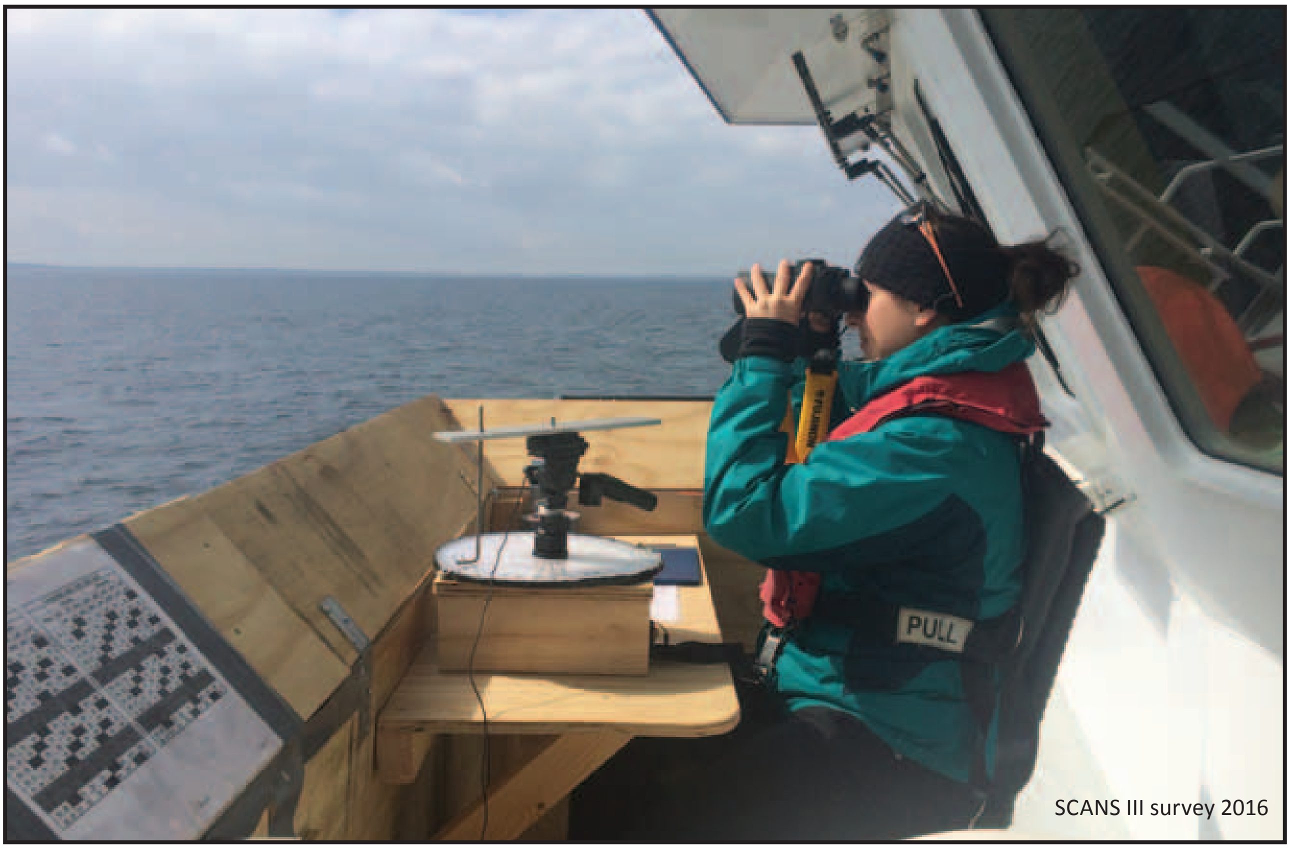
www.orcaweb.org.uk

COMMON DOLPHIN POPULATION ANALYSES AND THE APPLICATION OF ORCA'S CITIZEN SCIENCE

Common dolphins

Marine legislation is becoming ever more complex with large, long-term data sets essential to support evidence-based policy making (Hyder, 2015). In a world of growing concerns about human's impact on the environment and financial constraints on research, the use of citizen science is of particular importance as a cost-effective model to collect long-term data.

Citizen science is a term that refers to members of the public who volunteer as field assistants in scientific studies. These volunteers have no formal scientific training and come from all walks of life. Intensive training enables these enthusiasts to participate in the collection of scientific data in the field. ORCA have been utilising citizen scientists for over a decade to monitor cetacean populations in UK & European waters.



SCANS III survey 2016

This year ORCA collaborated with Plymouth University to explore how ORCA's citizen science can complement traditional or large-scale monitoring projects, such as the *Small Cetaceans in European Atlantic waters and the North Sea (SCANS)* survey. These large-scale, dedicated monitoring projects are extremely costly, and typically provide a snapshot of cetacean abundance. SCANS, for example, only occurs for one month every ten years across Europe, with the most recent one having been undertaken in 2016.

Complementing these large-scale monitoring projects with regular surveys through the year, such as those conducted by ORCA, could highlight emerging threats earlier and allow conservation management plans to be implemented sooner. For example, 2017 has seen increasing concern over the high levels of strandings of short-beaked common dolphin in the waters to the southwest of the UK, highlighting the need for 'near real-time' information. Using the 2006-2016 ORCA dataset for the short-beaked common dolphin in three sea regions (English Channel, Bay of Biscay and Celtic Seas), analysis was undertaken to establish a baseline for common dolphin density estimates, allowing us to better understand how the impact of bycatch is affecting common dolphin numbers within these regions. It also enables us in future years to assess the 'real time' impact bycatch is having on the populations that we are observing along these ferry and cruise routes.

Purpose-designed surveys vs opportunistic surveys

Purpose-designed surveys, such as those used by SCANS, provide abundance and density of surveyed animals within a given area, often using parallel or zig-zag lines to provide an even coverage of the study area. These surveys are expensive and time-consuming, typically using dedicated ships and aircraft to survey large areas, as well as utilising scientists who have knowledge of this field of study (Hammond *et al*., 2013, 2017).

ORCA's data is suitable for model-based analysis due to the opportunistic nature of ferry and cruise routes, which travel the same routes, day by day, year by year. Therefore, the trends and results obtained by ORCA's rich dataset cannot be extrapolated to the surrounding area that was not surveyed, as the routes are not likely to be representative of the whole area or population. However, ORCA's wealth of data, which spans eight months of the year for over a decade, might be used alongside purpose-designed snapshot surveys like SCANS.

Methodology

Field methodology

ORCA train and deploy citizen scientists (ORCA Marine Mammal Surveyors) on ferries and cruise ships, ('platforms of opportunity'), to record cetacean sightings data along well-travelled routes. The route is a fixed transect and surveyors cannot influence the route. Effort data is collected in the form of GPS co-ordinates of the route and of any sightings, observer names, vessel speed, observer platform height, and environmental conditions including sea state, visibility, and swell height. When a sighting is made, additional data is recorded, which includes species identification and estimated group size. The radial distance between observer and animal is also estimated by eye with the help of a binocular mounted reticle, whilst angle to the sighting is read from an angle board.

Data Analysis – detection function

Data from three ferry routes (Portsmouth – Santander, Portsmouth – Santander – Plymouth and Penzance – St Mary's), which cross the English Channel, Bay of Biscay and Celtic Seas, was combined for the analysis. Sightings in visibility less than 2km were omitted from the analysis as animals were not likely to be detected in these conditions. Sightings without a reticle distance were also omitted as exploratory analysis showed a large variance between estimated distance and distance calculated from reticle readings. Distances calculated from reticle readings were therefore deemed to be more accurate.


Common dolphin

The perpendicular distances (distance from the survey line to animal) were calculated using the radial distance and angle. Distances were then converted into 'bins' – for example, sightings in the 0-268m range were in the first bin, etc. A 'detection function' was created in the 'Distance' (Miller, 2017) and 'DSM' (Miller *et al.*, 2017) packages for R; a statistical computing program (R Core Team, 2017), which calculated the estimated probability of detection at different distances (Buckland *et al.*, 2015) as it is increasingly unlikely to spot cetaceans at greater distances. This function was used to calculate the effective strip width (ESW: the distance from the transect line that observers see as many animals beyond it as are missed within it) (Figure 10). This probability of detection was used to estimate the abundance on the travelled line, accounting for the estimated number of animals that were missed. One of the assumptions of the detection function is that all animals directly on the transect line are detected and recorded. As common dolphins are easily visible and typically travel in relatively large groups, displaying demonstrative surface behaviours with short dive times we can assume this to be true, or close enough to true to have had little influence on results (Hammond *et al.*, 2002; Canadas & Hammond, 2008, and Becker *et al.*, 2010).

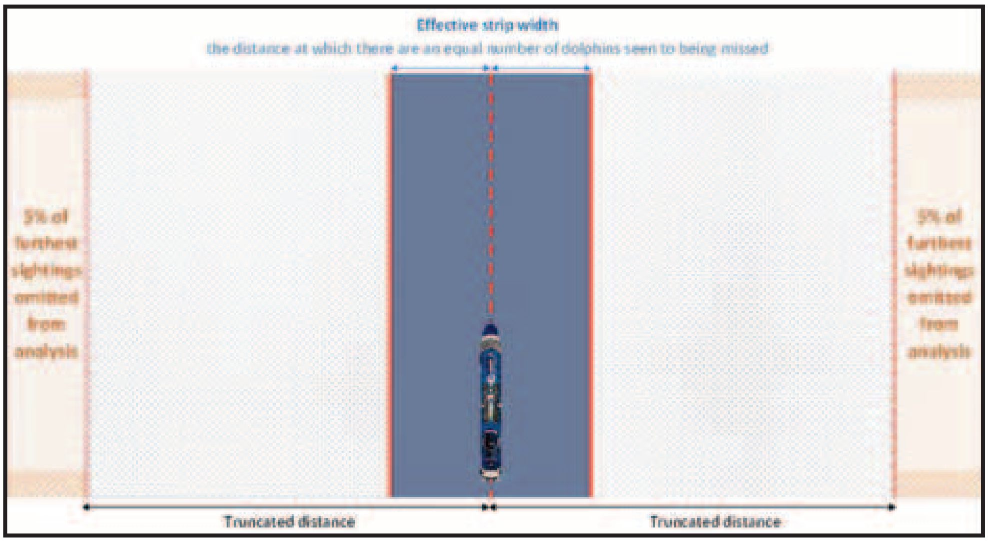


Figure 10 A diagram to show the effective strip width of the ships transect line.

Many detection model function variations were run, and the best model was selected following methods from Buckland (*et al.*, 2015). The estimated strip width was calculated using the following formula (The 'estimated probability of detection' is the overall probability determined from calculating the area under the curve of the detection function. The 'truncation distance' is the distance from the survey line from which sightings were seen, minus the furthest 5% of sightings as it is standard procedure to remove sightings at the greatest distances):

ESW = truncation distance x estimated probability of detection

Data Analysis – abundance estimation

In this study a Density Surface Model (DSM) was used. These are complex models that use spatial and environmental co-variates that may explain species distribution (e.g. depth, sea surface temperature, ocean fronts, or distance to continental shelf) to give a better estimate of abundance. For this study, due to time limitations and available environmental co-variates, depth and spatial coordinates were the only variables used to model distribution and abundance of common dolphins. The transects were split into approximately equal distances of 1,400m segments using ArcGIS 10.4 (ESRI, 2016). Each segment was assigned to a sea region and then buffered to have a width equal to the truncation distance (1,250m), creating a rectangle of effort represented in the detection function.

