



Managing a Dynamic North Sea in the light of its ecological dynamics: Increasing occurrence of large baleen whales in the southern North Sea

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ABSTRACT

A recent increase in sightings and strandings of humpback and to a lesser extent, fin whales in the southern North Sea has been well documented. This positive trend in the marine mammal community is to be welcome. A similar increase has been documented off the south and southwest coasts of Ireland over the past 20 years. The first international match of a humpback whale outside of Ireland was to the Netherlands in 2007, demonstrating a link between these two feeding grounds. Data from Ireland, largely obtained through citizen science, is presented as an insight into what may occur in the southern North Sea in the near future. Between 1999 and 2014 the number of individual humpback whales recorded in Ireland rose slowly. A dramatic increase occurred in 2015, when the number of individually identified whales increased from 30 to 66 and, to a lesser extent, in 2017 and

2020 when numbers increased by 10 and 12. By the end of 2020, there were 109 individual humpback whales in the Irish Humpback Whale Photo-id Catalogue. Inter-annual re-sighting rates are high with a mean \pm SD re-sighting rate of $63 \pm 20\%$ in years when 10 or more individual whales were recorded. Minimum residency times within a season ranged from 2 to 186 days with a mean \pm SD of 48.0 ± 10.3 days. Just over one fifth (21.3%) were recorded over a period of 10 days, or less, 45.3% over a period of 30 days or less and 13.5% over a period of at least 100 days. Thus humpback whales returning to Irish waters are remaining for an average of 7 weeks with 16% for over 3 months. A similar pattern may occur in the southern North Sea with continued monitoring. An increasing population of humpback whales will bring new management issues, which should be considered early in order to sustain this increase. Some of these issues are presented and discussed.

1. Introduction

A humpback whale *Megaptera novaengliae* was observed in May 2007 in the western Wadden Sea in The Netherlands (Campuysen, 2007). It remained in the area for four days “foraging in strong tidal currents in a deep gully very close to the dike of Den Helder and in shallow areas of the sandy beach of the island of Texel”. Campuysen (2007) reviewed records of humpback whales in Dutch and Belgium waters and concluded that humpback whales have always been rare, and “suggested that their recent occurrences were unprecedented and that there is an increase in numbers of humpback whales frequenting these waters”.

This same humpback whale observed in May 2007 in the Wadden Sea, was also recorded off Toe Head in Co Cork, Ireland (HBIRL#07, NAHBW#04790; 51.49°N, 9.202°W), 138 days later on 28 September 2007 (Ryan et al., 2015). On 16 November, 49 days after this sighting off Co Cork, it was once again recorded in the Netherlands, off Ijmuiden

(Wouter Jan Strietman *pers. comm.*). At the time this was the first match of an Irish humpback whale to a site outside of Irish waters. Almost five years to the day, on 17 November 2012, Frederik Broms (*pers. comm.*) documented the same humpback whale off Kvaløya, near Tromsø, northern Norway. Two years later on 11 November 2014, it was recorded again in Norway at Kaldfjorden (69.7°N, 18.7E). A remarkable story of an individual whale and the recording and movements of this whale, show the value of citizen science and the sharing of humpback whale images. Was this exceptional, or is this typical of current, or future, humpback whale movements in the southern North Sea?

1.1. Stranding records

Strandings of all cetacean species have increased in the UK and Ireland over the past century, which has largely been associated with increased recording effort (Coombs et al., 2019). Strandings of

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Mysticetes have increased mainly off the southwest coasts and western seaboard (McGovern et al., 2018; Coombs et al., 2019). Fin whales *Balaenoptera physalus* were regularly stranded and numbers were positively correlated to Year, Storm counts for each year, Maximum Sea Surface Temperature and NAO Index (Coombs et al., 2019). Strandings of sperm whales in the North Sea have also been associated with the NAO index (Pierce et al., 2007). Strandings of balaenopterids, dominated by fin whales, are also increasing on French coasts (Peltier et al., 2019). Pyenson (2011) suggested cetacean stranding records faithfully reflect patterns of richness and relative abundance in living communities and strandings almost always provide better diversity information about extant cetacean communities than live surveys. He concluded that stranding data are therefore relevant on studies of cetacean community change through time.

Strandings of large baleen whales (not including minke whales) in the English Channel, from Cornwall to Ramsgate (UK) and from Brest to Dunkirk (France), consisted mainly of fin whales which accounted for at least 80% of the 41 stranding records over the last 20 years (Fig. 1). Only five humpback whales were recorded stranded (in 2006, 2007, 2009, 2010 and 2012). There has been a very slight, but non-significant ($y = 0.0338x + 1.4857$ $R^2 = 0.0124$), increase in stranding records over this period (Fig. 2). Peltier et al. (2019) associated this increase on Atlantic coasts with increased ship strikes, which is now the predominant anthropogenic cause of death identified in large cetaceans.

Strandings of fin whales and, to a lesser extent humpback whales, are increasing in the southern North Sea (Haelters et al., 2018; Kinze et al., 2018; Leopold et al., 2018). A review of stranding records from the east coast of the UK (from Kent to Edinburgh), Belgium, the Netherlands, Germany and Denmark (excluding the Baltic) identified 31 fin whale stranding records since 2000, 18 from the east coast of the UK (CSIP pers. comm.) and 13 from the low countries (Table 1). Fin whales are not considered indigenous to the North Sea (Haelters et al., 2018) but there have been at least six stranding records of fin whales from the Netherlands, five from Germany and one each from Belgium and the outer Danish waters since 2000 (Table 1). Fin whales have also recently been found stranded in the inner Danish waters and on the Skagerrak coastline in 2010 and 2016, after having last been recorded stranded in 1958 (Kinze et al., 2018).

All except one of these recent fin stranding records were associated with ship collisions, some thought to be struck in the Bay of Biscay and carried into Dutch and Belgium ports (Haelters et al., 2018). The increase in fin whale records may, to some extent, be attributed to an

increase in reporting of these ship collisions (Ritter, 2012), but fin whales do frequently occur in the northern Celtic Sea at the approaches to the English channel and in increasing numbers in recent decades (Whooley et al., 2011).

