Looking out for Whales and Dolphins

THE STATE OF EUROPEAN CETACEANS 2019

UNIVERSITY OF PLYMOUTH

FOREWORD

Marine conservation has been making headline news recently – and about time too. We may be several decades late, but at last we're waking up to the impending catastrophe that is looming over the world's oceans and their myriad inhabitants.

Whales, dolphins and porpoises, in particular, face a barrage of threats. They are still hunted (a truly shocking thought in the 21st Century), they are struck by ships, hundreds of thousands of them drown in fishing nets every year, they ingest an insidious tide of plastic waste, they struggle against an onslaught of underwater noise and, as if that's not enough, they are now suffering the consequences of climate change.

They need all the help they can get. And that's where ORCA – one of my favourite charities – comes to the fore.

ORCA is good at many things. But it's particularly good at whales and people. Its vision is for the world's oceans to be alive with whales and dolphins, as they were a couple of hundred years ago. And its mission is to give everyone who cares about these magnificent animals an active role in safeguarding their future.

It's a brilliant concept. Relying on an outstanding and tireless army of trained volunteers – people from all walks of life, and of all ages, who give up their time to make the world a better place – ORCA painstakingly gathers the information essential for conservation. By creating a much more complete picture of the cetaceans in UK and European waters (which species live where and what threats they face) it identifies areas where they are most vulnerable and takes the necessary steps to protect them.

That's why 'The State of European Cetaceans 2019' is citizen science at its best: a veritable treasure trove of invaluable information and testament to the fact that, quite simply, ORCA gets the job done.

But this is just the first step in what is, inevitably, an uphill struggle. Saving whales, dolphins and porpoises is no longer something that conservation groups and dedicated individuals can fix alone. Politicians need to get on board and act now – before it is too late.

Mark Carwardine

Author of *Handbook of Whales, Dolphins and Porpoises* and ORCA patron

Humpback whale

KEY FINDINGS

'The State of European Cetaceans 2019' report is the latest milestone in ORCA's ongoing mission to use data collected by citizen scientists from platforms of opportunities (ferries and cruise ships) to improve the protection of whales, dolphins and porpoises within UK and European waters. Since 2001, trained volunteer Marine Mammal Surveyors have boarded ferries and cruise ships crossing the North-East Atlantic and beyond, recording the marine wildlife they observed. This is the fourth in a series of annual reports and builds on existing publications.

This report in particular looks at how citizen science can be used to better understand the habitat preferences of fin whales in the Bay of Biscay and how their distribution is affected by the density of marine traffic. The aim of this study is to reduce the number of large whales being hit by ships in areas where both whales and ships overlap in high densities.

Another critical part of this report is an examination of the multiple threats facing whales, dolphins and porpoises within European waters. The wide-ranging and cumulative threats that cetaceans face both on a regional and global scale are highlighted.

The State of European Cetaceans reports continue to demonstrate why ongoing, regular monitoring of cetaceans is vital. The compilation and analysis of real-time, long-term data are essential to make effective and informed decisions about the protection that our whales and dolphins so urgently need. Utilising ferry and cruise platforms is a highly effective tool to estimate the density, distribution and range of these animals in near real-time so that worrying patterns can be identified early.

Whilst citizen scientists can provide an army of watchful eyes thanks to the (extra) ordinary people who volunteer their free time in the name of science and conservation, we also need a commitment from governments to take swift and decisive action when evidence shows the growing threat to these animals and the habitats in which they live.

Common dolphins - Paul Soulby

Ferry & Cruise Survey Highlights (2018)

First surveys in the Eastern Pacific and South Atlantic Ocean

- ORCA regularly surveys nine regions: Arctic Waters; North Sea; English Channel; Celtic Sea; Irish Sea; Minches and West Scotland; Bay of Biscay and Iberian Coast; Wider Atlantic and the Mediterranean Sea. In 2018, the Eastern Pacific, and South Atlantic Ocean were also surveyed for the first time.

- In 2018, ORCA conducted 91 ferry surveys and 22 cruise surveys with a total survey distance of 50,901 km.

Over 12,500 cetaceans recorded

- ORCA surveyors reported a record number of cetacean encounters in 2018, with a total of 2,840 encounters across both ferry and cruise surveys, which amounted to 12,966 animals.

An encounter refers to a single sighting, consisting of one individual or a group of animals of the same species

- Overall, harbour porpoises were the most frequently recorded species (645 encounters), followed by common dolphins (480 encounters), humpback whales (285 encounters), fin whales (193 encounters), minke whales (126 encounters), white-beaked dolphins (82 encounters), bottlenose dolphins (68 encounters), and striped dolphins (67 encounters), with all other cetacean species recorded fewer than 30 times. Of these encounters, 2,195 were identified to species level, consisting of 11,253 individual animals.

Northern right whale dolphin: an ORCA first

- Twenty-nine different cetacean species were identified, including several species recorded in the Pacific and South Atlantic, where ORCA surveyors have not surveyed previously. Dall's porpoises, northern right whale dolphins, Pacific white-sided dolphins, dusky dolphins, Peale's dolphins, Commerson's dolphins and southern right whales were recorded for the first time.

Nearly 4,000 cetaceans seen from the UK ferry network

- There were 1,102 encounters of cetaceans from ferry surveys in 2018, consisting of 3,872 individuals, of which 966 encounters involved cetaceans identified as one of 13 cetacean species. Harbour porpoises were most frequently seen, with 426 encounters; however, common dolphins were the most numerous, with 2,125 animals recorded over 311 encounters.

- Most sightings were recorded on the Newcastle – IJmuiden route (226 encounters), predominantly consisting of harbour porpoises (165 encounters), white-beaked dolphins (37), and minke whales (17), closely followed by Plymouth – Santander – Portsmouth (223 encounters), with 156 common dolphins and 23 fin whale encounters.

Wildlife Officer Highlights (2014-2018)

Over 75,500 whales, dolphins and porpoises spotted

- Over five years, ORCA Wildlife Officers have recorded 79,764 animals, 75,544 of which were cetaceans. Twenty cetacean species have been identified. The majority of cetaceans were recorded in the Bay of Biscay, but cetaceans were recorded frequently across all routes. Common species were: common dolphins (encounters (n) = 4,502), harbour porpoises (n=1,447), fin whales (n=605), striped dolphins (n=352), bottlenose dolphins (n=261), minke whales (n=255), and Cuvier's beaked whales (n=248).


Wildlife Officers

Harbour porpoise hotspots identified

- There are clear hotspots for harbour porpoises in the North Sea and around the Hebrides, with fewer sightings in the English Channel and Celtic Sea.

White-beaked dolphins seen in the Bay of Biscay

- The majority of white-beaked dolphins have been recorded on the north-west side of the North Sea on the route the Wildlife Officers travelled between Newcastle and IJmuiden. This species typically prefers cooler waters. They are predicted to restrict their distribution around the UK to the northern tip of Scotland and the Hebrides by the end of the century, so it is surprising that they have been recorded in the Bay of Biscay, albeit in low numbers.

Minke whales recorded on all routes

- Recorded on all routes, minke whales were encountered at much higher rates in northern areas, in the Hebrides and along the Northumberland, Durham and Yorkshire coasts. Minke whales were also recorded frequently close to the Brittany coast, near the island of Ushant.

Fin whales and Cuvier's beaked whales frequently recorded in the Bay of Biscay

- Fin whales were frequently recorded in the Bay of Biscay, with increased encounter rates over deep pelagic waters. There were also records near the south coast of Ireland, over shallower waters.

- Cuvier's beaked whales were recorded only in the Bay of Biscay, typically in deeper water, with the highest encounter rates occurring in proximity to the sub-sea canyons.

Rare True's beaked whale: A new discovery

- In 2018, a pod of four True's beaked whales were recorded breaching repeatedly alongside a large passenger ferry. This species is rarely recorded alive. The animals in the most recent encounter were identified by independent experts, and one of the four individuals was observed to have a never-before-seen morphological feature, an additional pair of teeth, in addition to the typical two tusks.

Humpback whale: A first in Biscay

- Humpback whales have been anecdotally observed in the Bay of Biscay, but never before recorded during a dedicated survey.

Fin Whale Distribution: assessing the potential impact of ship strikes

Since 1992, it is estimated that the number of marine vessels worldwide has increased fourfold. Ship strikes do not discriminate between species of whale, class of marine vessel, or body of water. Whilst ship strikes are not as extensively studied as many other threats to whale populations, several studies suggest that collisions with vessels form a significant proportion of whale deaths.

Today, fin whales are classified as endangered with global populations estimated between 50,000 and 100,000, but it has been suggested that the projected recovery has been slowed by two factors: climate change affecting food sources and greater interactions with marine vessels.

The Bay of Biscay is a gulf of water situated north of Spain and west of France. Due to the topography of the Bay, the strong currents and winds create nutrient-rich upwellings attracting marine organisms across many trophic levels, from phytoplankton at the bottom to fin whales at the top. The Bay of Biscay is considered a high-risk area for ship strikes, where a high density of fin whales and shipping overlap.

Using citizen science data collected from ferries crossing the Bay of Biscay from 2015 to 2018, the study looked at how the habitat preferences of fin whales are affected by the density of the marine vessels.

Key findings included that fin whales were most prevalent in the Bay of Biscay in May and September, but are present throughout the summer months. Fin whales were found to prefer areas with fewer vessels, with a preference for deeper pelagic waters, but also warmer waters.

Building on this study more work is currently being undertaken to look at the overlap between whales and vessels to identify areas of concern within this region so longer-term appropriate mitigation measures can be introduced.

Fin whale

Threats to European Cetaceans

Whales, dolphins and porpoises depend upon the marine environment, but intensification of human activities has resulted in unprecedented changes to our oceans, threatening the survival of cetaceans on a global scale. On a daily basis whales, dolphins and porpoises are faced with significant and emerging threats, but these do not occur in isolation and it is the cumulative impact of the wide-ranging and ever-increasing threats that is of paramount concern.

Despite a moratorium on commercial whaling coming into effect over 30 years ago, hundreds of whales are killed for the commercial market each year. This cruel and unnecessary slaughter has no place in modern society and international collaboration is urgently needed to call on Iceland, Japan and Norway to end their hunts and trade in whale products with immediate effect.

Collisions between ships and cetaceans have significantly increased in recent decades. With the expansion of the human population, more goods are transported by sea, increasing marine traffic across all oceans. In some areas collisions between whales and ships have become a matter of survival for cetaceans on a population and a species level. It is therefore vital that we further understand this threat to marine mammals and take action to mitigate it, particularly where high density shipping traffic overlaps with high density whale areas, such as in the Bay of Biscay.

Alarm continues to grow over plastic pollution in our marine environment, and the toxic effects of legacy pollutants, such as polychlorinated biphenyls (PCBs), are unfortunately likely to be with us for decades to come. We need to change how we think of and use plastics, as our reliance on such products is having devastating results. This change must happen at all levels, including regulatory bodies, manufacturers, designers, and consumers. We therefore call upon policy makers to create pressure for such change to help turn the tide on plastic and toxic pollution.

Pilot whale - Charlie Moffat

Cetaceans live in a world of sound, and the ability to hear well is vital in all key aspects of their lives including communication, finding food, locating predators and navigation. Man-made noise in the marine environment is increasing in level and quantity, making these essential activities ever more difficult to perform. In addition, very loud, impulsive sounds such as those resulting from seismic surveys, underwater explosions and powerful military sonar, can cause displacement of animals from important habitats and even permanent hearing loss and death. Since man-made noise can propagate across vast stretches of ocean, and some cetacean species migrate thousands of kilometres, it is an issue that needs international regulation. There is an urgent need for governments to strengthen and standardise mitigation measures, and critically, to implement an effective noise reduction strategy.

The incidental capture and death of whales, dolphins and porpoises in fishing gear (bycatch) is not a new phenomenon, yet thousands of animals continue to succumb to such a fate in European waters every single year. In UK waters bycatch is a serious conservation and welfare issue with the majority of stranded animals' deaths attributed to bycatch. However, this issue is not without potential solutions and change needs to be driven by policy. Bycatch in the UK is largely localised and limited to specific fisheries, making the goal of achieving meaningful bycatch reductions, and even eliminating it, something that is realistic to achieve. We urge the UK Government to review fisheries management and practices, invest in new technologies that will reduce the incidence of bycatch and to phase out high-risk gear types such as set nets.

With human activity representing a key conservation threat for cetaceans, we have a responsibility to take action and safeguard our whales, dolphins and porpoises for future generations. Scientifically robust evidence is ever-growing and for governments to not act upon current evidence in real-time and take meaningful, effective mitigation measures is wholly irresponsible.

Entangled minke whale - Steve Truluck

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Acknowledgements

Shipping partners

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*correct as of 2018

Corporate members

Contributors

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ORCA volunteers

ORCA's offshore monitoring programme is entirely reliant on our network of volunteer Marine Mammal Surveyors. Each one plays a role in this vital monitoring work – whether in the past, present or future.

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

Sperm whale - Heather Bodie

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 and 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; 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 become Marine Mammal Surveyors and join our survey teams on board the ferry network and help to support our educational programmes. ORCA's projects reach over 100,000 people of all ages each year, providing memorable educational activities and remarkable wildlife experiences both on shore and offshore. By doing so, we are empowering local communities to become stewards of whales and dolphins and the marine environment in which they live.

ORCA Wildlife Guides and guests

The Report and its Purpose

'The State of European Cetaceans 2019' report is the fourth in a series of annual reports published by ORCA. It summarises the distribution and range of cetacean populations, with a focus in and around European waters using data collected on platforms of opportunity (namely ferries and cruise ships). This 2019 edition provides an update on the threats that cetaceans face, and presents key findings from the last 12 months. These include the 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 these species.

With ever-increasing commercial pressures impacting our oceans, justifiable concern is building about the health of our marine ecosystems. ORCA's cetacean monitoring programme helps to provide the year-round supporting evidence necessary 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 hotspots that must be given more protection as a matter of urgency.

This report is the culmination of 13 years of sightings and environmental data collected between 2006 and 2018 during more than 600 surveys. It highlights observations recorded during the 2018 survey season and uses a long-term dataset collected by citizen scientists to analyse the conditions that drive fin whale distribution in the Bay of Biscay.

Minke whale - Hannah Snead

SURVEY OVERVIEW

Humpback whale - Oliver Turpin

Survey Methodology

ORCA conducts surveys across line-transects according to distance sampling methodologies, a widely employed technique 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 vessel's bridge (or another forward-facing platform) aboard ferries. A standardised survey protocol is adhered to ensuring data collection is rigorous and comparable.

Similar methodologies are followed aboard cruise ships and by Wildlife Officers; however, survey effort is more variable due to different sized teams, and often teams are located on the open decks with passengers who can assist with surveying duties.

Survey areas

ORCA regularly surveys nine regions (Figure 1): Arctic Waters, North Sea, English Channel, Celtic Sea, Irish Sea, Minches and West Scotland, Bay of Biscay and Iberian Coast, Wider Atlantic and the Mediterranean Sea. In 2018, the Eastern Pacific, and South Atlantic Ocean were also surveyed for the first time.

Figure 1: OSPAR regions surveyed.

Since 2006, ORCA has conducted 558 dedicated distance sampling surveys on 19 ferry routes in partnership with eight ferry companies. Additionally, 87 surveys following an effort-based survey methodology have been conducted in partnership with six cruise companies. These partnerships have enabled survey effort in new locations, including the south-west of Greenland, the west coast of the United States of America, Argentina and the Falkland Islands.

Sea Region	Route Code	Route	Years Active	Company
North Sea	NsIJ	Newcastle – IJmuiden	2009 & 2011 – 2018	DFDS
	NcBg	Newcastle – Bergen	2006 – 2008	DFDS
	HwEb	Harwich – Esbjerg	2008 – 2014	DFDS
	ImGoBvIm	Immingham – Gothenberg – Brevik	2015	DFDS
	AbLw	Aberdeen – Lerwick	2006 – 2018	NorthLink
	Cruise	Various cruises	2006 – 2018	Saga, Silversea
Irish Sea	HsPd	Heysham – Douglas	2011 – 2013 & 2016	Isle of Man Steam Packet Company
	Cruise	Various cruises	2008 – 2018	Saga
Bay of Biscay and Iberian Coast	PlSt	Plymouth – Santander	2006 – 2008	Brittany Ferries
	PlStPm	Plymouth – Santander – Portsmouth	2009 – 2018	Brittany Ferries
	Cruise	Various cruises	2006 – 2018	Saga, P&O Cruises
English Channel	PlRc	Plymouth – Roscoff	2014 – 2018	Brittany Ferries
	PlRcCk	Plymouth – Roscoff – Cork	2017	Brittany Ferries
	PmCa	Portsmouth – Caen	2014 – 2018	Brittany Ferries
	PoCb	Poole – Cherbourg	2017 – 2018	Brittany Ferries
	DvCl	Dover – Calais	2016 – 2018	DFDS
	PmFb	Portsmouth – Fishbourne	2016 – 2018	Wightlink
	SoCo	Southampton – Cowes	2016 – 2018	Red Funnel
	Cruise	Various cruises	2006 – 2018	Saga
Celtic Sea	PzSm	Penzance – St Mary's	2009 – 2018	Isles of Scilly Travel
	Cruise	Various cruises	2009 – 2018	Saga
Mediterranean Sea	Cruise	Various cruises	2009 – 2018	Saga
Minches and West Scotland	UlSw	Ullapool – Stornoway	2018	Caledonian MacBrayne
	ObCs	Oban – Castlebay	2018	Caledonian MacBrayne
	ObTiCo	Oban – Tiree – Coll	2018	Caledonian MacBrayne
	Cruise	Various cruises	2009 – 2018	Saga
Wider Atlantic	Cruise	Various cruises	2009 – 2018	Saga
Arctic waters	Cruise	Various cruises	2009 – 2018	Saga, Silversea

Table 1: Routes surveyed by ORCA within the OSPAR regions between 2006 and 2018.