Depth (at mean tide height) was obtained from an online bathymetry database at a resolution of 463m2 (EMODNET Bathymetry Consortium, 2016). This was paired with the transect segments, which were imported into R. Each segment was associated with the number of sightings that occurred across its length and then the probability of detection, calculated in the detection function, was applied to each segment. This resulted in the estimated abundance per segment.

Common dolphin

Generalised Additive Models (GAMs) were used to model the spatial abundance of common dolphins to create DSMs. One-way thin plate regression smooths and two-way tensor smooths were used to model abundance with the spatial co-variates, with a one-way smooth of depth, and a two-way smooth of latitude and longitude using 'mgcv' library in R (Wood, 2006) also applied. Models were compared between those based on a negative binomial distribution and a Tweedie distribution, and the number of allowed knots in the smooth (k) was varied to investigate the best model fit. The best model was chosen using standardized model selection parameters (Wood, 2006).

Abundance was estimated with the best fit model by creating a prediction grid over the truncated visual sightings range on either side of the transect line. Abundance was estimated using a standard statistical technique (Borchers *et al.*, 1998; Hammond *et al.*, 2017), a Horvitz-Thompson-like estimator, and was queried for each region (English Channel, Bay of Biscay, Celtic Sea), with month and year queried separately. The coefficient of variance (CV) was calculated for each abundance estimate. This is a measure of uncertainty around the estimate, with low values showing high confidence in the estimate, and high values showing less certainty. An estimate of density was calculated using the following equation:

$$\text{Density km}^2 = \frac{\text{Abundance}}{\text{Kilometres of effort}}$$

Density, instead of abundance, should be used to compare results between regions and with other studies, as it takes into account the amount of effort undertaken. Abundance has only been reported for a subset of years and months where effort is comparable.

Results

In total 61,887km of effort data was used from the 11 years of data provided from the three ferry routes. Along these survey routes there were 862 sightings of common dolphins which ranged in group size from 1-1,000 individuals, with group sizes being similar between all three regions studied. The estimated abundance for common dolphins along all survey routes (no. of dolphins likely to be on the survey routes) for all years combined was 15,027 animals (Confidence interval (CI): 12,320 – 17,734), with the yearly average being estimated at 1,503 individuals (CI: 1,233 – 1,773).

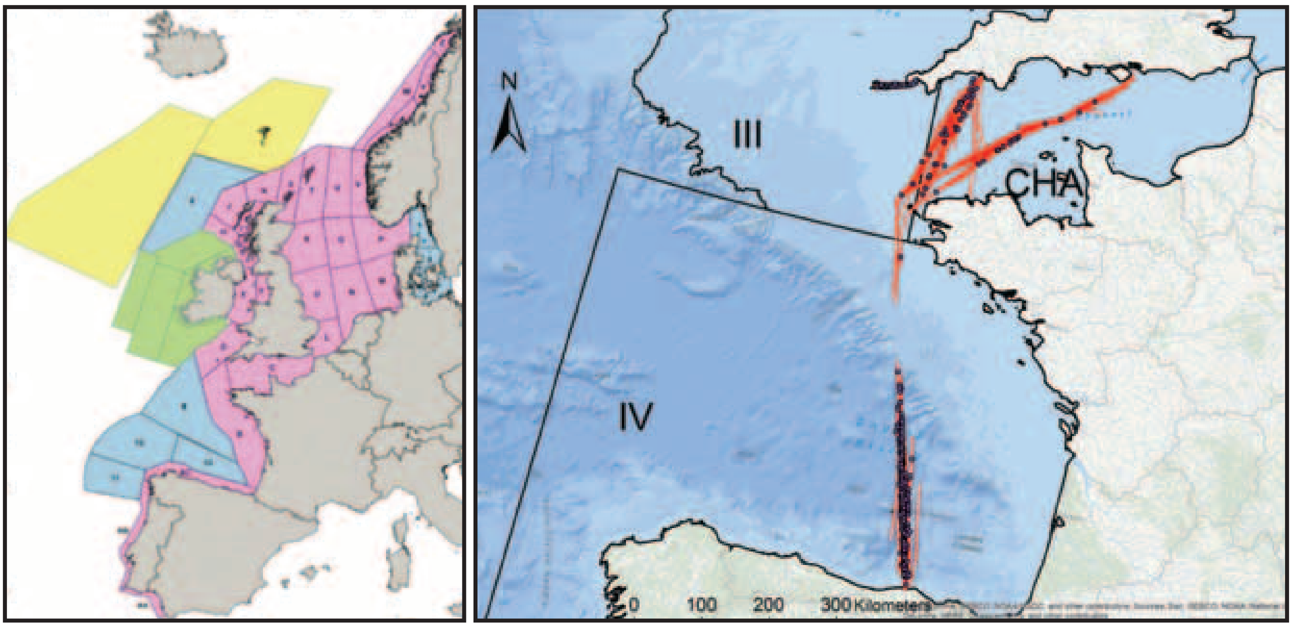


Figure 11 SCANS survey area (left), ORCA survey area (right).

This study estimated the highest abundance of common dolphins along the ferry routes in the Bay of Biscay with an average abundance of 970 animals per year (CI: 830 – 1,135), followed by the Celtic Sea with an average abundance of 414 animals per year (CI: 335 – 510), and the lowest average abundance was found in the English Channel with 119 animals estimated per year (CI: 91 – 154). These are considerably lower than that of the SCANS-III surveys undertaken in July 2016. This could in part be due to the wider survey area that SCANS undertook (Figure 11), suggesting that areas outside of the ferry routes may have higher densities of common dolphins. Previous research conducted by ORCA has shown that common dolphins have a preferred habitat on the outskirts of the Bay of Biscay, with higher numbers being sighted in this region despite there being reduced effort here (Figure 12) (ORCA, 2016). This therefore supports the theory that areas outside of the ferry route may have higher densities of common dolphins.

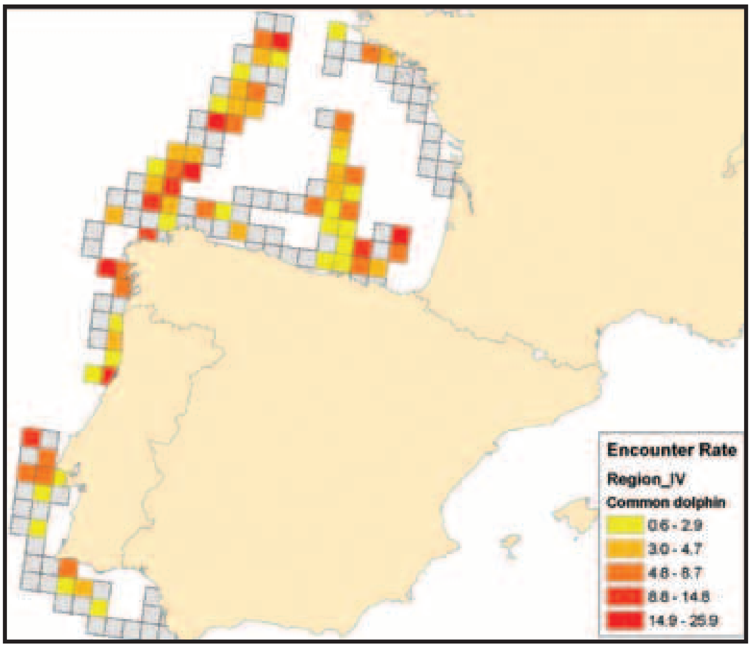


Figure 12 Encounter rate for the common dolphin within the Bay of Biscay and Iberian Coast.

Bay of Biscay

As density estimates take into account the amount of effort undertaken, these estimates were used to compare the three sea regions with SCANS. Overall, within the Bay of Biscay 25,780km of effort data was used and there were 538 sightings. During the 11-year survey period it was estimated that 9,704 animals (CI: 8,297 – 11,351) were present on the survey route through the Bay, with an estimated density of 0.38 animals per km2 (CI: 0.32 – 0.44). This density estimate is considerably lower than that of 0.784 animals per km2 (CI: 0.45 – 1.26) from the SCANS-III survey. However, ORCA's confidence interval is much smaller due to the large amount of effort and repeat visits to the area over the 11-year time span. No temporal trends were found in the subset data despite peaks in density in 2008, 2012 and 2015 (Figure 13). However, these are unlikely to be statistically significant due to the wide confidence intervals.

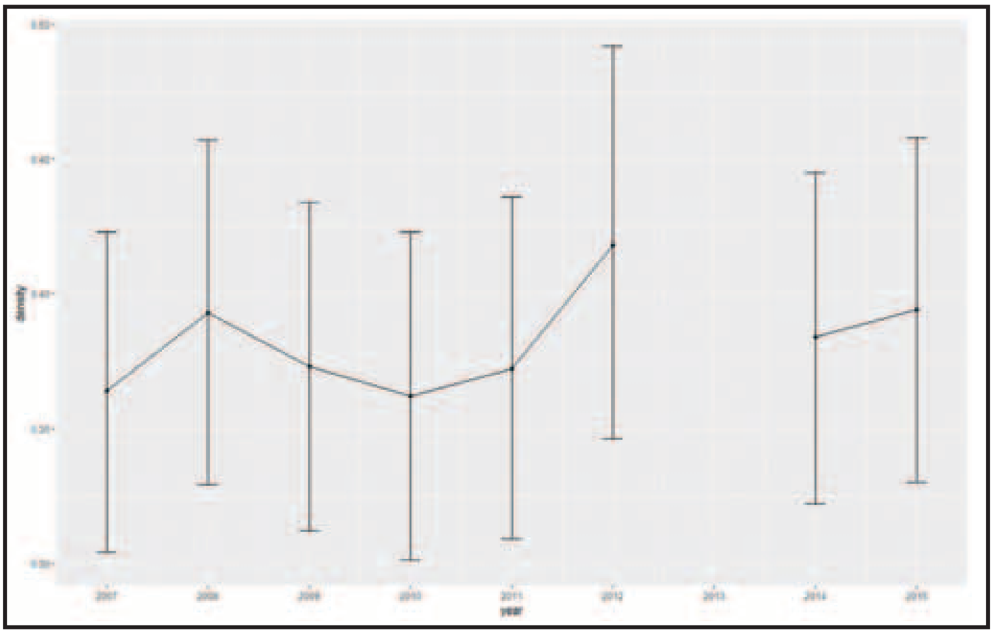


Figure 13 Density of common dolphins (per km2) in the Bay of Biscay, in April - July, 2007-2012, 2014 and 2015. Points represent the mean estimated density, with error bars showing 95% confidence intervals.

Celtic Seas

Despite ORCA's survey area in the Celtic Seas being much smaller than that of SCANS-III the density estimates from both are relatively similar with 0.33 (CI: 0.27 – 0.41) and 0.37 (CI: 0.09 – 0.68) animals per km2 respectively. When looking at ORCA's data as a whole (not related to effort), there appears to be a peak of sightings occurring in the month of October (Figure 14). When looking at densities across the years there appears to be a slight increase in the density of common dolphins in the Celtic Seas since 2012 (Figure 14), but due to the wide confidence intervals this is unlikely to be statistically significant.