Humpback whale strandings are still rare in the southern North Sea, with the first record reported in 1982. Of the 19 stranding records reported since 2000, 12 were from the east coast of the UK (CSIP pers. comm.) and seven from the low countries (Table 2). Humpback whales were first recorded stranded in Denmark in 1806, and more recently in 1905. The humpback stranded in Denmark in 2015 was the first in inner Danish waters (Kinze et al., 2018). The first humpback whale stranding record in the Netherlands dates back to September 2003, when a carcass was reported floating in the Nieuwe Waterweg (Campuysen, 2007). The first stranding of a humpback whale on the Belgium coast since 1751 was recorded in March 2006 (Leopold et al., 2018).

Of interest is the recent occurrence of stranded sei whales *Balaenoptera borealis* in the English Channel and southern North Sea. Individuals found stranded in 2011 and 2012 were reported as freshly dead or had died on the beach and one was found in 2019 floating at sea off the east coast of the UK (CSIP pers. comm.). One also stranded alive at Les Veys, northern France in October 2020 (Dabin, 2020). Sei whale populations were severely depleted in the Northeast Atlantic after extensive hunting from the end of the 19th century (Evans, 1980). They are thought to migrate along the western seaboard but Evans (1980) did report two historical stranding records in the southern North Sea from Essex, UK in 1948 and near Rotterdam, Netherlands in 1972. No sei whale sightings were reported in the southern North Sea by Reid et al. (2003) or van der Meij and Camphuysen (2006).

1.2. Sighting records

Despite historic stranding records of fin and humpback whales in the southern North Sea (Haelters et al., 2010), sightings of large baleen whales are rare. No sightings of fin or humpback whales were reported in the southern North Sea in reviews carried out by Evans (1980) and Reid et al. (2003). However recently O'Neil et al. (2019) reported on influxes of humpback whales into the Firth of Forth, Scotland towards the northern part of the southern North Sea in 2017 and 2018, during migration. van der Meij and Camphuysen (2006) reported only 10 sightings of large baleen whales over a 35 year period between 1970 and 2005. Most of these sightings were thought to be fin whales with sightings reported during eight months of the year but with no seasonal

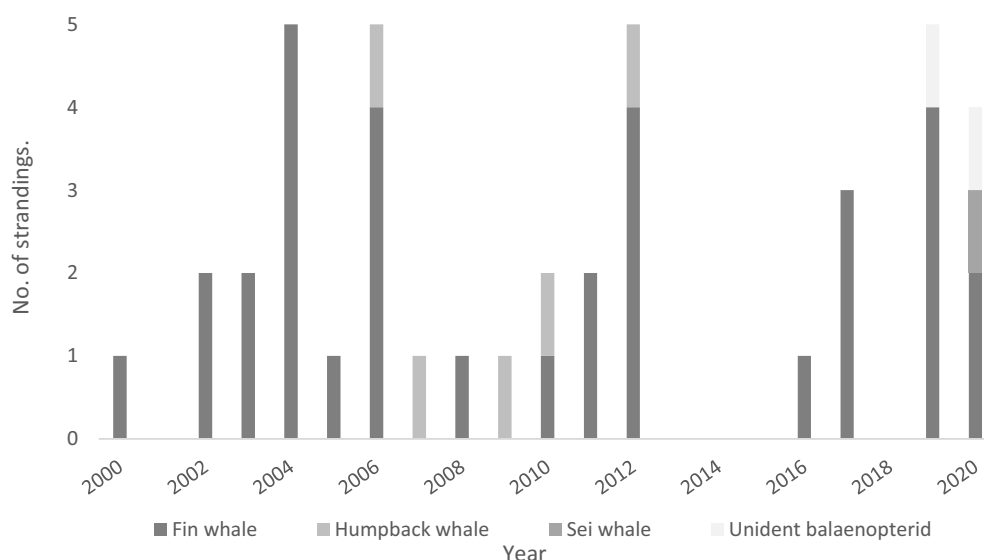


Fig. 1. Number of strandings of large baleen whales in the English Channel (England and France) between 2000 and 2020.

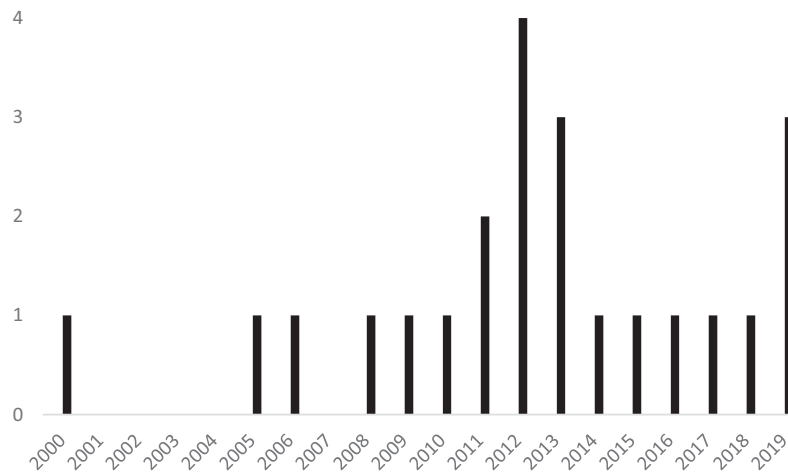


Fig. 2. Strandings of large baleen whales in the southern North Sea between 2000 and 2019 (data from Tables 1 and 2 and UK data).

Table 1

Recent reports of dead stranded fin whales found stranded or floating in the low countries of the southern North Sea (2000–2020).

