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Monitoring of Marine Mammal Strandings Along French Coasts Reveals the Importance of Ship Strikes on Large Cetaceans: A Challenge for the European Marine Strategy Framework Directive

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Edited by:

Joshua Nathan Smith,
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per le Scienze del Mare (CoNISMa),
Italy
Francine Kershaw,
Natural Resources Defense Council,
United States

*Correspondence:

Hélène Peltier
helene.peltier@univ-lr.fr;
hpeltier@univ-lr.fr

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Hélène Peltier^{1,2*}, Alain Beauvils³, Catherine Cesarini⁴, Willy Dabin¹, Cécile Dars^{1,2}, Fabien Demaret^{1,2}, Frank Dhermain⁵, Ghislain Doremus¹, Hélène Labach⁵, Olivier Van Canneyt¹ and Jérôme Spitz¹

¹ Observatoire Pelagis, UMS 3462, Université de La Rochelle – CNRS, La Rochelle, France, ² ADERA, Pessac, France,

³ Association CHENE, Allouville-Bellefosse, France, ⁴ Cétacés Association Recherche Insulaire, Corte, France, ⁵ Groupe d'Etude des Cétacés de Méditerranée, Sausset-les-Pins, France

The incidence of marine traffic has risen in recent decades and is expected to continue rising as maritime traffic, vessel speed, and engine power all continue to increase. Although long considered anecdotal, ship strikes are now recognized as a major threat to cetaceans. However, estimation of ship strike rates is still challenging notably because such events occurred generally far offshore and collision between large ships and whales go often unnoticed by ship crew. The monitoring of marine mammal strandings remain one the most efficient ways to evaluate the problem. In France, a national coordinated network collected data and samples on stranded marine mammals since 1972 along the Mediterranean and Atlantic French coasts. We examined stranding data, including photography and necropsy reports, collected between 1972 and 2017 with the aim to provide a comprehensive review of confirmed collision records of large whales in France. During this period, a total of 51 ship strike incidents were identified which represents the 1st identified causes of mortality for large whale in France. It has increased since 1972 with seven records during the 1st decade to reach 22 stranded animals observed between 2005 and 2017. This issue appears particularly critical in the Mediterranean Sea where one in five stranded whales showed evidence of ship strike. This review of collision records highlights the risk of a negative impact of this anthropogenic pressure on the dynamic of whale populations in Europe, suggesting that ship strike rates could not allow achieving the Good Environmental Status of marine mammal populations required by the European Marine Strategy Framework Directive.

Keywords: ship strikes, fin whales, sperm whales, strandings, monitoring, MSFD

INTRODUCTION

Marine traffic exerts a growing pressure on marine megafauna. Ships and other sea-faring vessels cause chemical pollution, modification of habitats and animal behavior (including through noise disturbance) as well as direct injuries through collisions with animals (Pirota et al., 2018). Although long considered anecdotal, ship strikes are now recognized as a major threat to cetaceans (Kraus et al., 2005; Douglas et al., 2008). Any vessel type may be involved in ship strikes, including tankers, cargo or cruise ships, ferry boats, whale watching vessels, and sailing vessels (Laist et al., 2001; Ritter, 2012). Ship strikes occur worldwide and have been reported in at least 11 large whale species (Laist et al., 2001). Several hotspots have been identified across the world where ship strikes seriously threaten the conservation status of whale populations, e.g., northern right whales in the Western North Atlantic, blue whales around Sri Lanka and fin whales in the Mediterranean Sea (Cates et al., 2017). The incidence of ship strikes has risen in recent decades and is expected to continue rising as maritime traffic, vessel speed, and engine power all continue to increase (Laist et al., 2001; Douglas et al., 2008).

A thorough understanding of the incidence and future threat of ship strikes is of major importance for large cetacean conservation but is challenging to achieve. Relatively little is known about the geographic distribution of ship strikes and the magnitude of their impact. The scarcity of direct reports and relevant data makes it challenging to provide quantitative indicators of absolute mortality at sea. The best source of information available on ship strike fatalities is the examination of stranded cetaceans (Laist et al., 2001).

Understanding the pressures faced by marine wildlife and implementing plans to mitigate them are crucial to achieving and maintaining a Good Environmental Status (GES) of European waters - the aim of the Marine Strategy Framework Directive (MSFD, 2008/56/EC). Good Environmental Status is defined as “the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive”. In order to understand the future threat of anthropogenic pressures, like the “extraction of, or mortality/injury to, wild species, (by commercial and recreational fishing and other activities)” (2008/56/EC, Annex III), we need to study their impact on populations in the past and present, and project the observed trends into the future. For cetaceans, this requires the efficient monitoring of populations and the development of quantitative indicators that reveal the degree to which human activities impact these populations (Santos and Pierce, 2015; Authier et al., 2017).

