# PEOPLE – MARINE MAMMAL INTERACTIONS

**EDITED BY:** Andrew Butterworth and Mark P. Simmonds
**PUBLISHED IN:** Frontiers in Marine Science

frontiers Research Topics

**ISSN 1664-8714**
**ISBN 978-2-88945-231-6**
**DOI 10.3389/978-2-88945-231-6**

## About Frontiers

Frontiers is more than just an open-access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

## Frontiers Journal Series

The Frontiers Journal Series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the Frontiers Journal Series operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

## Dedication to Quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews.

Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view.

By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

## What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the Frontiers Journals Series: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area! Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers Editorial Office: **researchtopics@frontiersin.org**

# PEOPLE – MARINE MAMMAL INTERACTIONS


Topic Editors:
**Andrew Butterworth,** University of Bristol, United Kingdom
**Mark P. Simmonds,** University of Bristol, United Kingdom


A humpback whale in Faxafloi Bay, Reykjavik, Iceland - entangled in fishing gear, and unentangled by British Divers Marine Life Rescue (BDMLR) and International Fund for Animal Welfare (IFAW) with permission from the Icelandic government in August 2015.
(http://uk.whales.org/blog/2015/08/happy-ending-for-nettie-humpback-entangled-off-iceland Accessed 12 6 17)
Photo credit: Andy Butterworth

Our relationships with marine mammals are complex. We have used them as resources, and in some places this remains the case; viewed them as competitors and culled them (again ongoing in some localities); been so captivated and intrigued by them that we have taken them into captivity for our entertainment; and developed a lucrative eco-tourism activity focused on them in many nations. When we first envisaged this special topic, we had two overarching aims:

Firstly, we hoped to generate critical evaluation of some of our relationships with these animals.

Secondly, we hoped to attract knowledgeable commentators and experts who might not traditionally publish in the peer-reviewed literature.

We were also asking ourselves a question about what responsibility mankind might have to marine mammals, on our rapidly changing planet?

The answer to the question; can, or should, humans have responsibility for the lives of marine mammals when they are affected by our activities? - is, in our opinion, 'yes' – and the logical progression from this question is to direct research and effort to understand and optimise the actions, reactions and responses that mankind may be able to take.

We hope that the papers in this special issue bring some illumination to a small selection of topics under this much wider topic area, and prove to be informative and stimulating.

**Citation:** Butterworth, A., Simmonds, M. P., eds. (2017). People **–** Marine Mammal Interactions. Lausanne: Frontiers Media. doi: 10.3389/978-2-88945-231-6

# Table of Contents

frontiers in Marine Science

EDITORIAL
published: 08 June 2017
doi: 10.3389/fmars.2017.00183

# Editorial: People – Marine Mammal Interactions

*Andy Butterworth* * *and Mark P. Simmonds*

*Clinical Veterinary Science, University of Bristol, Bristol, United Kingdom*

**Keywords: marine mammal, humans, interactions, welfare, policy making**

**Editorial on the Research Topic**

**People – Marine Mammal Interactions**

Our relationships with marine mammals are complex. We have used them as resources, and in some places this remains the case; viewed them as competitors and culled them (again ongoing in some localities); been so captivated and intrigued that we have taken them into captivity for our entertainment; and developed a lucrative eco-tourism activity focused on them in many nations (Brakes and Simmonds, 2011). In fact, the history and even the economic success of many maritime nations has been intimately intertwined with exploitation of marine mammals. In the United Kingdom, for example, stranded cetaceans were once used opportunistically for food, and this later developed into organized hunting, with the value of cetaceans recognized in 1,324 when a statute was enacted giving the English sovereign qualified rights to stranded and captured animals (Simmonds, 2011). The Scottish crown quickly moved to claim the same rights. Later, British interests moved from a focus on whale meat to whale oil and land stations and far-seas whaling followed. Ultimately, it was whale oil that helped to light the streets and factories of the industrial revolution and lubricate its machines. Britain was, of course, far from being alone in mining the whales for their oil and, come the twentieth century, as whale stocks dwindled, the UK was one of the founding member nations of the International Whaling Commission (IWC).

When we first envisaged this special topic, we had two overarching aims. Firstly, we hoped to generate critical evaluation of some of our relationships with these animals and, secondly, we hoped to attract knowledgeable commentators and experts who might not traditionally publish in the peer-reviewed literature. We were also asking ourselves a question about what responsibility humankind might have to marine mammals, on our rapidly changing planet. Readers will judge our success for themselves, from the papers in this special issue, which cover;

- “Aquatic bushmeat”—consumption in developing parts of the world;
- Bycatch—Gulf of Guinea;
- The recent evolution of the IWC;
- Welfare concerns relating to seal shooting—Scotland;
- Dolphin harassment—Gulf of Mexico;
- The welfare implications of marine debris for pinnipeds;
- “Small Type Coastal Whaling” and whaling policy—Japan; and
- The conservation implications of cetacean culture.

These are diverse, and challenging topics, although there are, of course, others that could have been addressed. Notable omissions might include consideration of marine noise pollution (e.g., Simmonds et al., 2014); chemical pollution (as recently highlighted by Jepson and Law, 2016) and more discussion of the various ongoing hunts of cetaceans and seals (e.g., Butterworth and Richardson, 2013; Butterworth et al., 2013; Butterworth, 2014; Simmonds and Corkeron, 2016) which currently take place in coastal and international waters.

OPEN ACCESS

***Edited and reviewed by:***
*Rob Harcourt,*
*Macquarie University, Australia*

****Correspondence:***
*Andy Butterworth*
*andy.butterworth@bris.ac.uk*

***Specialty section:***
*This article was submitted to Marine Affairs and Policy, a section of the journal Frontiers in Marine Science*

***Received:*** *15 March 2017*
***Accepted:*** *26 May 2017*
***Published:*** *08 June 2017*

***Citation:***
*Butterworth A and Simmonds MP (2017) Editorial: People – Marine Mammal Interactions. Front. Mar. Sci. 4:183. doi: 10.3389/fmars.2017.00183*

Powered by oil and gas, electricity, plastics and steel, the aeroplane, the car, and the gun, human influence, and creeping tentacles of human population growth can now be felt across the entire surface of the planet. The United Nations (United Nations, 2015) estimate that the global human population will reach 10.1 bn in 2100. Increasingly, the world's people live in cities; Osaka, Karachi, Jakarta, Mumbai, Shanghai, Manila, Seoul, Beijing, Mexico City, São Paulo, New York, Lagos, Los Angeles, and Cairo each now have close to or more than 20 million people. Delhi and Tokyo are forecast to reach 40 million people within the next decade. Humans and their cities need food and fuel, and spread across coastal land. Human wastes are driving climate change, ocean pollution (including marine debris), and air pollution. Even if population growth slows, humankind and its mark on the planet and its animals is already deeply scored into the surface of the earth, and will be for a long, geologically long, time.

The science of marine mammal–human interaction and marine mammal welfare is starting to enter the political arena at a high level. At its 65th meeting, in 2014, the IWC agreed to direct a programme of work to address human activities which can adversely affect cetacean welfare; including the welfare concerns that arise when large whales become entangled in fishing gear and to work on the methods used to euthanize stranded whales and the effectiveness of those methods. We attended the first IWC workshop (May 2016), which had a sole focus of considering non-whaling welfare issues (IWC, 2017). There is clearly a growing interest in marine mammals and human interactions.

Historically there has been an understandable focus on the effects of negative human marine mammal interactions. However, positive experiences and states are now recognized to be (at least) as important as negative states in their contribution to overall animal well-being. Marine mammal science is starting to include elements of not just the physical aspects of the animals life (injury, environmental change, pollution, noise) but also the mental state of the animal, whether the animal can express a range of "normal" behaviors, and whether the animal can fulfill its essential nature or "telos."

The answer to the question; can, or should, humans have responsibility for the lives of marine mammals when they are affected by the activity of mankind?—is, in our opinion, "yes"—and the logical progression from this question is to direct research and effort to understand and optimize the actions, reactions, and responses that mankind may be able to take. We hope that the papers in this special issue bring some illumination to a small selection of topics under this much wider topic area, and prove to be informative and stimulating.

## AUTHOR CONTRIBUTIONS

All authors listed, have made substantial, direct and intellectual contribution to the work, and approved it for publication.

## ACKNOWLEDGMENTS

We would like to thank the Humane Society International for sponsoring this special topic by covering the publishing fees. We also thank all of the referees for their very valuable contributions and the staff at Frontiers for their help.

## REFERENCES

Brakes, P., and Simmonds, M. P. (eds.). (2011). *Whales and Dolphins – Cognition, Culture, Conservation and Human Perceptions*. London: Earthscan Ltd.

Butterworth, A. (2014). The moral problem with commercial seal hunting. *Nature* 509:9. doi: 10.1038/509009a

Butterworth, A., Brakes, P., Vail, C. S., and Reiss, D. (2013). A veterinary and behavioral analysis of dolphin killing methods currently used in the "drive hunt" in Taiji, Japan. *J. Appl. Anim. Welfare Sci.* 16, 184–204. doi: 10.1080/10888705.2013.768925

Butterworth, A., and Richardson, M. (2013). A review of animal welfare implications of the Canadian commercial seal hunt. *Mar. Policy* 38, 457–469. doi: 10.1016/j.marpol.2012.07.006

IWC (2017). *Report of the Workshop to Support the IWC's Consideration of Non-Hunting Related Aspects of Cetacean Welfare*. IWC/66/WKM&WI Rep 01. 34 pages. Available online at: https://archive.iwc.int/pages/view.php?ref=6230&k=c0e34c50b4

Jepson, P. D., and Law, R. J. (2016). Persistent pollutants, persistent threats: polychlorinated biphenyls remain a major threat to marine apex predators. *Science* 352, 1388–1389. doi: 10.1126/science.aaf9075

Simmonds, M. P. (2011). "The British and the whales," in *Whales and Dolphins – Cognition, Culture, Conservation and Human Perceptions*, eds P. Brakes and M. P. Simmonds (London: Earthscan Ltd.), 56–75.

Simmonds, M. P., and Corkeron, P. (2016). A deal on whaling is a bad idea. A response to Gerber. *Front. Ecol. Environ.* 14:1263. doi: 10.1002/fee.1263

Simmonds, M. P., Dolman, S. J., Jasny, M., and Leaper, R. (2014). Marine noise pollution - increasing recognition but need for more practical action. *J. Ocean Technol.* 9, 71–90.

United Nations (2015). *UN Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2015 Revision, Vol. 1, Comprehensive Tables*. ST/ESA/SER.A/379.