Date	Country	Location	Length/ Gender	Reference
2/06/ 2001	Germany	Hornum, Isle of Sylt	15 m/Male	Borkenhagen (2011)
21/9/ 2005	Germany	Außenelbe Rede,	14 m/ Female	Borkenhagen (2011)
8/2006	Germany	NW of island of Neuwerk	17 m/Male	Borkenhagen (2011)
19/10/ 2008	Netherlands	Goeree	?	Keijl pers comm.
22/9/ 2009	Belgium	Antwerp	19.9 m/ Female	Haelters et al. (2018)
20/06/ 2010	Denmark	Vejle Fjord	Female	Kinze et al. (2018)
30/8/ 2011	Netherlands	Rotterdam	13.0 m/ Male	Keijl pers comm.
15/1/ 2012	Netherlands	Vlissingen	8.77 m/ Female	Keijl pers comm.
6/6/ 2012	Netherlands	Rotterdam	18.5 m/ Male	Keijl pers comm.
23/9/ 2012	Germany	Island of Juist	?	Kinze pers comm.
2/8/ 2013	Netherlands	Rotterdam	12.5 m/ Female	Keijl pers comm.
16/9/ 2013	Netherlands	's-Gravenzande	16.5 m/ Male	Keijl pers comm.
28/11/ 2013	Germany	Isle of Sylt	?	Possible fin whale, Siebert, U. pers. comm

peak. Only one humpback whale sighting was reported, that of a female and calf swimming off the coast of Katwijk and Scheveningen (Netherlands) in December 2003. They suggested fin whales were irregular visitors migrating through the area, possibly towards the Channel and on to the Atlantic Ocean and humpback whales were vagrants (van der Meij and Camphuysen, 2006). Since 2003, one or two fin whales have been sighted regularly in the inner Danish waters (Kinze et al., 2018), who suggested these intrusions into the Baltic Sea should not be regarded as erratic occurrences, but rather as foraging trips exploring potentially new feeding areas.

The first sighting of a humpback whale in the Netherlands was recorded in 2003 when a mother and calf were observed from December 2003 to January 2004 in Katwijk-Scheveningen (van der Meij and Camphuysen, 2006; Campuysen, 2007). Since this first sighting

Table 2

Recent reports of dead stranded humpbacks whales found stranded or floating in the low countries of the southern North Sea (2010–2020).

Date	Country	Location	Length/ Gender	Reference
18/8/ 2010	Netherlands	Katwijk	?	Leopold et al. (2018)
12/12/ 2012	Netherlands	Razende BoI, Texel	?	Leopold et al. (2018)
20/8/ 2014	Netherlands	Katwijk	16.8 m/Male	Keijl pers comm.
9/11/ 2015	Belgium	Ghent	11.6 m	Haelters et al. (2018)
23/2/ 2016	Denmark	Løkken	Female	Kinze et al. (2018)
20/8/ 2017	Netherlands	Texel	18.4 m/ Female	Keijl pers comm.
24/10/ 2018	Belgium	De Haan	18.0 m	Haelters et al. (2018)
20/8/ 2019	Netherlands	Vlissingen	15.7 m/Male	Keijl pers comm.
10/6/ 2019	Netherlands	Ter Heijde	14.4 m/ Female	Keijl pers comm.

humpback whale records have increased considerably and are now considered annual visitors (Leopold et al., 2018). The first sighting of a humpback whale in Belgium waters was recorded as recently as July 2011 (Leopold et al., 2018). Since 2008, there have been several sightings of humpback whales in Denmark on return trips to and from the Baltic proper (Kinze et al., 2018).

Kinze et al. (2018) suggested that as fin whales exhibit great flexibility in feeding, breeding, and navigational skills, frequent sightings during the last 15 years in the inner Danish waters indicate an adaptability potential to exploit food resources. Individuals seemingly seek and find so-called “food stations” where they prey on shoaling fish, and they have been documented to migrate between such stations. The slight increase in occurrence in Danish waters may reflect the general recovery of this species from whaling, in former natural habitats. This is probably also the case for the humpback whale, which is increasingly observed in Danish and neighbouring waters, and has been documented during 2008, 2012 and 2014 (Kinze and Jensen, 2015). Leopold et al. (2018) carried out a thorough review of records of stranded, floating and sighted humpback whales up to 2017. They reported 42 sightings of humpback whales in the Netherlands, six in Belgium and one in German waters between 2010 and 2018. They suggested that the status of the humpback whale has changed ‘overnight’ from a rare vagrant to an

annual visitor.

2. Potential drivers for increasing fin and humpback whales

What is driving the increased occurrence of humpback whales in the southern North Sea? Could this be a case of regional expansion of an increasing humpback whale population driven by climate change and other factors (Askin et al., 2017; Zein and Haugum, 2018)? Are these individuals prospecting new feeding grounds or returning to former feeding areas after centuries of population depletion? Should we be looking forward to new marine mammal communities in the southern North Sea and revising existing management plans to account for pressures on these iconic species? Leopold et al. (2018) suggested the increase in humpback whales could not simply be explained by population increase and suggested there had been a change in their behaviour. Here we explore broadly some of the relevant biology of humpback whale behaviour on feeding grounds and explore possible migration routes. We refer to recent research and monitoring off the south and southwest coasts of Ireland, collected largely as part of a citizen science project, as a case study of what may occur in the southern North Sea in the near future.

2.1. Distribution and occurrence

Humpback whales are one of the best studied and most familiar of all the large whale species. They occur worldwide in the Pacific, Atlantic and Indian Oceans. Their populations worldwide are thought to be recovering rapidly since the cessation of commercial whaling (Ruegg et al., 2013; Bortolotto et al., 2016). Humpback whales are returning to former breeding and feeding grounds in increasing numbers. They are also increasingly being observed outside these “traditional” sites in new areas including the Mediterranean (Frantzis et al., 2004; Ruíz et al., 2018) and the Celtic and North Seas (Campuysen, 2007; Ryan et al., 2015; O’Neil et al., 2019).