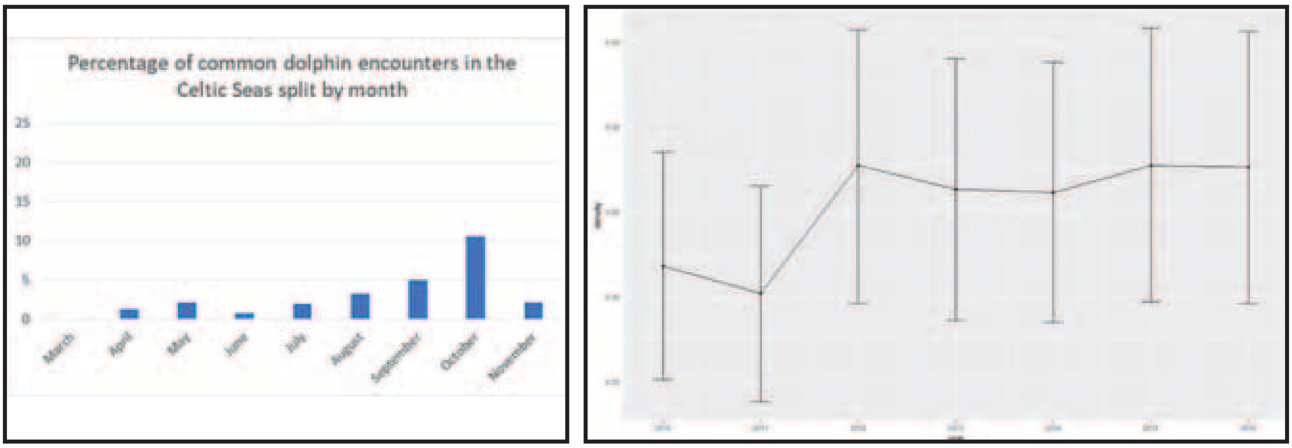


Figure 14 Percentage of common dolphin encounters in the Celtic Sea split by month (left). Common dolphin density (km2) in the Celtic Sea between April and September 2010-2016. Points represent the mean estimated density, with error bars showing 95% confidence intervals (right).

English Channel

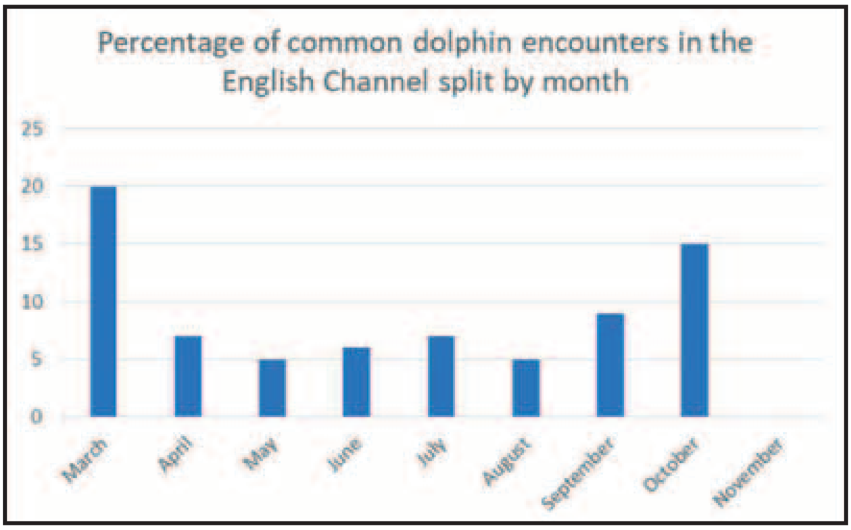


Figure 15 Percentage of common dolphin encounters in the English Channel split by month.

SCANS-III did not find any common dolphins within the English Channel, so although ORCA's density estimate is small it could be due to the dolphins being present in months other than those targeted by SCANS. The small number of sightings that ORCA have had over the 11-year period can easily be missed during 'snapshot' surveys like SCANS., ORCA's data from these 11 years also show that March and October demonstrated the highest number of common dolphin sightings (Figure 15), suggesting that this area may be a winter habitat for common dolphins. Work conducted by De Boer *et al.*, (2008) and Macleod, Brereton and Martin (2009) have also reported this. More survey effort by ORCA in the winter months may help to investigate this further in the future. The increased likelihood of missing occasional occurrences such as these common dolphins in the English Channel by surveys like SCANS is offset by the comprehensive survey design, targeting a large survey area. In comparison, ORCA and other long-term citizen science datasets are more likely to detect long-term trends and occasional occurrences, but are limited to a smaller area and a survey design which constrains estimates to the specific area covered. This highlights the importance of long-term datasets such as ORCA's in complementing purpose-designed based surveys like SCANS.

Discussion

Both the SCANS-III survey in 2016 and ORCA's long-term dataset show that common dolphin numbers across the three sea regions are relatively stable (Hammond *et al.*, 2017). This highlights how citizen scientists using platforms of opportunity can gather longer term trends within smaller areas, and help to display trends between months and years that may not be apparent from single surveys. ORCA's data could therefore help inform survey design to take temporal trends into account, targeting months with peak abundances. This study has shown that additional data and alternative methodologies such as those from ORCA are important in complementing designed surveys.

A key conservation concern is the number of short-beaked common dolphin strandings occurring along the coastlines of northwest Europe, which is believed to be linked to fisheries bycatch (Peltier *et al.*, 2017). In 2017 there has been a sudden increase in common dolphin strandings, particularly in the northern part of the Bay of Biscay (Peltier *et al.*, 2016, Peltier *et al.*, 2017). Any accurate data on the spatial use and abundance estimates of common dolphins in this area may help to explain the cause of these strandings and inform management strategies to reduce the incidence of future strandings. This is something ORCA intends to continue investigating in the coming years.

Most importantly this study has demonstrated how citizen science data collected by ORCA can help provide density estimates and relative abundances of common dolphins along their survey routes. In turn, this can be used for monitoring long-term trends. The numbers reported here are expected to be accurate within acceptable limits to allow comparisons with those of SCANS-III and other purpose-designed surveys. Abundance estimates of common dolphins exhibit similar broad spatial trends to that of SCANS-III, with the Bay of Biscay shown as a hotspot for these animals. This study has shown that ORCA's dataset has the potential to inform managers and conservation bodies on annual trends of cetacean species across several regions.

Common dolphin

THREATS TO CETACEANS

Our oceans are facing significant threats as a result of modern society and the relationship we have with our marine spaces. Damage caused by fishing practices to pollutants and whaling to ship strike are devastating the unique wildlife in our waters, and urgent action is needed if we are to safeguard the stunning biodiversity we enjoy for future generations.

Cetaceans are facing many of these threats across Europe and beyond. Where some populations are known to be stable or increasing, even more are in as precarious a position as ever.

This section outlines just a few of the human-induced threats facing cetaceans today, including bycatch, ship strike, commercial whaling, marine pollution and strandings. It is imperative that policymakers act quickly to reduce the vast and unchecked damage centuries of industrialisation have inflicted on the marine environment. ORCA knows that addressing these persistent threats requires real-time, long-term monitoring programmes. The time has come for governments to take responsibility and play their part in protecting our oceans.

Minke whale *Credit: CSIP-ZSL*

Bycatch in UK and European waters

Contributor: Sarah Dolman – Whale and Dolphin Conservation

Thousands of marine mammals are accidentally caught in fishing gear and die in UK and European waters each year. This is normally referred to as 'bycatch'. Despite being protected under European law and the UK having a national cetacean bycatch strategy, this has been an ongoing issue for decades. Many more die in the fishing gear of other nations fishing in UK waters and more again in European waters outside of the UK. Currently there are still no robust estimates for total bycatch in UK waters, including the English Channel and North Sea.

The diversity of odontocete (or toothed cetaceans) species that have been reported as being bycaught in gear in UK waters include harbour porpoise, common dolphin, striped dolphin, bottlenose dolphin, white-beaked dolphin, Atlantic white-sided dolphin, Risso's dolphin and pilot whale. Baleen whale species include minke and humpback whales (Deaville & Jepson, 2011). Of these, the species that are most commonly victims of bycatch are harbour porpoise and common dolphin. Each species is affected differently depending on the type of fishery and the area being fished.

Whale entanglements

Both minke whales and humpback whales come into UK waters to feed and both can become entangled in static creel fishing ropes, particularly in Scottish waters. Creel fishing involves the use of a string of baited pots, left in the water for a period of time. These are connected with a rope and each end of the rope is floated to the surface with a buoy. Thousands of creel sets are deployed around the UK coastline. As the whale glides through the water column with their mouth open to catch prey, they appear to accidentally take the rope (either the line to the surface or the rope between the pots) into their mouth. This is where most entanglements seem to start. They then often get increasingly entangled around their pectoral fins, body and tail stock. At up to 18 metres long, humpback whales are large (and strong) animals and will carry the gear away with them. In 2017 a humpback whale became entangled in the ropes of lobster pots off the Cornish coastline on two separate occasions. In both instances the whale had be to cut free by the British Divers Marine Life Rescue. Highlighting concerns that with more baleen whales entering coastal waters around the UK, the risk of bycatch in whales is increasing significantly.

Humpback whale entanglement *Credit: Elding Whalewatching*

At a maximum length of 10 meters, minke whales are smaller. Once entangled, they have less strength and weight behind them to pick up and tow the fishing gear. As a result, minke whales tend to get anchored and may be more likely to suffocate by drowning. Of the minke whales stranded and necropsied by the Scottish Marine Animal Stranding Scheme (SMASS), around half have shown signs of entanglement.

Entangled minke whale *Credit: CSIP-ZSL*

Globally, more than 1,700 large whale entanglements have been reported since 1979 (IWC, 2010), although it is recognised that entanglement reporting is grossly underestimated. One study estimates that fewer than 10% of active entanglement cases are reported (Robbins *et al*., 2009). The majority of fisheries are not monitored for entanglements and reporting levels are known to be low.

The US Marine Mammal Protection Act (MMPA) contains some of the most stringent management measures in the world to deal with whale entanglements, particularly as this is a primary cause of death in endangered North Atlantic right whales. However, even in the US, management measures put in place to date have generally been ineffective (Pace, Cole & Henry, 2014).

Entanglements can impair foraging abilities leading to starvation, result in physical injuries including haemorrhaging and severe tissue damage, and cause extreme pain for protracted periods of time. Entanglements are a concern for the welfare of individuals as well as a serious conservation concern. Yet, there remains no quantitative assessment and comparison of the scale of mortality and welfare implications of entangled whales. The international concern and media profile surrounding a live whale entanglement clearly demonstrates a high level of public concern for the welfare of individual whales.

Harbour Porpoises

Static or 'set' nets, such as gillnets, are recognised as a particular threat to many marine mammal species globally. In UK and European waters, static nets are an issue for the smallest of the UK's cetaceans, the harbour porpoise. Fishermen set and then leave these types of nets stationary in the water column to catch passing fish. Porpoises (along with other marine species) are accidentally caught, and subsequently drown. The nets, which range from 70 meters to several kilometres long, hang in the water and can be set for periods of hours or days depending on the target species of the fishery.