**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.

frontiers in Marine Science

REVIEW
published: 20 June 2016
doi: 10.3389/fmars.2016.00087

# Marine Mammal Behavior: A Review of Conservation Implications

*Philippa Brakes* and Sasha R. X. Dall*

*Centre for Ecology and Conservation, Biosciences, College of Life and Environmental Sciences, University of Exeter, Penryn, UK*

The three orders which comprise the extant marine mammals exhibit a wide range of behaviors, varying social structures, and differences in social information use. Human impacts on marine mammals and their environments are ubiquitous; from chemical and noise pollution, to marine debris, prey depletion, and ocean acidification. As a result, no marine mammal populations remain entirely unaffected by human activities. Conservation may be hindered by an inadequate understanding of the behavioral ecology of some of these species. As a result of social structure, social information use, culture, and even behavioral syndromes, marine mammal social groups, and populations can be behaviorally heterogeneous. As a result responses to conservation initiatives, or exploitation, may be complex to predict. Previous commentators have highlighted the importance of incorporating behavioral data into conservation management and we review these considerations in light of the emerging science in this field for marine mammals. Since behavioral canalization may lead to vulnerability, whereas behavioral plasticity may provide opportunity for resilience, we argue that for many of these socially complex, cognitive species understanding their behavioral ecology, capacity for social learning, and individual behavioral variation, may be a central tenant for their successful conservation.

**Keywords: marine mammals, sociality, behavior, social learning, culture, individual behavioral variation, personality, conservation**

OPEN ACCESS

***Edited by:***
*Mark Peter Simmonds, University of Bristol, UK*

***Reviewed by:***
*E. Christien Michael Parsons, George Mason University, USA*
*Andrew Butterworth, University of Bristol, UK*

****Correspondence:***
*Philippa Brakes*
*p.brakes@exeter.ac.uk*

***Specialty section:***
*This article was submitted to Marine Affairs and Policy, a section of the journal Frontiers in Marine Science*

***Received:*** *17 March 2016*
***Accepted:*** *19 May 2016*
***Published:*** *20 June 2016*

***Citation:***
*Brakes P and Dall SRX (2016) Marine Mammal Behavior: A Review of Conservation Implications. Front. Mar. Sci. 3:87. doi: 10.3389/fmars.2016.00087*

## INTRODUCTION

The extant marine mammals are found in three Orders *Cetacea, Sirenia,* and *Carnivora* (including suborder *Pinnipedia,* Family *Mustelidae,* and Family *Ursidae*). These species inhabit a diverse range of habitats from river, brackish, mangrove, and estuarine habitats, to coastal shallows and pelagic seas, with some even foraging at the edge of the abyssal plain. In addition, they have a diverse range of food items, from seagrass or zooplankton, through to fish, penguins, and other marine mammals. As a result of their diverse niches, they exhibit a wide range of behaviors. Some of their behaviors have been studied in detail, whereas others remain more mysterious. For example, the exceptional migration of the baleen whales is well-documented, while details about the more subtle, small-scale behavioral differences between marine mammals social groups is only now starting to emerge.

The importance of incorporating behavioral ecology into conservation efforts has long been argued for terrestrial mammals (Caro and Durant, 1995; Sutherland, 1998; Candolin and Wong, 2012), particularly where manipulations of the wild environment are possible to assist conservation efforts. The challenge that remains is to determine how insights into behavioral ecology can best be used to inform conservation efforts in the more alien marine environment.

Sociality and social learning are undoubtedly important considerations when conserving marine mammals. In 2010, Whitehead suggested that several factors complicate the conservation of species that learn socially, such as the rapid spread of novel behavior, the evolution of maladaptive behavior, or the inhibition of adaptive behavior (Whitehead, 2010). He argued that such factors have an influence on habitat suitability, responses to anthropogenic change, and even genetic structures. This is reflected in an analysis which revealed that of the toothed whales (*Odontoceti*), four species showed evidence of decrease in birth rates following exploitation, highlighting the effects beyond the dynamics of individual removals (Wade et al., 2012).

Behavioral variation among populations and individuals also has the potential to influence responses to management efforts and to enhance or hinder conservation. For example, understanding sperm whale (*Physeter microcephalus*) depredation of sablefish from demersal longlines across the Alaskan fishery has only been possible with emerging knowledge about the scale and spread of this behavior and whether noise from fishing vessels may be providing an acoustic cue for these whales (Thode et al., 2015). While research on killer whale (*Orcinus orca*) response to an acoustic harassment device, to prevent long-line depredation, indicated habituation to the device (Tixier et al., 2015). However, despite being habituated to the device, exposure to the sound it produces while depredating lines may result in potentially harmful hearing damage (Tixier et al., 2015).

In 1998, Sutherland noted that "The exciting research developments in animal behavior over the last two decades have had a negligible impact on conservation." He then reviewed 20 subjects in which the study of behavioral ecology could make a significant contribution to conservation (Sutherland, 1998). Here, we review this list specifically for marine mammal conservation, in light of the subsequent 18 years of research, and suggest some potential additions to the list.

## SMALL POPULATION EXTINCTIONS

Genetic, ecological, and behavioral factors can all contribute to making small populations particularly vulnerable to extinction. One of the most significant challenges for marine mammal conservation is determining demographically independent conservation units, based on acoustic, taxonomic, genetic, geographic, behavioral, social, or ecological features (Parsons et al., 2015). In highly social species, behavior may play a particularly important role in differentiation between units to conserve and in understanding the mechanisms of population persistence or decline.

Social species may benefit from the presence of conspecifics in a number of ways including predation risk dilution, collective anti-predator vigilance, "selfish herd" effects, predator confusion, cooperative foraging, resource defense, increased availability of suitable mates, allo-parental care, and reduction of inbreeding (Stephens et al., 1999; Krause and Ruxton, 2002). Whilst a handful of marine mammal species are solitary, many are social for at least part of their life cycle and as numbers decrease the ability to raise the alarm, defend against predators, forage, or breed cooperatively also generally declines. The Allee effect (Allee, 1931), which may result in precipitous decline, is defined as a positive relationship between any component of individual fitness and density of conspecifics (Stephens et al., 1999). But it is necessary to differentiate between component Allee effects (at the level of individual fitness) and demographic Allee effects (at the level of mean fitness), which may be important for predicting the persistence of small populations, particularly where a decrease in numbers results in reduced opportunities for cooperation. For example, obligate cooperative breeders rely on a minimum group size to subsist and studies in terrestrial mammals suggest that cooperative breeders (see Section Mating Systems and Inbreeding Depression) may be particularly susceptible to Allee effects. A new conceptual level, the group Allee effect, has been suggested for cooperative breeders (Angulo et al., 2013).

Smaller populations may also place limitations on the ability to find a suitable mate. This may be the result of changes in operational sex ratio as the population declines, which may be related to population density and changes in habitat, but other sexual selection pressures, such as the specifics of mate choice, may also have an influence on population growth rates, making smaller populations more prone to extinction. For example, there is evidence from sperm whaling records that following the reduction in abundance of larger males, that fertility rates were reduced (Clarke et al., 1980; Whitehead et al., 1997). Whether this reduced fertility rate was the result of female mate choice or other selection pressures is unknown.

Nevertheless, it has been suggested that in baleen whales, since male song may influence female mate choice, that preference for local or known dialects could theoretically cause pre-zygotic isolation between species, potentially a precursor to speciation (Beltman et al., 2004; Thornton and Clutton-Brock, 2011). Conversely, it has also been suggested that to avoid inbreeding depression female humpback whales may have a preference for novelty in song, which itself may drive the evolution of the males' song (Parsons et al., 2008).

The matter of how to define a "small population" has conventionally been resolved on genetic or geographic parameters (or both). Nevertheless, from the perspective of determining the influence of behavior for conservation efforts, delimiters based on specific behaviors may also be relevant for predicting population persistence. For example, Southern sea lions (*Otaria flavescens*), which have declined by over 90% in the Falkland Islands since the 1930s, exhibit two discrete foraging strategies; inshore and offshore. These strategies appear to be independent of intraspecific competition and are thought to be influenced by foraging site fidelity (Baylis et al., 2015). Using feeding strategies as a boundary between smaller sub-sets of the population may be a vital conservation tool.

In addition, of the three distinct populations of false killer whales (*Pseudorca crassiden*) recognized around the Hawaiian Islands, a significant difference in fisheries related scarring has been identified between these populations. This suggests that fisheries interactions are occurring at a higher rate in one population, with a bias toward females, suggesting that fisheries-related mortality is likely to be disproportionate across these distinct populations (Baird et al., 2014). Thus, behavior is relevant for determining "distinct population segments" (DSP) and it has been argued that attempts to limit DSPs to purely "evolutionarily significant units" could compromise management efforts, since the use of demographic and behavioral data would be reduced (Pennock and Dimmick, 1997).

## MATING SYSTEMS AND INBREEDING DEPRESSION

Some marine mammal species, such as sperm whales, killer whales and elephant seals (*Mirounga* sp.) exhibit dramatic sexual dimorphism, with the males being considerably larger than the females. It has been speculated that species which exhibit communal displays, such as leks may be more prone to small population extinctions (Sutherland, 1998; see Section Small Population Extinctions). Whilst there is only limited data on the mating display of some marine mammals (particularly for those species where mating occurs underwater), sexual dimorphism may provide some clues. In sperm whales it is not known whether copulation is forced by males, chosen by females or determined by other processes (Whitehead, 2003). Nevertheless, there is some evidence that the sexual dimorphism in sperm whales (males being three times the mass of females) tips the balance in favor of "roving" in higher latitudes among the males (up to 27 years), before moving to warmer waters when they begin effective breeding. It has been suggested that the advantages of continuing to feed and grow before seeking out females outweighs the opportunity to breed sooner (Whitehead, 1994), indicating some competitive advantage for larger males. In addition, it has been suggested that difference in feeding ecology between males and females in resident, fish-eating killer whales of the northeastern Pacific Ocean may either be a driver or consequence of sexual dimorphism in this species (Beerman et al., 2016).

Similarly, Northern elephant seals feed separately with males traveling north closer to shore, whereas females migrate west from the coast into the open ocean. Males also forage during benthic dives, whereas female foraging is characterized by pelagic dives interspersed with trips to the sea floor. It has been suggested that this resource portioning is the result of sexual dimorphism, with the females' smaller size necessitating foraging in areas with less predators (Le Boeuf et al., 2000).

Mating behavior clearly has implications for potential inbreeding and conservation. In Antarctic fur seals (*Arctocephalus gazella*), the territoriality of males and the behavior of females searching for suitable pupping locations are thought to combine to be responsible for the low re-mating frequency (Bonin et al., 2016). Whilst, Wade et al. (2012) noted that in four odontocete species examined there was evidence of a decrease in birth rates following exploitation. Suggested mechanisms include a deficit of adult females, a deficit of adult males, and disruption of mating systems (Wade et al., 2012). In addition, research on California sea lions (*Zalophus californianus*) suggests that inbreeding may also increase susceptibility to some pathogens (Acevedo-Whitehouse et al., 2003).