2.2. Migration routes

Humpback whales undergo one of the longest migrations of any marine mammal (Stevick et al., 2011). In the North Atlantic, there are two known main breeding areas; in the Caribbean and in Cabo Verde off West Africa (Wenzel et al., 2020). Known traditional feeding grounds include the NW Atlantic, Iceland and the Faroe Islands, northern Norway and Svalbard (Wenzel et al., 2009, 2020). Humpback whales from the Caribbean are thought to migrate along the mid-Atlantic ridge before splitting off to familiar feeding grounds (Kennedy et al., 2014). Migration routes to and from west Africa are poorly known, but the largest number of recaptures from eastern North Atlantic high latitude feeding grounds to Cabo Verde are to Norwegian and Icelandic waters. Humpbacks from Cabo Verde were also sighted in the Azores and there has been one re-sighting between Cabo Verde and Tenerife, Canary Islands (Wenzel et al., 2020). Recently, Berrow et al. (2021) reported on three photographic matches between Ireland and Cabo Verde, the first matches from Ireland to a known humpback whale breeding ground.

The southern North Sea was not thought to be along any traditional migration routes for large whales. The few sighting records of humpback whales in the southern North Sea have occurred throughout the year with no discernible peaks during periods of known northward or southward migrations (Campuysen, 2007). However, O’Neil et al. (2019) suggested humpback whales observed in the Firth of Forth, off the east coast of Scotland represented a migratory stopover during a southbound migration through the North Sea.

2.3. Population structuring on the feeding grounds

North Atlantic humpback whales feed during the summer in a number of relatively discrete regions, including the Gulf of Maine,

Newfoundland/Labrador, the Gulf of St. Lawrence, Greenland, Iceland, and Norway, including Svalbard (Stevick et al., 2003). Fidelity to these summer feeding areas is strong and is apparently maternally directed, with genetic analyses suggesting that the fidelity is maintained on an evolutionary timescale (Larsen et al., 1996; Palsbøll et al., 1997). Recently humpback whales have been recorded singing on feeding grounds throughout the spring and early summer when they might be expected to be on breeding grounds, suggesting some whales (females) remain on the feeding grounds (Vu et al., 2012; Martin et al., 2021). The presence of mother-calf pairs in the southern North Sea suggests there is potential for these migration or foraging journeys to be passed on to the next generation. Genetic samples of humpbacks recorded in the southern North Sea either from sampling stranded animals or biopsies of living individuals may elucidate whether these individuals share breeding grounds, or other feeding grounds, outside the southern North Sea.

2.4. Breeding grounds

Most humpback whales in the North Atlantic breed in the Caribbean. The Silver and Navidad Banks off the Dominican Republic are thought to be used by around 5000 individual humpback whales. Guadeloupe (southeast Caribbean; Lesser Antilles) is also a known breeding area but numbers there peak in April–May, two months later than off the Dominican Republic (Stevick et al., 2018). Abundance estimates have shown a steady increase in the population breeding in the Caribbean (Stevick et al., 2003). This is in comparison to abundance estimates from Cabo Verde, a small isolated island archipelago around 500 km west of Senegal, where the breeding population is thought to be in the low hundreds (Ryan et al., 2014a; Wenzel et al., 2020). Humpback whales are also likely to breed and calve in shallow bays off northwest Africa, but these waters are poorly surveyed (Waerebeek et al., 2013). Based on whaling records a third humpback whale breeding ground in the North Atlantic has long been hypothesized based (Ingebrigtsen, 1929) but to date has not been located. Six of the eight sightings of humpback whales reported here (Table 2) occurred between September and January. Humpback whale sightings peak in February on the main Caribbean breeding grounds off Dominican Republic but in April off Cabo Verde.

2.5. Diet

To sustain any population increase in humpback whales we must secure their food supply. Large baleen whales feed on a variety of pelagic fish prey, with crustaceans also important for species such as fin whales. Humpback whales have a broader diet than other baleen whales, with small pelagic fish such as sprat *Sprattus sprattus*, herring *Clupea harengus* and sandeel *Ammodytes* sp. being relatively more important. These prey provide a rich concentrated source of calories necessary to build reserves for the following migration and breeding seasons. Studies in the Celtic Sea have shown young sprat and herring, especially year class 0–1 were the most important fish prey components of both humpback and fin whales (Ryan et al., 2014b). These species typically shoal together when juveniles, and when spawning between late autumn and winter, the peak season for fin and humpbacks off the south coast of Ireland. Krill (*Meganyctiphanes norvegica* and *Nyctiphanes couchii*) was the single most important prey item in the diet of fin whales in the Celtic Sea (Ryan et al., 2014b). The humpback whale observed in the Netherlands in May 2007 was reported to be feeding on sandeels (Campuysen, 2007). Sprat were recovered from the stomach of a humpback whale that live stranded and died in the Netherlands in December 2012 (Besseling et al., 2015). What is the current status of these potentially important fish stocks in the southern North Sea? What effects will long term changes in climate have upon prey populations in the southern North Sea, and the higher predators that feed on them?

The North Sea is rich in fish diversity and abundance (Daan et al., 2009), but many fish species have been severely impacted by fishing pressures (Gislason, 2003). The southern North Sea coasts were

important nursery grounds for juvenile herring and sprat, but their abundance has declined significantly since the 1960s (Daan et al., 2009). The lesser sandeel *Ammodytes marinus*, is now one of the most abundant fish in the North Sea and is very important in the diet of many predatory species of fish, seabird and marine mammals. Boulcott et al. (2007) suggested sandeels in the North Sea are not one stock but show significant regional variation in reaching maturity. Sandeels lay demersal eggs between November and January, and their planktonic larvae are present in the water column between late January and May. Arnott and Ruxton (2002) evaluated potential associations between sandeel recruitment and some key biological and physical factors in the North Sea between 1983 and 1999. A negative relationship was detected between recruitment and the winter index of the North Atlantic Oscillation with warmer sea temperatures correlated with poorer than average recruitment. This effect was most pronounced in the south-western part of the North Sea, which is near the southern limit of the species' distribution. More southerly distributed species such as European sardines (*Sardina pilchardus*) and anchovies (*Engraulis encrasicolus*) are becoming re-established in the southern North Sea after a 30 year absence (Kanstinger and Peck, 2009). Both these species would be suitable prey for humpback whales.