Bottlenose dolphins - Rebecca Walker

Distance surveyed (effort)

In 2018, ORCA conducted 91 ferry surveys and 22 cruise surveys. The ferry surveys took place with eight ferry companies across 12 ferry routes. Two of these routes were in the North Sea (AbLw and NsId), four within the English Channel (DvCl, PmCa, PlRc and PoCb), one in the Celtic Sea (PzSm), one traversed the English Channel and Celtic Sea (PlRcCo), one route traversed the English Channel, Celtic Sea and the Bay of Biscay (PlStPm), and three routes were piloted in the Hebrides (UlSw, ObCs, ObTiCo; Table 1 and Figure 2). The 22 cruises were conducted on board Saga, P&O Cruises, Oceanwide Expeditions, and Silversea cruise ships across the North Atlantic, South Atlantic, Eastern Pacific, and Mediterranean Sea.

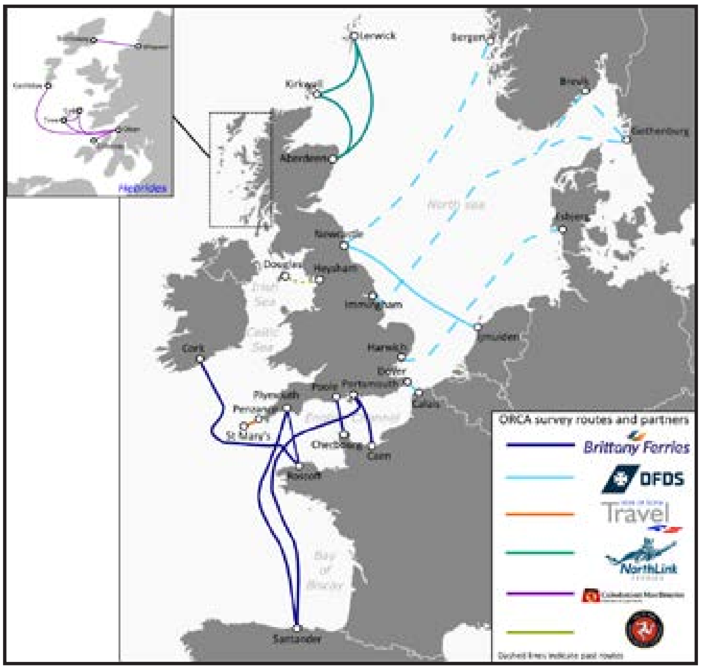


Figure 2: Ferry routes surveyed by ORCA in 2018.

The total surveyed distance in 2018 across all regions was 50,901 km (Figures 3 and 4). There was 28,536 km of survey effort from cruise ships, including the first survey effort for ORCA off the west of Greenland, the Eastern Pacific, and the South Atlantic oceans. This extended coverage added new species to our database (see below), and allowed data sharing with local research organisations, enabling increased conservation value from those cruises. There was also 22,365 km of survey effort on board ferries, with dedicated distance sampling surveys (Table 2). The survey route with the highest effort was found to be Portsmouth – Santander – Plymouth.

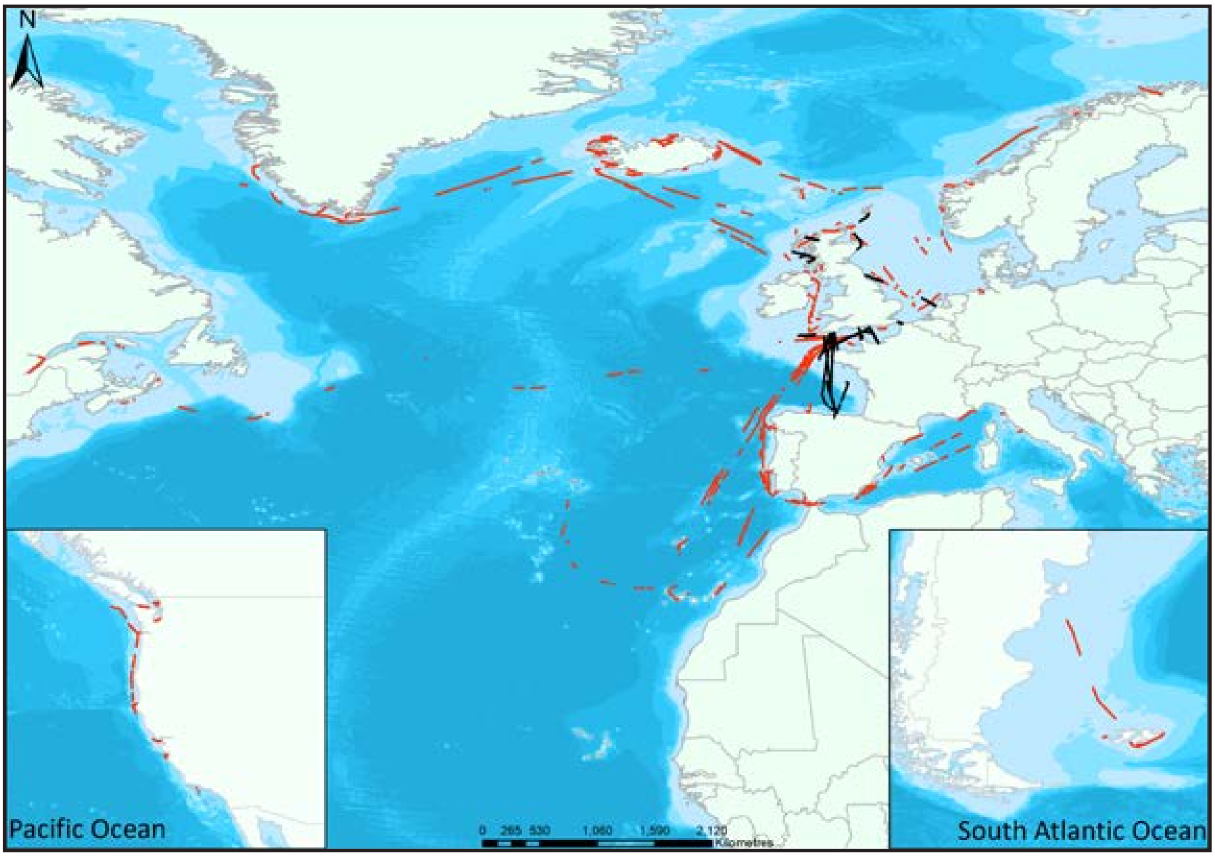


Figure 3: Cruise (red) and ferry (black) survey effort in 2018.

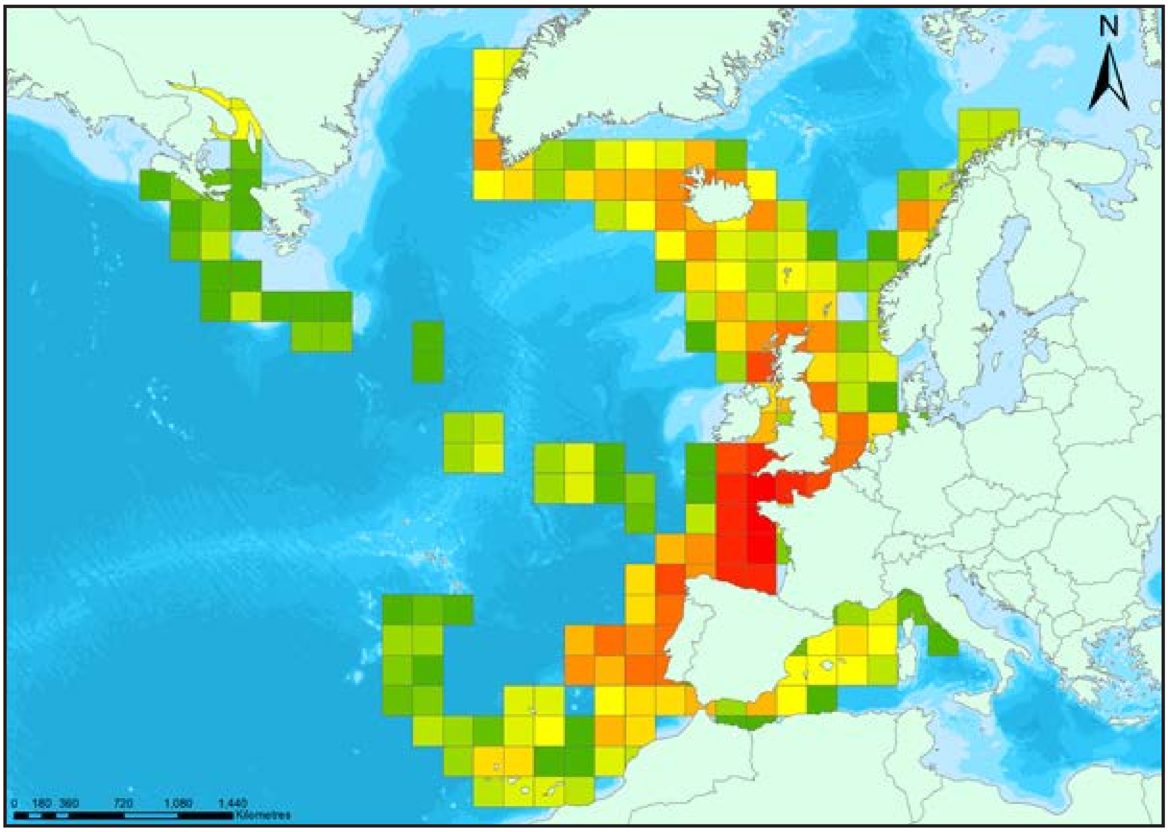


Figure 4: Relative amount of survey effort across the most frequently surveyed area in the North Atlantic, calculated as a total effort in km across 200 km grid cells. Green cells indicate relatively low effort, in an increasing scale of warmer colours to red which indicates the highest amount of effort.

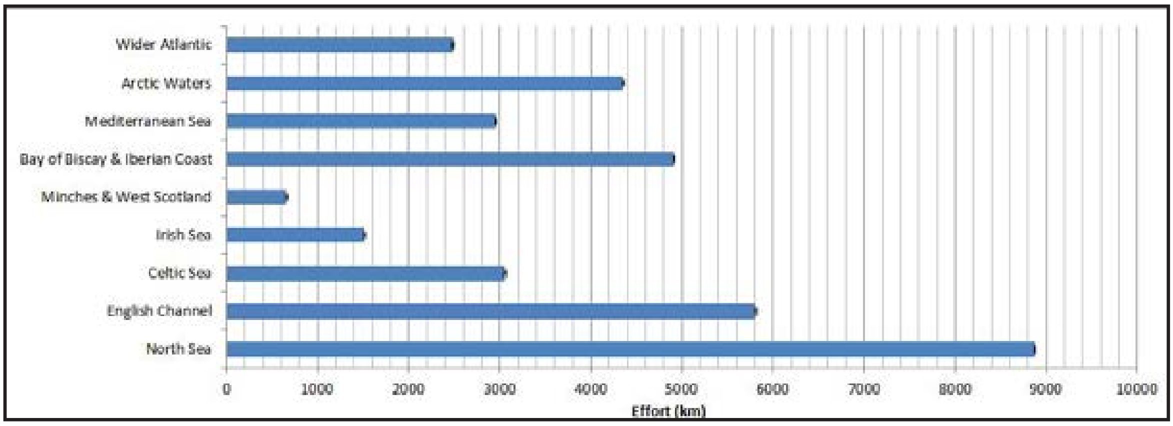


Figure 5: The total amount of effort (km) undertaken within each survey region in 2018.

Year	HsPd	HwEb	ImGoBvIm	NcBg	NsId	PlRc	PlRcCk	PlSt	PlStPm	PmCa	PzSm	DvCl	AbLw	PmFb	SoCo	PoCb	ObCs	ObTiCo	UlSw	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					15287
2017					7282	2708	385		6430	2912	4771	730	2109			891	210	122	188	28738
2018					3612	1184			5911	1767	2937	575	2632			983	1171	1003	590	22365
Total	2893	16763	4297	23115	36095	7469	385	5651	55985	8047	20129	1687	5657	107	111	1874	1381	1125	778	193549

Table 2: Total effort (km) undertaken on ferry routes. See Table 1 for route code meanings.

Sightings

ORCA surveyors reported a record number of cetacean encounters in 2018, with a total of 2,840 encounters across both ferry and cruise surveys, which amounted to 12,966 animals (Figure 6).

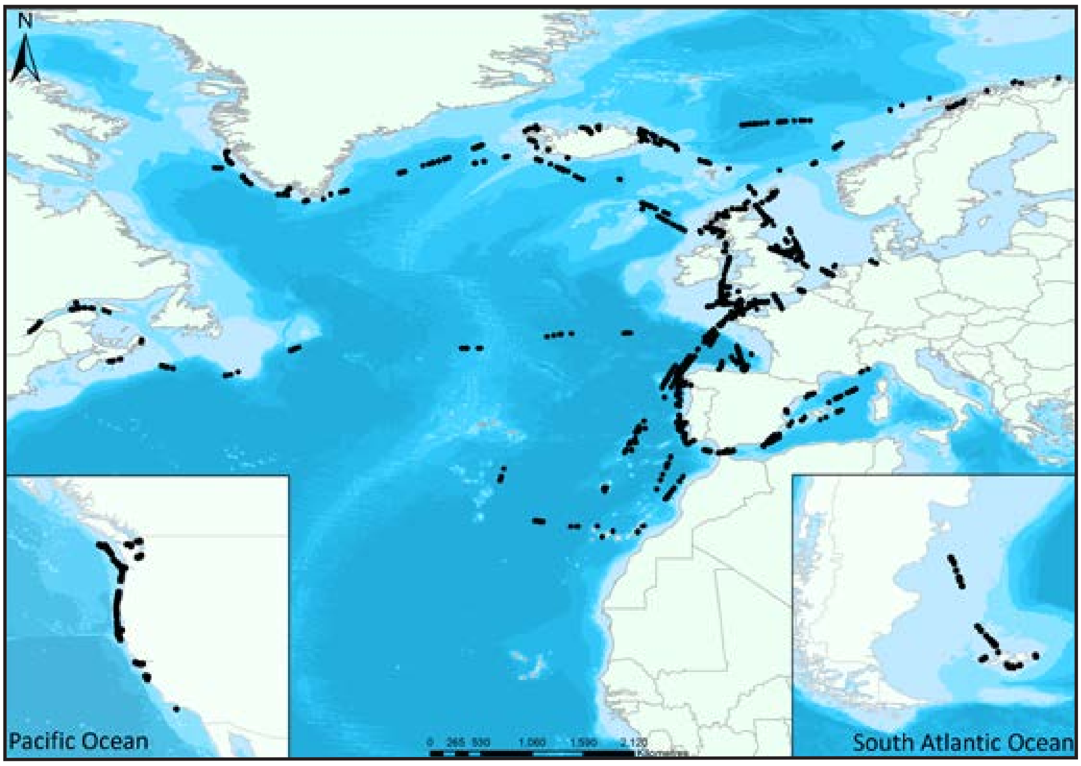


Figure 6: All sightings recorded by ORCA citizen scientists from ferries and cruise ships in 2018.

Of these, 2,195 were identified to species level, consisting of 11,253 individual animals (Table 3). Twenty-nine different cetacean species were identified, including several species recorded in the Eastern Pacific and South Atlantic Ocean, where ORCA have not surveyed previously. Dall's porpoises, northern right whale dolphins, Pacific white-sided dolphins, dusky dolphins, Peale's dolphins, Commerson's dolphins, and southern right whales were recorded for the first time.

Overall, harbour porpoises were the most frequently recorded species (645 encounters), followed by common dolphins (480 encounters), humpback whales (285 encounters), fin whales (193 encounters), minke whales (126 encounters), white-beaked dolphins (82 encounters), bottlenose dolphins (68 encounters), and striped dolphins (67 encounters), with all other cetacean species recorded fewer than 30 times.