The latest UK report to the EU estimated that 1,200 - 1,500 porpoises were bycaught in UK fishing nets in 2015 (Northridge, Kingston & Thomas, 2016). Currently, almost all of the EU gillnet fisheries in the North Sea are conducted without bycatch monitoring programmes. There are no requirements for small vessels (under 12 meters) to mitigate, monitor and report marine animals that get caught in nets. In fact, only 27 of the UK's fleet of 6,000 vessels were required to use pingers (acoustic deterrent devices) to reduce bycatch in 2015 (Northridge, Kingston & Thomas, 2016). A preliminary assessment of overall harbour porpoise bycatch rates by the International Council for the Exploration of the Sea (ICES) (2014) noted that in the North Sea bycatch rates of some fisheries may be above any proposed 'reference limits', and are therefore expected to have population level effects.

Harbour porpoise *Credit: CSIP-ZSL*

Common Dolphins

Common dolphin deaths in fishing gear occur predominantly in the English Channel and have been occurring in this region for decades. As a result, the south and the southwest coast of England are one of a number of European hot spots for common dolphin strandings. 2017 has been a particularly bad year, with more than 150 dolphins stranding during the 2016/2017 winter in the southwest alone. Of those necropsied, approximately the same number have been caught in fishing gear as in previous years, but a large proportion of animals have stranded in a condition that is too decomposed for any assessment to be undertaken, meaning cause of death remains unknown. Common dolphins are caught in very high numbers in UK waters by both our own fleets and other fleets, including French vessels. For every dolphin that is observed bycaught on board a fishing vessel, data from strandings tells us that approximately ten more have died (Peltier *et al*., 2016). This may be even higher when we consider that many bycaught animals may not end up as strandings and therefore will go undetected.

A Defra (Department for Environment, Food and Rural Affairs) report estimates that 285 common dolphins were caught in UK gillnets alone in 2016, a similar number to previous years (Northridge, Kingston & Thomas, 2016). No estimates are available for the number of dolphins accidentally caught in trawlers.

In the Bay of Biscay and English Channel, common dolphin bycatch is mostly reported in trawl fisheries targeting sea bass or albacore tuna. The greatest threat comes from pelagic trawls and particularly pair-trawls, where a net approximately as wide as a football pitch and higher than a three-storey house is dragged through the water between two fishing vessels to catch schooling fish. Dolphins sometimes swim into the nets to feed on the catch and become trapped, or are caught as the net is hauled. Because they can't get to the surface to breathe, they suffocate and die.

As data is limited, there is a lack of confidence in the numbers of deaths that are reported. The number of stranded dolphins alone indicates real figures are likely to be far higher, particularly for common dolphins that die in large numbers in the southwest of the UK each year.

Despite the number of common dolphin deaths being high for decades, the number of dolphins stranded in France in 2017 is unprecedented; 700 – 800 individuals stranded between February and March 2017 (Peltier *et al*., 2017). Post-mortem analysis demonstrates that bycatch accounted for around 80% of the deaths of those stranded in France. Peltier *et al*. (2017) suggests that thousands have died in fishing gear again this year, continuing the trend established in the previous two decades.

Strandings data also reveals that the number of dolphins dying in fishing gear is 'one order of magnitude higher' than the figures produced by the existing EU bycatch observer programme (Peltier *et al*., 2012). This programme aims to ensure that Member States monitor bycatch levels and implement measures to reduce deaths. This analysis adds to previous evidence that the existing EU bycatch monitoring and mitigation programme (Regulation 812/2004) is not fit for purpose and fails to prevent the deaths of many thousands of dolphins, porpoises and whales throughout European waters.


Common dolphin

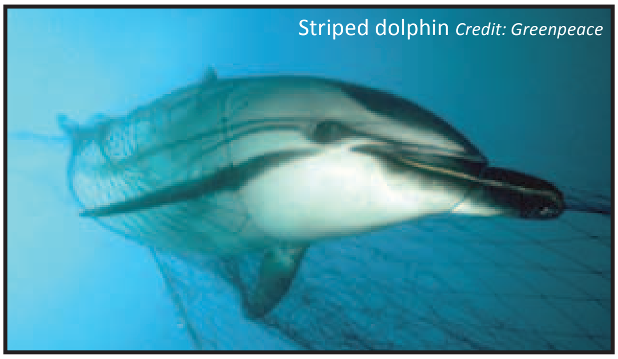
What the future holds

Despite the large-scale threat posed by bycatch, few solutions are being employed to reduce the death toll. We need to urgently use all effective solutions available, particularly where scientists have shown that bycatch levels may be having a population level effect, such as for common dolphins around the southwest coast of the UK.

There are ways to minimise unintended mortality and mitigate welfare impacts by avoiding areas where endangered or vulnerable species or small populations are known to be present. Furthermore, ongoing enforcement of monitoring and mitigation can be used to determine quantitative metrics and to improve compliance. Various measures can be applied, including spatial measures (such as moving away from areas where dolphins are encountered) and the use of pingers to deter dolphins from the fishing gear.

Different management approaches will be required for different fisheries, taking into account regional differences in species composition, types of fisheries present and the density and spatial distribution of cetaceans. The UK fleet is mostly made up of small vessels, yet small vessels have few obligations to report, which means we have very little geospatial data on fishing activities, and minimal understanding of which marine species are being accidentally caught in nets.

The lack of ongoing reporting on-board commercial fishing vessels re-emphasises the vital role of ORCA's long-term monitoring of common dolphins, particularly in the southwest of England and through the Bay of Biscay. Comparing the 2017 ORCA common dolphin findings with the baseline that has been established through our recent analysis will highlight any negative impact bycatch has had on the common dolphin distribution and population around the Celtic Seas region.


Striped dolphin *Credit: Greenpeace*

Ship Strike

Contributors: Russell Leaper – International Fund for Animal Welfare, Jennifer Lonsdale OBE - Environmental Investigation Agency, Ruth Coxon - MSc Student: Nottingham Trent University

Whales and dolphins being struck by ships is one of the most significant threats facing cetaceans. Commercial shipping is a global activity, occurring in every ocean and it is estimated that 90% of the world's industrial goods are transported by sea. With an ever-increasing human population, it is perhaps inevitable that shipping traffic is set to rise with the consequence being that more whales and dolphins will be vulnerable to being hit by large vessels.

Cetaceans, as marine mammals, must come to the surface to breathe and, when they do, are occupying the same space on the sea surface as marine vessels. Highest mortalities are seen when high shipping traffic overlaps with high whale density hotspots or where individual whales aggregate. Worldwide, fin whales are the species most commonly reported being struck by ships (Laist *et al.*, 2001). Some of the busiest shipping lanes in the world, such as the Bay of Biscay are hotspots for cetaceans.

The International Whaling Commission (IWC) is the global regulatory body with responsibility for the conservation of cetaceans. Globally they have outlined 12 whale populations that are at heightened risk of ship strike, which includes both sperm whale and fin whale populations in the Mediterranean Sea (Cates *et al.*, 2017). The IWC recognises that reducing the spatial overlap of both high numbers of whales and high numbers of vessels is likely to remain the best means of reducing ship strikes, followed closely by implementing vessel speed reductions. The actual number of whales killed every year from being hit by ships remains unclear, but is likely to be significantly greater than the numbers that are reported (Williams & O'Hara, 2010; Rockwood *et al.*, 2017).

A baleen whale killed by ship strike

It is a global threat

High levels of mortality in blue, fin and humpback whales are being reported along the west coast of the US where shipping lanes around San Francisco are overlapping with a high density of whales. Along the west coast of Canada, lethal vessel strikes are being reported for humpback whales and fin whales, notably in the major shipping gateway of Juan de Fuca Strait (Nichol *et al.*, 2017).

Similarly, the seas around the Canary Islands provide an important area for immature female sperm whales. This archipelago reports a high number of deaths of sperm whales from ship strikes (Fais *et al.*, 2016). Off the coastline of Greece around the Hellenic Trench, major shipping routes coincide with known areas of high sperm whale density. This group of sperm whales is particularly vulnerable as it is a recognised as a sub-population and classified as endangered by the IUCN (MEPC 69/10/3). Another area of concern is around the southern tip of Sri Lanka as shipping routes across the northern Indian Ocean converge at this point, resulting in the highest open ocean densities of ship traffic globally. These routes overlap with a very high density of blue whales (Priyadarshana *et al.*, 2016).

The North Atlantic right whale is at risk of extinction from the impact of ship strikes and bycatch. What is particularly alarming is that 2017 has been a devastating year for the North Atlantic right whale population. There has been an unprecedented loss of 12 animals in 9 months, representing 2% of the estimated global population. Catastrophically, the copepods (small animals on which the whales feed) have found a new summer home in the middle of the snow crab fishery in the Gulf of St Lawrence. This Canadian fishery is the world's largest producer of snow crab and is the second most valuable fishery export product in Canada, valued at more than $400 million (Government of Canada, 2015). The right whales have followed the copepods into this high-density shipping area and the recent deaths have been attributed to ship strike and net entanglement. In previous years, the right whales' preferred summer feeding ground was near the coast of Cape Cod, US. Mandatory speed restrictions of less than 10 knots were enforced across this area (before the whales migrated further north to Canada) and during this time there were no deaths reported from ships strikes. This demonstrates how speed limits of 10 knots can be an extremely effective measure in reducing the risk of ship strike (Laist *et al.*, 2014).

North Atlantic right whale *Credit: Mark Carwardine*

Fin whale populations remain at high risk of ship strike, particularly in the Mediterranean Sea and the Bay of Biscay where high whale densities overlap with high shipping traffic. Ship strikes are a major issue in the Mediterranean, with up to 40% of the fin whales washed ashore having died from traumatic ship strike injuries (Notarbartolo di Sciara *et al.*, 2003; Panigada *et al.*, 2006).

In October 2017 a 30-ton juvenile male fin whale was brought into Sheerness Harbour in Kent on the front of a cargo vessel which had transited through the Bay of Biscay. Post-mortem results concluded that injuries to the body were consistent with being struck by a vessel.

Fin whale *Credit: MichaelJTetley*

ORCA's role in preventing this threat

The fin whale is considered endangered by the IUCN Red List of Threatened Species (Reilly *et al.*, 2013), due to a 70% population decline over the past three generations (1929-2007), (IUCN 2001).

In the European Atlantic, the fin whale population is estimated to be around 18,000 individuals with the highest numbers seen in the Bay of Biscay region (Hammond *et al.*, 2017). Coupled with extremely high shipping traffic, fin whales in the Bay of Biscay are at high-risk of being hit by ships (Evans, Baines & Anderwald, 2010). However, more work is needed to understand if the fin whales are showing consistent patterns of distribution within this area before any mitigation measures can be proposed. This is where ORCA's long-term monitoring programme can play a critical role to help address this type of conservation question.

Understanding how whales behave around large ships, particularly during close/near-miss encounters (defined as less than 50m from the vessel), may help provide evidence for technological interventions to mitigate ship strikes from occurring. This summer, ORCA, in partnership with Brittany Ferries and Nottingham Trent University, undertook a research project on behavioural responses of fin whales with large ferries, which built on a previous ORCA study by Aniceto *et al.*, (2016).