Small pelagic fish are short-lived and their biomass fluctuates considerably and unpredictably. These factors do not favour provision of a regularly used feeding area for large whales. Large whales require a large enough food resource to make it worthwhile to feed. With such fluctuating resources maybe these large whales are more likely to only periodically pass through the southern North Sea, stopping occasionally to feed when prey concentrations are sufficient. However, traditional spawning or nursery areas, with good biomass, could support large baleen whales and as recovery plans build sprat and herring stocks in the southern North Sea we may see the regular and predictable appearance of humpback whales to coastal waters of the southern North Sea.

3. Twenty years of humpback whale documented in Ireland

Historically humpback whales were rarely recorded in inshore Irish waters (Fairley, 1981). Prior to 2000 there were just 15 sighting records reported to the Irish Whale and Dolphin Group (IWDG) since 1984 (Berrow et al., 2010). Between 2000 and 2020, the IWDG received 1159 sightings, with 1021 since 2010. Mean (\pm SD) number of sightings per annum increased from 13.8 ± 7.7 between 2000 and 2009 to 86.1 ± 40.4 between 2010 and 2020. As well as this significant increase in the

number of sightings each year (t -test, $P < 0.001$), the number of individuals per sighting has also significantly increased from 1.3 ± 0.6 between 2000 and 2009 to 2.0 ± 1.6 between 2010 and 2020 (ttest $P < 0.05$). Most sightings (>92%) of humpback whales reported to the IWDG were from the south and southwest coasts and within 12nmls from land (Ryan et al., 2015). The sighting rate of fin whales in this area has also increased, though may have declined in recent years.

Some of this increase can be attributed to increased recording effort, especially with the increase in whale-watching vessels operating in the area, but a real increase in the occurrence of humpback whales in coastal Irish south and southwest waters is apparent (Fig. 3).

Historical information on the presence of humpback and other large baleen whales in Ireland is equivocal. By the time commercial whaling stations were operational in Ireland, humpback whales were already considered severely depleted by whaling operations occurring elsewhere, especially on their breeding grounds (Fairley, 1981). Only six humpback whales were caught during commercial whaling between 1908 and 1922 off northwest Ireland in County Mayo. Fin whales however were still abundant with nearly 600 whales caught over the same period, accounting for 66% of the total landings (Fairley, 1981). Records of their historical presence are absent but if large baleen whales such as fin and humpbacks were as frequent in inshore Irish waters along the south and southwest coasts as they appear now, we may have expected this to have been documented in the literature.

Humpback whales were only very occasionally recorded from Cape Clear Island, west Cork during extensive sea-watching, where a bird observatory has operated since autumn 1959 (Sharrock and Gilmour, 1973). Fin whales were more frequently observed in the British Isles than any other large whale species, with most of the sightings recorded along the western seaboard of Ireland (Evans, 1980). Whether fin and humpback whales off the south and southwest coasts of Ireland are returning to former feeding grounds or their increase is due to regional expansion is not clear. The current distribution and occurrence of humpback and fin whales in the Irish Celtic Sea have been strongly associated with herring spawning grounds especially in the autumn and winter (Volkenandt et al., 2015). These spawning grounds are well known and have been used for centuries (Molloy, 2006), suggesting foraging opportunities for large whales may have also been present for a long period.

The first humpback whale photo-identification images in Ireland were obtained in September 1999, when three individuals were filmed around the Kinsale Gas rigs, County Cork (see Ryan et al., 2015 for

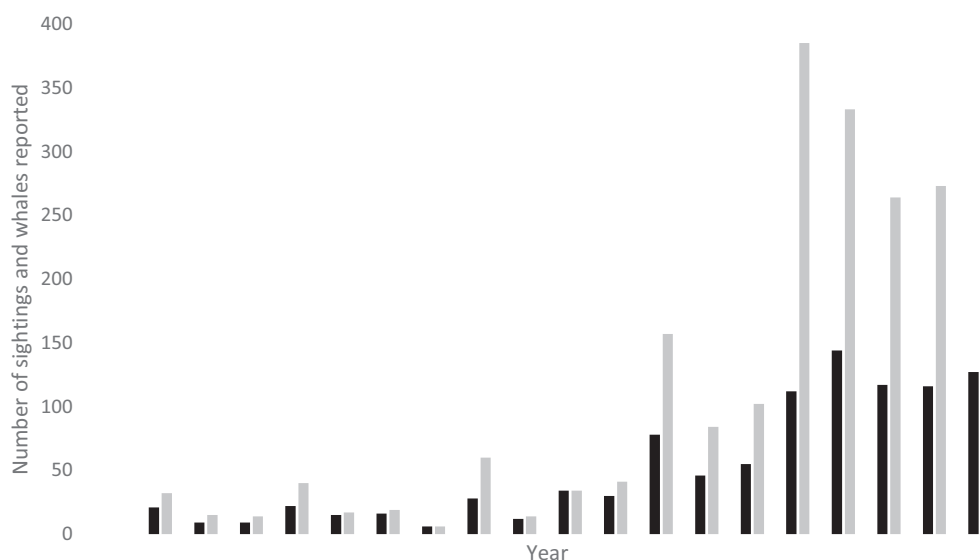


Fig. 3. Number of humpback whale sightings (black) and individuals (grey) submitted to the IWDG between 2000 and 2020.

methods). It took another eight years to add an additional five individual whales to the catalogue and 13 years to record a total of 20 individual humpbacks (Berrow et al., 2019). In 2015, the number of individually identified whales increased from 30 to 66, following an apparent incursion of previously unidentified whales into inshore waters, especially off west County Kerry. Big increases in the numbers of new individuals, also occurred but to a lesser extent, in 2017 and 2020 when 10 and 12 new whales were added to the Irish catalogue. At the end of 2020, there were 109 individual humpback whales in the Irish Humpback Whale Photo-identification Catalogue (Fig. 4).