White-beaked dolphin - Micky Maher

Species	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Harbour porpoise (*Phocoena phocoena*)	75	61	60	76	83	175	199	271	338	206	369	372	645	**2930**
Bottlenose dolphin (*Tursiops truncatus*)	8	9	19	18	8	33	12	24	25	16	30	60	68	**330**
Common dolphin (*Delphinus delphis*)	26	64	58	54	108	143	102	220	129	312	373	487	480	**2556**
Striped dolphin (*Stenella coeruleoalba*)	4	6	2	12	13	27	16	28	14	23	87	133	67	**432**
Risso's dolphin (*Grampus griseus*)	1	2	1	2	1	5	4	6	10	3	9	26	19	**89**
White-beaked dolphin (*Lagenorhynchus albirostris*)	4	11	3	3	1	28	19	46	79	21	54	43	82	**394**
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	1	1				2	1	1	2	6		6		**20**
Atlantic spotted dolphin (*Stenella frontalis)*												20	26	**46**
Rough-toothed dolphin (*Steno bredanensis)*												1		**1**
Killer whale (*Orcinus orca*)	1		1	1		2	4	2	11	9	13	4	13	**61**
False killer whale (*Pseudorca crassidens*)	1											2	1	**4**
Long-finned pilot whale (*Globicephala melas*)	2	13	7	10		6	20	2	3	8	6	20	25	**122**
Short-finned pilot whale (*Globicephala macrorhynchus*)										3	2	4	3	**12**
Sperm whale (*Physeter macrocephalus*)	3	3	2	7	5	8	2	14	11	13	15	42	20	**145**
Beluga (*Delphinapterus leucas*)							6			3	2		17	**28**
Northern bottlenose whale (*Hyperoodon ampullatus*)	10	2	3		2	1	1		5	8	1	7	19	**59**
Cuvier's beaked whale (*Ziphius cavirostris*)	2	2	3	8	3	10	12	6	8	12	9	15	8	**98**
Sowerby's beaked whale (*Mesoplodon bidens*)		1		1	1	6	1	1	1	2	2	2	1	**19**
True's beaked whale (*Mesoplodon mirus*)		1								1			1	**3**
Minke whale (*Balaenoptera acutorostrata*)	6	9	9	15	16	36	52	43	79	44	50	102	126	**587**
Fin whale (*Balaenoptera physalus*)	6	14	74	11	6	42	27	28	49	35	95	105	193	**685**
Sei whale (*Balaenoptera borealis*)		1			1		2	2	6		5	14	11	**42**
Humpback whale (*Megaptera novaeangliae*)			1		1	3	7	10	31	25	32	89	285	**484**
Blue whale (*Balaenoptera musculus*)							3	4	3	1	13	1	4	**29**
North Atlantic right whale (*Eubalaena glacialis)*												1		**1**
Bryde's whale (*Balaenoptera edeni)*											1	3		**4**
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	**1559** / 23	**2114** / 29	
Number of surveys per year	19	25	27	28	25	39	43	46	64	64	71	73	91	
Average no. of encounters per survey	8	8	9	8	10	14	11	15	13	12	16	21	23	

Table 3: Number of encounters of each species 2006 – 2018.

Sightings by ferry route

There were 1,102 encounters of cetaceans on ferry surveys in 2018, consisting of 3,872 individuals, of which 966 encounters involved cetaceans identified as one of 12 cetacean species (Table 4). Harbour porpoises were most frequently seen, with 426 encounters; however, common dolphins were the most numerous, with 2,125 animals recorded over 311 encounters.

Most sightings were recorded on the Newcastle – IJmuiden route (226 encounters), predominantly consisting of harbour porpoises (165), white-beaked dolphins (37) and minke whales (17); closely followed by Plymouth – Santander – Portsmouth (223 encounters), with 156 common dolphins and 23 fin whales.

Species	PmCa	AbLw	PzSm	NsId	PlStPm	PoCb	ObTiCo	DvCl	ObCs	UlSw	PlRc	Total
Harbour porpoise	21	125	43	165	5	2	11	16	16	15	7	426
Bottlenose dolphin	2	19	1	6	18	3	0	4	1	1	7	62
Common dolphin	0	1	83	0	156	0	1	0	17	16	37	311
Striped dolphin	0	0	0	0	9	0	0	0	0	0	0	9
Risso's dolphin	0	0	4	0	0	0	0	0	2	1	0	7
White-beaked dolphin	0	10	0	37	0	0	0	0	0	0	0	47
Killer whale	0	2	0	1	0	0	0	0	0	0	0	3
Long-finned pilot whale	0	0	1	0	0	0	0	0	0	0	0	1
Northern bottlenose whale	0	0	0	0	1	0	0	0	0	0	0	1
Cuvier's beaked whale	0	0	0	0	6	0	0	0	0	0	0	6
Minke whale	0	13	7	17	5	0	7	0	11	9	1	70
Fin whale	0	0	0	0	23	0	0	0	0	0	0	23
Total number of encounters	23	170	139	226	223	5	19	20	47	42	52	966

Table 4: Number of encounters for identified cetaceans in 2018.

Risso's dolphin - Elfyn Pugh

Wildlife Officers

In addition to the dedicated efforts of volunteer survey members, Wildlife Officers have been employed by ORCA, collecting standardised data since 2014. Similar to the protocol used on cruise ships, Wildlife Officers collect data from the open decks, across a network of ferries.

Operating for up to nine months of the year, Wildlife Officers live on board ferries, providing educational content to passengers and collecting data, often every day for the entire season. This provides fine-scale temporal coverage that is unique for visual cetacean surveys.

Wildlife Officers have collected data on vessels operated by Brittany Ferries, DFDS and Caledonian MacBrayne, crossing the Hebrides, North Sea, English Channel, Bay of Biscay and Celtic Sea (Figure 7). A breakdown of the Wildlife Officer routes is shown in Table 5.

Survey effort was relatively evenly distributed across the routes between 2014 and 2018, apart from the English Channel and the Bay of Biscay, due to two ships operating simultaneously in this area for much of the year (Figure 8). All survey effort is shown in Figure 8; however, subsequent figures which account for survey effort across sightings only show grid cells that contain over 50 km of effort, within that 50 km^2 grid cell. This omitted 13 cells.

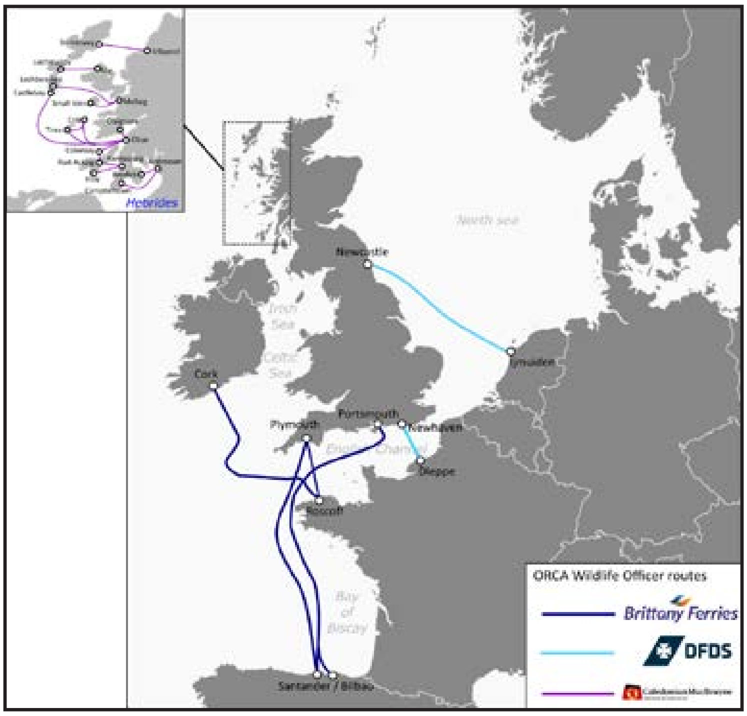


Figure 7: Ferry routes surveyed by ORCA Wildlife Officers in 2018.

Company	Region	Route	Vessel	Years
Brittany Ferries	English Channel, Celtic Sea, Bay of Biscay	Portsmouth – Santander – Plymouth – Roscoff – Cork – Roscoff – Plymouth – Santander – Portsmouth	Pont-Aven	2014 – 2018
	English Channel, Bay of Biscay	Portsmouth – Santander – Portsmouth – Bilbao – Portsmouth	Cap Finistère	2014 – 2018
DFDS	English Channel	Newhaven – Dieppe	Seven Sisters, Cote d'Albatre	2018
	North Sea	Newcastle – IJmuiden	KING Seaways	2014 – 2018
Caledonian MacBrayne	Minches and West Scotland	Various	Various	2018

Table 5: Routes serviced by Wildlife Officers 2014 – 2018.

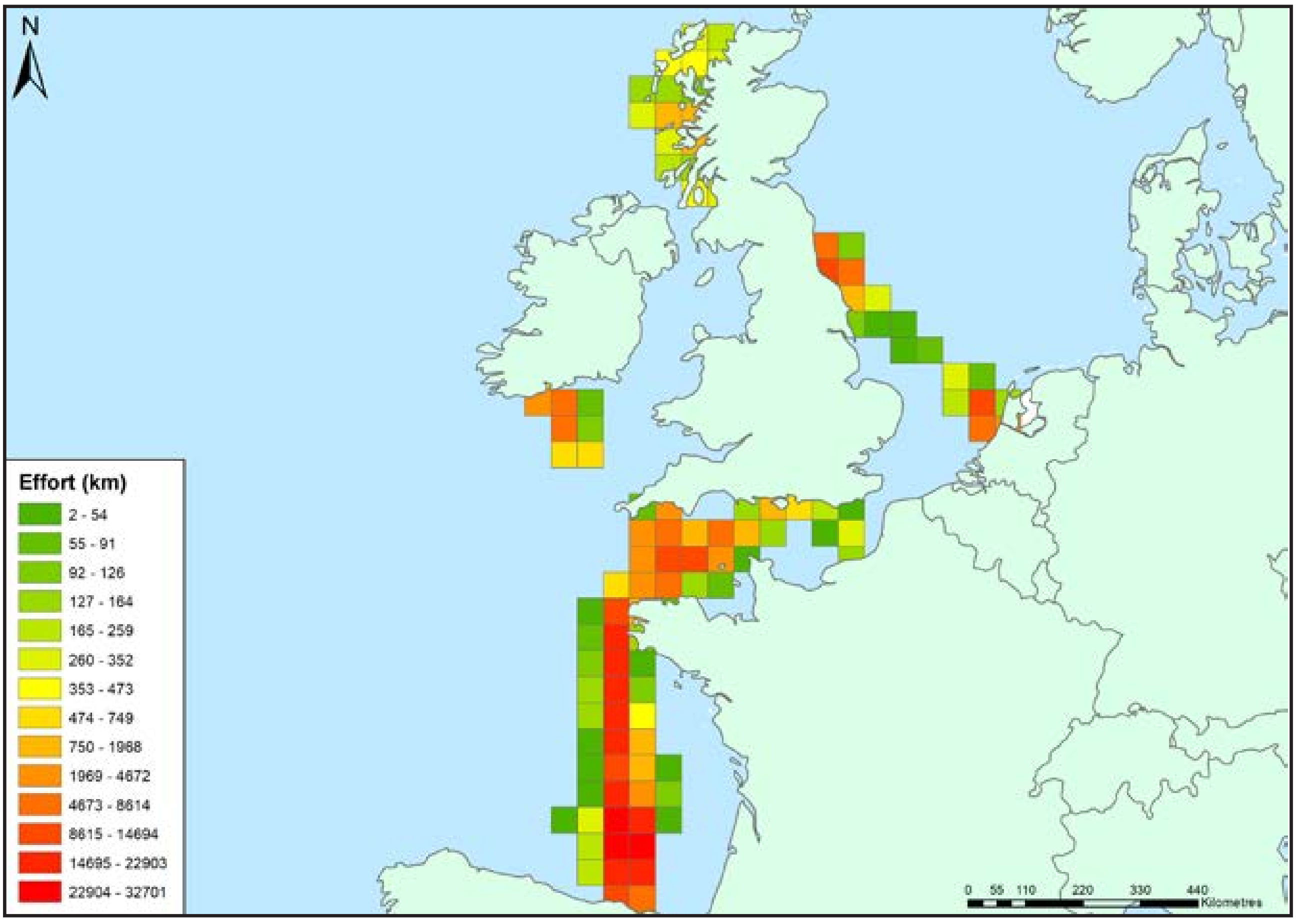


Figure 8: Distribution of survey effort by Wildlife Officers, 2014 – 2018.

The near-continuous data collection that is facilitated by Wildlife Officers living on board ferries for up to nine months of the year provides a unique opportunity to investigate temporal changes of cetacean occurrence. The summary of sightings presented here merely scratches the surface of the potential ability of this dataset to inform of patterns and drivers.

Cuvier's beaked whale - Charlotte Kirchner

Sightings

Over five years, Wildlife Officers have recorded 79,764 animals, 75,544 of which were cetaceans. Twenty cetacean species have been identified (Table 6). The majority of cetaceans were recorded in the Bay of Biscay, but cetaceans were recorded frequently across all routes. Common species were: common dolphins (encounters (n) = 4,502); harbour porpoises (n=1,447); fin whales (n=605); striped dolphins (n=352); bottlenose dolphins (n=261); minke whales (n=255) and Cuvier's beaked whales (n=248).

Species	Number of encounters	Number of individuals
Harbour porpoise	1,447	3,124
Bottlenose dolphin	261	1,755
Common dolphin	4,502	50,513
Striped dolphin	352	3,299
Risso's dolphin	20	159
White-beaked dolphin	261	1,211
Atlantic white-sided dolphin	3	7
Atlantic spotted dolphin	1	1
Killer whale (Orca)	16	39
Long-finned pilot whale	36	202
Sperm whale	48	60
Northern bottlenose whale	12	28
Cuvier's beaked whale	248	530
Sowerby's beaked whale	3	12
True's beaked whale	1	4
Minke whale	255	273
Fin whale	605	861
Sei whale	27	37
Humpback whale	1	1
Blue whale	2	5

Table 6: Number of encounters for all cetaceans identified to species level.

When encounter rates were calculated across the three regions that have effort in multiple months, there are large variations between years – represented by wide confidence intervals (the light blue shaded region) in Figure 9. Encounter rates are marginally higher on average in April and August in the Bay of Biscay, and there is a slight peak at the end of the season in the Hebrides. The signal in encounter rate in the North Sea is clearer, with a peak in June and fewer sightings per km either side of the season. This summary includes all weather conditions, therefore better conditions may bias increased encounter rates and vice-versa.

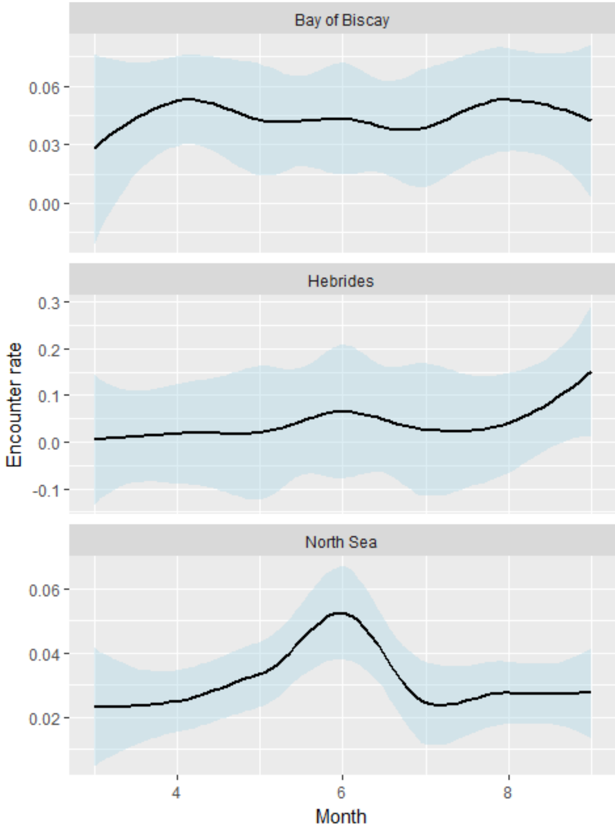
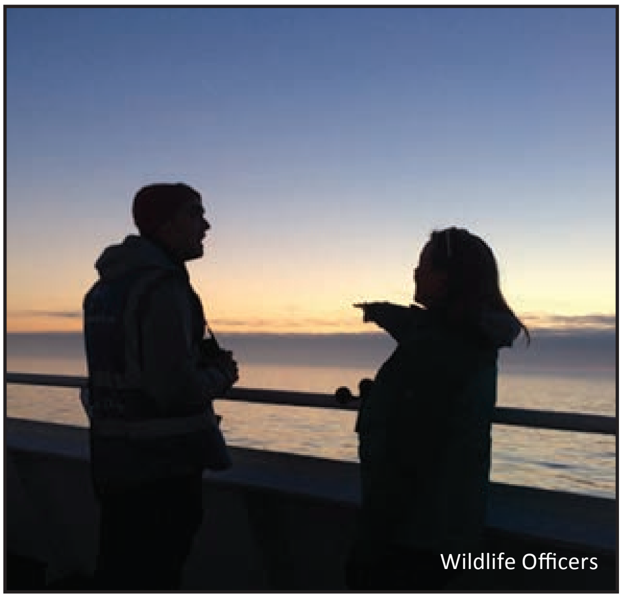


Figure 9: Encounter rate (encounters per km of effort) of cetaceans in the Bay of Biscay, Hebrides and North Sea.

Overall sightings

The majority of encounters occur in the Bay of Biscay, with similarly high numbers close to the coast in the North Sea (Figure 10). However, the amount of survey effort is inconsistent between and within regions due to the timings of deck watches, daylight hours, and the length of Wildlife Officer programmes both within a season, and the number of years that they have been running.