The research project involved collecting behavioural and spatial data over a period of two months on board a large Brittany Ferries vessel which travelled on twice-weekly return trips over the Bay of Biscay. Its aim was to reveal whether sight, sound or a combination of both are used by the whales in determining their location relative to the ship and to what level they facilitate their evasive response.

Preliminary results show that fin whales encountered at distance but within headings along the midline of the ship (344-16 degrees) were encountered again within 150 metres of the ship, suggesting these to be angles with a high strike-risk.

It was also shown that at 1.5-2km from the ship, fin whales were making slight alterations to their swimming trajectory and showed gradual increases in their respiration rates, which suggested that at this distance the whales may be detecting the ship's rough location. At 200-600 metres from the ship the whales showed significant changes in respiration rates and sudden behavioural changes, indicating these to be critical distances. Some of the behaviours observed included a quick change in heading, a rapid change in swimming pace, evasive rolling and the lack of blow exhalations at the surface.

By understanding more about the behavioural responses of whales around large vessels it is hoped that such findings can help support future measures to reduce ship strikes.


Dead fin whale, victim of ship strike

Commercial whaling

The practice of hunting whales has taken place for centuries. However due to the sustained, widespread decimation of numerous whale populations, the International Whaling Commission (IWC) introduced the moratorium on whaling in 1986. Despite this global ban on commercial whaling some countries -Norway, Iceland and Japan- still hunt whales, resulting in thousands of animals being killed each year.

Norway

Norway recommenced commercial whaling activities for North Atlantic minke whales within its Exclusive Economic Zone in 1993. Countries exercising an objection to the moratorium set their own catch limits, but must provide information on their catches and associated scientific data to the IWC. In Norway, minke whale catch quotas have risen on an annual basis and are currently set at 999 for the 2017 hunting season. Despite a quota of 880 in 2016, Norway killed 591 minke whales through commercial whaling (IWC, 2017).

Minkie whale *Credit: Michael J Tetley*

Iceland

Commercial whaling only began in Iceland in 1948 and following the implementation of the moratorium, Iceland continued to conduct a 'scientific' whaling programme. In 2006 commercial whaling was resumed, with take quotas established for North Atlantic minke whales and North Atlantic fin whales within its Exclusive Economic Zone. In 2016, Iceland killed 46 minke whales, but did not kill any fin whales (IWC, 2017). However, in July 2016, 1,530 tonnes of fin whale meat and products were exported to Japan. To date this shipment has not yet entered the Japanese mark*et al*though it arrived in the Japanese port on the 9th September 2016.

Fin whale *Credit: Dave Chilcott*

Most whale meat in Iceland is consumed by tourists, not Icelanders. And with increasing evidence that such meats are highly contaminated with toxins (such as PCBs) there is a serious public health risk. Not only are tourists directly contributing to the number of whales killed, they are also putting their own health in grave danger.

Although commercial whaling continues in Iceland, whale watching is growing dramatically. It now represents the second largest leisure sector in Icelandic tourism, and provides significant value to the Icelandic economy. With whaling practices posing direct and indirect risks to the whale watching industry (Parsons & Monaghan-Brown, 2017) it could be argued that Iceland would benefit from ceasing commercial whaling activities to safeguard this growing sector.

Box 1 Japan

The year after the whaling ban came into effect, Japan launched its scientific whaling programme, focussing on Antarctic and North Pacific regions, as well as coastal whaling around Japan. Special permits are in place for set quotas of Bryde's, sei, sperm and minke whales to be taken on an annual basis by the Japanese whaling fleet. In 2016 Japan reported killing a total of 488 whales under its special permit, consisting of 26 Bryde's, 90 sei and 372 minke whales (IWC, 2017).

Japanese whaling ship *Credit: Customs & Border Protection Service, Commonwealth of Australia/ CC-By-SA-3.0*


Fin whale

A serious welfare concern

Whaling practices have long been regarded as cruel, with the whale suffering significantly from distress and inflicted pain, despite advances in modern hunting technology (Waugh & Monamy, 2016). Data on Japanese whaling methods shows an average time to death of ten minutes, with some animals taking up to 25 minutes to die (Gales, Leaper & Papastavrou, 2008). In addition to the cruelty involved, an emerging concern is the threat to human health. More evidence is coming to light that the high levels of contaminants in cetacean tissues can be transferred to humans upon consumption. Combined with welfare concerns, it is hard for countries such as Norway, Iceland and Japan, to justify their continued whaling activity.

Marine pollution

Marine pollution is a major problem across the world. The issue comprises three main facets: chemical waste, underwater noise and marine litter. Over 80% of chemical waste and marine litter originates from land based activities, such as land runoff and direct discharge of waste. The negative effects of marine pollution on the wildlife in our oceans are at unprecedented levels. However, despite the severity of the problem, monitoring the effects of such pollution is challenging, mainly because samples from animals are very hard to obtain. Two threats of increasingly serious concern in the present day are pollution from both plastics and polychlorinated biphenyls (PCBs).

Plastics

Plastics are a category of synthetic materials made from a wide range of organic polymers. They are extremely malleable and can be molded into solid objects, combining flexibility with durability and cheap production costs. As a result, plastic replaced many traditional materials to mass produce everyday items in the 1940s, spawning a revolution in a wide range of industries. However, despite the broad practical benefits, plastics degrade incredibly slowly, as the chemical bonds that make them so durable also renders them largely resistant to natural degradation processes.

Marine plastic pollution

Plastic accounts for approximately 10% of the waste generated in our industrialised society (Barnes *et al*. 2009; Hopewell *et al*. 2009), with an estimated 80,000 - 219,000 tonnes of microplastics flushed into the sea each year from Europe alone (House of Commons Environmental Audit Committee, 2017). One of the most substantial modern uses of plastics is disposable packaging, which accounts for over one third of all plastic production, most of which is discarded within a year of use.

Microbeads
Credit: Oregon State University/CC-BY-SA-2.0

Microbeads (plastics less than 1mm in size) also account for a significant proportion of plastic use, being found in many cosmetic and cleaning products. These are manufactured to wash down the drain and, due to their small size, they are bioavailable to most species across all trophic levels (Rochman *et al*., 2015). Plastic waste is now accumulating at an unprecedented rate in every natural habitat from the poles to the equator, with the marine environment as heavily impacted as terrestrial environments. Current estimates suggest that at least 8 million pieces of plastic enter the oceans each year, and experts warn there will be more plastic than sea life in the marine environment by 2050 (by weight) (World Economic Forum, 2016).

How plastics impact cetaceans

Plastics are commonly seen in the marine environment, and the ubiquity of this pollutant has resulted in many species either ingesting plastic waste or becoming entangled within it. This results in devastating damage to a wide range of species and causes injury, impaired movement, toxicity, starvation and death (Gregory, 2009).

Sadly, it is the durability of plastics that is resulting in the most destructive impacts. A plastic bottle can remain in the marine environment for at least 450 years, slowly but inevitably fragmenting over time into microscopic pieces that are essentially everlasting. As a consequence, they are at serious risk of ingestion, providing a mechanism for the transfer and accumulation of hazardous chemicals throughout the food chain.

Compared to entanglement, the incidence of marine debris ingestion is far more frequent (Baulch & Perry, 2014). Ingestion can be direct (mistaking plastic for prey) or indirect (consuming prey that has eaten plastic). Since the animals (such as cetaceans) that eat this plastic debris cannot break it down, they store the plastic in their digestive system, which ultimately results in starvation.

Marine litter; plastic bottles washed in on the tide

Plastic bags

Plastic bags have come under considerable scrutiny in recent years, with numerous examples of cetaceans washing up with plastic bags in their stomachs. The most recent incident occurred on the Island of Sotra, southwest Norway in February 2017. A Cuvier's beaked whale live stranded in a severely emaciated state and was ultimately euthanized for welfare reasons. A post-mortem found 30 plastic bags filling the entirety of the animal's stomach and intestines, which had stopped the individual from feeding for some time. In 2015, a scheme came into force in England to reduce the number of single-use plastic carrier bags and the litter associated with them. This scheme required large businesses (over 250 employees) to charge 5p for plastic carrier bags. Since the scheme was introduced, the number of bags used in England has been reduced by 80% (DEFRA, 2017). This was reflected in the Marine Conservation Society's Great British Beach Clean which reported 40% fewer plastic bags since the 5p charge scheme was introduced (MCS, 2017).

Plastic bag in the marine environment *Credit: NOAA*

Mitigation measures

In March 2017, Indonesia (the world's second largest plastic producing country) pledged to reduce marine plastic waste by 70% within eight years by creating a national tax on plastic bags whilst also investing in industries that make packaging and other items from alternative materials such as cassava and seaweed. Governments across the world, including the UK, have acted to ban or impose a charge for single-use plastic bags, as well as banning microbeads with varying degrees of success. The Netherlands was the first to ban cosmetic microbeads in 2014, with the USA and the UK quickly following by announcing plans to phase out the use of microbeads in cleaning, medical and cosmetic products by 2020 (Trager, 2016). Canada has also added microbeads to their list of toxic substances.

Innovative tools such as Seabins are also widely available to actively remove floating plastics, including micro-plastics. However, the most significant barrier is still one of education; from lessons and data collection, to activities on how to design and build products and technology in a more sustainable way. Education is the real solution that will help reduce the impact of plastics in our oceans and conserve our marine wildlife.

PCBs

PCBs, or polychlorinated biphenyls, are a group of man-made organic chemicals that persist in the environment, posing a significant threat to both wildlife and human health. These chemical compounds have been produced commercially since the 1930s. They are incorporated into many industrial applications including transformers and capacitators (examples of closed applications), and flame-resistant coatings, paints and machinery (examples of open applications). However, following evidence of their toxicity and the severe and damaging impact on human health and the wider environment, production and use was banned in Europe in the 1980s (Van den Berg *et al.*, 1998).

Despite these bans, PCBs from sources such as existing open application sources, landfills and stockpiles continue to make their way into the environment, often leaching into water courses and as a result posing a significant threat to our marine wildlife. As PCBs do not readily break down and persist for long periods of time (over 100 years) in the natural environment. They have been monitored travelling vast distances across international boundaries, and have the ability to pollute some of the most remote areas of the planet. This makes them one of the most indiscriminate threats facing the marine environment.

Seaweed
Credit: Tom Corser_CC-BY-SA-2.0

Why are cetaceans at such risk?

Marine species are at the greatest risk of impact from PCBs. Marine sediment often serves as a reservoir for such pollutants, and these stores are regularly mobilised during disturbances such as dredging, bottom trawling and extreme weather events (Roberts, 2012; Nicolaus *et al.*, 2015). Once mobilised, PCBs will travel through the marine environment for extended timescales. They pose a significant risk as they can easily enter the food chain through absorption by microorganisms, and they are known to readily bio-accumulate up the food chain (Eggleton & Thomas, 2004). As whales and dolphins are long-lived apex predators, they accumulate the highest concentrations of PCBs from their food, storing them in their blubber, and suffering the greatest toxic effects as a result.