We review five decades of whale stranding data collected along the French coasts in order to document the importance of ship strikes on populations of large whales and provide baseline data for future assessments. This is a step toward the development of a ship strike mortality indicator, which would serve as a means to better understand the importance of ship strikes in European waters in the future and identify ways to mitigate them in context of GES achievement through the MSFD.

MATERIALS AND METHODS

Stranding data was collected by the French National Stranding Network following standardized observation and sampling protocols set in place in the 1980s. This network is made up of around 400 trained volunteers distributed along the coasts of mainland France. Examination protocols include taking external measurements, photographs, and observations of all stranded cetaceans. According to the accessibility and the decomposition status of carcasses, tissues are regularly but not systematically sampled and examined (blubber, skin, internal organs, muscles, and skeleton).

Ship strike was determined as the cause of death if animals were recovered on ship bows or behind propellers, or with strong evidence of ship strikes. Evidence of ship strike includes: deep propeller cuts, significant bruising, oedema, internal bleeding radiating from a specific impact site, fractures and ship paint marks (Jensen and Silber, 2004; Douglas et al., 2008).

Observation effort has been stable since the late 1980s (Authier et al., 2014), so trends can therefore be interpreted with greater confidence for the last three decades. The earlier stranding records (1972–1982) must be carefully interpreted.

Because of low number of records, data were collated in histograms by 10-year intervals to improve the understanding of trends. Spatially, results are described following different marine sub-areas used in MSFD: the Western Mediterranean Sea (WMS), the Bay of Biscay (BB), the Celtic Sea (CS) and the Channel and North Sea area (CNS).