Wildlife Officers

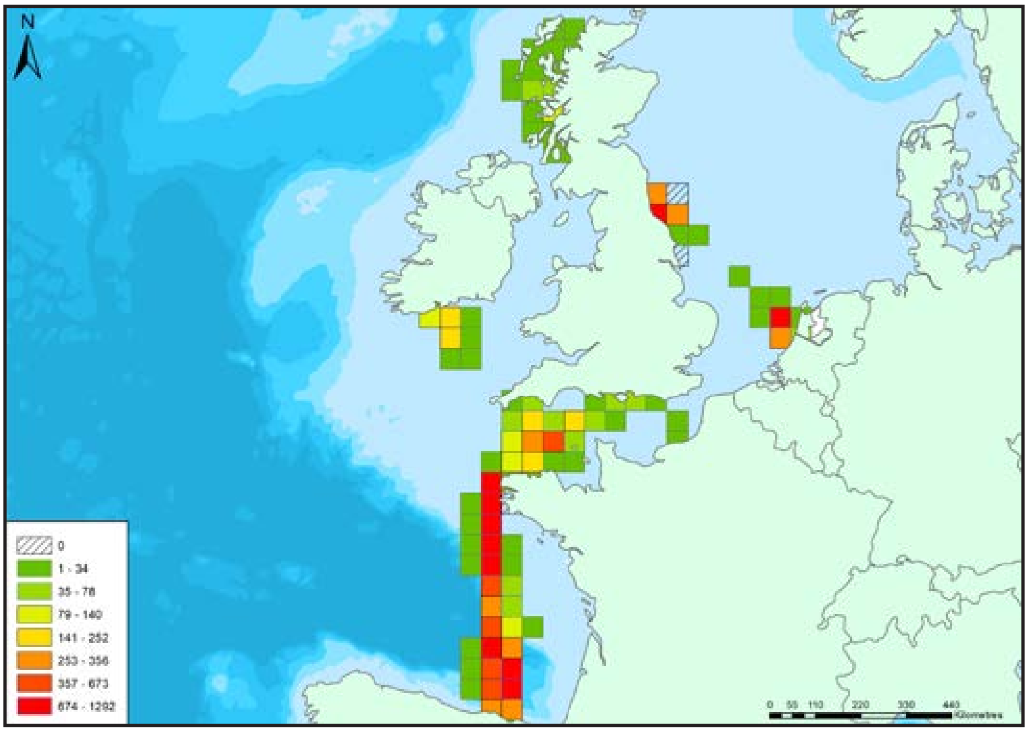


Figure 10: Count of cetaceans recorded per 50 km^2 grid cell.

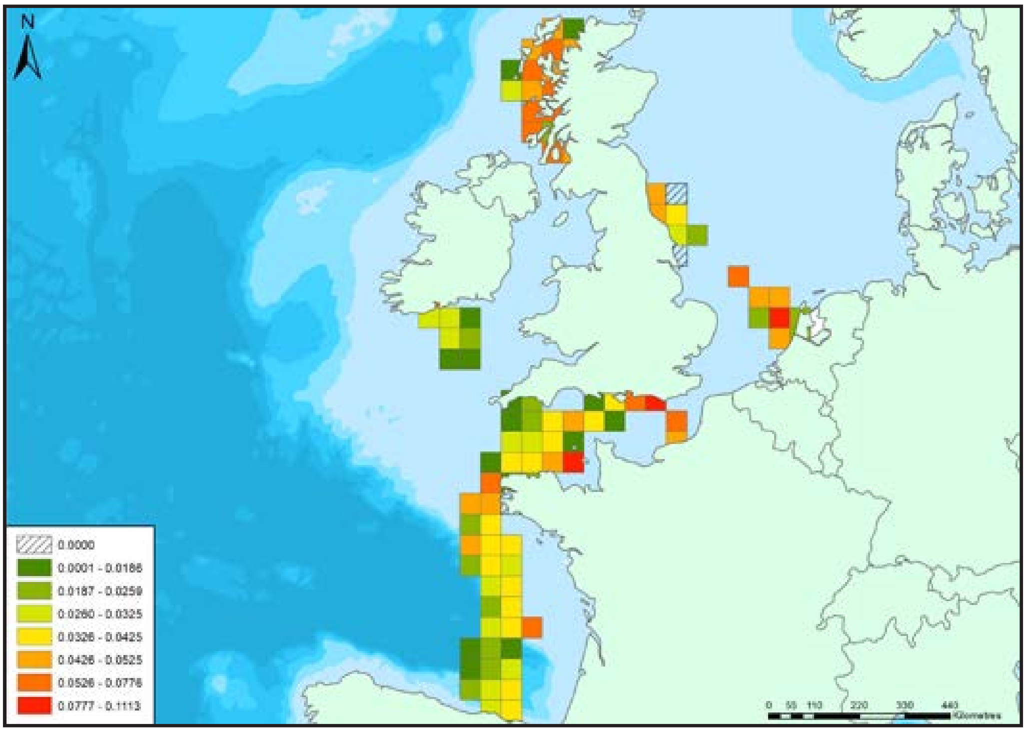


Figure 11: Encounter rate (encounters per km^2 survey effort) across all Wildlife Officer routes, 2014 – 2018.

Encounter rate

Despite there being more encounters in the Bay of Biscay (as shown in Figure 10), there is also an abundance of survey effort. When survey effort is taken into account, and encounter rate is calculated, areas of more frequent sightings are highlighted (Figure 11). Encounter rates are variable throughout routes, with some higher encounter rates occurring around the Brittany coast, the eastern English Channel and eastern North Sea. The Hebrides has comparatively uniform encounter rates, with large numbers of cetaceans seen per km of survey effort.

Sighting per species

Harbour porpoise

There are clear hotspots for harbour porpoises in the North Sea and around the Hebrides, with fewer in the English Channel and Celtic Sea (Figure 12). All sightings are constrained to the continental shelf, which is to be expected from extensive literature identifying a near-shore distribution and widespread preference for shallow waters where they feed on small fish (Embling, 2010; Hammond *et al.*, 2013; ORCA, 2018).

Bottlenose dolphin

Bottlenose dolphins were recorded in all regions, with higher encounter rates in southern areas of the Hebrides, near Newcastle and south of Cork (Figure 12). They were also recorded regularly throughout the entire surveyed area in the Bay of Biscay, but the higher encounter rates occurred on the continental shelf or close to land. The animals recorded belong to several populations, both coastal and offshore.

Common dolphin

Recorded on all routes, common dolphins are widespread, but occur in highest numbers during the surveyed period (March – September) in the Bay of Biscay (Figure 12), an abundance that is well documented (Kiszka *et al.*, 2007; ORCA, 2018; Robbins *et al.*, 2019a). Common dolphin habitat is partitioned from white-beaked dolphins, with common dolphins preferring temperatures higher than 14°C (MacLeod *et al.*, 2008). Here common dolphins feed on fish such as sardine, anchovy, sprat and horse mackerel (Meynier *et al.*, 2008) and small amounts of cephalopods (Pusineri *et al.*, 2007). Whilst the data collection ends in September, common dolphins are documented to utilise the English Channel more in winter months (MacLeod *et al.*, 2009).

Striped dolphin

Despite often being recorded in mixed-pods with common dolphins, striped dolphins are recorded over a much reduced range within the area studied. They were recorded only in the Bay of Biscay, with higher encounter rates over deeper waters, with infrequent observations over the continental shelf (Figure 12). Striped dolphins consume a wide variety of prey, primarily fish species, but are able to change their diet as they move into shallower shelf waters (Spitz *et al.*, 2006). Previous studies have found striped dolphins to be more abundant in the Bay of Biscay during winter months (MacLeod *et al.*, 2009).


Striped dolphin - Paul Soulby

Risso's dolphin

Risso's dolphins were recorded infrequently but over a wide area, with sightings in the Hebrides, English Channel, Celtic Sea and the Bay of Biscay (Figure 12). Photographs taken of Risso's dolphins in the Hebrides have been shared with local organisations to support their population monitoring, using individual markings for identification.

White-beaked dolphin

The majority of white-beaked dolphins have been recorded on the north-west side of the North Sea on the route the Wildlife Officers travel between Newcastle and IJmuiden (Figure 12). This species typically prefers cooler waters below 14°C (MacLeod *et al.*, 2008) and have been recorded in lower numbers around the UK as waters warm (MacLeod *et al.*, 2005; Michel *et al.*, 2009). They are predicted to restrict their distribution around the UK to the northern tip and the Hebrides by the end of the century (Lambert *et al.*, 2014); so it is surprising that they have been recorded in the Bay of Biscay, albeit in low numbers.

Pilot whale

Pilot whales were predominantly recorded in the Bay of Biscay, with the highest encounter rates occurring around the continental shelf edge (Figure 13).

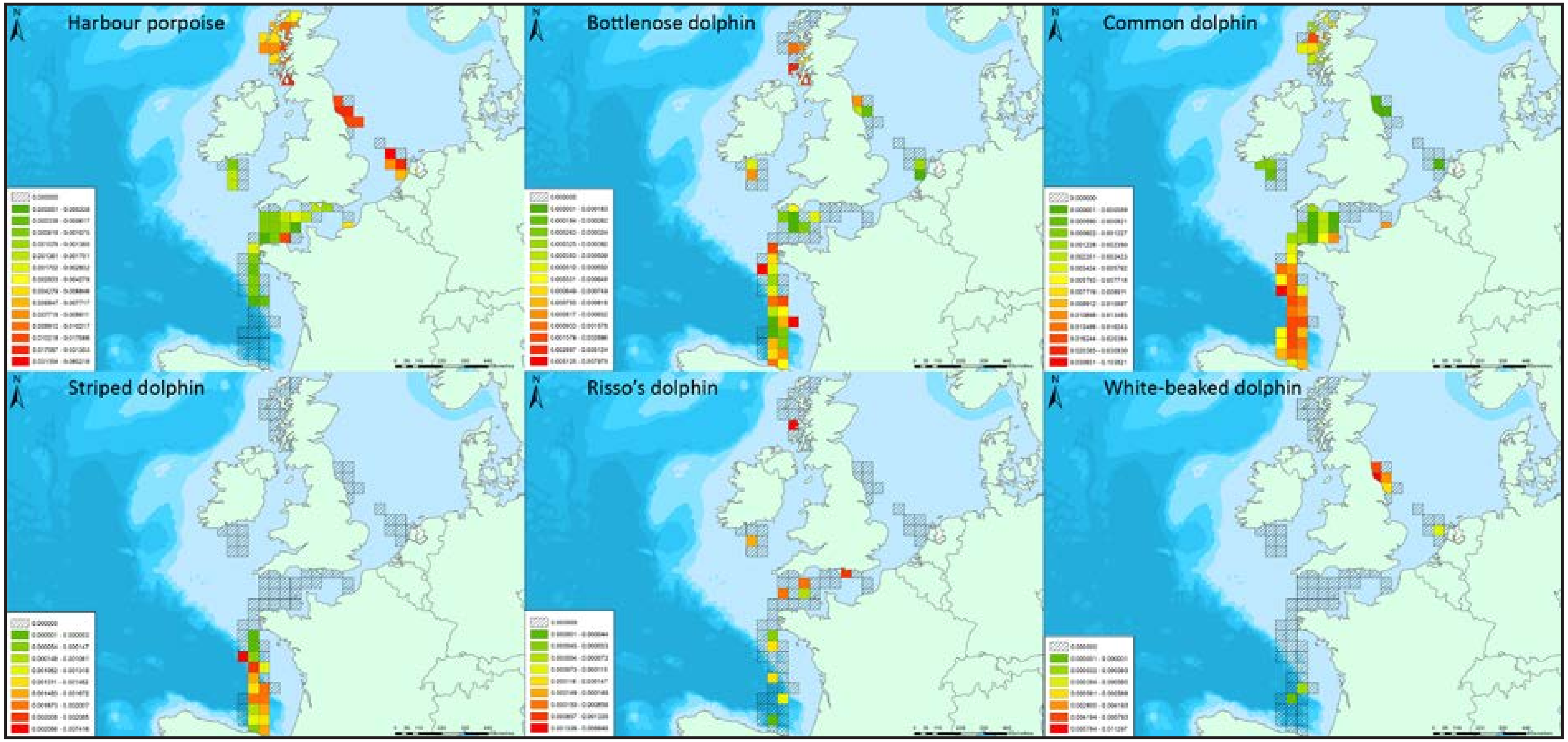


Figure 12: Encounter rates of harbour porpoises, bottlenose dolphins, common dolphins, striped dolphins, Risso's dolphins and white-beaked dolphins per 50 km² across all the Wildlife Officer routes, 2014 – 2018.

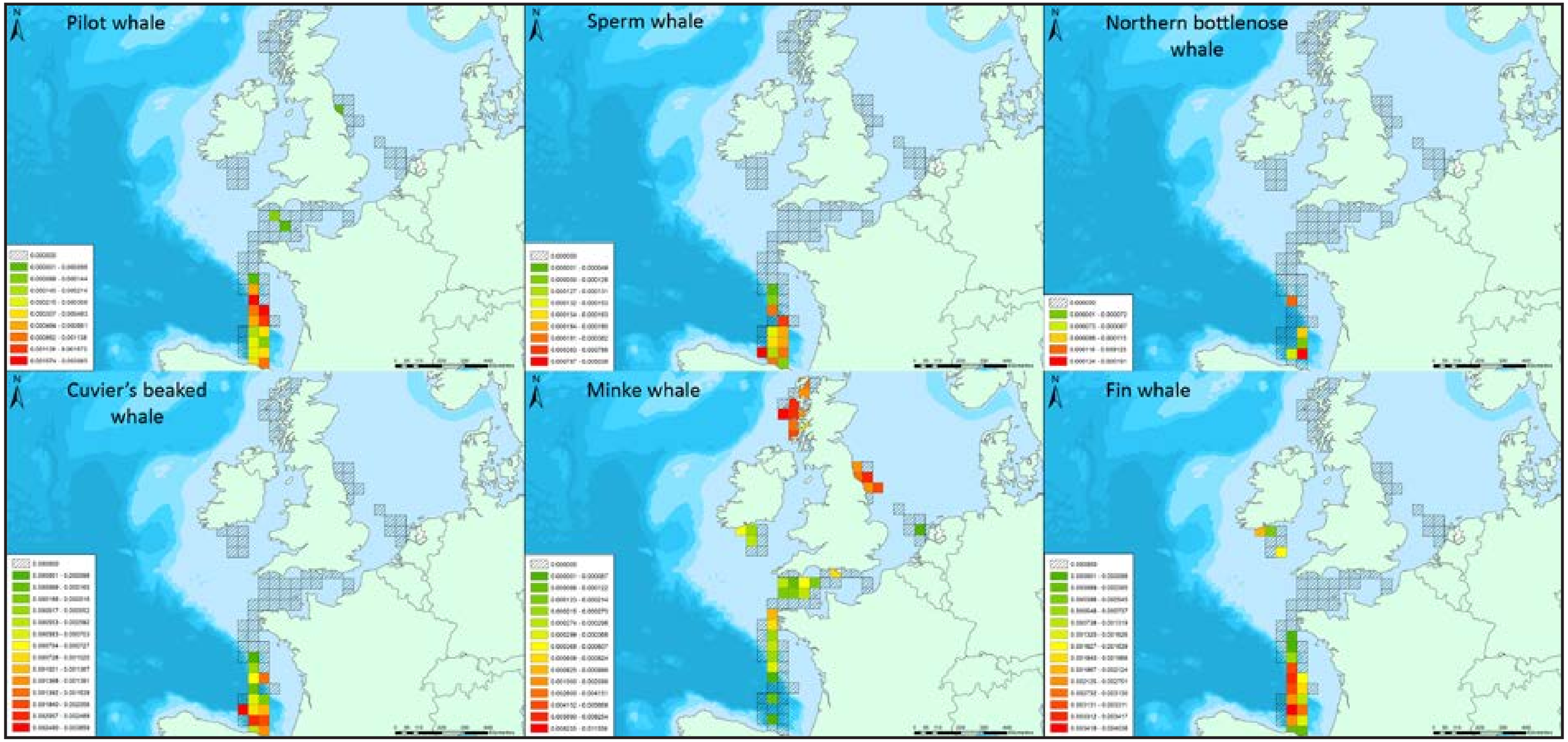


Figure 13: Encounter rates of pilot whales, sperm whales, northern bottlenose whales, Cuvier's beaked whales, minke whales and fin whales per 50 km^2 across all the Wildlife Officer routes, 2014 – 2018.

Sperm whale

Sperm whales were recorded only in the Bay of Biscay, with the highest encounter rates occurring along the continental shelf edge and in deep water (Figure 13).

Fin whale

Fin whales were frequently recorded in the Bay of Biscay, with increased encounter rates over deep pelagic waters (Figure 13). There were also records near the south coast of Ireland, over shallower waters. For more details on fin whale distribution within the Bay of Biscay, refer to pages 29 – 33 which analyses this.

Minke whale

Recorded on all routes, minke whales were encountered at much higher rates in northern areas, in the Hebrides and along the Northumberland, Durham and Yorkshire coasts (Figure 13). Minke whales were also recorded frequently close to the Brittany coast, near the island of Ushant.

Humpback whale

In 2018, a humpback whale was recorded. These have anecdotally been recorded in the Bay of Biscay, but have never before been confirmed in the ORCA dataset.

Northern bottlenose whale

Despite being recorded only 12 times over five years, northern bottlenose whales were always seen in deep water, over the deep-sea canyons on the southern edge of the Bay of Biscay, and near the continental slope (Figure 13), similar locations recorded by Kiszka *et al.* (2007).