European waters are a global PCB hotspot and, despite initial declines in PCB concentrations in cetaceans following the ban, levels have now stabilised at values exceeding marine mammal toxicity thresholds in several European species, including bottlenose dolphin, striped dolphin and orca (Pinzone *et al*., 2015; ICES, 2016; Jepson *et al*., 2016). Such sustained PCB concentrations are associated with long-term population declines a result of both a weakened immune system (leading to the subsequent increased vulnerability to disease) and impaired reproduction resulting in falling birth rates (Vos *et al*., 2003; Jepson *et al*., 2005). Furthermore, the relatively long lactation periods in cetaceans results in considerable PCB transmission from mother to calf.

PCBs are fat soluble where the high-fat milk produced by cetaceans can contain excessive levels of PCBs and maternal off-loading of such contaminants can have fatal consequences. The fat- soluble nature of PCBs also means cetaceans can store high levels in their blubber, which build up over time as more contaminated prey are consumed and create cumulative biological impacts. Subsequently, in periods of reduced prey availability cetaceans begin to break down their fat reserves as a way to supplement their energy levels. This mobilises the toxic PCBs into the animal's body where they can cause profound physiological damage, adding to their levels of stress (Lavandier *et al*., 2016).

PCBs in orcas

The orca remains the mammal with the highest known concentrations of PCBs on Earth, with very high levels observed throughout its range (Jepson & Law, 2016). The high trophic level, longevity and very increased risk of maternal transfer of PCBs, make this species particularly vulnerable to the devastating effects of toxic contamination and orcas are likely to suffer both on-going population declines and localised extinctions.

Two pods of orcas reside in in the Strait of Gibraltar, comprising of 36 individuals in total. These pods have been monitored annually since 1999, and over a 13 year period exhibited the lowest recorded reproductive rates for orcas globally, consistent with PCB induced reproductive toxicity (Jepson *et al*., 2016).

In January 2016, a female orca, identified as Lulu, was found dead on the Isle of Tiree in the Inner Hebrides, Scotland. As a member of the UK's only pod of resident orcas, now consisting of just eight individuals, this was a significant loss. Although the primary cause of death was identified as being a result of entanglement in fishing lines, subsequent post-mortem results revealed that Lulu had one of the highest levels of PCBs ever recorded in an animal. An unprecedented 957mg/kg of PCBs were found in her blubber, greater than 100 times the limit considered safe for marine mammals (Kannan *et al*., 2000). Findings also indicated that, despite Lulu being at least 20 years old, she had never reproduced. Her high PCB levels were likely to have had detrimental biological consequences, such as reproductive failure and immunosuppression. This would explain why the pod has not produced a calf for over 20 years.

These results do not bode well for the future of this small group and it is very likely that these challenges will result in the only resident orca pod found in British waters eventually becoming extinct.

Orca *Credit: Edward Butler*

Beluga *Credit: Mark Carwardine*

A global issue

Due to their persistent and mobile nature, PCBs pose a significant threat to apex marine predators at a global level, not just in Europe. In the St Lawrence River near the eastern coast of Canada, a population of belugas have seen their numbers dramatically decrease over the last century. This area is highly polluted and scientists have found higher concentrations of PCBs in this population when compared to beluga inhabiting less contaminated Arctic Waters (Hobbs *et al.*, 2003). With fewer than 500 individual beluga remaining in the St Lawrence River, this population is another that is at real risk of extinction, apparently as a result of the impact of PCBs.

Mitigation measures and the future

In 2004, the Stockholm Convention was developed as a global framework to address the issue of organic pollutants (including PCBs), committing over 90 signatory countries to a) phase out the use of PCBs by 2025 and b) ensure elimination of PCBs by 2028 (Stockholm Convention, Annex A, Part II (a), (e), 2001). The UK is one of the signatory countries.

To date, signatories have focused their efforts on eliminating PCBs in closed applications, and no specific strategies have been implemented regarding PCBs in open applications. The open applications are still widely in use and are considered a significant global source of PCBs entering a variety of habitats, with these applications now believed to be largely responsible for environmental leaching of PCBs (Stuart-Smith & Jepson, 2017). With estimations of 83% (corresponding to 14 million tonnes) of the total amount of PCB contaminated materials still requiring elimination, it can be considered that European mitigation efforts to eliminate PCBs are insufficient and will not be able to reduce the threat to cetaceans in any meaningful way.

Emerging scientific evidence continues to show that elevated PCB concentrations are a major cause of contemporary declines in both European and global cetacean populations. It is therefore vital that monitoring programmes, including those conducted by ORCA Marine Mammal Surveyors, and more effective mitigation measures are in place to help understand and save these threatened cetacean populations.

Stranding events

Each year around the globe, thousands of whales, dolphins and porpoises become stranded ashore, hitting the headlines on a regular basis. Cetaceans can strand alive (often being unable to return to their natural environment unaided) or they can strand dead. These events may consist of a single stranding (one individual animal) or a mass stranding (two or more animals, excluding a mother/calf pair, within the same geographic region and tidal cycle).

Although the cause of cetacean strandings remains largely unknown, incidents have been associated with disorientation, disease, geomagnetic alterations, weather events and anthropogenic factors such as bycatch, ship strike, noise exposure and the accumulation of contaminants (Castège *et al.*, 2013). In the case of mass strandings, social structure also often plays a role. Cetacean species that mass strand are frequently pelagic (offshore), gregarious animals that form long-term, social bonds. Unfortunately this complex, cohesive nature can mean that when one individual within the pod becomes stranded the entire group may follow and as a result mass stranding events can involve hundreds of animals (Téllez, Mignucci-Giannoni & Caballero, 2014).

Cetacean stranding in UK and European waters

Since the official recording of cetacean strandings commenced in 1913 by the Natural History Museum, approximately 17,500 individuals and 28 different species have been found stranded around the British Isles. This represents almost a third of all known cetacean species worldwide. In the UK the most frequently stranded cetaceans are the harbour porpoise and common dolphin.

Harbour porpoise

The number of harbour porpoises stranding around the UK appears to be increasing and a prevailing high level of mortality has been attributed to bycatch (Leeney *et al.*, 2008). Porpoises found suffering from starvation has also dramatically risen during the 21st century, making up 16% of UK strandings compared with just 4% in the 1990s. The two most likely explanations are a shortage of small fish or a rising porpoise population. ORCA's The State of European Cetaceans report published in January 2017 showed a southerly shift in the distribution of harbour porpoises surveyed within the North Sea, which was linked to the decline in sand eel abundance in this sea region. Other possible causes of harbour porpoise stranding include parasitic infections, accumulation of toxic contaminants and attacks from bottlenose dolphins (Ross & Wilson, 1996; Jepson *et al.*, 2005).

Harbour porpoise stranding *Credit: BDMLR*

Common dolphin

Over the last few years there has been an increase in the number of common dolphin strandings in Europe, particularly in the southwest of England where it is the most frequently stranded cetacean. Common dolphin strandings typically exhibit a seasonal occurrence, with the majority of dead dolphins, in the western English Channel and southern shelf and slope of the Bay of Biscay, occurring in winter months between October and March (Peltier *et al.*, 2014). Bycatch is by far the predominant cause of death reported for stranded common dolphins (averaging 75% of post-mortemed carcasses) and is mostly associated with seabass (Dicentrarchus labrax) and albacore tuna (Thunnus alalunga) pelagic trawlers (Northridge *et al.*, 2006; Rogan & Mackey, 2007; Leeney *et al.*, 2008; Spitz *et al.*, 2013). With a recent study estimating very high bycatch numbers inferred from strandings ranging from 3,650 (2,250–7,000) to 4,700 (3,850–5,750) dolphins per-year, depending on methodological choices (Peltier *et al.*, 2016), there is a real possibility that this threat could negatively impact overall common dolphin population numbers.


Common dolphin

Box 2 Common dolphin stranding, Fareham Creek – 28th September 2017

On 28th September 2017 a dolphin was reported to be swimming around the waters near the mouth of the Wallington River at Fareham, Hampshire. As this dolphin was located in an inland water body, several miles from the sea it was apparent that there was something wrong. British Divers Marine Life Rescue (BDMLR) were alerted to assess the dolphin and as trained BDMLR Marine Mammal Medics, and only a short drive from the location, staff from ORCA were some of the first on the scene. The dolphin was identified as a common dolphin and after initially appearing to be swimming normally, the animal live stranded. It quickly became apparent that the juvenile female was notably malnourished and was euthanized on welfare grounds. The Cetacean Strandings Investigation Programme (CSIP) will conduct a post-mortem on the dolphin to investigate the cause of stranding.


Common dolphin Fareham Stranding

Recent mass stranding events

Sperm whale stranding *Credit: Chris Lowe BDMLR*

January 2016 triggered the start of a mass stranding event of sperm whales in the North Sea. Sperm whale strandings (single or groups of animals) are irregular in the North Sea, but have been documented in this region since the Middle Ages (Pierce *et al*., 2007). Prior to the 2016 event the most recent incidents were of two mass strandings in 1994 and 1996 consisting of 25 and 27 sperm whales respectively. The latest mass stranding occurred between January 8th and February 4th 2016, when 29 male sperm whales stranded along the coasts of the UK, Netherlands, Germany and France, with six individuals washing up on UK shorelines. The majority of these animals stranded dead, but a few washed up alive. However, in spite of efforts to refloat the whales they subsequently died.

Sperm whales that strand in the North Sea are predominantly males. Pods of females and young remain at lower latitude feeding and breeding grounds, whereas males leave the family unit at 10-15 years old, forming bachelor groups which migrate into northern waters where they undertake seasonal movements. One known migration route passes west of the British Isles, through the Faroe - Shetland Channel and into the Norwegian Sea (Evans, 1997; Pierce *et al*., 2007). Due to the lack of suitable habitat, sperm whales are not usually found in the North Sea. However, some animals do enter the North Sea, thought to be when they are travelling southwards between Norway and Shetland (Pierce *et al*., 2007; Vanselow *et al*., 2017). The shallow, gently sloping topography impedes navigation and individuals often become disorientated and strand.

Sperm whale stranding *Credit: CSIP-ZSL*

Mass pilot whale stranding *Credit: Jamie Dyer, BDMLR*

Theories to explain the causes and mechanisms leading to disorientation and mass strandings of sperm whales include poor health, ingestion of debris, changes in water temperature, meteorological events and human activities, such as underwater noise, entanglement and ship strike (Mazzariol *et al*., 2011). Post-mortem results from 22 of the whales that stranded in 2016 indicated that they were in good nutritional health and not experiencing any debilitating diseases. Much debate has therefore ensued as to why these animals stranded, illustrating the importance of continued research to inform understanding and prevention of this global concern. The most recent proposed theory is that solar flares and geomagnetic storms may affect the whale's navigation systems (Vanselow *et al*., 2017).

From a global perspective, the third-largest recorded mass stranding event in New Zealand's history occurred in February 2017. More than 600 pilot whales stranded in Golden Bay at Farewell Spit on New Zealand's South Island in two separate events over a three day period. Farewell Spit is renowned for cetacean mass strandings due to its shallow depth, gently sloping seabed and large tidal range – extensive tidal flats are exposed at low tides and can extend more than 7km out from the high tide mark (Ogle, 2017). This impedes navigation and results in the animals becoming disorientated and stranding as the tide quickly recedes. In total over 300 of the pilot whales died, whilst the other animals were refloated with the aid of volunteers.