It is important to understand the relationship between different breeding systems and inbreeding depression (Sutherland, 1998). Inbreeding depression is the result of non-random mating of close relatives, with a resultant lowering in population fitness. However, the effects of inbreeding are controversial and not always easily predicted (Huisman et al., 2016), as evidenced by the case of the recovering Northern elephant seal (*Mirounga angustirostris*) population. Despite at one point being reduced to a population of likely <20 individuals, this species exhibits significant inbreeding with little genetic diversity and yet the populations do not yet show any obvious signs of inbreeding depression (Weber et al., 2004).

In contrast, the Northern right whale (*Eubalaena glacialis*) which suffered similar population decimation, failed to make a similar recovery following whaling, with the total minimum population currently estimated at 465 (NOAA, 2015). Research suggests that this population is suffering from reduced fertility, fecundity, and juvenile survivorship. It has been suggested that these factors may be the result of low genetic diversity (in comparison to other right whale populations; Schaeff et al., 1997; Kraus et al., 2001), but that the low genetic variability in this species may be the result of slow but continual erosion of alleles during the last 800 years of the population's decline (Waldick et al., 2002). In addition, there is evidence for post-copulatory gamete selection in right whales, thought to be the result of genetic incompatibility arising from two potential mechanisms: fetal abortion when the offspring are too similar to the mother; or increased fertilization rates and successful pregnancy from genetically dissimilar gametes (Frasier et al., 2013). This may further complicate the influence of mate choice on genetic diversity.

Also in contrast to the Northern elephant seal populations, a small population of Weddell seals at White Island in Antarctica, estimated to be around 80 individuals, is thought to have been founded by only three females and two males. This population exhibits such profound inbreeding that it results in low pup survival (Gelatt et al., 2010).

Nevertheless, along with the Northern elephant seal, Juan Fernandez fur seals (*Arctocephalus philippii*), is another species that has recovered significantly despite reaching the brink of extinction. Variability in response to inbreeding across marine mammals indicates that some species may be more sensitive to inbreeding depression than others (Hoelzel et al., 2009).

## SPECIES ISOLATION

Behavior, and in particular social learning, may be drivers for speciation (Beltman et al., 2004). But species isolation may cause genetic bottlenecks to develop or create independent evolutionary trajectories. Behavior itself, and particularly social information use, may cause effective population isolation to develop for population segments in sympatry (Riesch et al., 2012).

Extirpation has the potential to remove localized adaptations and potentially eliminate unique evolutionary paths. It has been suggested that for the morphologically and genetically distinct Maritimes walrus (*Odobenus* sp.) localized extinction as a result of hunting, curtailed an evolutionary trajectory that would have enabled this species to evolve along a different path to other north Atlantic walrus (McLeod et al., 2014).

However, hybridization, a spontaneous phenomenon which is suspected in several cetacean (Brown et al., 2014; Hodgins et al., 2014) and pinniped (Lancaster et al., 2010) species also has conservation implications. Depending on the fitness of the hybrids, hybridization may alter gene flow and species boundaries (Lancaster et al., 2010). The effects of hybridization may be difficult to predict in a rapidly changing marine environment (for a review see Schaurich et al., 2012). For sympatric species (living in the same or overlapping habitat), behavioral diversity, such as different habitat use resulting from foraging specializations, may help to reduce encounter rates between species and maintain discrete gene pools (Sobel et al., 2010).

## DISPERSAL IN FRAGMENTED POPULATIONS

The degradation of habitats can lead to the fragmentation of populations and remains an ongoing conservation issue. Key causes of population fragmentation in marine mammals are displacement, through noise, fishing, harassment, or some other environmental stressor, or change in prey abundance or dispersal. Some species may be better equipped to adapt to differing food availability, for example through adapting foraging specializations (Tinker et al., 2008; Ansmann et al., 2012). But other species don't have this flexibility, sirenians are obligate seagrass feeders and thus may disperse into fragmented populations in search of new food patches following extensive damage to seagrass beds (Prins and Gordon, 2014).

Key to predicting how populations may fragment as a result of habitat degradation is an understanding of the range of possible dispersal behaviors. Sutherland (1998) noted a need for a better understanding of how animals search, sample and select new patches (or boarder habitat) and this remains a significant question for marine mammals. This is not only true for resident populations—vs. more transient cohorts—but may also be relevant for understanding changes to migration patterns between critical feeding and breeding habitats. But interpreting responses to disturbance can be complex. Bejder et al. (2006) argue that incorrect application of the term habituation may result from situations where more sensitive individuals have already left a disturbed study area before assessment.

Fragmentation of social groups may be caused by other anthropogenic effects, such as hunting, bycatch, or harassment. Dispersal behavior is also relevant to the rate and extent of the spread of disease. The rate of infection is dependent upon the frequency with which susceptible individuals come into contact with uninfected individuals. For example, elucidation of dispersal and social interactions may be important for predicting transmission of the phocine distemper virus epidemics across harbor seal populations (*Phoca vitulina*) in north-western Europe (Bodewes et al., 2013).

## PREDICTING THE CONSEQUENCES OF ENVIRONMENTAL CHANGE

Predicting the consequences of environmental change is best understood by looking at the patterns of density dependent processes (Sutherland, 1996) i.e., how vital rates (such as mortality and fertility) are regulated by population density. To understand the role of behavior in some density dependent processes it is necessary to have data on the type of breeding systems, social structure and the transmission of social information within and between populations, as well as an understanding of individual decision making. Such data can be difficult to collect in the marine environment. Nevertheless, some studies provide insights into these processes and may provide opportunities for predicting the consequences of human-induced rapid environmental change (HIREC; Sih et al., 2011) in marine environments.

For example, understanding how population density influences competition (and resource depletion) within feeding habitats may provide some useful insights into the effects of environmental change (Sutherland, 1995). It has also been argued that there are many modulating factors that can influence how wildlife respond to disturbance including; age, anti-predator strategy, habitat type, and even timing of the disturbance. As a result of these many confounding factors, some of which appear to have non-linear and complex effects, the difficulty of finding general patters may be amplified at higher levels of organization toward populations and species (Tablado and Jenni, 2015).

Arguably the most pressing environmental issue of this era, which is increasingly being regarded as the "Anthropocene" (Waters et al., 2016)—because within this epoch human activities are having significant global impact—is the rising atmospheric carbon dioxide and the resultant change in climate. This is producing discernable shifts in marine ecosystems, particularly in relation to temperature, circulation, stratification, oxygen content, and acidification (Doney et al., 2012). From the perspective of marine mammal conservation, it has long been thought that these effects will be most acutely felt in the polar regions, which are particularly vulnerable to sea-ice retreat and which may be the destination of species migrating toward the poles as temperatures rise (Kovacs et al., 2011). Whilst some marine mammals may be able to adapt more readily to rapid change, others may not (Moore and Huntington, 2008). For example, killer whales are now able to access new regions of the Artic as a result of receding sea ice. But as apex predators their presence may have an influence on other marine mammal populations such as beluga (*Delphinapterus leucas*) and bowhead whales (*Balaena mysticetus*; Ferguson et al., 2010). It remains unknown whether this expansion of their range is opportunistic, or the result of undocumented environmental pressures.

However, whilst there has been a focus on the effects of climate change on polar and tropical marine ecosystems (such as reef habitat), the effects may be more ubiquitous than first anticipated, with potential range shifts likely to occur across wider latitudes (Lambert et al., 2011). Other species, such as some of the river dolphins and the beaked whales (about which less is known), may also face significant challenges as a result of the effects of climate change on their habitat.

Polar bears (*Ursus maritimus*), have become the flag-ship species for climate change, precisely because they are so vulnerable to changes in sea ice coverage (for a review see Stirling and Derocher, 2012). However, of the 19 subpopulations, there is increasing evidence that response to the loss of sea ice may vary considerably temporally and geographically and may be related to density-dependent effects (Rode et al., 2014). This variability among sub-populations highlights the difficulty of providing accurate general population projections, where perhaps sub-population projections would be more helpful, especially in light of the rate of change within the summer and winter sea-ice coverage.

## REDUCING PREDATION

Whilst introducing predators is not common practice in the marine environment, reduced predation from marine mammals can be a goal for some fisheries. One solution is the culling of predators, which has ethical and welfare considerations and its efficacy is controversial (Yodzis, 2001). Invariably, it is more appropriate to deploy non-lethal methods to manipulate predator behavior, such as seal scarers, an acoustic repellent system (for examples see: Schakner and Blumstein, 2013). Successful outcomes are dependent on an accurate assessment of the interaction between predator and fishery (which can be elusive; Morissette et al., 2012) and the deployment of such a device may also cause disturbance, or displacement, for other marine mammals besides the target species. In such cases, maintaining fish stocks for exploitation is, strictly speaking, not a conservation goal but rather an industry goal, which often neglects the importance of diversity within food webs and ecosystems, or the implications of the impact of commercial fisheries on marine mammal populations (DeMaster et al., 2001).

Sutherland (1998) argues that research on individual or social learning can have an important role in tackling conservation issues associated with predation (Sutherland, 1998). Research on dugong avoidance of sharks showed, unsurprisingly, that in relatively dangerous shallow habitat, dugongs avoided continuous series of resting bouts in the presence of these predators. Whereas, in deeper water habitats their response to the presence of sharks were more modest (Wirsing and Heithaus, 2012). Data on the range of natural responses to predators may be particularly useful for addressing conservation issues associated with excessive predation of endangered species.

Population size may also be an important factor in relation to predicting the consequences of predation. For example, when Steller sea lions (*Eumetopias jubatus*) were less abundant in the Aleutian Islands (1990s) and in Southeast Alaska (1960s) predation by killer whales was thought to influence population projections. However, predation by killer whales seemed to have little effect when the populations became more abundant (Guénette et al., 2006).

## RETAINING CULTURAL SKILLS

Research on non-human culture has progressed a pace, particularly in cetaceans since Sutherland (1998) identified these original 20 areas of interest (see for example Rendell and Whitehead, 2001; Whitehead and Rendell, 2015). Social learning is a prerequisite for culture, which can be defined as: "*information or behavior—shared within a community—which is acquired from conspecifics through some form of social learning*" (Whitehead and Rendell, 2015, p. 12). Social learning and culture are not only relevant to terrestrial conservation in terms of ensuring that captive-bred or translocated animals have the rights skills to survive in the wild (as Sutherland (1998) suggests), but culture is also now recognized as having important implications for the conservation of wild populations (Whitehead, 2010; CMS, 2014).