Cuvier's beaked whale

Cuvier's beaked whales were recorded only in the Bay of Biscay, typically in deeper water with the highest encounter rates occurring in proximity to the sub-sea canyons (Figure 13).

True's beaked whales

The frequency and long-term nature of the monitoring effort afforded by this protocol has also provided sightings of rarer species. In 2018, a pod of four True's beaked whales (*Mesoplodon mirus*) were recorded breaching repeatedly alongside the *Pont-Aven* (Figure 14). This is a species which is very rarely recorded alive (Weir *et al.*, 2004). The animals in the most recent encounter were identified by independent experts, and one of the four individuals was observed to have a never-before-seen morphological feature: another pair of teeth in addition to the typical two tusks (Robbins *et al.*, 2019b).

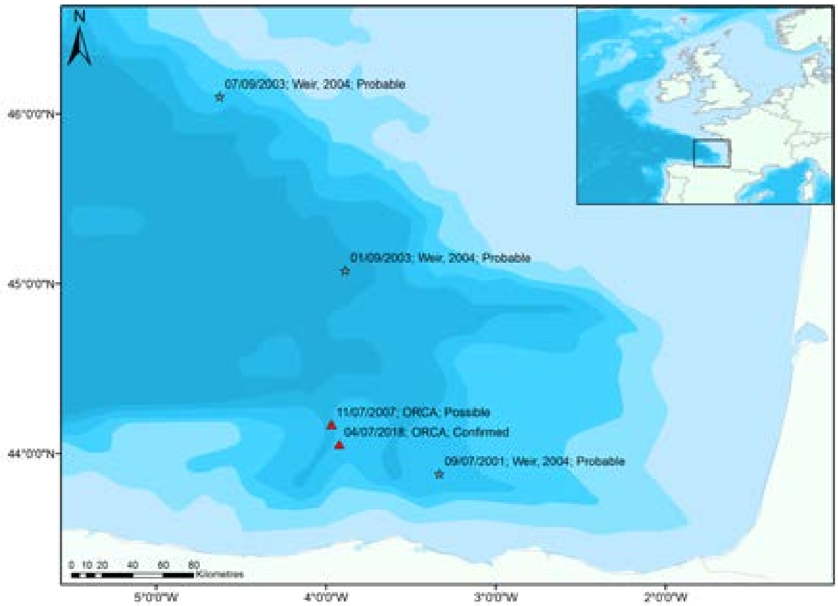


Figure 14: Locations of published True's beaked whale sightings. The record from 04/07/2018 was confirmed by experts from photographs (Robbins *et al.*, 2019b).

The first five years of data have mirrored established distribution patterns of common cetacean species, and highlighted some unusual occurrences of species such as humpback whales and True's beaked whales which may not have been recorded by traditional and infrequent surveys. Wildlife Officers collect data at a fine-scale temporal resolution, allowing seasonal and inter-annual patterns to be investigated. The above is only a simple summary and the below novel research utilises these data at a higher level, to investigate areas of importance for fin whales in the Bay of Biscay. It is important to continue building upon this long-term time series, with longer survey seasons and developing new routes in other areas. Further monitoring with this methodology and subsequent statistical analyses will provide key insights into the patterns of cetacean occurrence in European waters, and such knowledge is crucial to successful conservation management.

CONTRIBUTING TO CETACEAN CONSERVATION

ORCA is committed to the conservation of cetaceans through evidence-based science. Long-term monitoring has accumulated a large dataset covering a wide area, allowing spatial and temporal trends to be investigated. These data are analysed in-house and by postgraduate students at a variety of universities to explore changes in distribution, population dynamics and densities. Results from these studies are disseminated in this report, in peer-reviewed publications, and through interfaces with scientific working groups and panels in order to affect policy and positive change.

Fin whale - Paul Soulby

Modelling the distribution of fin whales (*Balaenoptera physalus*) in the Bay of Biscay to assess the potential effects of ship strikes

Contributor: *William Tingle* (University of Plymouth), supervised by *Dr Clare Embling* (University of Plymouth) and *James Robbins* (ORCA, University of Plymouth)

Introduction

Fin whales (*Balaenoptera physalus*) are the second largest whale species, measuring up to 26 metres and weighing 74 tonnes (Mason, 2006). They feed on small crustaceans and shoaling fish (Aguilar & García-Vernet, 2018). Fin whales were a target species for whalers and it was recorded that 725,000 individuals were killed between 1905 and 1976 in the southern hemisphere alone (Cooke, 2018). Today, fin whales are considered endangered (IUCN, 2019) and are still recovering from whaling. Current estimates suggest global populations are between 50,000 and 100,000 individuals after rising from an estimated 38,000 individuals in 1997 (Aguilar & García-Vernet, 2018). Although, it has also been suggested that population estimates of fin whales are underestimated (Williams & O'Hara, 2010). However, it is speculated that warmer waters in polar regions, linked to climate change, will lower the amount of prey in their key feeding area (Tulloch *et al.*, 2018) and affect the whales' recovery.

Another factor behind a slower recovery in the numbers of fin whales is linked to greater interactions with marine vessels. Since 1992, it is estimated that the number of marine vessels worldwide has increased fourfold (Tournadre, 2014). With rising vessel numbers, there is an increased likelihood of ship strikes, which are already known to cause a large number of whale deaths. A report studying 30 years of fin whale carcass data from the Pelagos Sanctuary for Mediterranean Marine Mammals, a marine protected area of 84,000 square kilometres north of Sardinia, concluded that 16% of all fin whale fatalities could be attributed with certainty to collision with a marine vessel (Panigada *et al.*, 2006). Another study of ship strikes in the Canary Islands analysed 59 whale carcasses that had washed up on shore and determined that 10.6% of these deaths could also be attributed to collisions with marine vessels (Carrillo & Ritter, 2010). A study into whale deaths in French coastal waters (Peltier *et al.*, 2019) found that, between 1972 and 2017, 12.9% of the 396 carcasses were diagnosed as being caused by ship strikes; of these 76.5% were fin whales. With fin whales under pressure in so many places, it is vital to identify other locations in which they may also fall victim to ship strikes.

The Bay of Biscay

This study focuses on the Bay of Biscay, which is located north of Spain and west of France. The edge of the continental shelf is situated within this region, causing the water depth to quickly change from shallow to very deep – up to 4,735 m. This area of water contains lots of nutrients, which are carried to the surface from deep depths by currents (upwellings); this makes the area very productive and supports a wide variety of organisms. Furthermore, the Bay of Biscay is also situated in the middle of a major shipping route for western European countries, where there is an estimated doubling in the number of container and bulk carrier ships between 2015 and 2030 (Kaplan & Solomon, 2016). The combined marine traffic and rich feeding grounds have amplified the conditions for ship strikes, but these have only been recorded individually for the last 40 years (Jensen *et al.*, 2004). A study by Cates *et al.* (2017) identified three areas in which fin whales were considered to be at high risk of ship strikes due to large overlaps: the Pelagos Sanctuary, the Balearic Islands and the Eastern Alboran Sea. The most recent quantifiable study on fin whale ship strikes in the Bay of Biscay concluded that groups of fin whales were more frequently found near shipping lanes than individuals, and a significant proportion of them were at 'high-risk angles' to be struck by boats (Aniceto *et al.,* 2016). This study implies that, once fin whales are in areas of high shipping density, they are poorly prepared to deal with any imminent threats. All studies before this were individual cases and anecdotal evidence of whales killed by marine vessels. Ship strikes have been recorded as far back as 1976 (Laist *et al.,* 2001) but no doubt extend far before then too.

A study assessing the effects of historical whaling on the projected population growth of five species of whales, krill and shrimp found that fin whale numbers were increasing slower than estimated (Tulloch *et al.*, 2018). This was thought to be due to a reduction in their prey as sea temperatures increased at lower latitudes between 60°S and 60°N. With the population of fin whales recovering slower than projected, there is a clear need for studies into this species, especially concerning ship strikes. One study in British Columbia found ship strikes were not the cause of enough fin whale deaths in the region to be considered concerning or for shipping route legislation to change (Williams & O'Hara, 2010). Whilst the core of this study contained valuable data on ship strike modelling, it focused on an area with lower shipping density. Therefore, this might not be the case for fin whales in regions of higher shipping density.

Fin whale - Sanne Bakkers

An investigation modelling the population distribution of North Atlantic right whales, whose numbers have been greatly reduced by ship strikes, was part of the basis for the ship strike rule, which came into effect in 2008 (Merrick, 2005). This piece of legislation restricted any vessel greater than 65 feet (19.8 m) in length from going faster than 10 knots in seasonal management areas on the east coast of the USA. After this law was introduced, the number of fin whale deaths dropped from 2.0 per year between 2000 and 2006, to 0.33 deaths per year between 2006 and 2012 (van der Hoop *et al.*, 2015). The distribution modelling involved in this investigation was paramount to the protection of these whales and adds validation to any further modelling on cetacean ship strikes.

This study aims to model the habitat preferences of fin whales and investigate if their distribution is affected by the density of marine vessels in this region. The result of this will help with understanding the potential effects of a higher shipping density on fin whales in the Bay of Biscay. Though there is a lack of quantifiable study into fin whale mortalities, the apparent inclination for fin whales to be hit by marine vessels (Douglas *et al.,* 2008) means that any study into modelling fin whale ship strikes may be of great importance to their continued recovery.

Methods

Data was collected by Wildlife Officers between the months of April and September 2014 - 2018 from the cruise ferries *MV Cap Finistère* and *Pont-Aven*. The survey effort data collected on board these ferries was divided into 7 km segments, using Marine Geospatial Ecology Tools (MGET) in ARCMAP (Roberts *et al.,* 2010). Any segment of survey effort with a sea state 5 or above on the Beaufort scale was removed from the analysis (Laran & Gannier, 2008).

The associated sea surface temperature, chlorophyll *a* concentration (acting as a proxy for primary production), depth and shipping density for each 7 km segment was used to assess their impact on fin whale distributions. These environmental variables were used as they have previously been found to be linked with fin whale distribution (Woodley & Gaskin, 1996; Laran & Gannier, 2008). The sea surface temperature and chlorophyll *a* concentrations were obtained from NASA Modis and the seawater depth data were sourced from the EMODNET Bathymetry Portal. Whereas, the Bay of Biscay shipping density data was obtained from a study of worldwide mapping of global ship traffic created by Halpern *et al.* (2015). A series of models (Generalised Additive Models) were used to test whether variables including sea surface temperature, chlorophyll *a* concentrations, depth, shipping density, month and year, might have affected the distribution of fin whales in the Bay of Biscay. Variables were modelled individually, and combined with others, to assess the impacts on fin whale distribution. For the final model, a backwards stepwise selection process was followed which initially incorporated every variable. The one variable which showed the least significance ($p < 0.01$) was removed from the model at each successive stage. This, thereby, gradually reduced the total number of variables in the model until all variables were found to significantly affect whale distribution. The final chosen model would therefore be the optimal environmental model for fin whale sightings in the Bay of Biscay.

Results

Throughout the Bay, whale sighting density was highest in the southern regions (Figure 15). The optimal model showed the variables to significantly affect fin whale distribution were depth, sea surface temperature and month. Whilst shipping density and chlorophyll *a* concentrations were not found to be significant in this final model as the aforementioned variables appeared to be more important, shipping density was found to significantly affect fin whale distribution when modelled on its own. When modelled on its own, the results showed there were significantly more fin whales in areas of low shipping density than in areas of high shipping density (Figure 16). There also appeared to be a preference of fin whales found in waters with a depth greater than 2,257 m (Figure 17). When comparing between survey years, fin whale sightings and sea surface temperature were greatest in 2018 (Figure 17), whilst chlorophyll *a* concentrations were greatest in 2016, before dipping in 2017. At temperatures above 19.83°C, the number of fin whales sighted increased with rising sea surface temperatures up to the maximum recorded temperature of 23.85°C. The months with the greatest number of sightings were May, August and September. It was also found that the potential of sighting a whale was reduced in sea states greater than Beaufort 3.

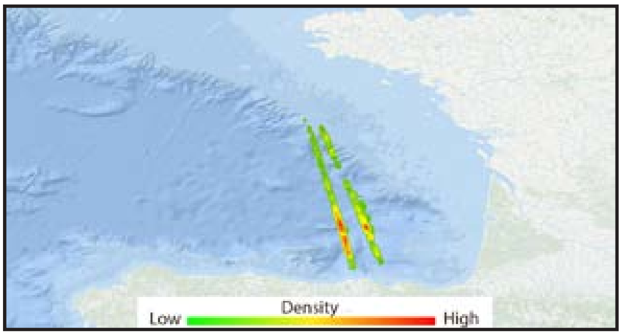


Figure 15: Heat map of fin whale sighting density displayed as a green (low) – red (high) colouration, between 2014 and 2018. The blue shows seawater depth, with the darker shades representing deeper waters.

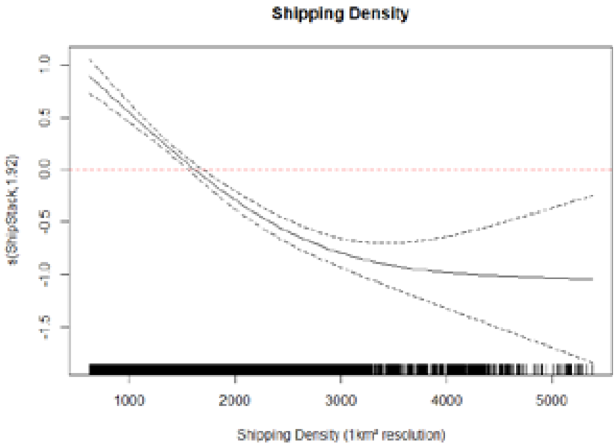


Figure 16: The relationship between the number of fin whale sightings and shipping density as the solid black line (1.92 degrees of freedom). The 95% confidence intervals were plotted as dotted lines around the smooth.

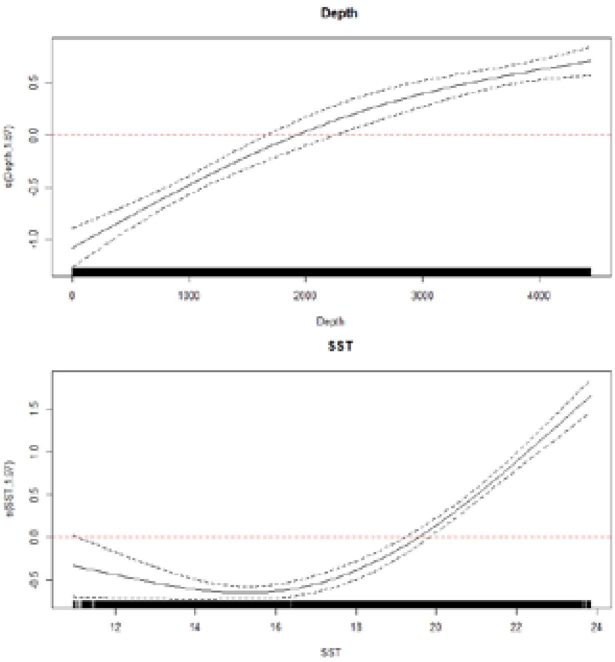


Figure 17: The relationship between the number of fin whale sightings and depth (top; 1.87 degrees of freedom) and sea surface temperature (SST) (bottom; 1.97 degrees of freedom) as the solid black line. The 95% confidence intervals were plotted as dotted lines around the smooth.

Fin whale - Paul Soulby

Discussion

A significant number of fin whales were spotted at areas of low shipping density, which could imply a behavioural change to avoid collisions or to stop their calls being drowned out by shipping noise (Castellote *et al.,* 2012). If this is the case, then the future of fin whales in the Bay of Biscay is uncertain. Furthermore, there is evidence that the Bay of Biscay matches the fin whale's preferred criteria of deep, sloping warm waters (Forcada *et al.,* 1996; Laran & Gannier, 2008), so it could be an unidentified hotspot. If this is the case, the increasing density of marine vessels may potentially drive fin whales away from this habitat. This in turn could lead to greater competition for food in other regions and a knock-on effect on global fin whale population. Alternatively, as shipping density was not found to significantly affect whale distribution in the optimal model in this study, this could also suggest that, if the waters are ideal for feeding, fin whales will still inhabit areas that have a higher shipping density. If this is the case, a rise in the number of marine vessels worldwide could have catastrophic effects on the recovery of fin whale numbers. It remains to be seen if rising vessel density will cause fin whales to move away from the Bay of Biscay or remain there and be more prone to ship strikes.

The significant occurrence of fin whales in waters deeper than 2,000 m is consistent with previous studies of populations in the Mediterranean basin (Forcada *et al.,* 1996). It is thought that the whales do not seek the deep water directly rather the nutrient upwelling that comes with it (Woodley & Gaskin, 1996; Laran & Gannier, 2008). Similarly, the preference of fin whales towards areas with a sea surface temperature warmer than 19°C is consistent with previous studies (Gregr & Trites, 2001; Laran & Gannier, 2008). Between 1982 and 2014 in the Bay of Biscay, there has been a rise in average sea surface temperature of 0.26°C ±0.03 (Costoya *et al.,* 2015). If this trend continues, the models from this study indicate the number of fin whales in the Bay of Biscay will increase too. However, the maximum preferred water temperature for fin whales to inhabit is unclear from this study as no evidence was found as to what their upper limit might be. When considering the main phytoplankton species, *Karenia mikimotoi*, found in the Bay of Biscay (Smythe-Wright *et al.,* 2014) – which forms the basis for the marine food chain in this region – their optimal temperature is 28°C (Shen *et al.,* 2016). Therefore, potentially as the temperature of the Bay rises, so will the amount of phytoplankton and, as a result, fish. The highest temperature recorded during the five years of surveys was 23.85°C, so the waters will have to warm a considerable amount before phytoplankton consider it too hostile an environment to inhabit.