RESULTS

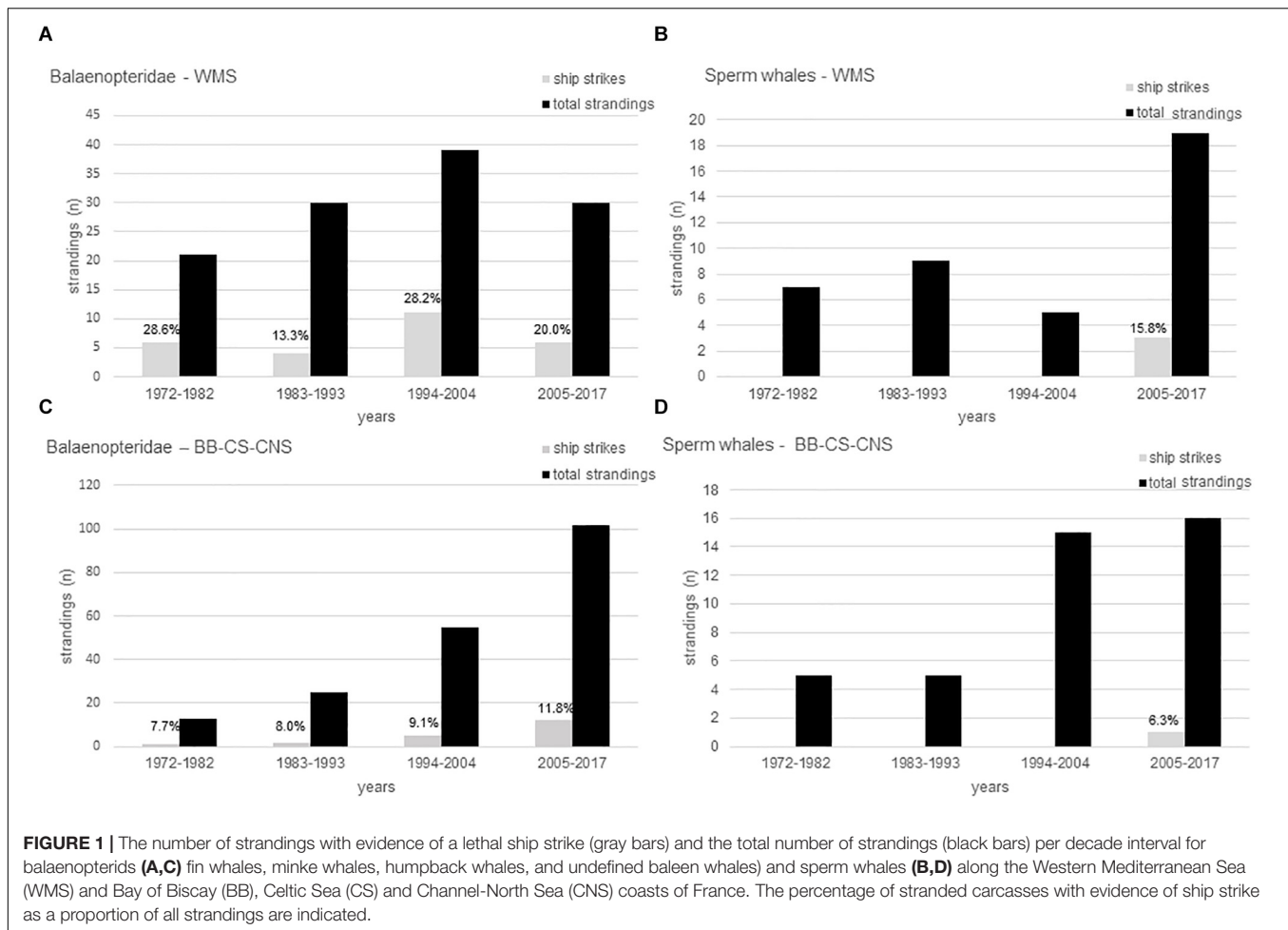
Species Composition of Strandings

A total of 396 large whale strandings were recorded in France between 1972 and 2017, of which 51 (12.9%) were diagnosed as being caused by ship strikes (details provided in **Supplementary Table S1**). Balaenopterids represented 79.5% of the total strandings, 315 in total, and sperm whales represented the remaining 81 strandings (20.5%). Ship strike incidents included 39 fin whales (76.5%), 4 minke whales (7.8%), 2 humpback whales (3.9%), 4 sperm whales (7.8%) and 2 unidentified baleen whales (3.9%). Of the fin whales killed by ship strikes, 16 were males, 13 females, and 9 were not identifiable. The average length of males was 14.6 m (\pm 3.5 m) and 16.1 m (\pm 2.6 m) for females.

Due to the high representation of fin whales in the total sample of ship strike events (83% of balaenopterids), all balaenopterids (fin whales, minke whales, humpback whales, and unidentified balaenopterids) were collated for analysis.

Temporal Trends

The total number of strandings have increased over the last 46 years for sperm whales in the Atlantic Ocean and Mediterranean Sea as well as balaenopterids in the Atlantic Ocean. Strandings of balaenopterids in the Mediterranean Sea increased steadily until the last decade during which the number of strandings slightly decreased (**Figure 1**).



Evidence of ship strikes were only reported for sperm whales in the last decade, while balaenopterid strikes are documented as early as 1972 and increased over the decades: a total 18 baleen whale strikes were reported along French coasts between 2005 and 2017 (Figure 1). The proportion of balaenopterid strandings caused by ship strike per decade was variable in the Mediterranean Sea ($22.5\% \pm 7.3\%$) and increased over the decades along the Atlantic coast. The proportion of total strandings caused by ship strikes remained stable over the decades. Ship strike induced strandings occurred throughout the year but more frequently between the months of July and November (67% of ship strike strandings) (see Supplementary Table S1).

Geographic Distribution of Ship Strikes

Strandings due to ship strike were more frequent along the Mediterranean coast than the Atlantic coast (Figure 2). 28 whales were struck and found stranded in the Mediterranean Sea (including 24 fin whales, one humpback whale and three sperm whales) compared to 21 whales in Atlantic Ocean and English Channel (15 fin whales, four minke whales, one humpback whale, and one sperm whale). The majority of ship strikes reported on the Mediterranean coast were recovered on the eastern part of the