Pilot whales are the most common species to mass strand and this is partly thought to be due to the formation of strong, stable groups. When an individual member of the pod strands, the complex social bonds are so strong that it causes part, or all, of the group to follow and become stranded themselves. Observations at mass stranding events confirm the maintenance of this group cohesion even under the adverse conditions surrounding a stranding, with animals often re-stranding if members of the pod are still ashore.

With cetacean strandings being a global issue affecting numerous species, it is critical to understand the factors leading to such events. Information gathered from stranded animals, along with long-term datasets, such as those collected by ORCA, is essential to investigate such trends over spatial and temporal scales.

THE FUTURE

Bottlenose dolphin

ORCA's passionate and dedicated citizen scientists have given their time and energy to collect the vital data which is the foundation of this report. They have all done so with the selfless objective of developing a more complete picture of our whales, dolphins and porpoises, so that they can be afforded greater protection and preserved for future generations.

ORCA are fully committed to continuing to protect cetaceans across the UK and Europe, and we are planning to have even more impact moving into 2018 by:

- Launching three new survey routes in the important marine habitats across the west coast of Scotland
- Delivering a record number of cruises, with new partners and routes, expanding ORCA's dataset further than ever before
- Expanding the Wildlife Officer and education programmes to ensure that even more members of the public can learn about whales and dolphins and their conservation
- Develop new partnerships across the marine sector and beyond, helping those that operate at sea to make good decisions and act as good corporate citizens


ORCA Marine Mammal Surveyors

ORCA can provide an army of watchful eyes thanks to our volunteers, but we need action from governments when our evidence indicates a serious emerging threat or problem. One of ORCA's key objectives is to engage people from all walks of life as active participants in the collection of scientific data. By doing this and providing a platform for citizens to participate as scientists, awareness is raised about the threats facing our marine wildlife. And with that awareness comes recognition about what steps governments can take to improve marine habitats for cetaceans and indignation when they do not. As well as being citizen scientists, ORCA's supporters are articulate, informed citizen-advocates and campaigners.

Central governments must take a leadership role, developing effective and impactful marine protection policy that ensures industry is held to account and respecting UK and European cetaceans.

Industries must move towards more sustainable business models that work with, not against, the ocean, and choose environmentally friendly alternatives across their operations to minimise their impact on marine spaces.

References

Aniceto, A. S., Carroll, J., Tetley, M. J., & Van Oosterhout, C. (2016). Position, swimming direction and group size of fin whales (Balaenoptera physalus) in the presence of a fast-ferry in the Bay of Biscay. *Oceanologia, 58(3), 235-240.*

Barnes D. K. A., Galgani F., Thompson R. C., Barlaz M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Phil. Trans. R. Soc. B 364:1985–1998.*

Baulch, S., & Perry, C. (2014). A sea of plastic: evaluating the impacts of marine debris on cetaceans. Marine Pollution Bulletin, 80(1),210–221.

Becker, E. Forney, K. Ferguson, M. Foley, D. Smith, R. Barlow, J. Redfern, J. (2010). Comparing California Current cetacean—habitat models developed using in situ and remotely sensed sea surface temperature data. *Marine Ecology Progress Series. 413:163–182.*

Borchers, D. Buckland, S. Goedhart, P. Clarke, E. Hedley, S. (1998). Hovitz-Thompson estimators for double-platform line transect surveys. *Biometrics. 54(4):1221–1237.*

Buckland, S. Rexsted, E. Marques, T. Oedekoven, C. (2015). *Distance sampling methods and applications*. Springer, New York, NY.

Canadas, A. Hammond, P. (2008). Abundance and habitat preferences of the short-beaked common dolphin *Delphinus delphis* in the southwestern Mediterranean: implications for conservation. *Endangered Species Research. 4:309–331.*

Castège, I., Soulier, L., Hémery, G., Mouchès, C., Lalanne, Y., Dewez, A., ... & D'Amico, F. (2013). Exploring cetacean stranding pattern in light of variation in at-sea encounter rate and fishing activity: Lessons from time surveys in the south Bay of Biscay (East-Atlantic; France). *Journal of Marine Systems, 109, S284-S292.*

Cates, K., DeMaster, D. P., Brownell Jr, R. L., Silber, G., Gende, S., Leaper, R., Ritter, F. and Panigada, S. (2017). Strategic Plan to Mitigate the Impacts of Ship Strikes on Cetacean Populations: 2017-2020 [online]. IWC Strategic Plan to Mitigate Ship Strikes. Available at: https://arabianseawhalenetworkdotorg.files.wordpress.com/2017/02/cates-et-al-2016-iwc-ship-strike-strategic-plan.pdf

De Boer, M. Leaper, R. Keith, S. Simmonds, M. (2008). Winter abundance estimates for the common dolphin (Delphinus delphis) in the western approaches of the English Channel and the effect of responsive movement. *Journal of Marine Animals and Their Ecology. 1:15–21.*

Deaville, R., & Jepson, P.D. (2011). UK Cetacean Strandings Investigation Programme Final report for the period 1st January 2005-31st December 2010. London, UK: Institute of Zoology, Zoological Society of London

DEFRA (2017). *Single-use plastic carrier bags charge: data in England for 2016 to 2017*. Retrieved from: https://www.gov.uk/government/publications/carrier-bag-charge-summary-of-data-in-england/single-use-plastic-carrier-bags-charge-data-in-england-for-2016-to-2017

Eggleton, J., & Thomas, K. V. (2004). A review of factors affecting the release and bioavailability of contaminants during sediment disturbance events. *Environment International, 30(7), 973-980.*

EMODnet Bathymetry Consortium (2016). EMODnet Digital Bathymetry (DTM). http://doi.org/10.12770/c7b53704-999d-4721-b1a3-04ec60c87238

ESRI (2016). ArcGIS Desktop: Release 10.4. Redlands, CA: Environmental Systems Research Institute.

Evans, P.G.H. (1997). Ecology of sperm whales (Physeter macrocephalus) in the Eastern North Atlantic, with special reference to sightings & strandings records from the British Isles.

Evans, P., Baines, M. E. and Anderwald, P. (2010). Risk assessment of potential conflicts between shipping and cetaceans in the ASCOBANS Region. ASCOBANS. 6-06. Available at: http://www.ascobans.org/sites/default/files/basic_page_documents/AC18_6-04_rev1_ProjectReport_ShipStrikes.pdf

Fais, A., Lewis, T. P., Zitterbart, D. P., Álvarez, O., Tejedor, A., & Soto, N. A. (2016). Abundance and distribution of sperm whales in the Canary Islands: can sperm whales in the archipelago sustain the current level of ship-strike mortalities?. *PloS one, 11(3).*

Gales N., Leaper R., and Papastavrou V. (2008). Is Japan's whaling humane? *Marine Policy 32:408–412.*

Government of Canada (2015). Fisheries and Oceans: Snow crab [online]. Available at: http://www.dfo-mpo.gc.ca/fm-gp/sustainable-durable/fisheries-peches/snow-crab-eng.htm

Gregory, M. R. (2009). Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society, B: Biological Sciences, 364(1526):2013–2025.*

Hammond, P. Berggren, P. Benke, H. Borchers, D. Collet, A. Heide-Jorgensen, M. Heimlich, S. Hiby, A. Leopold, M. 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.,…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. S., Lacey, C., Gilles, A., Viquerat, S., Boerjesson, P., Herr, H., ... & Teilmann, J. (2017). Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys. Wageningen Marine Research.

Hobbs, K. E., Muir, D. C., Michaud, R., Béland, P., Letcher, R. J., & Norstrom, R. J. (2003). PCBs and organochlorine pesticides in blubber biopsies from free-ranging St. Lawrence River Estuary beluga whales (Delphinapterus leucas), 1994–1998. *Environmental Pollution, 122(2), 291-302.*

Hopewell J., Dvorak R., Kosior E. (2009). Plastics recycling: challenges and opportunities. *Phil. Trans. R. Soc. B 364: 2115–2126.*

House of Commons Environmental Audit Committee (2017). *Environmental impact of microplastics.* Retrieved from: https://publications.parliament.uk/pa/cm201617/cmselect/cmenvaud/179/179.pdf

Hyder, K., B. Townhill, L. G. Anderson, J. Delany, and J. K. Pinnegar. (2015). Can citizen science contribute to the evidence-base that underpins marine policy? *Marine Policy, 59:112-120.*

ICES (2016) Report of the Working Group on Marine Mammal Ecology (WGMME), 8-11 February 2016, Madrid, Spain. ICES CM 2016/ACOM: 26. 117 pp.

ICES WGBYC. (2014). Bycatch of small cetaceans and other marine animals – Review of national reports under Council Regulation (EC) No. 812/2004 and other published documents. Advice April 2014. 8pp.

International Union for the Conservation of Nature (IUCN). (2001). Balaenoptera physalus http://www.iucnredlist.org/details/2478/0

IWC (2010) The Annual Report of the International Whaling Commission. The International Whaling Commission

IWC (2017) The Annual Report of the International Whaling Commission. The International Whaling Commission

Jepson, P. D., Bennett, P. M., Deaville, R., Allchin, C. R., Baker, J. R., & Law, R. J. (2005). Relationships between polychlorinated biphenyls and health status in harbor porpoises (Phocoena phocoena) stranded in the United Kingdom. *Environmental Toxicology and Chemistry, 24(1), 238-248*

Jepson, PD and Law, RJ (2016) Persistent pollutants, persistent threats: Polychlorinated biphenyls remain a major threat to marine apex predators. *Science 352: 1388-1389.*

Jepson, P. D., Deaville, R., Barber, J. L., Aguilar, À., Borrell, A., Murphy, S., … Law, R. J. (2016). PCB pollution continues to impact populations of orcas and other dolphins in European waters. *Scientific Reports, 6, 18573.*

Kannan, K., Blankenship, A. L., Jones, P. D., & Giesy, J. P. (2000). Toxicity reference values for the toxic effects of polychlorinated biphenyls to aquatic mammals. *Human and Ecological Risk Assessment, 6(1), 181-201.*

Laist, D. W., Knowlton, A. R., Mead, J. G., Collet, A. S. and Podesta, M. (2001). Collisions between ships and whales. *Marine Mammal Science, 17(1), 5-75.*

Laist, D. W., Knowlton, A. R., & Pendleton, D. (2014). Effectiveness of mandatory vessel speed limits for protecting North Atlantic right whales. *Endangered Species Research, 23(2), 133-147.*

Lavandier, R., Arêas, J., Quinete, N., de Moura, J. F., Taniguchi, S., Montone, R., ... & Moreira, I. (2016). PCB and PBDE levels in a highly threatened dolphin species from the Southeastern Brazilian coast. *Environmental Pollution, 208, 442-449.*

Leeney, R. H., Amies, R., Broderick, A. C., Witt, M. J., Loveridge, J., Doyle, J., & Godley, B. J. (2008). Spatio-temporal analysis of cetacean strandings and bycatch in a UK fisheries hotspot. *Biodiversity and Conservation, 17(10), 2323.*

MacLeod, C. Brereton, T. Martin, C. (2009). Changes in the occurrence of common dolphins, striped dolphins and harbour porpoises in the English Channel and Bay of Biscay. *Journal of the Marine Biological Association of the United Kingdom. 89(5):1059–1065.*

Miller, D. (2017). Distance: Distance Sampling Detection Function and Abundance Estimation. R package version 0.9.7. https://CRAN.R-project.org/package=Distance

Miller, D. Rexstad, R. Burt, L. Bravington, M. and Hedley, S. (2017). dsm: Density Surface Modelling of Distance Sampling Data. R package version 2.2.15. https://CRAN.R-project.org/package=dsm

Mazzariol, S., Di Guardo, G., Petrella, A., Marsili, L., Fossi, C. M., Leonzio, C., ... & Podestà, M. (2011). Sometimes sperm whales (Physeter macrocephalus) cannot find their way back to the high seas: a multidisciplinary study on a mass stranding. *PLoS One, 6(5).*

Nichol, L. M., Wright, B. M., Hara, P. O., & Ford, J. K. (2017). Risk of lethal vessel strikes to humpback and fin whales off the west coast of Vancouver Island, Canada. *Endangered Species Research, 32, 373-390.*

Nicolaus, E. M., Wright, S. R., Bolam, T. P., Barber, J. L., Bignell, J. P., & Lyons, B. P. (2016). Spatial and temporal analysis of the risks posed by polychlorinated biphenyl and metal contaminants in dab *(Limanda limanda)* collected from waters around England and Wales. *Marine pollution bulletin, 112(1), 399-405.*

Northridge, S.P., Morizur, Y., Souami, Y., Van Canneyt, O. (2006). PETRACET: Project EC/FISH/2003/09 Final Report to the European Commission 1735R07D.