The migration routes of fin whales are not well understood and the data that does exist focuses on Mediterranean winter feeding grounds (Canese *et al.,* 2006) or Arctic mating seasons (Simon *et al.,* 2010), but there are no studies proximal to the Bay of Biscay. The general migratory trend for fin whales is to feed near the poles during the summer and reproduce around the equator during the winter (Mizroch *et al.,* 1984). This migratory calendar may account for the spike in fin whale sightings during May and then again in September; fin whales could be using the Bay of Biscay to feed as they move between the equator and the pole. If this is true, the rise in vessel density may be turning a key migration stopover into an area of high risk for fin whales. Feeding grounds with low shipping density have been identified as a key factor in the recovery of southern humpback whale populations (Constantine *et al.,* 2014), so the same is very likely true of fin whales.


Fin whale

Throughout the five years of data collection, the survey and environmental conditions stayed consistent with one exception: the number of whale sightings in 2018. The cause of this increase in sightings is unknown, although it could be that other environmental variables that were not modelled in this study might have influenced this. Similarly, previous studies have shown chlorophyll *a* concentrations to be a key indicator of fin whale distribution (Littaye *et al.,* 2004; Laran & Gannier, 2008) and yet greater concentrations were not found to influence distribution in this study and the reason for this is unclear. Furthermore, the models indicated that fin whales preferred regions of low chlorophyll *a* concentration. Therefore, if there is an explanation for the substantial increase in fin whale sightings, it is not explained by the variables analysed in this study.

Ship strike prevention

This study suggests a future in which the Bay of Biscay may be populated with more fin whales and vessels, making ship strike prevention vital to the recovery of fin whale numbers in this region. Whilst the threat of ship strikes varies with each species of whale, one of the greatest challenges involved in preventing ship strikes is that, not only are the number of marine vessels increasing, the average individual vessel is becoming both faster and quieter. The bow of the boat can often block the noise of the engine and create a shadow zone in front of the vessel, known as the bow null effect, which prevents whales in front of the boat from hearing it coming (Allen *et al.,* 2012a). There have been anecdotes of North Atlantic right whales only moving away from oncoming vessels when the vessels themselves were on top of the whale (Laist *et al.,* 2001). However, all species of whale have very poor acceleration, so early detection of vessels is paramount to its survival. If a whale cannot detect a boat until it is less than 100 m away, there is a very high chance of it colliding with the vessel or being sucked into the propellers as it tries to dive out of the way (Kite-Powell *et al.,* 2007).

Despite this serious concern, there is no agreed consensus for maritime authorities to prevent ship strikes. The current main method is an agreement to slow larger vessels down and remain vigilant in areas known to have high whale densities. If a vessel reduces its speed from 25 knots to 10 knots, it can reduce the chance of a ship strike by 40% (Silber *et al.,* 2010). However, there are very few regions in which this is bound by law, and such legislation would be very difficult to implement on the high seas or in areas of water adjacent to several countries.

As this study was not conducted on the main shipping lanes, it cannot account for fin whale distribution within the highest shipping density regions of the Bay of Biscay. Therefore, for future studies assessing the distribution of fin whales along the major shipping lanes travelling through the Bay of Biscay, it would be beneficial to further understand the extent of interaction between whales and vessels. This is especially crucial when considering the expected increase of whales and vessels within this region.

This study highlights the importance of collecting long-term datasets using citizen science to assess the health of fin whales in the Bay of Biscay, as it concludes that their distribution is influenced more by temperature, depth and the time of year than by the density of shipping in that area. Ship strikes have been found to cause up to 16% of fin whale mortalities in some parts of the world (Panigada *et al.,* 2006) but the true impact of vessel collision is unclear due to a lack of population estimates and study into migratory routes. Sea surface temperature and shipping density are both increasing in the Bay of Biscay. The combination of these two factors has the potential to be disastrous for fin whale populations as they seek to make the most of greater nutrient upwellings but may collide with more marine vessels whilst doing so. The lack of study into fin whale populations makes quantifying the potential losses difficult, but enough evidence suggests that prevention of fin whale ship strikes is vital to their recovery.

Fin whale - Ross Wheeler

THREATS AND ISSUES

Our oceans are facing significant threats as a result of modern society and our interaction with the marine environment. Damage can be caused by a variety of threats and the combined pressure from these is devastating the unique wildlife in our waters, meaning urgent action is required to safeguard the biodiversity we enjoy for future generations.

This section outlines just a few of the anthropogenic threats facing cetaceans today, including bycatch, ship strike, commercial whaling, underwater noise and marine pollutants. These threats can lead to cetaceans stranding on shores, an occurrence which is also highlighted in this section. It is critical that policy makers act quickly to mitigate the damage we have inflicted upon the marine environment. For effective measures to be put in place, monitoring programmes are vital to investigate long-term changes in populations and acute impacts of more immediate threats.

Minke whale trapped inside a herring weir - Phoebe Smith

Commercial Whaling

Contributor: *Jennifer Lonsdale* (Environmental Investigation Agency)

During the 20th century, 2.9 million whales were killed by the commercial whaling industry operating around the globe. This is likely the single largest removal of any animal in terms of total biomass in human history. Illegal and unreported whaling means that depletion may have been even higher. Global whale populations were decimated, driving several to the brink of extinction (EIA, 2018a).

The international ban on commercial whaling (the moratorium) was agreed by the International Whaling Commission (IWC) in 1982 and implemented in 1986. One of the 20th century's most effective conservation and welfare measures, it has saved several whale species from extinction and continues to provide vital protection as whale populations slowly recover.

Iceland, Japan and Norway ignore the ban and kill whales for commercial purposes, setting their own quotas justifying them by using loopholes in the IWC's Convention (IWC, 1946). These three countries have killed at least 38,629 whales since 1986. The hunts are subject to virtually no international scrutiny and they refuse to submit welfare and other data to the IWC.

Norway has an official objection to paragraph 10(e) of the IWC Schedule (IWC, 1946), which determines the commercial whaling ban. It allocates its own quotas for the hunting of minke whales.

Iceland did not lodge a formal objection to the moratorium and was therefore obliged to abide by it. Using the loophole of Article VIII of the Convention, between 1986 and 1990, Iceland authorised special permit whaling (scientific research whaling) taking 292 fin whales and 70 sei whales (IWC, 2019a). It left the IWC in 1992 and re-joined in 2002 with a disputed reservation to the moratorium on commercial whaling. Eighteen IWC Contracting Governments objected to its reservation (IWC, 2018). Iceland has issued its own commercial whaling quotas for fin and minke whales in its Exclusive Economic Zone (EEZ) since 2006.

On 30th June 2019, Japan left the IWC and has issued quotas for commercial whaling within its

Fin whale victim of Icelandic whaling © Greenpeace territorial waters and EEZ. Prior to leaving the IWC, Japan carried out whaling for scientific research, killing minke whales in the Southern Ocean Whale Sanctuary, and minke, Brydes and sei whales in the north-west Pacific.

Iceland, Norway and Japan hold reservations to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2017) ban on international trade in whale products and therefore ignore it. Since 2008 over 10,800 tons of fin and minke whale products have been exported to Japan from Norway and Iceland. This includes 1,500 tons of whale products exported in 2018 (EIA, 2018b).

Norway

Norway kills more whales than Iceland and Japan combined. Minke whaling quotas for the 2018 and 2019 hunting seasons were set at 1,278 each year. In 2018, 434 were taken and in 2019, 429 were taken (Råfisklaget.no) (Norges Råfisklag, 2019).

Fin whale - Dave Chilcott

From 2011 to 2017, Norwegian whalers killed 1,095 male minke whales and 2,884 females of which 2,003 were pregnant (EIA, 2018a). It is most likely that this ratio is similar for 2018 and 2019.

Announcing the 2019 quotas, Minister, Harald T. Nesvik stated, *"I want to make sure that whaling remains alive. Whale meat tastes good and it is good for your health."* (WDC, 2019). However, the quota is far higher than the numbers of whales actually taken. Falling consumer demand, higher fuel prices and difficulties with finding whales have limited whaling. In 2018, in response to the oversupply, the Norwegian Råfisklaget Sales Association (which sets conditions for sales of whale meat) required that whalers secure a sales agreement for all their whale meat, fixing the price and quantity before they started hunting (EIA, 2018a).

Iceland

Iceland's whaling quotas were due for renewal in 2019. A number of Parliamentarians called for a thorough review of the reputational impact of whaling on Iceland's fishing, agriculture and tourism, before new whaling quotas could be issued. They also called for an assessment comparing with other economic sectors, the income and export earnings and jobs generated by the whaling industry. The Prime Minister Katrín Jakobsdóttir, a member of the anti-whaling Left Green party, indicated that new fin whaling quotas would not be issued until the completion of the review which was due to be undertaken by the end of 2018.

The Government released a report authored by an economist concluding that whaling was of overall benefit to the Icelandic economy and did not impact tourism. The report was greeted with anger from the whale watch community and questions were raised about its bias and reliance on old or inaccurate data. Even the Fisheries Minister Kristjan Thor Juliusson, who commissioned the report, was forced to admit that it was flawed. However, he issued new quotas of 209 fin whales and 217 minke whales for each year until 2023 (EIA, 2019a).

2019 is the first year, however, since 2003 that no whales have been killed in Iceland (RÚV, 2019). Minke whalers decided to focus on fishing for other species. Hvalur hf. received a fin whaling permit valid for 2019 to 2023 but did not carry out any whaling, which it claimed were due to delays in receiving its licence to whale.

Hvalur hf. has not submitted a hunting record for the last two years, which may lead to the company losing its recently received licence to whale in the future. The permit clearly states that a captain shall record the hunting in a journal provided by the Directorate of Fisheries. The journal requires information on ships, captains, shooters, hunting time, number of harpoons which strike each fin whale, and the number of harpooned fin whales that are lost (Iceland Review, 2019).

Japan

On 30th June 2019, the Japanese Government abandoned its so-called research whaling and withdrew as a member of the IWC (IWC, 2019b). Acting outside international law, it has unilaterally issued its own commercial whaling quotas for 187 Bryde's whales, 52 minke whales, and 25 sei whales in its territorial waters and EEZ. Japan's hunts will not be subject to any independent supervision, control or compliance with respect to the whales taken and the killing methods used.

Prior to leaving the IWC, in 2019 Japan carried out special permit whaling, killing minke whales in the Southern Ocean Whale Sanctuary (The Maritime Executive, 2019) and in its coastal waters (EIA, 2019b). Products from these hunts are being sold in Japan.

Of the 333 whales killed in the Antarctic in the 2018/9 summer, 186 were males and 147 females. Just over 50% of the females were adult, and many were pregnant. The previous season, of the 333 minke whales killed, 181 were females, and 122 of these were pregnant (The Maritime Executive, 2019).

In addition to these hunts, hundreds of other species are killed in Japan including Baird's beaked whales, pilot whales, bottlenose dolphins and Dall's porpoises. In Taiji, live dolphins are captured for sale to marine parks and aquariums around the world (International Marine Mammal Project, 2019). Cetacean meat and blubber are not commonly eaten in Japan despite significant marketing efforts to promote consumption. In line with falling interest by Japanese consumers, over 3,500 supermarkets, including major chains such as AEON, Ito-Yokado and Seiyu, have stopped selling cetacean products in Japan. Internet giants Google, Amazon and Rakuten have all ended sales of these products in Japan (EIA, 2018a).

There has long been concern about the sustainability of hunting the smaller cetacean species in Japan's coastal waters. It has failed to conduct up-to-date assessments of the status of all species hunted; population structure and the impact of the removals; collect and publish data on struck and loss rates, bycatch sex and age composition of catches (EIA, 2013).

Concern is now being raised about the impact of carrying out commercial whaling within Japan's EEZ. No assessment has been made of the population and ecosystem impacts of the newly introduced hunts, which is fundamentally reckless and unjustifiable.

Minke whale - Eve Englefield

Marine Pollutants

The marine environment contains an array of pollutants, from the well-publicised macroplastics, to invisible modern chemicals (Islam & Tanaka, 2004), and legacy toxins which continue to present problems to marine fauna despite being banned decades ago (Desforges *et al.,* 2018). Many of these pollutants enter from coastal environments from runoff and industrial activities.

Polychlorinated biphenyls (PCBs) are a group of industrial pollutants that are still having devastating effects on higher predators including cetaceans, despite being widely banned more than 40 years ago. They are man-made organic chemicals that were commercially produced since the 1930s. PCBs had industrial applications and were used in transformers and capacitors, flame-resistant coatings, paint and machinery.

After they were found to be toxic with impacts on human health and the environment, they were banned in Europe in the 1980s (Van den Berg *et al.,* 1998). Despite this ban, PCBs from sources such as existing open application sources (paint, coatings and machinery), landfills and stockpiles, continue to enter the environment. PCBs can persist in the environment for long periods of time, and are having a continued impact on cetaceans.

More in-depth information on PCBs can be read in the 2018 version of this report (ORCA, 2018). PCBs can enter the food chain through absorption by microorganisms, where they work their way up and bioaccumulate in long-lived predators (such as cetaceans) that store these pollutants in their blubber. Predators that eat large fish such as tuna or sharks, or other marine mammals, are at greatest risk of accumulating large doses of PCBs. Recent research has shown that bottlenose dolphins in the English Channel contain some of the highest concentrations of persistent organic pollutants (POPs), including PCBs (Zanuttini *et al.,* 2019).

Common dolphin - Heather Bodie

Plastics

Contributor: *Dr Sarah Nelms* (Postdoctoral Researcher at the University of Exeter)

In recent years, plastic pollution has become one of the most widely recognised issues facing the world's oceans and there has been growing concern, from both the scientific community and the general public, about its omnipresence within aquatic ecosystems and the potential to cause harm. It is estimated that between 4.8 and 12.7 million metric tons of plastic enter the oceans every year (Jambeck *et al.,* 2015), and, since it does not biodegrade but persists for an unknown amount of time, the amount of plastic accumulating in marine ecosystems is increasing exponentially (Barnes *et al.,* 2009).

For marine megafauna, such as marine mammals, turtles, sharks and seabirds, plastics pose a risk from entanglement and ingestion. Entanglement in items such as derelict fishing gear, sheet plastic and strapping can cause amputation of limbs, strangulation, increased drag and the associated energetic costs, a reduced ability to forage and avoid predators or vessels, and an increased likelihood of starvation and suffocation (Votier *et al.,* 2011; Allen *et al.,* 2012b; Duncan *et al.,* 2017; Parton *et al.,* 2019). Though cetaceans are known to become entangled in debris (Baulch & Perry, 2014), pinnipeds (seals, sea lions, fur seals, and walruses) seem to be more susceptible and 67% of species have been recorded with entanglements (Laist, 1997; Jepsen & de Bruyn, 2019). Due to their playfulness and curiosity, younger animals in particular are attracted to items such as monofilament line and net, which can become entangled on flippers or around the neck, and constrict as the animal grows. Entanglement such as this is clearly a welfare issue, but the wider population-level effects and global trends are not yet clear. Mortality as a result of entanglement is, however, likely to hamper the recovery of vulnerable species or populations which are already under pressure from other threats.

Consumption of plastic pollution by marine mammals can occur by two main pathways – direct or indirect ingestion. Direct ingestion of both macroplastics (pieces larger than 5 mm in size), and microplastics (less than 5 mm in size), can be due to a number of different reasons, such as indiscriminate feeding strategies (e.g. filter feeders; Besseling *et al.,* 2015), mistaken identity when plastic resembles prey items (Secchi & Zarzur, 1999; de Stephanis *et al.,* 2013), or naivety and curiosity, as may be the case in young animals (Baird & Hooker, 2000). Consumption of macroplastics can cause injuries such as, ulcerations, lacerations, obstructions and lesions, and may lead to sub-lethal effects such as dietary dilution, dehydration and starvation (Stamper *et al.,* 2006; Levy *et al.,* 2009; Alexiadou *et al.,* 2019). Deep-diving odontocetes, such as beaked whales and sperm whales, appear to have a higher tendency to consume and become compromised by plastic pollution than other species. For example, a recent study by Alexiadou *et al.* (2019), reported that plastic was found in the stomachs of nine individuals from four species (sperm whale, Cuvier's beaked whale, harbour porpoise, and Risso's dolphin) from the eastern Mediterranean Sea (Greece), with the highest frequency of occurrence in sperm whales. They surmised that mortality was caused by gastric blockage from the plastic in three of the individuals.

Fish in plastic debris - Mae Dorricott

Indirect ingestion – or trophic transfer – occurs when microplastics present within seawater are eaten by secondary consumers, such as fish, which are in turn eaten by predators and the microplastics move up the food chain (Nelms *et al.,* 2018). A study investigating scats (poo) from captive grey seals (*Halichoerus grypus*) and the digestive tracts of wild-caught mackerel, demonstrated that trophic transfer could be an indirect, yet potentially major, route of microplastic ingestion for marine top predators. An assessment was carried out into microplastic ingestion in wild marine mammals (50 individuals from 10 species of cetaceans and pinnipeds) that stranded around the British coast. Microplastics were found in every animal examined, but overall the numbers of particles per animal were low, suggesting that they eventually pass through the gut or are regurgitated (as is sometimes the case for some odontocetes species; Nelms *et al.,* 2019a). The amount of microplastics found in the scat of seals is linked to the prey species consumed (Nelms *et al.,* 2019a).