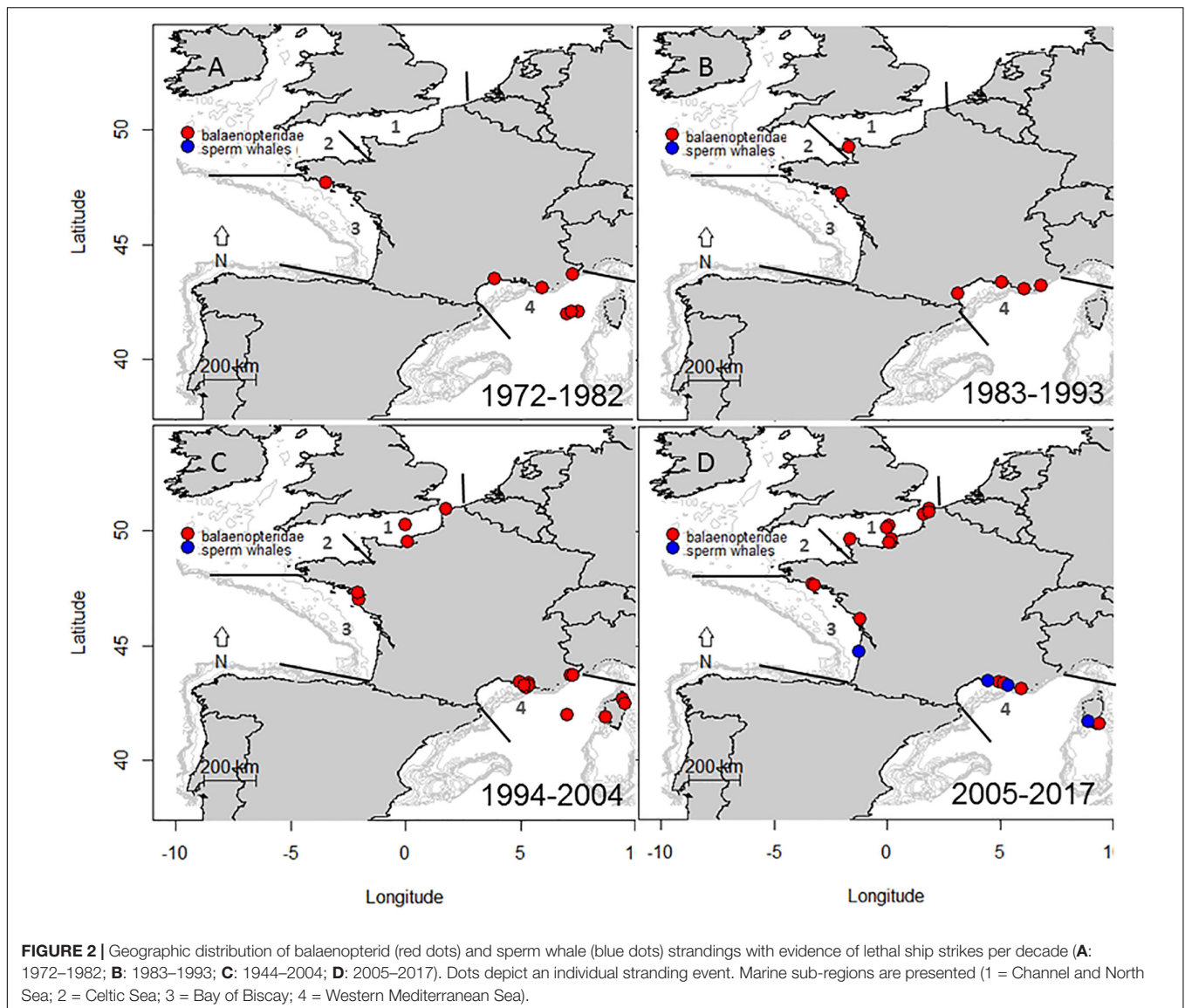
Gulf of Lion and the Ligurian Sea (97%), an area which includes the Pelagos Sanctuary.

DISCUSSION

Ship strikes were the predominant anthropogenic cause of death identified in large cetaceans along both Atlantic and Mediterranean coasts. This is in line with the results of studies in other parts of the world that report a direct correlation between the global increase of shipping activity, engine power, and vessel speed (Laist et al., 2001; Ritter, 2012; Cates et al., 2017). Vessel speed correlates positively with the probability of ship strikes and the severity of injuries (Vanderlaan and Taggart, 2007; Douglas et al., 2008; Ritter, 2012; Conn and Silber, 2013).

The increase of large whale strandings does not appear to be related to an increase in public awareness or reporting pressure, at least for the last three decades during which observation effort was stable. Temporal changes in strandings are therefore likely due to changes in cetacean abundance and distribution, and/or changes in the intensity of pressures (Peltier et al., 2012).