Whilst there are many types of learning, social learning is arguably the most relevant to the consideration of the conservation of marine mammals. Social learning can entail fewer costs to the individual than individual learning and enables novel behavior to spread rapidly, so adaptation can occur faster than through genetic change alone (Boyd and Richerson, 1985). HIREC may provide a number of novel cues and opportunities for social learning for marine mammals, generating unique selection pressures. It has been argued that "a cognitive mechanism that causes avoidance of novel food is as encumbering as a specialized feeding apparatus that prevents an animal from eating that food" (Greggor et al., 2014, p. 490). It can similarly be argued that the learning of a social norm and the drive to conform may likewise inhibit the spread of adaptive behavior, in a similar manner to neophobia (fear or dislike of anything new or unfamiliar).

But the occurrence and consequences of innovations can be difficult to predict. Malthus (1798) famously predicted that the projected increase in human populations would lead to "vice and misery," but failed to account for the fact that humans had the capacity to innovate and socially transmit methods for increasing their own food supply (Davies et al., 2012). Nevertheless, caution should be applied when predicting how social learning may assist or hinder wildlife adaptation to change as there may be anthropogenic (Donaldson et al., 2012), ecological, cognitive (Greggor et al., 2014), or cultural (Whitehead, 2010) interactions and constraints in play. There is also evidence for individual variation in social learning within species and a continuum of phenotypic plasticity (i.e., a range of ways in which the genes can manifest in different environments) has been suggested (Mesoudi et al., 2016).

Social learning in marine mammals is most famously evidenced in the transmission of humpback whale song (*Megaptera novaeangliae*; Noad et al., 2000; Garland et al., 2011) and more recently through the spread of a novel feeding method, known as "lobtail feeding" (Allen et al., 2013). The occurrence of these two apparently independent elements of social learning suggest that this species can maintain more than one independently evolving culture (Allen et al., 2013).

Social transmission and cultural constraints may influence conservation outcomes. North Atlantic right whales (*E. glacialis*) have shown a very poor recovery following intensive whaling during the sixteenth and seventeenth centuries. Right whales are now almost entirely absent in the waters of Labrador (Katona and Kraus, 1999). It is thought that whilst oceanic climate change may play a role in this lack of recovery, perhaps the removal of such a significant proportion of the population through whaling destroyed cultural knowledge about critical habitat, or other significant cultural knowledge that may be inhibiting recovery (Whitehead et al., 2004).

Also, since baleen whale calves are thought to learn migratory routes and likely other habitat knowledge from their mothers, such as the location of critical feeding or breeding habitat, or areas of high predator density, some may be more reluctant to explore new areas, culminating in slower range recovery following extirpation (Clapham et al., 2008; Carroll et al., 2011, 2014; Baker et al., 2013). It has been suggested that loss of cultural knowledge and resultant limited range recovery may be one factor inhibiting a recovery of the North Atlantic right whale population (Mate et al., 1997). This has been demonstrated for southern right whales (*Eubalaena australis*) where, following extensive whaling, the remaining populations are now limited to two distinct feeding areas as a result of maternally directed site fidelity, despite the availability of other suitable feeding habitat (Carroll et al., 2014, 2016).

Research on the social structure of migrating beluga whales (*D. leucas*), an odontocete species, also suggests that cultural conservatism enables social groups to learn migratory routes. However, a potential cost may be that this conservatism could impede the re-colonization of extirpated areas (Colbeck et al., 2013).

As well as ecological cultural knowledge, conservative cultures, in which individuals must conform in order to "fit in," may lead to the suppression of novel behaviors. Conformist cultures may inhibit adaptive learning, with preference for cultural norms potentially suppressing ecologically useful behavioral adaptations, or leading to valuable habitats being overlooked (Whitehead, 2010). A striking example of this is provided by the southern resident population of killer whales which feed preferentially on chinook salmon (*Oncorhynchus tshawytscha*; Ford and Ellis, 2006). It is argued that since these killer whales seem very reluctant to use a variety of other prey-items available to them, this conformist prey specialization may be a constraint on the population's resilience, since it is contingent on the availability of the salmon (Ford et al., 2010; Whitehead, 2010). In addition to prey preferences, cultural conformism may also inhibit an individual's adaptive use of space, through dispersal or migration. For example, it has been suggested that killer whales may continue to use traditional areas despite increases in chemical and noise pollution (Osborne, 1999).

Whitehead suggest that in some instances cultural behavior may be maladaptive (Whitehead, 2010) and that mass stranding of species such as the highly social pilot whales may be at least partly be associated with conformist cultures (Rendell and Whitehead, 2001). Nevertheless, there are many other possible causes of mass stranding and the difficulty in such instances is to separate out anthropogenic, cultural and other natural causes.

Sutherland (1998, p. 804) noted: "A better understanding of cultural evolution would have considerable consequences for conservation." Although, social learning has been identified in many terrestrial mammals (Thornton and Clutton-Brock, 2011), research on social learning and investigation into potential unique cultures in other marine mammals species besides cetaceans is limited. This is an area where directed examination of social transmission across all marine mammal species would likely benefit conservation efforts in the future.

## BEHAVIORAL MANIPULATIONS

Many terrestrial conservation projects involve manipulating behavior (Sutherland, 1998). This is rarer in the marine environment, where such manipulations can be more challenging. As far as the authors are aware, there are no conservation schemes to alter the migration routes of marine mammals, or reserves set up with the sole intention of attracting marine mammals to a formerly uninhabited area. Instead there is emphasis on reducing environmental threats and identifying critical habitat (particularly breeding or feeding habitat) for protection (Hoyt, 2011).

Nevertheless, non-lethal deterrents are used to manipulate marine mammal behavior, with efforts focused on reducing bycatch and depredation from fisheries. Such deterrents act by creating the sense of a perceived risk associated with utilizing the resource, often with the use of sound (Schakner and Blumstein, 2013). But such manipulations could be improved with insights from comparative cognition (Greggor et al., 2014).

Successful mitigation of environmental threats and identification of critical habitat requires a good understanding of the behavioral ecology of the species and population specific behavior. Some instances of behavioral manipulation in marine mammals arise as the result of opportunistic interaction with humans, although these may not necessarily be directly associated with conservation efforts, they may have conservation implications.

Interactions with human activities, such as co-operative fishing (Daura-Jorge et al., 2012), trawling (Chilvers et al., 2001; Pace et al., 2011; Ansmann et al., 2012), depredation (i.e., taking fish from fishing gear; Esteban et al., 2016b), provisioning, or begging (Mann and Kemps, 2003; Donaldson et al., 2012), can provide a novel foraging niche, which marine mammals can learn to utilize through social transmission. As a result there is a risk of social groups becoming dependent on these human activities, in what has been termed "anthropo-dependence" (CMS, 2014).

## RELEASE SCHEMES

Release of marine mammals into the wild is relatively rare (in comparison with terrestrial mammal breeding and release schemes), but sea otter recovery from near extinction in the 1700s and 1800s has been facilitated by conservation release schemes. Nevertheless, recovery to the full extent of their former range has been sporadic, possibly as a result of problems with habitat quality and research on the influence of age, sex, or social structure on dispersal into new habitat may enable predictions of future distribution (Lafferty and Tinker, 2014).

For other marine mammals species release is more common in relation to rescue and rehabilitation. Whilst there are strong welfare motivations for rescue and release—and rescue and release can be successful (Sharp et al., 2016)—a number of significant issues associated with the release of marine mammals have been identified. These include: potential conflict with fisheries, ignorance of recipient population ecology, genetic disparity, and the potential for the spread of novel or anti-biotic resistant pathogens (Moore et al., 2007). In addition, depending on the circumstances and longevity of the rehabilitation period, there are potential issues associated with finding suitable social units with corresponding culture or social knowledge for a release candidate. Also, for young rescued and rehabilitated mammals, such as harbor seal (*P. vitulina* richardii) pups, there is evidence that a developmental window associated with learning specific behaviors from their mothers may be missed if rehabilitation occurs during the nursing period (Gaydos et al., 2013). This highlights the need to integrate a species behavioral ecology into decision making about rescue and release schemes for marine mammals.

## HABITAT REQUIREMENTS OF SPECIES OF CONSERVATION CONCERN

In order to determine habitat requirements for any marine mammal of conservation concern, it is essential to have information on the diversity of prey, home range, sensitivities to specific anthropogenic threats (such as noise from vessel traffic, entanglement etc.) and knowledge about breeding behavior. Understanding social structure and dispersal behavior are also likely to be important. But for some marine mammal species (particularly those that exhibit some degree of foraging plasticity), it is important to ensure that protected habitats are sufficiently diverse (for example by including steep sloping habitat) that they offer opportunities for new foraging strategies or prey items, to provide resources for resilience to HIREC through innovation and social learning.

Under the United States Endangered Species Act of 1973 (ESA; 16 U.S.C. §1531 et seq.), critical habitat should provide the physical and biological features essential to the conservation of endangered or threatened species. For marine mammals these features include: space for individual and population growth and normal behavior; shelter; food, water, air; and sites for breeding and rearing offspring. In addition, critical habitat may also include areas beyond the species range at the time of listing, but which are considered essential to their conservation.

Killer whales have been shown to be more vulnerable to disturbance from vessels when they are feeding, rather than when resting, traveling, or socializing, leading to the recommendation that protected area management strategies should target feeding "hotspots," thus prioritizing the protection of habitat used for the behavior in which a species is most vulnerable to anthropogenic disturbance (Ashe et al., 2010).

Defining critical habitat for migratory species can be particularly challenging. Different types of habitat may have several functions for some migratory species. For example, in humpback whales it has been suggested that subarctic feeding grounds provide not only an opportunity for foraging but also for song progression and exchange and may act as opportunistic mating grounds for migrating or overwintering whales (Magnúsdóttir et al., 2015).

## MINIMUM AREA NECESSARY FOR RESERVES

There are many challenges associated with determining the size and composition of marine protected areas or reserves for highly social marine mammal species. Among the various threats to marine mammals which reserves can help to mitigate are fisheries entanglement, bycatch, prey depletion, and ship strikes. Protecting cetacean habitat from anthropogenic noise may be a particularly salient consideration in relation to behavioral ecology (see Section Noise and Behavior), particularly where noise overlaps with communication or echolocation (Melcón et al., 2012; Veirs et al., 2015).

Sound can travel much greater distances in water than in air and the range over which some of the larger marine mammals may be in social contact with each other may even extend to the level of ocean basins (Whitehead and Rendell, 2015). As a result marine protected area networks and zoning are an essential tool for ensuring the integrity of marine mammal populations (Hoyt, 2011). Protecting "opportunity sites" has also been suggested to capitalize on protecting important wildlife habitat that already has low anthropogenic noise (Williams et al., 2015).

Behavior is clearly relevant in relation to delineation of marine protected areas. The challenge is determining which behavior is either the best indicator, or the most vulnerable to anthropogenic threats (see Section Habitat Requirements of Species of Conservation Concern). For example, Bryde's whales (*Balaenoptera edeni*) around the coast of Brazil may use coastal areas for feeding and migrate to deeper oceanic habitat for breeding (Gonçalves et al., 2015), highlighting the need for protected areas to encompass the range of lifecycle events associated with vital rates, with connectivity between critical habitat.