Large plastic debris - Paul Soulby

Now that we know marine mammals regularly ingest microplastics, the next steps are to fill the knowledge gap in our understanding of their impacts on animal health. Microplastic ingestion may affect marine mammals in three main ways. Firstly, as plastic pieces degrade, they become smaller and smaller until they are classed as nanoplastics, sub-micron-sized particles invisible to the naked eye. It is possible that when ingested, they are able to pass through the gut wall and into the bloodstream, potentially reaching organs such as the liver or the lymphatic system which is responsible for immune function (da Costa *et al.,* 2016; Fackelmann & Sommer, 2019). Currently, our knowledge of this process is limited as the minute size of nanoplastics, and the lack of appropriate technology, makes them difficult to detect and therefore restricts our ability to investigate their presence in wild animals (Lead *et al.,* 2018).

The second potential impact from microplastic ingestion is exposure to chemical contaminants that are present on and within plastic, such as PCBs and plasticisers (substances added to resin to promote flexibility). Due to their small size and large surface area to volume ratio, microplastics can be associated with chemical concentrations that are orders of magnitude higher than the surrounding seawater (Teuten *et al.,* 2009; Ziccardi *et al.,* 2016). Population declines in some marine mammal species have been linked to elevated burdens of such chemicals present within the marine environment. Currently, the extent to which plastic ingestion further exposes marine mammals to these chemicals, compared to their usual dietary and environmental input, is not known.

Lastly, plastic ingestion may lead to increased vulnerability to disease. Research has found that plastic in the environment can be colonised by a diversity of bacteria and consumption of plastic could lead to greater exposure to pathogens. For example, one study found that plastic pellets (nurdles) on Scottish beaches were colonised by bacteria, such as E. coli and species of Vibrio (Rodrigues *et al.,* 2019). Another study looking at coral reefs found the likelihood of disease increased from 4% to 89% when corals were in contact with plastic pollution (Lamb *et al.,* 2018). We do not yet know whether the same could occur for marine mammals and so further research is needed.


Bottlenose dolphin - Roxanne Withy

Bycatch

Contributor: *Sarah Dolman* (Whale and Dolphin Conservation)

In UK and European waters thousands of cetaceans die every year as a result of incidental capture and asphyxiation in fishing gear. This is usually referred to as 'bycatch'. Bycatch happens when non-discriminatory fishing methods cross paths with non-target animals such as cetaceans, sharks, turtles and seabirds, which are often attracted by large amounts of fish caught, or are unable to escape gear as it passes through the water column. Not only is bycatch a conservation concern, it is also a welfare concern for the animals caught, as death can be protracted, or if non-fatal, injuries could have long-term impacts (Dolman & Brakes, 2018).

This is a global problem, with interspecific (between different species) variation in the susceptibility to bycatch, based on distribution and behaviour. In the UK, an estimated 1,500 small cetaceans are bycaught a year (Northridge *et al.,* 2018), and a concerning number of baleen whales are entangled in rope and lines from pot-based fisheries (Ryan *et al.,* 2016). There are large numbers of animals caught in EU fisheries (Table 7 provides some examples). Despite binding legal requirements to monitor and reduce bycatch, cetacean bycatch monitoring has been insufficient in most fisheries and areas (ICES, 2011; Northridge, 2011; Desportes, 2014; ICES, 2016; Read *et al.,* 2017), to generate reliable estimates of bycatch. Measures to reduce bycatch have been limited and not always directed at the most problematic fisheries.

Entangled minke whale - SMASS Orkney 2019

Region	Sea / Country	Member State(s)	Species	Gear	Level of Impact	Reference
North Sea	North Sea and Inner Danish Waters	Denmark, Germany, Sweden, United Kingdom, The Netherlands, Belgium	Harbour porpoise	Static nets	Population	Vinther, 1999
North Western Waters / North Sea	Scottish Waters	United Kingdom	Humpback whale	Creel gear	Population	Ryan *et al.*, 2016
North Western Waters	Bay of Biscay, English Channel	France, Spain, United Kingdom	Common dolphin	Various, incl trawls – pair, high opening	Population	Peltier *et al.*, 2016; ICES, 2016
South Western Waters	Iberian Peninsula	Portugal, Spain	Harbour porpoise	Various (purse, seine, trawl and longline, polyvalent and beach seine)	Population	Sequeira, 1996; López *et al.*, 2002, 2003; López-Fernández and Martinez-Cedeira, 2011; López *et al.*, 2012; Read *et al.*, 2013; Pereira, 2015; Read, 2016; Llavona Vallina, 2018
South Western Waters	Andalusia	Spain	Bottlenose dolphin	Unknown	Population	ICES, 2015
Baltic Sea	Baltic Proper	Germany, Poland, Sweden, Latvia, Lithuania, Finland	Harbour porpoise	Static nets	Population	Benke *et al.*, 2014; ICES, 2008; ICES, 2015; Scheidat *et al.*, 2008
North Sea	North Sea and English Channel	Belgium, Denmark, France, Germany, The Netherlands, Sweden, United Kingdom	Harbour porpoise	Static nets	Insufficient data	Northridge *et al.*, 2010
North Western Waters / North Sea	UK waters	United Kingdom	Minke whale	Creel gear, ghost netting	Insufficient data	Northridge *et al.*, 2010
North Western Waters	Celtic and Irish Sea	Ireland, United Kingdom	Harbour porpoise	Static nets	Insufficient data	ICES, 2015
North Western Waters	Celtic Sea	Ireland, United Kingdom	Common dolphin	Static nets	Insufficient data	Tregenza *et al.*, 1997; Reeves *et al.*, 2013
North Western Waters	Celtic Sea	Ireland, United Kingdom	Striped dolphin	Static nets	Insufficient data	Reeves *et al.*, 2013
North Western Waters	Bay of Biscay, Celtic Sea	France, Ireland, Spain, United Kingdom	Common dolphin	Historic tuna drift nets	Insufficient data	Rogan & Mackay, 2007; Reeves *et al.*, 2013
North Western Waters	Bay of Biscay, Celtic Sea	France, Ireland, Spain, United Kingdom	Striped dolphin	Historic tuna drift nets	Insufficient data	Rogan & Mackay, 2007; Reeves *et al.*, 2013
North Western Waters	Bay of Biscay	France, Ireland, Spain, United Kingdom	Striped dolphin	Static nets	Insufficient data	Morizur *et al.*, 1999
North Western Waters	Irish waters	Ireland	Minke whale	Trammel nets	Insufficient data	Cosgrove *et al.*, 2013
South Western Waters	NW Spain	Spain	Common dolphin	Pair-trawls	Insufficient data	Fernández-Contreras *et al.*, 2010
South Western Waters	Portuguese waters	Portugal	Common dolphin	Purse-seine nets	Insufficient data	Marçalo *et al.*, 2015

Table 7: Cetacean bycatch in European waters by Common Fisheries Policy region (Dolman *et al.*, 2019).

There is still much to be done in order to eliminate cetacean mortality in fisheries. For change to happen stakeholders (e.g. fishermen and women; hereafter 'fishers') need to be involved in discussions about how to understand and best mitigate threats, as their livelihoods are inexplicably linked to their methods of capture. Working in partnership with fishers and fisheries managers is central to successful bycatch management efforts. Fishers do not want to catch cetaceans and other protected species, but they may need to be convinced about the value of providing accurate data on bycatch and for implementing management approaches. Ongoing outreach and collaboration are central to successful efforts to assess and reduce bycatch. EU Member States need to focus attention to enable the achievement of meaningful bycatch reductions.


Entangled humpback whale, Scotland - Andy Gilbert

Member States need to implement scientifically robust bycatch monitoring schemes to include mandatory monitoring covering a predetermined percentage of the fleet using independent observers and/or remote electronic monitoring (REM), regardless of vessel size; more accurate monitoring of fishing effort; mandatory reporting of all bycatch by fishers; and compliance efforts for monitoring and mitigation measures. Fishing licences or permits should be suspended for vessels/fishers that deny access to observers or deployment of REM. Alternatively, vessels/fishers who comply with the obligation might receive a commercial incentive (e.g. to be allowed a higher quota, or sell their catch at a higher price). Member States need to implement scientifically robust management measures to reduce bycatch, with enforcement and assessment of effectiveness and compliance. This is the highest priority for those fisheries identified as having a likely population-level impact (see Table 7) and, in turn, will reduce the number of individuals suffering welfare impacts.

As a priority, management measures are urgently required for the following populations:

- **Harbour porpoise:** Baltic Proper, Iberian Peninsula, Celtic Sea, English Channel, North Sea and inner Danish waters
- **Common dolphin:** Bay of Biscay, English Channel
- **Bottlenose dolphin:** Andalusia
- **Humpback and minke whale:** Scottish waters

Change also needs to be driven by policy and regulations being updated, to facilitate up-to-date information on best practice and population-level concerns. This can be at an EU, national, and local level. EU cetacean bycatch legislation (Council Regulation (EC) No. 812/2004) has been found to have significant weaknesses (European Commission, 2009; 2011; ICES, 2013; 2014; 2015; 2016) and in April 2019 the European Parliament plenary voted for Regulation 812/2004 to be repealed, and approved a new replacement Regulation. In July 2019, a new EU Regulation titled 'Conservation of fisheries resources and the protection of marine ecosystems through technical measure' became law. The Technical Measures Regulation combines about 30 pieces of EU fisheries conservation legislation that determine the conditions under which fishers may fish, including the incidental catches of cetaceans in fisheries (previously covered by Regulation 812/2004). This new Regulation has entered into force and will influence how the UK and other Member States tackle protected species bycatch and wider conservation of species and habitats in fishing activities.


Entangled California sea lion - James Robbins

On protected species bycatch specifically, the Regulation includes an obligation for technical measures to ensure that bycatch of sensitive species is 'minimised and where possible eliminated'. This is consistent with the ASCOBANS (Agreement on the Conservation of Small Cetaceans of the Baltic, North-East Atlantic, Irish and North Seas) aspiration towards zero bycatch, with regard to whales, dolphins and porpoises.

In Article 4, the new regulation also provides that technical measures must 'aim to ensure' that the levels of cetacean bycatch do not exceed the limits in EU law and international agreements binding on the EU. Therefore, although the new regulation does not tighten the bycatch limits, it opens up new legal avenues for implementing measures that will be key for increasing compliance and maximising the impact of existing obligations in EU law related to the prevention and monitoring of bycatch. Monitoring and reporting need to be improved between EU Members States, as currently other countries that fish within UK waters do not contribute data on bycatch.

Whilst it is encouraging that the EU are creating new conservation measures that are legally binding, the advent of 'Brexit' means that the UK may not adopt these laws once they have left the EU. This report was written prior to the Brexit deadline, and if it was carried out, it is likely that nobody will be clear on the legislation adopted for some time. Michael Gove (previously Secretary of State for Environment, Food and Rural Affairs of the UK) has reported the UK's ambition to become "*a world leader in managing our resources while protecting the marine environment*", however, the Government needs to ensure this is a priority. Measures required under the EU Regulation should be a minimum standard, whether the UK is part of the EU or not in future.

The new EU Regulation provides Member States with opportunities to improve protected species bycatch measures, including through implementation of joint recommendations on a regional basis, but the European Commission will need to enforce implementation. Looking ahead, many thousands of cetaceans, and other protected species, could be saved by implementation of robust national and regional management measures. The Technical Conservation Measures could help us to achieve this, but will require the UK and other Member States to be motivated and compelled to do so. Regardless of the new EU Regulation, the UK has this opportunity through the development of a world-leading bycatch strategy, and we will continue to do all we can until cetacean bycatch is eliminated.

Humpback whale line entanglement on left pectoral fin - Nick Richards

Ship Strike

Contributor: *Russell Leaper* (International Fund for Animal Welfare)

Whales being struck by vessels is one of the most prevalent threats facing cetaceans today (Peel *et al.,* 2018). As mammals, they spend a portion of their time at the surface to breathe, which may be extended to feeding, or recovering from the energetic demands of feeding at depth (Constantine *et al.,* 2015). When at the surface, whales share this space with maritime traffic, and are at risk of close-encounters and collisions (Izadi *et al.,* 2018). Maritime traffic is expected to increase alongside human populations, with larger and faster ships being built to satisfy the need for transport of our goods, an estimated 90% of which are transported by sea. Ship strikes between vessels and cetaceans have increased significantly in recent decades (Arregui *et al.,* 2019; Ritter & Panigada, 2019), and therefore, it is important that we understand this threat to marine mammals and attempt to mitigate it.


Common dolphin with propeller injuries - CSIP-ZSL

The actual occurrence rate of ship strikes is still largely unknown, and is likely to be significantly under-reported (Williams & O'Hara, 2010; Rockwood *et al.,* 2017). It's thought this is in part due to crew of large vessels over 100 m in length not normally being aware that a collision event has occurred (Peel *et al.,* 2018). The majority of whales killed by vessels sink to the depths of the water column, rather than drifting ashore. If carcasses do end up on the shore, many of them may be in poor condition so that cause of death cannot be confirmed, or it is unclear whether damage present on the carcass was received at the time of death, or post-mortem when the carcass was afloat at sea. However, new research has shown that fat embolisms can be used to help determine the cause of death in sperm whales, and whether trauma occurred before, or after death (Arregui *et al.,* 2019). This method could help to attribute stranded whales in poor condition to ship strike, whereas previously the cause of death may have been unknown.

Highest mortalities occur where high densities of shipping activity overlap with high densities of whales, and therefore an understanding of at-risk whale distributions, behaviour, habitat use and areas where they are most threatened is important for conservation (Rockwood*,* 2017). Whales are most at-risk during critical activities in surface waters, such as feeding and resting post-dive, with species that spend more time closer to the surface at greater risk. Lactating humpback whales have been found to mainly rest close to the surface, within reach of the draught of commercial ships (Bejder *et al.,* 2019). If calves are still dependent, they will not survive if the female is injured or killed.

Most large whale species appear particularly susceptible due to a limited ability to manoeuvre away from vessels at close proximities, or do not attempt to move at all (Nowacek *et al.,* 2004). The threat-level facing cetaceans is dependent on species and location, with some species' behaviours making them more susceptible, and at greater risk in areas of high-density vessel traffic. Nearly 60% of stranded sperm whales in the Canary Islands have died from ship strike (Arregui *et al.,* 2019), and approximately 10% of sperm whales in the Pelagos Sanctuary possess scars likely caused by collisions with vessels (Di-Meglio *et al.,* 2018). Despite the small likelihood of ship-struck animals being beach-cast, 12.9% (51 out of 396) of whales stranding on French shores have been found to be caused by ship strike (Peltier *et al.,* 2019).

Although the majority of reports and published studies of ship strikes involve large whales in the northern hemisphere, it is not only large whales that are struck by vessels (Van Waerebeek *et al.,* 2007; Dwyer *et al.,* 2014). Nor is the problem limited to the northern hemisphere (Van Waerebeek *et al.,* 2007; Peel *et al.,* 2018). An analysis of stranded cetaceans on UK shores found that the cause of death of 1.1% of cetaceans stranded between 1991 and 2017 was from collisions with vessels, when unknown causes were omitted. Despite only 39 causes of death being attributed to ship strike during this time providing a relatively small sample size, the findings do highlight that it's not only large whales that are affected (Deaville *et al.,* 2019). The results show that the proportion of animals struck by ships was higher between 2011 and 2017 than 1991 and 2017. The species displaying signs of ship strike between 2011 and 2017 were: harbour porpoises (10 out of 516, 1.9%), common dolphins (7 out of 184, 3.8%), Risso's dolphins (1 out of 14, 7.1%), sperm whales (1 out of 13, 7.7%), Sowerby's beaked whales (1 out of 13, 7.7%), Cuvier's beaked whales (1 out of 3, 33.3%), minke whales (2 out of 23, 8.7%), and fin whales (2 out of 7, 28.6%). These proportions are higher than those of Peltier *et al.* (2019) who provided the proportion of total strandings attributed to ship strikes instead of only those where the cause of death was identified. Fin whales are the most frequently reported struck cetacean species globally (Laist *et al.,* 2001), which has been discussed in previous reports (ORCA, 2018). There appears to be an increase in the last decade of cetacean mortality from encounters with vessels (Deaville *et al.,* 2019), and therefore successful mitigation and management is required to minimise this threat.


Fin whale victim of ship strike

Currently, the best mitigation measures relate to changing where, or the speed that, vessels operate at. Re-routing shipping lanes away from areas that are important for whales can significantly decrease the threat to whales, with potentially small alterations. A study of the Hellenic Trench in the Mediterranean found that moving lanes further offshore, to areas with sparser sperm whale occurrence, would lead to approximately 70% reduction in ship strike, with


Rissos dolphin victim of ship strike - CSIP-MEM

only a maximum of 11 nautical mile deviation for major routes, and around 5 nautical miles for the majority of vessels (Frantzis *et al.,* 2019).