High densities of large cargo vessels in major shipping routes create a serious risk of ship strikes. The Ushant Traffic Separation



Scheme in the English Channel and the Mediterranean Sea are two of the most important waterways of the world (Lloyds Maritime and Intelligence Unit, 2008). Individuals injured in these shipping routes may, however, strand great distances from the location they were struck or never strand at all. One study described a fin whale carcass being dragged over 1100 km by a cruise ship after a ship strike (Laist et al., 2001). Therefore, despite stranding data being the best source of information available to determine ship strike incidence, the degree to which they are representative of actual ship strikes is limited and the threat of ship strikes may be under- or overestimated based on stranding numbers.

Based on their known distribution, fin whale densities were expected to be highest on the continental slope of the BB and the oceanic area of the Pelagos Sanctuary in the summer months, and absent in the English Channel (Laran et al., 2017a,b). The relative number of ship strikes in the English Channel

may have been over-estimated: animals injured in adjacent areas of the Atlantic Ocean may have drifted to shores along the English Channel. Ship strikes in the BB may have been underestimated: the majority of collisions would likely have occurred in the dense shipping routes far from the coast beyond the continental shelf. Animals that stranded along the shores of the BB after collisions in these parts would have drifted long distances to the shores. The bad drift conditions in the BB in summer (Peltier et al., 2013) (when whale density and therefore collision risk is high) could have prevented some carcasses from reaching the coast at all. Moreover, because of the long travel time coupled with the aggravated decomposition of the carcass after blunt force trauma, the animals could have reached the shores in too bad a state to be able to identify evidence of ship strike.

Fin whales are of particular concern in French Mediterranean waters. A recent study estimated that the fin whale population

in the French Mediterranean Sea numbered only 2,500 individuals [CI 95% = 1472–4310] (Laran et al., 2017a) in the summer. The small population is characterized by limited gene flow (Palsbøll et al., 2004) and is thus particularly vulnerable to anthropogenic pressures (Panigada et al., 2006; Panigada and Notarbartolo di Sciara, 2012).

Aguilar et al. (1988) reported fin whale sexual maturity at a size of 17.4 m for females and 18.5 m for males. The majority of fin whales that stranded following a ship strike had not yet reached maturity: eight of the 13 females and 15 of the 16 males. Immature fin whales seem to be more vulnerable to ship strikes than mature animals, a result that is supported by the findings of other studies (Laist et al., 2001; Panigada et al., 2006; Douglas et al., 2008). Laist et al. (2001) also reported that a high proportion (75%) of northern right and humpback whale fatalities due to ship strikes were calves and juveniles. Immature whales may be more naïve to ships and spend more time surfacing when vessels are in the vicinity.

Scientists need to identify the main pressures within each MSFD component in order to develop monitoring schemes and indicators to assess the condition of European marine environments, to evaluate the efficiency of mitigation measures, and to recover GES. A challenge for the second MSFD 6 years cycle will be to complete the currently used set of indicators (focused on cetacean abundance and distribution, bycatch, and contaminant issues) to allow for a broader assessment of species and the pressures they face, especially large whales (e.g., ship strikes). The development of quantitative indicators to monitor the levels and the impacts of ship strikes on large whale populations is vital for future cetacean studies under the MSFD. Such indicators could document the criteria on biodemographic parameters (called D1C3), which require estimating mortality rates.

In the context of the next GES assessment in 2024, the proper assessment of ship strike mortality on cetacean populations in European waters through the MSFD requires: (1) the stimulation of transboundary collaboration at a basin scale to collect enough standardized data over a large enough area to be relevant for such large and mobile species (Authier et al., 2017), and (2) the development and use of quantitative indicators and thresholds adapted to the low occurrence of ship strike records. Overcoming these challenges would be an important step in integrating ship strike risk and impact in the future assessment of GES for cetaceans.

ETHICS STATEMENT

This work was carried out in the respect of European regulation regarding the use of stranded dead cetacean for scientific and conservation purposes. The authors have therefore adhered to general guidelines for the ethical use of animals in research, the legal requirements in Europe. No living animals were used for this study, only dead cetaceans found stranded along European coasts by several organisations were considered. No samples were used for this study.

AUTHOR CONTRIBUTIONS

HP performed the analyses and wrote the manuscript. WD, CD, FDe, GD, and OVC coordinated the French stranding network and collected the stranding data. AB, CC, FDh, and HL collected the stranding data. JS supervised and corrected the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fmars.2019.00486/full#supplementary-material>

TABLE S1 | Details of the 51 large whale strandings with evidence of lethal ship strikes along the coasts of mainland France for different marine sub-areas between 1972 and 2017. Total numbers par MSFD reporting cycles according to marine sub-regions are presented [number of individuals (reporting cycle)].

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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