Since culture can evolve faster than genetic lineages, marine mammals that exhibit social learning and the transmission of culture may also require more regular review of marine protected areas and their efficacy: as behaviors change and culture evolves, habitat requirements may change. Whilst some cultures may be very stable and may last many generations, some cultures may evolve more rapidly in response to changes in the environment. Where possible, this should be accounted for at the outset, by ensuring that protected areas are large enough to accommodate such shifts and by ensuring management plans include areas with flexible high protection zones (Hoyt, 2009, 2011). This type of adaptive and dynamic management (Bengtsson et al., 2003; Game et al., 2009) is important for resilience. For example, if dramatic shifts in behavior as a result of rapid social learning occur that have implications for conservation, plans can be adapted.

In addition, it has been argued that during designation of marine protected areas, attention should be paid to the wider ecosystem and how this supports specific habitat and behaviors. For example, for killer whale populations that feed on salmon, consideration should not only be given to the habitat in which these whales are feeding, but also to the river systems which support their prey (Hoyt, 2009, 2011; Ashe et al., 2010).

## CAPTIVE BREEDING

Captive breeding for marine mammals is fraught with difficulty, largely as a result of the challenges associated with successfully reproducing the unique physical and social environment required for these species, particularly those with extensive home ranges. For example, researchers recorded a killer whale traveling from the Antarctic Peninsula to Brazil and back again over the course of just 42 days, a journey of some 9400 km (Durban and Pitman, 2012).

But the physical limitations of the captive environment are only part of the picture. Providing the right social environment for mating and successful rearing of offspring of highly socially marine mammals may be particularly challenging. For example, in the wild, killer whales live in multi-generational societies, with distinct ecotypes differing in morphology, communication, prey, and foraging strategies (Pitman et al., 2010; Riesch et al., 2012). These complex societies cannot be replicated in the captive environment and although killer whales of different ecotypes may produce viable offspring in captivity, these hybrids are unlikely to be suitable for release. It is argued that the failure to successfully reintroduce the captive killer whale know as Keiko back into the wild, who more readily associated with dolphins than killer whales from his own pod, suggests that correctly assimilating cultural traditions could be age specific (Simon et al., 2009; Riesch et al., 2012).

As a result, compared with fertility rates in the wild, captive breeding rates and survival to age milestones for some species, such as killer whales, are poor (Small and Demaster, 1995; Jett and Ventre, 2015). The emerging knowledge on the behavioral ecology of many of the larger marine mammals is unlikely to ameliorate this problem, but instead serve to demonstrate lack of suitability for successful captive breeding and re-introduction (see also Section Release Schemes).

## REPRODUCTIVE BEHAVIOR AND REPRODUCTIVE PHYSIOLOGY

Sutherland (1998) posits that opportunities for manipulating reproductive behavior and physiology in wild populations are underexplored. Whilst this remains true for many marine mammal species, this approach has many practical difficulties, particularly for those marine mammals that live their entire lifecycle in the water. But even for those species that spend some time on land, from the perspective of practicality and economics, there is likely more merit is exploring the conditions, both social and environmental, required for optimal breeding in the wild.

Reproductive behavior in marine mammals includes polygyny and promiscuity and pinnipeds species that breed on land compete for reproductively active females by defending breeding territories. Notably, those pinnipeds that breed in the water or on ice (walrus and ice seals), which may have more difficulty defending an unstable environment, tend to be less polygynous. Cetaceans exhibit a range of mating strategies. Toothed cetaceans tend to exist in social groups, which may indicate an important role for others in the rearing of offspring (allo-parental care). Whereas, the basic social unit in baleen whales is considered to be the cow-calf pair, with shorter periods of maternal care than in the toothed cetaceans (for a full dicussion of marine mammal mating systems see: Berta et al., 2015). Nevertheless, the role of a male or female "escort" to a humpback whale cow-calf pair remains under debate and highlights the need for further research on some aspects of marine mammal mating systems in order that conservation efforts can target optimal conditions for breeding.

## CENSUS TECHNIQUES

For marine mammals that spend most or all of their life cycle in the water, census techniques have to make assumptions about the likelihood of being "caught" (for example during mark recapture techniques). Better understanding of surfacing behavior, or regularity and range of vocalizations, as well as knowledge of dispersal across patchy habitat, may enhance the resolution of some census techniques, particularly for more cryptic species, such as the beaked whales (Yack et al., 2013). One technique in particular, which aims to quantify song dynamics and identify individual humpback whales by their distinct vocalizations, holds promise as a population identifier for monitoring trends across vast habitat (Garland et al., 2013) and the use of environmental DNA (eDNA) in marine habitats may also assist in understanding dispersal, by detecting the presence or absence of some species (Foote et al., 2012). In addition, molecular census techniques used to elucidate dispersal patterns and fragmentation in cryptic terrestrial mammals, such as the giant panda (*Ailuropoda melanoleuca*; Zhan et al., 2006) may have application for marine mammals, where adequate fecal sampling is practical.

## EXPLOITATION

Patterns of exploitation are influenced by the behavior of both hunters and their prey (Sutherland, 1998). Similarly, the distribution of whaling vessels has been compared with the ecological theory of ideal free distribution, in which the number of individuals that will aggregate in various patches of resource is proportional to the amount of resource available in each patch. However, records of sperm whaling in the Galapagos Islands in the 1800s, suggest a violation of the ideal free distribution. It is speculated that this may be a result of inaccuracies in the information available to these early whalers (Whitehead and Hope, 1991).

For many marine mammals the history of hunting is well-chronicled, but the numbers taken is often less well-documented (Ivashchenko et al., 2011; Ivashchenko and

Clapham, 2015). As a result determining pre-exploitation abundance can be challenging and controversial. For example, models for mDNA sequence variation provide estimates for North Atlantic fin (*Balaenoptera physalus physalus*) and humpback (*M. novaeangliae*) whale populations 6 to 20 times higher than present day populations (Roman and Palumbi, 2003).

One important potential behavioral issue of concern for exploited marine mammals is the buffer effect, where at low densities individuals concentrate in the best habitat, but at higher densities are more dispersed over a wider area (Brown, 1969). This can give a false indication of abundance to hunting communities searching in localized areas of high density, whilst the overall population may be in decline. This may be an important consideration in the geo-political wrangling between whalers, scientists, and governments, and in decision making on protection of polar bear habitat (Rode et al., 2014). Sutherland (1998) contends that it is precisely this effect that led to the confidence of the fishing community which brought about the collapse of the Atlantic cod (*Gadus morhua*) fishery off the eastern-coast of Canada. Marine mammal conservation efforts will doubtless benefit from improved knowledge of dispersal trends, particularly in relation to changing environments and patchy distribution of resources.

## INCREASE IN HUMAN POPULATION

Sutherland (1998) notes: "the overwhelmingly important problem to humanity and biodiversity is the increase in human population." Since the paper's publication in 1998 there are around 1.4 billion additional humans on the planet and although the growth rate has dropped a little, the total human population is likely to rise to around 9.6 billion by 2050 (UNFPA, 2011). While reproductive decision making is a behavioral ecology issue, even within our own species (Sutherland, 1998), there are also many socio-economic issues related to the decision processes and this topic remains both largely taboo (a cultural issue) and the single biggest threat to conservation efforts.

The human population explosion, combined with the procurement and use of fossil fuels—in particular the ubiquitous use of plastics, which accumulate in the marine environment—remains one of the largest threats to marine mammal populations (Simmonds, 2012). This is particularly true for species inhabiting coastal areas where the impacts are often more concentrated (Brakes and Simmonds, 2011). But solutions to problems such as marine debris are not always straight forward. It was hoped that the introduction of biodegradable plastics would go some way toward curbing the marine plastics issue. However, it is now thought that the biodegradation of plastics occurs in conditions rarely met in the ocean environment (Kershaw, 2015) and that other solutions must be sought.

## DISCOUNTING

It has been asserted that discounting by human decision-makers favors the over-exploitation of long-lived species as the long-term benefits of sustainable yield once discounted, may be less than the short-term benefit of overexploiting (Clark, 1990; Henderson and Sutherland, 1996). Discounting is potentially a problem for some marine mammal species, which are often long-lived and lowly fecund. Whilst sustainability of resource use into the future may in some cases temper over-exploitation, the basic discounting principle that the opportunity to utilize a resource now, combined with the risk that these resources may not be available in the future, can drive over-exploitation of marine mammals populations (Ivashchenko et al., 2011; Ivashchenko and Clapham, 2015) and may be a motivation for under reporting. Whilst there are some legal and practical conservation measures designed to prevent over exploitation, the uncertainty associated with the potential effects of climate change and other threats to marine mammal populations could potentially lead hunters to favor higher discount rates, particularly if the likelihood of population persistence into the future is uncertain.

## INCREASE IN CONSERVATION CONCERN

Sutherland (1998) predicted that public and media interest in behavioral ecology has a considerable role in encouraging interest in conservation and shaping the views of the next generation of biologists. Indeed, public interest in animal behavior in wild populations has only increased in the last 15 years with improvements in technology and a proliferation of media outlets for wildlife documentaries and news. Insight into the lives of marine megafauna has benefitted from this revolution as the deployment of affordable remote monitoring technology continues to burgeon. This is leading to a golden age of discovery of the lives and habits of many marine mammals species.

Research comparing public attitudes toward wildlife between the United States, Japan and Germany highlighted that differing attitudes are the result of biogeographical and cultural difference between countries (Kellert, 1993). Later research on public attitudes toward dolphins suggested that these species remain poorly understood by the wider public with potentially harmful behaviors toward wild dolphins being widespread (Barney et al., 2005). More recent research in the Caribbean island of Aruba, where there is not yet a whale watching industry, indicates that support for marine mammal conservation among residents is high, whilst knowledge about species richness and identity is low, suggesting that detailed knowledge is not necessarily a prerequisite for positive public attitudes toward conservation (Luksenburg and Parsons, 2014).

## CONSERVING BEHAVIOR

It has been argued that specific behavior, such as wildebeest (*Connochaetes* sp.) migrations or bathing in hot springs by Japanese Macaques (*Macaca fuscata*) may be of sufficient interest to warrant conservation in itself (Sutherland, 1998). Whilst the emphasis of conservation bodies such as the IUCN is on maintaining genetic diversity, there is a strong argument that maintaining behavioral diversity may also play a central role in ensuring sufficient variety for resilience to environmental change.