Northridge, S.P., Kingston, A.R., and Thomas, L.J. (2016). Annual Report on the Implementation of Council Regulation (EC) No. 812/2004 during 2015. DEFRA, 2016. 44 pp.

Notarbartolo Di Sciara, G., Zanardelli, M., Jahoda, M., Panigada, S., & Airoldi, S. (2003). The fin whale Balaenoptera physalus (L. 1758) in the Mediterranean Sea. *Mammal Review, 33(2), 105-150.*

Ogle, M. (2017). Managing the Welfare of Marine Mammals at Mass Strandings in Golden Bay, New Zealand. *Marine Mammal Welfare: Human Induced Change in the Marine Environment and its Impacts on Marine Mammal Welfare, 17, 137.*

ORCA (2016). *The State of European Cetaceans.* Retrieved from: http://www.orcaweb.org.uk/uploads/Our_Work/ORCA-The_State_of_European_Cetaceans_(2006-2015).pdf

Pace R.M., Cole T.V.N., Henry, A.G. (2014). Incremental fishing gear modifications fail to significantly reduce large whale serious injury rates. *Endangered Species Research. 26:115-126.* https://doi.org/10.3354/esr00635

Panigada, S., Pesante, G., Zanardelli, M., Capoulade, F., Gannier, A., & Weinrich, M. T. (2006). Mediterranean fin whales at risk from fatal ship strikes. *Marine Pollution Bulletin, 52(10), 1287-1298.*

Parsons E.C.M., Monaghan-Brown D. (2017) From Hunting to Watching: Human Interactions with Cetaceans. In: Butterworth A. (eds) Marine Mammal Welfare. *Animal Welfare, vol 17.*

Peltier, H., Dabin, W., Daniel, P., Van Canneyt, O., Dorémus, G., Huon, M., & Ridoux, V. (2012). The significance of stranding data as indicators of cetacean populations at sea: modelling the drift of cetacean carcasses. E*cological Indicators, 18, 278-290.*

Peltier, H., Jepson, P. D., Dabin, W., Deaville, R., Daniel, P., Van Canneyt, O., & Ridoux, V. (2014). The contribution of stranding data to monitoring and conservation strategies for cetaceans: Developing spatially explicit mortality indicators for common dolphins *(Delphinus delphis)* in the eastern North-Atlantic. *Ecological Indicators, 39, 203-214.*

Peltier, H., Authier, M., Deaville, R., Dabin, W., Jepson, P. D., Van Canneyt, O., ... & Ridoux, V. (2016). Small cetacean bycatch as estimated from stranding schemes: The common dolphin case in the northeast Atlantic. *Environmental Science & Policy, 63, 7-18.*

Peltier, H., Van Canneyt, O., Dabin, W., Dars, C., Demaret, F., & Ridoux, V. (2017). New Fishery-related Unusual Mortality and Stranding Events of Common Dolphins in the Bay of Biscay, February-March 2017, France.

Pierce, G.J., Santos, M.B., Smeenk, C., Saveliev, A. & Zuur, A.F. (2007). Historical trends in the incidence of strandings of sperm whales *(Physeter macrocephalus)* on North Sea coasts: an association with positive temperature anomalies. *Fisheries Research. 87, 219–228.*

Pinzone, M., Budzinski, H., Tasciotti, A., Ody, D., Lepoint, G., Schnitzler, J., ... & Das, K. (2015). POPs in free-ranging pilot whales, sperm whales and fin whales from the Mediterranean Sea: influence of biological and ecological factors. *Environmental Research, 142, 185-196.*

Priyadarshana, T., Randage, S. M., Alling, A., Calderan, S., Gordon, J., Leaper, R., & Porter, L. (2016). Distribution patterns of blue whale *(Balaenoptera musculus)* and shipping off southern Sri Lanka. Regional Studies in *Marine Science, 3, 181-188.*

R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Reilly, S. B., Bannister, J. L., Best, P. B., Brown, M., Brownell Jr., R. L., Butterworth, D. S., Clapham, P. J., Cooke, J., Donovan, G. P., Urbán, J. and Zerbini, A. N. (2013). *Balaenoptera physalus* [online]. Available at: http://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T2478A44210520.en

Rochman, C. M., Kross, S. M., Armstrong, J. B., Bogan, M. T., Darling, E. S., Green, S. J., Smyth, A. R., Veríssimo, D. (2015) Scientific Evidence Supports a Ban on Microbeads. *Environmental Science & Technology, 49(18):10759−10761.*

Roberts, D. A. (2012). Causes and ecological effects of resuspended contaminated sediments (RCS) in marine environments. E*nvironment International, 40, 230-243.*

Rockwood, R.C., Calambokidis, J. and Jahncke, J. (2017). High mortality of blue, humpback and fin whales from modeling of vessel collisions on the US West Coast suggests population impacts and insufficient protection. *PloS one, 12 (8).*

Rogan, E., Mackey, M. (2007). Megafauna bycatch in drift nets for albacore tuna (Thunnus alalunga) in the NE Atlantic. *Fisheries Research 86, 6–14.*

Ross, H. M., & Wilson, B. (1996). Violent interactions between bottlenose dolphins and harbour porpoises. *Proceedings of the Royal Society of London B: Biological Sciences, 263(1368), 283-286.*

Spitz, J., Chouvelon, T., Cardinaud, M., Kostecki, C., & Lorance, P. (2013). Prey preferences of adult sea bass Dicentrarchus labrax in the northeastern Atlantic: implications for bycatch of common dolphin *Delphinus delphis. Journal of Marine Science, 70(2), 452-461.*

Stockholm Convention (2001). Stockholm Convention on persistent organic pollutants; http://chm.pops.int/. http://chm.pops.int/Convention/tabid/54/language/enUS/Default.aspx#convtext

Stuart-Smith, S. J., & Jepson, P. D. (2017). Persistent threats need persistent counteraction: Responding to PCB pollution in marine mammals. *Marine Policy, 84, 69-75.*

Téllez, R., Mignucci-Giannoni, A. A., & Caballero, S. (2014). Initial description of short-finned pilot whale *(Globicephala macrorhynchus)* genetic diversity from the Caribbean. *Biochemical Systematics and Ecology, 56, 196-201.*

Trager, R. (2016). US bans microbeads from personal care products. https://www.chemistryworld.com/news/us-bans-microbeads-from-personal-care-products/9309.article

Van den Berg, M., Birnbaum, L., Bosveld, A. T., Brunström, B., Cook, P., Feeley, M., ... & Kubiak, T. (1998). Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. *Environmental health perspectives, 106(12), 775.*

Vanselow, K. H., Jacobsen, S., Hall, C., & Garthe, S. (2017). Solar storms may trigger sperm whale strandings: explanation approaches for multiple strandings in the North Sea in 2016. *International Journal of Astrobiology, 1-9.*

Vos J.G., Bossart G.D., Fournier M. and O'Shea T.J. (eds) (2003). Toxicology of Marine Mammals. Taylor and Francis, London

Waugh, C. A., & Monamy, V. (2016). Opposing Lethal Wildlife Research When Nonlethal Methods Exist: Scientific Whaling as a Case Study. *Journal of Fish and Wildlife Management, 7(1), 231-236.*

Williams, R. and O'Hara, P. (2010). Modelling ship strike risk to fin, humpback and killer whales in British Columbia, Canada. *Journal of Cetacean Research and Management, 11 (1), 1-8.*

Wood, S. (2006). *Generalized Additive Models* (Texts in Statistical Science), Chapman & Hall.

World Economic Forum (2016). The New Plastics Economy: Rethinking the future of plastics. http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf

Appendix

ORCA Distance Sampling survey protocol

Each surveyor in the team rotates through each of the following positions/role every thirty minutes; port observer, data recorder, starboard observer, rest. This ensures surveyor fatigue does not impact the quality of data.

Two surveyors are on effort (watch) at any given time; one on the starboard and one on the port side of the observation platform. The starboard observer scans a 100° area of the sea (from 90° off the starboard side to 10°) and the port observer scans a 100° area of the sea (from 90° off the port side to 10° to starboard). Surveyors scan the area for cetacean presence by eye and using reticle binoculars (7x50 Opticron Marine-2®). Distance to the animal is measured with the reticle binoculars and an angle reading is taken from the front of the ship to the animal using an angle board.

Sightings are identified to species level where possible, and classified as definite, probable or possible to indicate the level of certainty. When species identification cannot be confirmed sightings are downgraded to the lowest taxonomic certainty (e.g. unidentified dolphin / unidentified beaked whale/ medium cetacean etc.).

The data recorder collects environmental data every thirty minutes or when environmental conditions change, with factors including vessel position, course and speed (obtained from the ships instruments). They record all sightings data, and survey effort is conducted up to Beaufort sea state six.

On surveys with a duration >3 hours the team includes four surveyors, with this fourth individual on rest.

As of 2014 all ORCA cruise surveys utilised a different surveying protocol; the ORCA Observation Protocol. Public engagement is an important role in ORCA cruise surveys, resulting in surveyors not being able to continuously observe the sea for cetaceans without the distraction of members of the public and the Observation Protocol takes this into account. The only alteration to the Distance Sampling Protocol is that when an animal is sighted no angle reading is taken. Although data collected via the Observation Protocol cannot be used to inform abundance estimates, cetacean density and distribution trends can still be reported.

"The State of European Cetaceans reinforces the critical role that citizen scientists have to play in protecting our wildlife, and I am hopeful that policy makers will give it significant weight as they work to protect our marine life."

Chris Packham

Television presenter, wildlife expert, photographer, author and ORCA patron.

ORCA Looking out for Whales and Dolphins

www.orcaweb.org.uk

Charity No: 1141728, Company No: 7463043