Nearly all these records have been submitted by citizen scientists who sent images with sightings data to the IWDG for validation and data-basing (see Berrow et al., 2010 for details on the IWDG sighting scheme). Over this period humpback whale images, with associated data, have been photographed on 884 occasions, with a mean of 96 ± 15 events per annum, over the past five years. This remarkable dataset spanning 20 years shows the value of citizen science, when combined with a robust data collection, validation and feedback procedures. These data can also be used to calculate re-sighting rates across years to explore whether the same whales are returning each year and to establish minimum occupancy rates to investigate whether whales are staying in Irish waters or passing through *en route* to higher latitude feeding grounds elsewhere.

Re-sighting rates have been consistently high. Re-sighting rates in any year ranged from 0% (i.e. none of the whales identified had been re-sighted in previous years) to 84% (Table 3). In years where the IWDG have recorded 10 or more individual whales each year ($n = 9$) the mean \pm SD re-sighting rate was $63 \pm 20\%$. The re-sighting rate is increasing, despite a steady increase in the number of individual humpback whales being recorded annually (Fig. 5), suggesting this high-re-sighting rate is not due to small numbers of individual whales recorded each year, but is due to the same individual whales returning to inshore Irish waters between years.

Between 2001 and 2020, the same individual whale was recorded on at least two occasions in Irish waters within the humpback whale season (March to January) on 192 occasions. This enabled minimum residency times of individual whales to be calculated. Minimum residency times within a season ranged from 2 days to 186 days with a mean \pm SD of 48.0 ± 10.3 days. The distribution is shown in Fig. 4, with 27.5% of

humpback whales recorded over a period of 10 days or less. Over one-half (50.4%) were recorded over a period of 30 days or less but 16.5% were recorded over a period of at least 100 days (Fig. 6). Thus humpback whales returning to Irish waters are remaining for an average of almost seven weeks and some for over four months. These residency times are a minimum as individual whales may remain for much longer in Irish waters but were not captured through photo-id.

Clearly, what we have documented in Ireland, along the south and southwest coasts is an increase in the occurrence of humpback whales, especially over the past 5–10 years. Many of the same individual whales are returning each year and remaining in inshore waters for weeks, or months, at a time. This implies there is sufficient food to support these whales enabling them to stay for extended periods, and providing we protect this food source and minimise other pressures, their continued seasonal presence should continue and increase into the near future.

4. Future

The role of cetaceans, especially large baleen whales, in the processes and stability of our seas and oceans is not known. They have been described as “marine ecosystem engineers”, especially the deep-diving species which facilitate the transfer of nutrients from deep to surface waters which can then act as a “fertiliser” (Roman et al., 2014). Bossart (2011) suggested marine mammals were prime sentinel species because many species have long life spans, are long-term coastal residents, many feed at a high trophic levels, and have unique fat stores that can serve as depots for anthropogenic toxins. As many species share the coastal environment with humans and may compete for the same prey, they may also serve as effective sentinels for public health (Bossart, 2011). We live in a period where the numbers of large whales are increasing following huge reductions during centuries of over-exploitation. Some populations are approaching pre-exploitation levels (Bortolotto et al., 2016). If humpback and other large baleen whales continue to increase in the southern North Sea, what are the implications for current management and conservation plans?

The main issues which may affect humpback whales in the future in the southern North Sea were discussed by Leopold et al. (2018). These included disturbance, ship collisions, entanglement and crucially, securing the food supply for these large predators.

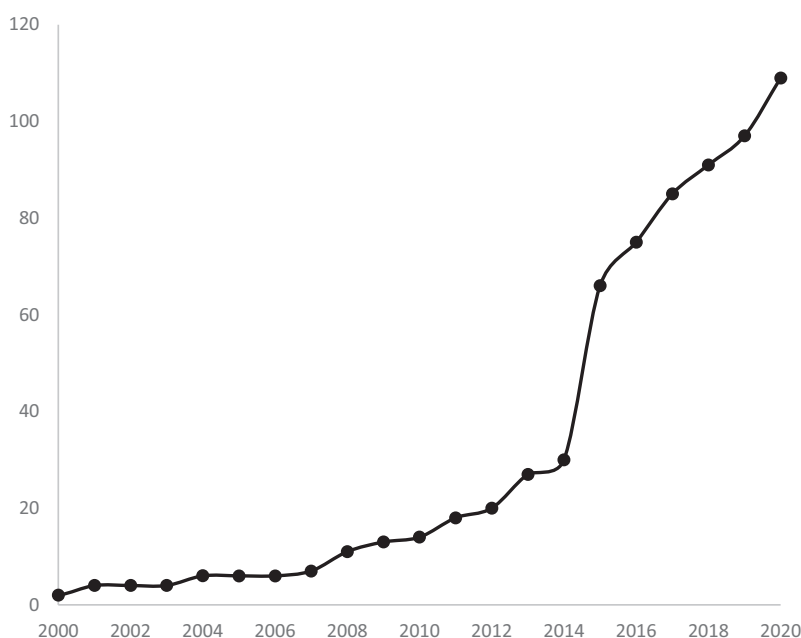


Fig. 4. Cumulative number of individual humpback whales recorded in Ireland (2000–2020) through photo-identification.

Table 3
Re-sighting rate of individual humpback whales in Irish waters (2000–2020).

	Year																				
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
No. identified	0	2	1	1	6	1	0	2	10	2	1	6	10	11	9	45	35	30	35	37	42
% re-sighted	0	0	25	25	83	14	0	25	60	50	0	16	70	36	66	20	71	73	80	84	71

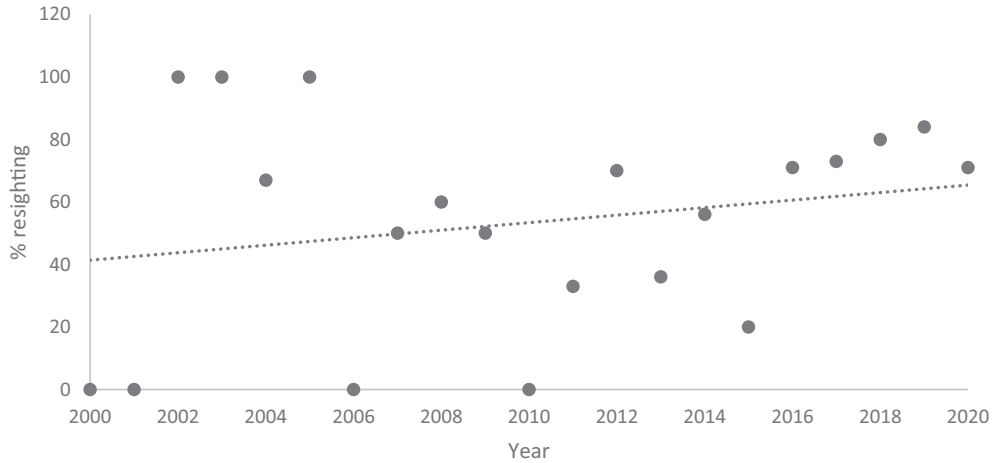


Fig. 5. Re-sighting rate of individual humpback whales in Irish waters (2000–2020).