It can perhaps further be argued that some non-human cultures, such as some of those exhibited by whales and dolphins, may be worthy of preservation for their own intrinsic value, irrespective of their potential facility to species conservation. UNESCO (the United Nations Education, Scientific and Cultural Organization) argues that cultural heritage extends not only to objects and monuments, but also encompasses behaviors inherited from our ancestors including "oral traditions, performing arts, social practices, rituals, festive events, knowledge, and practices concerning nature and the universe or the knowledge and skills to produce traditional crafts" (UNESCO, 2016). Whilst many of these remain uniquely human cultures, there is strong evidence among whales and dolphins for culture including, vocal dialects, the transmission of migratory routes, and knowledge about tool use (Whitehead and Rendell, 2015; see Section Retaining Cultural Skills). If we consider that knowledge may be as vital a currency as genes for some social species, maintaining the diversity of non-human intangible cultural heritage may be as important for some marine mammals as it is for humans.

## CONSEQUENCES OF ENVIRONMENTAL CHANGES ON BEHAVIOR

The implications of behavior for conservation of marine mammals have been reviewed here extensively. But Sutherland (1998) also argued that it is important to consider the implications of environmental change on behavior itself. Specifically it is important to consider how environmental change, including exploitation, may create selection pressures that may influence marine mammal behavior.

Acknowledging the limitations of the data reviewed, Wade et al. (2012) argue that odontocetes (toothed cetaceans) may be less resilient than mysticetes (baleen whales) to overexploitation. In contrast, research on the restructuring of a dolphin population following a change in human use of the environment from trawling to post-trawling periods within Moreton Bay, Australia, showed that since the reduction in trawling the social networks of the two social groups had become less differentiated and that previous partitioning into two communities disappeared (Ansmann et al., 2012). These contrasting findings highlight the complexity with which social dynamics may be influenced by differing anthropogenic environmental change and how some species and populations may demonstrate adaptability and be more robust to change, whereas others may be less resilient. This complexity may be further compounded by the synergistic manner in which some anthropogenic threats may operate, making forecasting the consequences for behavior a greater challenge.

Marine mammals inhabit a vast array of habitats and as a result threats from HIREC are myriad. It is also important to consider the spatio-temporal scale of the species in question when assessing changes in behavior as a result of environmental factors (Lomac-Macnair and Smultea, 2016).

## NOISE AND BEHAVIOR

One anthropogenic threat, not singled out by Sutherland (1998) but of specific relevance to marine mammal behavior, is noise. Sound travels more than four times faster in water than in air and noise, whether natural or anthropogenic, can interfere with marine mammal communication, sociality, navigation, and foraging (particularly for those species that echolocate). Nevertheless, whilst noise is a natural phenomenon in the oceans, there is evidence that humpback whales may not be able to cope with an increase in anthropogenic noise in the same way that they offset fluctuations in natural noise (Dunlop, 2016).

As anthropogenic ocean noise increases there is concern that the effects of auditory masking may be having far reaching effects for some marine mammals populations (Erbe et al., 2015). The effects of noise may not be limited just to the receiver. The Lombard (1911) effect predicts that noise may elicit anti-masking behavior in the sender, for example changing call rate or frequency. For example, research on fin whale (*B. physalus*) 20-Hz song showed that male fin whales modify song characteristics under increased background noise resulting from shipping and seismic air guns (Castellote et al., 2012).

Several theories have been posited as to the cause of the decline in tonal frequencies of blue whale song, such as increasing ocean noise, sexual selection, increasing population recovering following exploitation, competition with other species, such as fin whales and even ocean acidification (McDonald et al., 2009). However, it has also been suggested that social learning may have played a role in this now worldwide phenomenon (Whitehead and Rendell, 2015), which may be the result of anti-masking behavior.

Potential effects of noise on the lower frequency communication of the baleen whales has been under discussion for some time, but there is now evidence that the range of frequencies emitted by various types of shipping traffic within coastal areas include higher frequency noise within the range used by killer whales for both communication and echolocation (Veirs et al., 2015).

## FURTHER CONSIDERATIONS

Whilst the synergies between behavioral ecology and conservation science have blossomed in the years since Sutherland (1998) raised the issue of disconnect between these two fields, the examination of his 20 key areas of interest shows that there is still a considerable way to go for behavioral ecology to be fully incorporated into conservation science and policy making for marine mammals.

In addition to the 20 key areas raised by Sutherland, there are arguably a number of other emerging issues in behavioral ecology that also warrant consideration for marine mammals, including different social learning mechanisms, social structure, social role, and personality.

Social information and fine scale social structure (Williams and Lusseau, 2006; Kurvers et al., 2014; Esteban et al., 2016a) may strongly influence social dynamics and potentially vital rates. These influences may be synergistic or opposing and warrant a more sophisticated approach toward managing social species, particularly those which exhibit social transmission.

How social segments within marine mammal populations are connected and how information flows between them also requires further elucidation (for example see: Rendell et al., 2012; Filatova et al., 2013), particularly since multi-level societies may have differing behavioral responses to anthropogenic change (Whitehead et al., 2012; Cantor et al., 2015). The roles of individuals within their social groups and even the ontogeny of senescence may have important implications for survivorship and conservation (Brent et al., 2015).

Since maintaining behavioral diversity is important for adaptation to novel environments, one of the principle goals of conservation, beyond conserving genetic biodiversity, should also be to conserve a wide range of behaviors and in some populations this may also include protecting discrete cultural units.

Understanding behavioral plasticity is also undoubtedly an important consideration for predicting how a species may respond to changes in their environment. The degree of plasticity within behavioral repertoires may provide important opportunities for adaptation (Ansmann et al., 2012; Mann et al., 2012). Although resilience as a result of behavioral plasticity may act as a buffer to ecological change, there is also concern that behavioral adaptation could mask emerging ecological issues. For example, whilst a species may switch prey in the face of ecological pressures, if such buffers then become exhausted the consequences of change could be more rapid (CMS, 2014). This highlights the need to monitor changes in prey choice for endangered species that exhibit a high degree of behavioral plasticity.

In addition to the more general characterization of a species overall behavioral plasticity, behavioral syndromes, consistent individual differences in behavior (CIDs or personality variation) may influence individuals' ability to cope with novel conditions (Sih et al., 2004). For example, individuals with flexible, exploratory, bold, or aggressive behavioral tendencies may be able to cope better with HIREC (Sih et al., 2011). However, in captivity there are concerns that reduced behavioral diversity and selection for personality traits that better suit the captive environment may lead to propagation of personality types and behavior that is ill-suited for the wild, potentially reducing viability for successful release (Carere and Maestripieri, 2013).

For a discussion on the consequences of animal personality for population persistence and social dynamics see Wolf and Weissing (2012). However, empirical studies into personality variation in wild marine mammals are rare (see for example: Estes et al., 2003; Twiss et al., 2012) and are likely to remain so for some of the more enigmatic species, such as the beaked whales. But even for those more accessible marine mammals whose behavioral repertoires and ecology are well-researched it is important not to conflate behavioral polymorphism with personality variation. An empirical framework for evaluating personality variation has been suggested to avoid such pitfalls (Dall and Griffith, 2014).

## CONCLUSION

There is no doubt that a better understanding of the behavioral ecology of many marine mammals is important for their conservation. It is difficult to envision any approach toward conserving a population of modern humans, which merely preserved their genetic integrity and did not also consider their behavior. We have some understanding and experience of the complexity of human decision making: amid our different cultures, environments, and circumstances we make choices about what to eat, who to socialize with, where to live, how many offspring to have etc. All of which can influence our fertility rates and survival.

Similarly, while efforts to conserve marine mammal biodiversity focus strongly on maintaining genetic integrity and diversity, the emerging evidence indicates that sociality and behavioral diversity may also be central to individual, social group, and population viability. The challenge ahead is teasing out the most relevant factors and understanding how to incorporate this new knowledge into management models and conservation efforts for marine mammals.

## AUTHOR CONTRIBUTIONS

PB initiated the review and with assistance and comments from SD developed the revised manuscript.

## FUNDING

Lead author's research is funded by WDC (Whale and Dolphin Conservation). Article submission has been funded by the Humane Society International (HSI) as part of their funding for this special edition.

## ACKNOWLEDGMENTS

The authors would like to thank Erich Hoyt, Regina Asmutis-Silvia, and Mark Simmonds for helpful comments and conversations during the development of this manuscript.

## REFERENCES

Acevedo-Whitehouse, K., Gulland, F., Greig, D., and Amos, W. (2003). Inbreeding: disease susceptibility in California sea lions. *Nature* 422, 35. doi: 10.1038/422035a

Allee, W. C. (1931). *Animal Aggregations. A study in General Sociology*. Chicago, IL: University of Chicago Press.

Allen, J., Weinrich, M., Hoppitt, W., and Rendell, L. (2013). Network-based diffusion analysis reveals cultural transmission of lobtail feeding in humpback whales. *Science* 340, 485–488. doi: 10.1126/science.1231976

Angulo, E., Rasmussen, G. S., Macdonald, D. W., and Courchamp, F. (2013). Do social groups prevent allee effect related extinctions?: the case of wild dogs. *Front. Zool.* 10:11. doi: 10.1186/1742-9994-10-11

Ansmann, I. C., Parra, G. J., Chilvers, B. L., and Lanyon, J. M. (2012). Dolphins restructure social system after reduction of commercial fisheries. *Anim. Behav.* 84, 575–581. doi: 10.1016/j.anbehav.2012.06.009

Ashe, E., Noren, D. P., and Williams, R. (2010). Animal behaviour and marine protected areas: incorporating behavioural data into the selection of marine protected areas for an endangered killer whale population. *Anim. Conserv.* 13, 196–203. doi: 10.1111/j.1469-1795.2009.00321.x

Baird, R. W., Mahaffy, S. D., Gorgone, A. M., Cullins, T., McSweeney, D. J., Oleson, E. M., et al. (2014). False killer whales and fisheries interactions in Hawaiian waters: evidence for sex bias and variation among populations and social groups. *Mar. Mammal Sci.* 31, 579–590. doi: 10.1111/mms.12177

Baker, C., Steel, D., Calambokidis, J., Falcone, E., González-Peral, U., Barlow, J., et al. (2013). Strong maternal fidelity and natal philopatry shape genetic structure in North Pacific humpback whales. *Mar. Ecol. Prog. Ser.* 494, 291–306. doi: 10.3354/meps10508

Barney, E. C., Mintzes, J. J., and Yen, C.-F. (2005). Assessing knowledge, attitudes, and behavior toward charismatic megafauna: the case of dolphins. *J. Environ. Educ.* 36, 41–55. doi: 10.3200/JOEE.36.2.41-55

Baylis, A. M. M., Orben, R. A., Arnould, J. P. Y., Peters, K., Knox, T., Costa, D. P., et al. (2015). Diving deeper into individual foraging specializations of a large marine predator, the southern sea lion. *Oecologia* 179, 1053–1065. doi: 10.1007/s00442-015-3421-4

Beerman, A., Ashe, E., Preedy, K., and Williams, R. (2016). Sexual segregation when foraging in an extremely social killer whale population. *Behav. Ecol. Sociobiol.* 70, 189–198. doi: 10.1007/s00265-015-2038-2

Bejder, L., Samuels, A., Whitehead, H., and Gales, N. (2006). Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. *Anim. Behav.* 72, 1149–1158. doi: 10.1016/j.anbehav.2006.04.003

Beltman, J. B., Haccou, P., and Ten Cate, C. (2004). Learning and colonization of new niches: a first step toward speciation. *Evolution* 58, 35–46. doi: 10.1111/j.0014-3820.2004.tb01571.x

Bengtsson, J., Angelstam, P., Elmqvist, T., Emanuelsson, U., Folke, C., Ihse, M., et al. (2003). Reserves, resilience and dynamic landscapes. *Ambio* 32, 389–396. doi: 10.1579/0044-7447-32.6.389

Berta, A., Sumich, J. L., and Kovacs, K. M. (2015). *Marine Mammals: Evolutionary Biology*. Amsterdam: Elsevier Science.