Speed restrictions can allow animals and crew more time to react to avoid a collision (Ritter & Panigada, 2019). Even voluntary speed restrictions and area closures can reduce the threat to whales, and such voluntary measures have been implemented in Canada (Vanderlaan & Taggart, 2009; Chion *et al.,* 2018), New Zealand (Constantine *et al.,* 2015), and the Antarctic (IAATO, personal communication) among others. Conversely, voluntary measures are not always enough, with speeds in some locations, such as California (McKenna *et al.,* 2012), being largely unchanged; however, a recent study did find that marine users broadly supported speed restrictions or new shipping routes in the Southern California Bight (Redfern *et al.,* 2019). Restricting speed to 10 knots reduces the risk of ship strike substantially, and as little as a 10% reduction in vessel speeds across the global fleet could reduce the overall risk by around 50% (Leaper, 2019).

Slower vessel speeds have been introduced for economic reasons to save fuel, but in some cases speed restrictions may result in higher costs to shipping companies (Gonyo *et al.,* 2019). Nevertheless, there are several additional benefits to slowing down vessels, alongside reducing the risk to cetaceans (Leaper, 2019). The aforementioned 10% reduction in speed globally could reduce greenhouse gas emissions by around 13% (Faber *et al.,* 2017), and improve the likelihood that emission targets are met by 23% (Comer *et al.,* 2018). Underwater noise pollution is generally reduced at slower speeds (Joy *et al.,* 2019), with a 10% speed reduction across the global fleet likely to reduce the total sound energy from shipping by around 40% (Leaper, 2019). With multiple benefits, not only a reduction in the risk of ship strike to cetaceans, the need for reduced vessel speeds globally is hard to ignore.

Anthropogenic Noise

Contributor: *Rebecca Walker* (Natural England)

Our seas and oceans are filled with different sounds. The natural environment produces sound through processes including waves, rain, cracking and moving ice, and seismic/volcanic activity, as well as sound created by marine life including invertebrates such as snapping shrimp, marine mammals and various species of fish. The properties of water allow sound to travel much quicker (around 4.5 times) and much farther than in air (OSPAR, 2009). Therefore, marine organisms have evolved to live in and use this world of sound. Marine mammals have a highly developed auditory sense and use sound for essential biological and ecological aspects of their lives, including locating and capturing prey, avoiding predators, navigation and communication (which, for the largest whales, can extend across whole oceans).

Sound can be described by its frequency (pitch) and intensity (loudness). Sound intensity reduces as it travels away from a sound source, but not all sounds travel and dissipate in the same way. High frequency sounds dissipate (attenuate) more quickly than low frequency sounds, which is why low frequency calls from species such as the blue whale can be heard over very large distances.

Noise can be defined as unwanted sound. Anthropogenic (man-made) noise in our seas and oceans has increased over the last 100 years with the invention of motorised vessels, echo sounders and other navigational equipment, an increase in shipping, as well as activities such as oil and gas exploration, military activities and marine construction. Man-made noise can range in frequency and intensity and be categorised into two types; impulsive and non-impulsive (continuous). Impulsive noise is produced by activities, such as seismic air gun surveys for oil and gas, pile driving in marine constructions, underwater blasting or detonation of unexploded ordinance, and navy sonar. Non-impulsive noise is predominantly caused by shipping. Whilst marine mammals are adapted to living in a world of sound, the additional noise from human activities can affect them in various ways, depending upon the intensity, frequency and nature of the sound source (Table 8).

Source	Possible effects
Shipping and other vessel activity (e.g. recreational vessels)	Masking of natural sounds (e.g. vocalisations), displacement from preferred habitat, behavioural change
Seismic surveys (airguns, sub-bottom profilers) *	Death, physical injury, permanent or temporary hearing loss, masking, displacement from preferred habitat, behavioural change
Low- or mid-frequency active sonar *	Death, physical injury, permanent or temporary hearing loss, masking, displacement from preferred habitat, behavioural change
Pile driving *	Death, physical injury, permanent or temporary hearing loss, masking, displacement from preferred habitat, behavioural change
Other sonars (depth sounders, fish finders) *	Displacement from preferred habitat, behavioural change
Explosions *	Death, physical injury, permanent or temporary hearing loss, displacement from preferred habitat, behavioural change
Acoustic deterrents (ADDs) and pingers *	Temporary hearing loss, masking, displacement from preferred habitat, behavioural change
Dredging	Masking, displacement from preferred habitat, behavioural change
Drilling	Masking, displacement from preferred habitat, behavioural change

Table 8: Types of anthropogenic noise and their potential impact on marine mammals. Impulsive sounds are marked with an asterisk (adapted from Boyd *et al.,* 2008).

Potential impacts on marine mammals

Marine mammals hear and produce sounds at a range of frequencies (Table 9), from low frequency calls of a blue or fin whale (7 Hz) to ultrasonic clicks of some dolphin and porpoise species (160+ kHz), as well as all frequencies in between. As such, the frequency of man-made noise is important as it will affect species differently depending on their hearing range. However, underwater noise causes various effects on marine mammals depending on its intensity and nature, ranging from behavioural changes and displacement from preferred habitat, through to masking of natural sounds (e.g. vocalisations), hearing loss, physical injury and even death (Table 8). One simple way of considering impacts from man-made noise is to imagine zones of diminishing impact with increasing distance from the noise source (Figure 18). However, it is worth noting that this is a simplistic 2D view of the 3D marine world and research has shown that noise levels can vary widely with distance and depth and may not necessarily conform to simple laws of diminishing impact with distance (Madsen *et al.,* 2006).

Hearing group	Example species	Generalised hearing range
Low Frequency (LF) cetaceans	Baleen whales	7 Hz to 35 kHz
Mid Frequency (MF) cetaceans	Dolphins, toothed whales, beaked whales	150 Hz to 160 kHz
High Frequency (HF) cetaceans	True porpoises	275 Hz to 160 kHz
Phocid Pinnipeds (PW) (underwater)	True seals	50 Hz to 86 kHz

Table 9: Marine mammal hearing groups (NMFS, 2018).

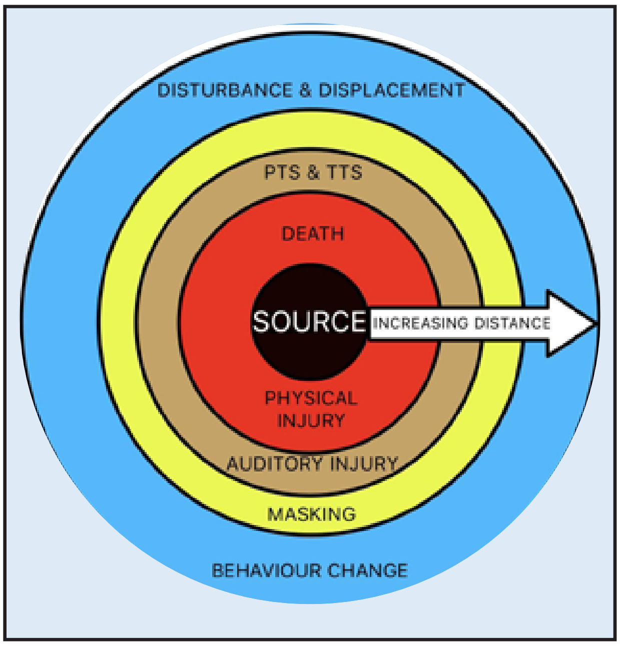


Figure 18: Zones of noise impact and influence (adapted from Richardson *et al.,* 1995 and Dooling *et al.,* 2015). PTS – permanent threshold shift, TTS – temporary threshold shift.

Death and physical injury

Very loud impulsive sounds, such as those resulting from underwater explosions, can cause death or physical injury at very close ranges. Underwater explosions generate a high intensity physical shock wave as well as an auditory sound wave, and this shock wave can cause crushing, fracturing or haemorrhaging of body tissues and organs (von Benda-Beckmann *et al.,* 2015). In addition, the very high noise levels can cause animals to panic, with Brownlow *et al.* (2015) suggesting that the clearance of unexploded ordnance from a military practice range could have been a factor triggering a mass stranding event of long-finned pilot whales in 2011. Certain types of naval sonar (low- or mid-frequency active sonar) have been shown to cause rapid behavioural changes in deep-diving marine mammals, causing them to cease feeding, but also surface too quickly, leading to something akin to decompression sickness (the bends), and resulting in death (Jepson *et al.,* 2003). Pile driving for marine construction or airgun use within seismic surveys for oil and gas, also have the potential to cause death or physical injury at very close distances from the noise source.

Permanent or temporary hearing loss

Permanent and temporary threshold shift (PTS and TTS respectively) both represent changes in an animal's hearing ability at certain frequencies. PTS is permanent hearing loss, whilst TTS is temporary, with hearing recovering over several hours or days. Humans may experience TTS as a temporary impairment of hearing after attending a loud music concert. Impulsive noise from human activities (pile driving, underwater detonations etc.) can cause both PTS and TTS at larger distances than that which cause injury or death. There are a number of scientific studies that have looked at the noise levels at which animals start to experience TTS, and this TTS onset level is used to estimate the noise level at which an animal might experience PTS. A recent publication from the National Marine Fisheries Service (NMFS) in the USA has reviewed the research to date and produced technical guidance and criteria for assessing PTS and TTS on marine mammals (NMFS, 2018), which are routinely used by industry and government advisors to assess the impact of human activities on marine mammals.

Masking

Masking occurs when a noise is loud enough to prevent or impair/reduce the detection range of biologically relevant sound signals, such as calls from calves or other individuals, detection cues of prey, or the identification of potential dangers, such as a nearby predator. For example, background noise from shipping and recreational vessels has been recorded to interfere with killer whale communication, potentially affecting foraging activities (Foote *et al.,* 2004). Such impacts can contribute to potentially serious effects on an individual or reductions in a population, but teasing out the impact of masking alone over other stressors is challenging and cannot yet be undertaken with confidence. However, cetaceans are resilient and have the capability of communicating over a range of frequencies. Ansmann *et al.* (2007) reported that common dolphins had changed (raised) the frequency of their whistles in the English Channel, possibly as a result of increased shipping noise in the area.

Behavioural change and disturbance

Like masking, behavioural change or disturbance can be very difficult to measure and quantify. It is defined as the changing of an animal's activity in reaction to a noise, such as a change from feeding to travelling (i.e. moving away from the noise source). These reactions can lead to short-term reductions in fitness (e.g. having to feed in a less productive area) and can potentially lead to decreases in long-term health or abundance. Models have been developed to try and calculate the possible impact of underwater noise disturbance on marine mammals (King *et al.,* 2015), but there is a lack of data and many parameters still have to be estimated by experts. However, scientific research continues to help fill these data gaps as it is being published all the time.

Risso's dolphin - Lauren Horncastle

What does the UK do to protect marine mammals from underwater noise?

The UK is a signatory to various international conventions such as OSPAR (the Convention for the Protection of the Marine Environment of the North-East Atlantic). As a signatory to these Conventions, there are a number of agreements that the UK must meet, which informs UK policy, an example of which is the Marine Strategy. As part of the Marine Strategy, there are a number of indicators of Good Environmental Status with associated targets to meet. A number of these indicators and targets relate to underwater noise, which has allowed the development of initiatives such as the Marine Noise Registry; a UK database of noise-creating activities. The Marine Strategy also links to other UK strategies, such as the Dolphin and Porpoise Conservation Strategy, which is under consultation at the time of writing this report and contains several actions to protect marine mammals from underwater noise. The UK therefore has a duty to monitor, measure and mitigate underwater noise to limit the impact upon cetaceans.

Strandings

Contributor: *Rob Deaville* (Zoological Society of London/Cetacean Strandings Investigation Programme)

Strandings can be defined as when 'a live or dead marine mammal swims or floats onto shore and becomes 'beached' or incapable of returning to sea' (Geraci & Lounsbury, 2005) and they have occurred globally throughout recorded history. There are a wide range of potential drivers of stranding events and prior to the relatively recent inception of modern strandings investigation programmes, the distinction between those that may have been caused or influenced by human activities and those that had a more natural cause were frequently unclear.

Stranded pilot whale - Charlie Philips

The study of stranding events at their simplest level enables the determination of presence or absence of cetacean species in a given area over a given timeframe. Indeed, some species are only known from stranding events and a new species of beaked whale has been recently described following the study of a stranded individual (Morin *et al.,* 2017). The investigation at post-mortem of individual strandings facilitates the determination of causes of death and allows the differentiation of those that may be due to anthropogenic activities (e.g. entanglement in fishing gear or ship strike) from those that are not (e.g. interspecific aggression).

Strandings are not always a negative sign. The historical dataset collected in the UK by the Natural History Museum (NHM) from 1913 (Coombs *et al.,* 2019) shows that humpback whales were not recorded stranded in the UK until the mid-1980s. This correlates with a potential increase in population size following the moratorium on commercial whaling in 1986 and helps illustrate that an increase in strandings can sometimes be the result of an increase in regional population density. In fact, the absence of strandings of a particular species can paradoxically sometimes be cause for much greater conservation concern than an increase in strandings. Historical stranding datasets like those collected by the NHM can therefore prove valuable in assessing the possible impact of historical and extant pressures.

In the UK, approximately 800 cetacean strandings are recorded every year by the collaborative UK Cetacean Strandings Investigation Programme (CSIP), which has been tasked with the monitoring and investigation of stranded cetaceans since 1990. The CSIP records data on all reported strandings and also recovers around 150 stranded animals each year to investigate at post-mortem and try to establish a cause of death and from this, learn more about the threats these species face in UK waters. A recently published seven-year review of strandings investigation in the UK between 2011 and 2017, described the collation of data on nearly 5,000 individual strandings and 1,030 post-mortem examinations (Deaville *et al.,* 2019). Infectious disease related mortality and incidental entanglement in fishing gear (bycatch) were two of the most common findings over this period, although the likelihood of a particular cause of death varied significantly between species.

Within the UK stranding network, bycatch represents the single largest direct anthropogenic cause of mortality in stranded cetaceans examined at necropsy. Between 1990 and 2017, of the 3,744 stranded cetaceans examined at post-mortem, 738 were diagnosed as dying due to bycatch or entanglement (Deaville *et al.,* 2019). Post-mortem examinations of these bycaught individuals also revealed the significant welfare issue that bycatch can pose. Beyond the diagnosis of bycatch, strandings research generates a wide range of samples and data that helps inform efforts to understand and mitigate this issue (Tindall *et al.,* 2019).

Marine pollution can be chemical, acoustic or physical in nature and strandings investigation and associated research plays a vital role in helping to understand their potential impact on cetaceans. Within the UK stranding network, the impact of physical pollution through accidental ingestion of marine debris appears to be relatively low, with only one single case of debris ingestion related mortality in nearly 30 years and over 4,000 necropsies (Deaville *et al.,* 2019). However, on a wider regional basis the picture is rather more mixed, with higher marine debris ingestion rates reported in stranded cetaceans examined in the Mediterranean Sea (ACCOBAMS/ASCOBANS, 2018). A recent study on UK stranded marine mammals revealed the presence of microplastic particles in every examined marine mammal, albeit in relatively low numbers (Nelms *et al.,* 2019b). The potential impact microplastic and nanoplastic particles may be having at both an individual and wider population level and their possible association with chemical pollutants and microbiota remains unclear. Further research, in part derived from investigation of stranded individuals, is warranted to try to learn more about this emerging issue.

A significant body of work on the potential impacts of chemical pollution has been published in recent years (Jepson *et al.,* 2005; Jepson *et al.,* 2016; Jepson & Law, 2016). Some persistent organic pollutants, such as PCBs are of particular concern, as they can have immunosuppressive effects and cause reproductive impairment (Murphy *et al.,* 2015) and have also been linked to the decline of apex predators like killer whales (*Orcinus orca*) across parts of Europe (Desforges *et al.,* 2018). Despite being banned across Europe over 30 years ago, the toxic effects of legacy pollutants like PCBs are unfortunately likely to be with us for decades to come. Analysis of samples from stranded animals and correlation with their associated health status derived from necropsies has underpinned much of this work and will continue to inform research on the impacts of chemical pollutants.

Stranded harbour porpoise - Dan Jarvis

Even within long-established networks such as the CSIP, efforts to increase regional reporting effort can prove valuable, with volunteer networks like those run by the Cornwall Wildlife Trust Marine Strandings Network (Cornwall Wildlife Trust, 2019) in south-west England acting as a model for increasing effort in other parts of the country. Efforts to assist response to stranding events and help build capacity within new stranding networks is beginning to take place on a global basis such as the International Whaling Commission's recent Strandings Initiative (IWC, 2019c). Increasing synergy between stranding networks through the integration of their datasets can also help assess the impacts of anthropogenic pressures on a wider regional basis.

Strandings investigation can reveal a wealth of information on both human pressures and natural drivers of mortality and also helps generate a broad variety of ancillary data that are impossible to obtain through other means. Collectively, such investigations underpin and inform a wide range of scientific research, helping shed light, not just on the causes of strandings and the threats that cetaceans face, but also help to reveal a significant amount of detail about their lives and the wider health of the marine ecosystem.

UK strandings can be reported to the CSIP by calling 0800 652 0333.

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"ORCA's innovative research is always breaking new ground, giving us a better understanding of whales and dolphins, how we can keep them safe from hazards such as ship strikes or bycatch. This report is further evidence of the amazing impact that a group of dedicated, hard-working volunteers can have in protecting our oceans for future generations."

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

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