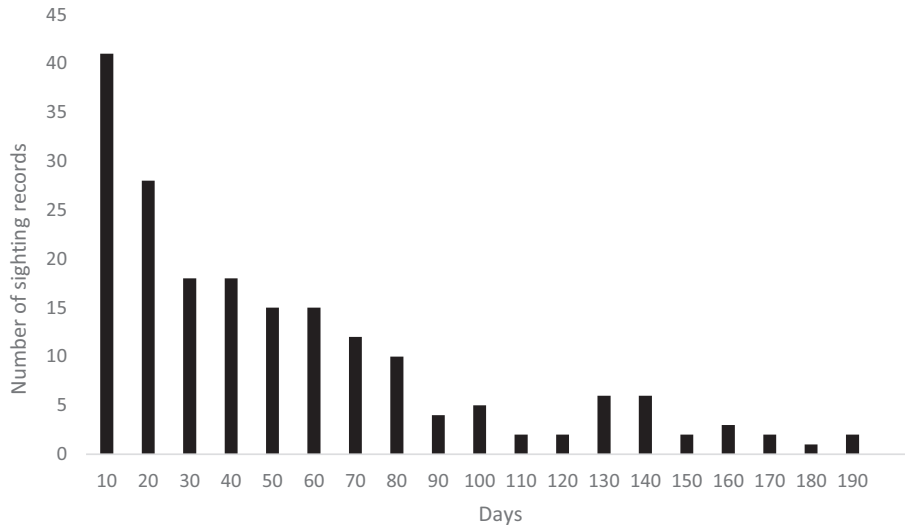


Fig. 6. Minimum residency times of individual humpback whales recorded in Ireland (2001–2020).

Peltier et al. (2019) attributed much of the increase in fin whale strandings on French coasts to ship strikes rather than an increase in public awareness or reporting pressure, at least over the last three decades. They suggested that temporal changes in strandings were likely due to changes in the intensity of pressures as well as cetacean abundance and distribution. The southern North Sea is one of the busiest shipping lanes in the world, with major ports especially at Rotterdam and Antwerp. Clearly fin whales are already consistently involved in ship collisions, as indicated by the number of fin whales stranded in the Channel with evidence of ship collisions as the cause of death. Peltier et al. (2019) suggested the relative number of ship strikes in the English Channel may have been over-estimated as animals injured in adjacent areas of the Atlantic Ocean may have drifted to shores along the English Channel. This is supported by the observations of those arriving into

harbours in the Netherlands and Belgium on the bulbous bows of large vessels in deteriorated body condition, suggesting many were struck outside the North Sea. As numbers of fin whales increase in the Celtic Sea and Bay of Biscay, the potential for ship collisions also increases. Thus increased strandings of fin whales may reflect general increases in fin whale abundance in these approaches, rather than abundance in the southern North Sea. Although humpback whales are also frequently involved in ship collisions worldwide (Ritter, 2012) only one, from Belgium, was reported in the southern North Sea as a potential victim of ship strike (Campuysen, 2007). It's likely that increased strandings of humpback whales in the southern North Sea are not associated with ship collisions. The probability of ship collision increases with vessel speed (Vanderlaan and Taggart, 2007) and measures to reduce vessel speed in areas frequented by right whales (*Eubalaena glacialis*) have successfully

reduced collisions in the northwest Atlantic (Conn and Silber, 2013). Reducing vessel speed may have other benefits such as reduced carbon emissions but would require good knowledge on large whale surface distribution and co-operation from shipping companies.

Humpback whales can be vulnerable to disturbance. They occur close to shore and often around harbours and places with high human activity. Fournet et al. (2018) showed that humpback whales increased the source levels of their calls as ambient noise levels increased. Also the probability of a humpback whale calling decreased when noise from boats was present, compared to when only natural sounds were present. Increasing ocean noise may lead to masking. Increased disturbance through marine tourism can be significant if not managed (Schaffar et al., 2010). The development of whalewatching worldwide has been well documented (Hoyt, 2009) and has been shown to potentially have a negative impact on individuals (Currie et al., 2021). Humpback whales are a popular target for whalewatching vessels, even on an opportunistic basis, if in a coastal area even for only a short period of time. There are a suite of guidelines and management tools available to reduce these impacts (Currie et al., 2021). In Ireland a Marine Notice 15 of 2005 (Anon, 2005), which can be enforced through a Statutory Instrument (SI), outlines how boats should behave around whales and dolphins. These include maintaining a minimum distance of 100 m, a distance of 200 m between any other boats in the vicinity, maintain boat speed below 7kts and do not corral whales or dolphins between boats. These are all standard guidelines worldwide but they can now be legally enforced in Ireland through this SI and apply to recreational craft as well as commercial operators. However, this SI has not been tested in the Irish courts.