Bodewes, R., Morick, D., van de Bildt, M. W., Osinga, N., Rubio García, A., Sánchez Contreras, G. J., et al. (2013). Prevalence of phocine distemper virus specific antibodies: bracing for the next seal epizootic in north-western Europe. *Emerg. Microbes Infect.* 2:e3. doi: 10.1038/emi.2013.2

Bonin, C. A., Goebel, M. E., O'Corry-Crowe, G. M., and Burton, R. S. (2016). Impacts of ecology and behavior on Antarctic fur seal remating and relatedness. *J. Exp. Mar. Bio. Ecol.* 476, 72–77. doi:10.1016/j.jembe.2015.12.008

Boyd, R., and Richerson, P. J. (1985). *Culture and the Evolutionary Process*. Chicago, IL: University of Chicago Press.

Brakes, P., and Simmonds, M. P. (2011). *Whales and Dolphins: Cognition, Culture, Conservation and Human Perceptions*. London: Routledge.

Brent, L. J. N., Franks, D. W., Cant, M. A., Croft, D. P., Brent, L. J. N., Franks, D. W., et al. (2015). Ecological knowledge, leadership, and the evolution of menopause in killer whales. *Curr. Biol.* 25, 1–5. doi: 10.1016/j.cub.2015.01.037

Brown, A. M., Kopps, A. M., Allen, S. J., Bejder, L., Littleford-Colquhoun, B., Parra, G. J., et al. (2014). Population differentiation and hybridisation of Australian snubfin (*orcaella heinsohni*) and indo-pacific humpback (*sousa chinensis*) dolphins in North-Western Australia. *PLoS ONE* 9:e101427. doi: 10.1371/journal.pone.0101427

Brown, J. L. (1969). The buffer effect and productivity in tit populations. *Am. Nat.* 103, 347. doi: 10.1086/282607

Candolin, U., and Wong, B. B. M. (2012). *Behavioural Responses to a Changing World: Mechanisms and Consequences*. Oxford: Oxford University Press.

Cantor, M., Shoemaker, L. G., Cabral, R. B., Flores, C. O., Varga, M., and Whitehead, H. (2015). Multilevel animal societies can emerge from cultural transmission. *Nat. Commun.* 6, 8091. doi: 10.1038/ncomms9091

Carere, C., and Maestripieri, D. (2013). *Animal Personalities: Behavior, Physiology, and Evolution*. University of Chicago Press. Available online at: https://books.google.co.nz/books/about/Animal_Personalities.html?id = bBTZXOWoae8C&pgis=1 (Accessed May 4, 2016).

Caro, T. M., and Durant, S. M. (1995). "The importance of behavioural ecology for conservation biology: examples from serengeti carnivores," in *Serengeti II: Dynamics, Management, and Conservation of an Ecosystem*, eds A. R. E. Sinclair and P. Arcese (Chicago, IL: University of Chicago Press), 451–472.

Carroll, E. L., Fewster, R. M., Childerhouse, S. J., Patenaude, N. J., Boren, L., and Baker, C. S. (2016). First direct evidence for natal wintering ground fidelity and estimate of juvenile survival in the New Zealand southern right whale *Eubalaena australis*. *PLoS ONE* 11:e0146590. doi: 10.1371/journal.pone.0146590

Carroll, E. L., Rayment, W. J., Alexander, A. M., Baker, C. S., Patenaude, N. J., Steel, D., et al. (2014). Reestablishment of former wintering grounds by New Zealand southern right whales. *Mar. Mammal Sci.* 30, 206–220. doi: 10.1111/mms.12031

Carroll, E., Patenaude, N., Alexander, A., Steel, D., Harcourt, R., Childerhouse, S., et al. (2011). Population structure and individual movement of southern right whales around New Zealand and Australia. *Mar. Ecol. Prog. Ser.* 432, 257–268. doi: 10.3354/meps09145

Castellote, M., Clark, C. W., and Lammers, M. O. (2012). Acoustic and behavioural changes by fin whales (*Balaenoptera physalus*) in response to shipping and airgun noise. *Biol. Conserv.* 147, 115–122. doi: 10.1016/j.biocon.2011.12.021

Chilvers, L. B., Corkeron, P. J., Chilvers, B. L., and Corkeron, P. J. (2001). Trawling and bottlenose dolphins' social structure. *Proc. R. Soc. Lond. B Biol. Sci.* 268, 1901–1905. doi: 10.1098/rspb.2001.1732

Clapham, P. J., Aguilar, A., and Hatch, L. T. (2008). Determining spatial and temporal scales for management: lessons from whaling. *Mar. Mammal Sci.* 24, 183–201. doi: 10.1111/j.1748-7692.2007.00175.x

Clark, C. W. (1990). *Mathematical Bioeconomics*. New York, NY: Wiley-Interscience.

Clarke, R., Aguayo, A., and Paliza, O. (1980). Pregnancy rates of sperm whales in the southeast pacific between 1959 and 1962 and in comparison with those from Paita, Peru between 1975 and 1977. *Rep. Int. Whal. Comm. Spec.* 2: 151–158.

CMS (2014). *Report of the CMS Scientific Council Workshop on the Conservation Implications of Cetacean Culture*. Available online at: http://www.cms.int/sites/default/files/document/Inf_10_14_ScC_WG_Rpt_on_Cetacean_Culture_Eonly.pdf

Colbeck, G. J., Duchesne, P., Postma, L. D., Lesage, V., Hammill, M. O., and Turgeon, J. (2013). Groups of related belugas (*Delphinapterus leucas*) travel together during their seasonal migrations in and around Hudson Bay. *Proc. Biol. Sci.* 280:20122552. doi: 10.1098/rspb.2012.2552

Dall, S. R. X., and Griffith, S. C. (2014). An empiricist guide to animal personality variation in ecology and evolution. *Front. Ecol. Evol.* 2:3. doi: 10.3389/fevo.2014.00003

Daura-Jorge, F. G., Cantor, M., Ingram, S. N., Lusseau, D., and Simões-Lopes, P. C. (2012). The structure of a bottlenose dolphin society is coupled to a unique foraging cooperation with artisanal fishermen. *Biol. Lett.* 8, 702–705. doi: 10.1098/rsbl.2012.0174

Davies, N. B., Krebs, J. R., and West, S. (2012). *An Introduction to Behavioural Ecology*. Chichester: Wiley-Blackwell.

DeMaster, D. P., Fowler, C. W., Perry, S. L., and Richlen, M. F. (2001). Predation and competition: the impact of fisheries on marine-mammal populations over the next one hundred years. *J. Mammal.* 82, 641–651. doi: 10.1644/1545-1542(2001)082<0641:PACTIO>2.0.CO;2

Donaldson, R., Finn, H., Bejder, L., Lusseau, D., and Calver, M. (2012). The social side of human-wildlife interaction: wildlife can learn harmful behaviours from each other. *Anim. Conserv.* 15, 427–435. doi: 10.1111/j.1469-1795.2012.00548.x

Doney, S. C., Ruckelshaus, M., Emmett Duffy, J., Barry, J. P., Chan, F., and English, C. A., et al. (2012). Climate change impacts on marine ecosystems. *Ann. Rev. Mar. Sci.* 4, 11–37. doi: 10.1146/annurev-marine-041911-111611

Dunlop, R. A. (2016). The effect of vessel noise on humpback whale, *Megaptera novaeangliae*, communication behaviour. *Anim. Behav.* 111, 13–21. doi: 10.1016/j.anbehav.2015.10.002

Durban, J. W., and Pitman, R. L. (2012). Antarctic killer whales make rapid, round-trip movements to subtropical waters: evidence for physiological maintenance migrations? *Biol. Lett.* 8, 274–277. doi: 10.1098/rsbl.2011.0875

Erbe, C., Reichmuth, C., Cunningham, K., Lucke, K., and Dooling, R. (2015). *Communication masking in marine* mammals: a review and research strategy. *Mar. Pollut. Bull.* 103, 15–38. doi: 10.1016/j.marpolbul.2015.12.007

Esteban, R., Verborgh, P., Gauffier, P., Giménez, J., Foote, A. D., and de Stephanis, R. (2016a). Maternal kinship and fisheries interaction influence killer whale social structure. *Behav. Ecol. Sociobiol.* 70, 111–122. doi: 10.1007/s00265-015-2029-3

Esteban, R., Verborgh, P., Gauffier, P., Giménez, J., Guinet, C., and de Stephanis, R. (2016b). Dynamics of killer whale, bluefin tuna and human fisheries in the strait of gibraltar. *Biol. Conserv.* 194, 31–38. doi: 10.1016/j.biocon.2015.11.031

Estes, J. A., Riedman, M. L., Staedler, M. M., Tinker, M. T., and Lyon, B. E. (2003). Individual variation in prey selection by sea otters: patterns, causes and implications. *J. Anim. Ecol.* 72, 144–155. doi: 10.1046/j.1365-2656.2003.00690.x

Ferguson, S. H., Higdon, J. W., and Chmelnitsky, E. G. (2010). The rise of killer whales as a major Arctic predator. in *A Little Less Arctic: Top Predators in the World's Largest Northern Inland Sea, Hudson Bay*, eds S. H. Ferguson, L. L. Loseto, and M. L. Mallory (Dordrecht: Springer), 117–136.