Entanglement of large whales in fishing gear is of increasing concern in the Northeast Atlantic and European waters (Ryan et al., 2016; Basran et al., 2019). The threat of entanglement in the Northwest Atlantic to endangered northern right whales and humpbacks is well known, but increasingly entanglement is seen as an emerging threat in the Northeast Atlantic. At least 25% of 379 individual humpback whales photographed off Iceland, showed evidence of non-lethal entanglements with fishing gear (Basran et al., 2019). In Ireland, although there have been some well documented humpback whale entanglements from Wexford off the southeast coast to Donegal off the northwest (IWDG unpubl. data), the extent and impact of entanglement has not been quantified. However, it is unlikely to be significant at the population level, but may be an important welfare issue. In the southern North Sea, Campuysen (2007) reported a calf observed with its mother off the coast near Scheveningen in the Netherlands in December 2003, which was caught and drowned in fishing gear. Within a year a young female was found washed up dead at Vlieland with a rope around her head (Campuysen, 2007). The fishing gear identified was not the type used in the North Sea, which implied the whale become entangled elsewhere and carried the gear for some time (van der Meij and Camphuysen, 2006). Though unlikely to be significant at the population level, entanglement of large whales is a highly emotive issue and can also lead to potential high losses of fishing gear and any future interactions with whales should be reported.

Marine mammals are known to accumulate concentrations of persistent organic pollutants (POP). Concentrations in some odontocete species are above the toxic threshold leading to chronic impacts on their health and survival (Jepson et al., 2016). However, baleen whales typically have lower concentrations, reflecting their foraging at lower trophic levels and typically shorter lifespans than odontocetes. Ryan et al. (2013) showed concentrations of POP compounds in humpback whales were generally an order of magnitude lower in whales sampled in Ireland compared to the Western North Atlantic. Concentrations of legacy POPs (PCBs, DDTs) were not thought to be at a level to compromise the animals' health, though new emerging pollutants have not been measured. Concentrations of POPs could be used to delineate population structure (Ryan et al., 2014a). Ingestion of marine debris by marine mammals has been of concern for many years. Macro-debris

(>0.5 mm) frequently occurs in the stomachs of dolphins and porpoises and other odontocetes (Lusher et al., 2018) but few baleen whales have been sampled due to the logistics involved. Micro-plastics (<0.5 mm) are of more recent concern (Lusher et al., 2018). One Humpback whale from the North Sea was reported with microplastics in its intestines (Besseling et al., 2015). Fin whales have also been shown to contain microplastics in (Fossi et al., 2012), which is thought to lead to increase exposure to POPs as micro-plastics may act as small sponges attracting pollutants such as organochlorines and heavy metals and as such should be considered an emerging issue to baleen whales (Fossi et al., 2012) though the impact is likely to be small.

Probably the greatest challenge, and the one issue, which can have the most positive impact on increasing whale populations is maintaining food supply. Humpback whales, and perhaps to a lesser extent, fin whales, are foraging in coastal waters in the southern North Sea when occurring for extended periods. Small pelagic prey such as sandeels, sprat and herring have been identified as preferred prey items. Can fisheries management plans incorporate the requirements of increasing whale populations to ensure an adequate food supply? Providing for predator requirements in fisheries models requires information on prey type and size/age class, proportion of different prey in the diet and the abundance of whales. Information on residency times in different fisheries areas is important too. Some of these data are more easily obtained than others. An Ecosystem Approach to Fisheries Management (EAFM) (Morishita, 2008) greatly provides opportunities to incorporate predator requirements into fisheries models but real, practical examples in EU waters for whales are still hard to find. In Ireland an Environmental Management Plan (EMP) (Ryan and Berrow, 2013) was prepared for the Celtic Sea Herring Management Advisory Committee (CSHMAC), which includes representatives of fishing co-operatives and fish producer's organizations, as well as fisheries scientists and environmental NGOs, and provides advice to relevant statutory departments on herring management and oversee's a recovery plan. This EMP included recommendations on research into the foraging behaviour, diet and abundance of whales and considered the designation of No Take Zones within 6nmls of the coast. In December 2018, the Irish Minister of Marine announced that vessels >18 m in length will be restricted from trawling within 6nmls from the coast and baseline from 1 January 2020 (Policy Directive 1 of 2019), apart from for sprat, which was to be phased out over a period of three years. This ruling was over-turned in October 2020 following a high court appeal from affected fishers, citing it was in breach of fair procedures. Restrictions in fishing by large trawlers would likely benefit large whales feeding inshore off the Irish coast and the current Minister for Marine has lodged an appeal. While it seems likely that the Directive will be upheld in time, this does demonstrate the challenges faced when trying to implement conservative fisheries management actions on fisheries for small pelagic stocks.

The role of "citizen science" in monitoring humpback whales has been documented throughout the world (Tonachella et al., 2012; Bruce et al., 2014; Pirota et al., 2019). Humpback whales typically occur near to the coast, can be very active, will tolerate boats and are very popular in the media. As demonstrated in Ireland, and recently in parts of Scotland (O'Neil et al., 2019), citizen science could contribute very high quality data to monitor the presence of individual humpback whales in the southern North Sea. Kinze et al. (2018) suggested that successful management of native and putative new species will require national prioritization to support continuous efforts to register live and stranded cetaceans. Establishing recording schemes and promoting encounters through social media when they occur, including the provision of photo-id data, is to be encouraged and can bring very positive benefits especially if management issues arise. Recording fin whales is more challenging as they are typically offshore and collaboration with shipping companies, and maritime activities (offshore windfarms) and research projects operating offshore in the southern North Sea may be fruitful in soliciting more sightings.

5. Conclusions

There is strong evidence of the increasing presence of large baleen whales, especially fin and humpback whales in the southern North Sea. Sightings of humpback whales, which is an iconic species, are increasingly in the southern North Sea. Their populations are increasing worldwide, including the North Atlantic. Similar increases over the last 10–20 years off the south and southwest coasts of Ireland may provide an insight into what may occur in the southern North Sea over the coming decades. We have shown a high inter-annual re-sighting rate of individual humpback whales off Ireland. Many of the same individuals return year after year and some between decades, whilst remaining in inshore Irish waters for weeks or months at a time. This is to be welcomed and demonstrates the ability of some species to overcome exploitation, once these pressures are removed. The potential long-term implications of a population increase in humpback whales for conservation management should be considered, to ensure this increase continues and humpback whales become a regular and important component of the southern North Sea marine ecosystem.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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