Filatova, O. A., Burdin, A. M., and Hoyt, E. (2013). Is killer whale dialect evolution random? *Behav. Processes* 99, 34–41. doi: 10.1016/j.beproc.2013.06.008

Foote, A. D., Thomsen, P. F., Sveegaard, S., Wahlberg, M., Kielgast, J., Kyhn, L. A., et al. (2012). Investigating the potential use of environmental DNA (eDNA) for genetic monitoring of marine mammals. *PLoS ONE* 7:e41781. doi: 10.1371/journal.pone.0041781

Ford, J. K. B., and Ellis, G. M. (2006). Selective foraging by fish-eating killer whales Orcinus orca in British Columbia. *Mar. Ecol. Prog. Ser.* 316, 185–199. doi: 10.3354/meps316185

Ford, J. K. B., Ellis, G. M., Olesiuk, P. F., and Balcomb, K. C. (2010). Linking killer whale survival and prey abundance: food limitation in the oceans' apex predator? *Biol. Lett.* 6, 139–142. doi: 10.1098/rsbl.2009.0468

Frasier, T. R., Gillett, R. M., Hamilton, P. K., Brown, M. W., Kraus, S. D., and White, B. N. (2013). Postcopulatory selection for dissimilar gametes maintains heterozygosity in the endangered North Atlantic right whale. *Ecol. Evol.* 3, 3483–3494. doi: 10.1002/ece3.738

Game, E. T., Bode, M., McDonald-Madden, E., Grantham, H. S., and Possingham, H. P. (2009). Dynamic marine protected areas can improve the resilience of coral reef systems. *Ecol. Lett.* 12, 1336–1346. doi: 10.1111/j.1461-0248.2009.01384.x

Garland, E. C., Goldizen, A. W., Rekdahl, M. L., Constantine, R., Garrigue, C., Hauser, N. D., et al. (2011). Dynamic horizontal cultural transmission of humpback whale song at the ocean basin scale. *Curr. Biol.* 21, 687–691. doi: 10.1016/j.cub.2011.03.019

Garland, E. C., Noad, M. J., Goldizen, A. W., Lilley, M. S., Rekdahl, M. L., Garrigue, C., et al. (2013). Quantifying humpback whale song sequences to understand the dynamics of song exchange at the ocean basin scale. *J. Acoust. Soc. Am.* 133, 560–569. doi: 10.1121/1.4770232

Gaydos, J. K., Ignacio Vilchis, L., Lance, M. M., Jeffries, S. J., Thomas, A., Greenwood, V., et al. (2013). Postrelease movement of rehabilitated harbor seal (*Phoca Vitulina Richardii*) pups compared with cohort-matched wild seal pups. *Mar. Mammal Sci.* 29. doi: 10.1111/mms.12002

Gelatt, T. S., Davis, C. S., Stirling, I., Siniff, D. B., Strobeck, C., and Delisle, I. (2010). History and fate of a small isolated population of Weddell seals at White Island, Antarctica. *Conserv. Genet.* 11, 721–735. doi: 10.1007/s10592-009-9856-6

Gonçalves, L. R., Augustowski, M., and Andriolo, A. (2015). Occurrence, distribution and behaviour of Bryde's whales (Cetacea: Mysticeti) off south-east Brazil. *J. Mar. Biol. Assoc. U.K.* 1–12. doi: 10.1017/S0025315415001812

Greggor, A. L., Clayton, N. S., Phalan, B., and Thornton, A. (2014). Comparative cognition for conservationists. *Trends Ecol. Evol.* 29, 489–495. doi: 10.1016/j.tree.2014.06.004

Guénette, S., Heymans, S. J. J., Christensen, V., and Trites, A. W. (2006). Ecosystem models show combined effects of fishing, predation, competition, and ocean productivity on Steller sea lions (*Eumetopias jubatus*) in Alaska. *Can. J. Fish. Aquat. Sci.* 63, 2495–2517. doi: 10.1139/f06-136

Henderson, N., and Sutherland, W. J. (1996). Two truths about discounting and their environmental consequences. *Trends Ecol. Evol.* 11, 527–528. doi: 10.1016/S0169-5347(96)20083-7

Hodgins, N. K., Dolman, S. J., and Weir, C. R. (2014). Potential hybridism between free-ranging Risso's dolphins (*Grampus griseus*) and bottlenose dolphins (*Tursiops truncatus*) off north-east Lewis (Hebrides, UK). *Mar. Biodivers. Rec.* 7, 1–7. doi: 10.1017/S175526721400089X

Hoelzel, A. R., Goldsworthy, S. D., and Fleischer, R. C. (2009). "Population genetic structure," in *Marine Mammal Biology: An Evolutionary Approach*, ed A. R. Hoelzel (Oxford: Blackwell Science), 325–352.

Hoyt, E. (2009). "Marine Protected Areas," *in Encyclopedia of Marine Mammals, eds* W. F. Perrin, B. Wursig, and J. G. M. Thewissen (San Diego, CA: Academic Press), 696–704.

Hoyt, E. (2011). *Marine Protected Areas for Whales, Dolphins, and Porpoises: A World Handbook for Cetacean Habitat Conservation and Planning*. Routledge.

Huisman, J., Kruuk, L. E. B., Ellis, P. A., Clutton-Brock, T., and Pemberton, J. M. (2016). Inbreeding depression across the lifespan in a wild mammal population. *Proc. Natl. Acad. Sci. U.S.A.* 113, 201518046. doi: 10.1073/pnas.1518046113

Ivashchenko, Y. V., and Clapham, P. J. (2015). What's the catch? *validity of whaling data for Japanese catches of sperm whales in the North Pacific. R. Soc. Open Sci.* 2:150177. doi: 10.1098/rsos.150177

Ivashchenko, Y. V., Clapham, P. J., and Brownell, R. L. (2011). Soviet illegal whaling: the devil and the detail. *Mar. Fish. Rev.* 73, 1–19.

Jett, J., and Ventre, J. (2015). Captive killer whale (*Orcinus orca*) survival. *Mar. Mammal Sci.* 31, 1362–1377. doi: 10.1111/mms.12225

Katona, S. K., and Kraus, S. D. (1999). "Efforts to conserve the North Atlantic right whale," *in Conservation Management of Marine Mammals*, eds J. Twiss and R. RR (Washington, DC: Smithsonian), 311–331.

Kellert, S. R. (1993). Attitudes, knowledge, and behavior toward wildlife among the industrial superpowers: United States, Japan, and Germany. *J. Soc. Issues* 49, 53–69. doi: 10.1111/j.1540-4560.1993.tb00908.x

Kershaw, P. J. (2015). *Biodegradable Plastics and Marine Litter: Misconceptions, Concerns and Impacts on Our Marine Environments*. Available online at: http://unep.org/gpa/documents/publications/BiodegradablePlastics.pdf (Accessed February 24, 2016).

Kovacs, K. M., Lydersen, C., Overland, J. E., and Moore, S. E. (2011). Impacts of changing sea-ice conditions on Arctic marine mammals. *Mar. Biodivers.* 41, 181–194. doi: 10.1007/s12526-010-0061-0

Kraus, S. D., Hamilton, P. K., Kenney, R. D., Knowlton, A. R., and Slay, C. K. (2001). Reproductive parameters of the North Atlantic right whale. *J. Cetacean Res. Manag.* 2, 231–236.

Krause, J., and Ruxton, G. D. (2002). *Living in Groups*. Oxford: Oxford University Press.

Kurvers, R. H. J. M., Krause, J., Croft, D. P., Wilson, A. D. M., and Wolf, M. (2014). The evolutionary and ecological consequences of animal social networks: emerging issues. *Trends Ecol. Evol.* 1–10. doi: 10.1016/j.tree.2014.04.002

Lafferty, K. D., and Tinker, M. T. (2014). Sea otters are recolonizing southern California in fits and starts. *Ecosphere* 5, 1–11. doi: 10.1890/ES13-00394.1

Lambert, E., MacLeod, C. D., Hall, K., Brereton, T., Dunn, T. E., Wall, D., et al. (2011). Quantifying likely cetacean range shifts in response to global climatic change: implications for conservation strategies in a changing world. *Endanger. Species Res.* 15, 205–222. doi: 10.3354/esr00376

Lancaster, M. L., Goldsworthy, S. D., and Sunnucks, P. (2010). Two behavioural traits promote fine-scale species segregation and moderate hybridisation in a recovering sympatric fur seal population. *BMC Evol. Biol.* 10:143. doi: 10.1186/1471-2148-10-143

Le Boeuf, B. J., Crocker, D. E., Costa, D. P., Blackwell, S. B., Webb, P. M., and Houser, D. S. (2000). Foraging ecology of Northern elephant seals. *Ecol. Monogr.* 70, 353–382. doi: 10.2307/2657207

Lomac-Macnair, K., and Smultea, M. A. (2016). Blue whale (*Balaenoptera musculus*) behavior and group dynamics as observed from an aircraft off Southern California. *Anim. Behav. Cogn.* 3, 1–21. doi: 10.12966/abc.02.01.2016

Lombard, E. (1911). Le signe de l'elevation de la voix. *Ann. Mal. Oreille, Larynx Nez Pharynx.* 37, 101–119.

Luksenburg, J. A., and Parsons, E. C. M. (2014). Attitudes towards marine mammal conservation issues before the introduction of whale-watching: a case study in Aruba (southern Caribbean). *Aquat. Conserv. Mar. Freshw. Ecosyst.* 24, 135–146. doi: 10.1002/aqc.2348

Magnúsdóttir, E. E., Miller, P. J. O., Lim, R., Rasmussen, M. H., Lammers, M. O., and Svavarsson, J. (2015). Humpback whale (*Megaptera novaeangliae*) song unit and phrase repertoire progression on a subarctic feeding ground. *J. Acoust. Soc. Am.* 138, 3362–3374. doi: 10.1121/1.4935517

Malthus, T. (1798). *An Essay on the Principle of Population*. London: J Johnson.

Mann, J., and Kemps, C. (2003). "The effects of provisioning on maternal care in wild bottlenose dolphins, Shark Bay, Australia," in *Marine Mammals and Humans: Towards a sustainable balance*, eds N. Gales, M. Hindell, and R. Kirkwood (Clayton: CSIRO Publishing), 304–320.

Mann, J., Stanton, M. A., Patterson, E. M., Bienenstock, E. J., and Singh, L. O. (2012). Social networks reveal cultural behaviour in tool-using dolphins. *Nat. Commun.* 3, 980. doi: 10.1038/ncomms1983

Mate, B. R., Nieukirk, S. L., Kraus, S. D. (1997). Satellite-monitored movements of the northern right whale. *J. Wildl. Manage*. 61, 1393–1405. doi: 10.2307/3802143

McDonald, M., Hildebrand, J., and Mesnick, S. (2009). Worldwide decline in tonal frequencies of blue whale songs. *Endanger. Species Res.* 9, 13–21. doi: 10.3354/esr00217

McLeod, B. A., Frasier, T. R., and Lucas, Z. (2014). Assessment of the extirpated maritimes walrus using morphological and ancient DNA analysis. *PLoS ONE* 9:e99569. doi: 10.1371/journal.pone.0099569

Melcón, M. L., Cummins, A. J., Kerosky, S. M., Roche, L. K., Wiggins, S. M., and Hildebrand, J., a (2012). Blue whales respond to anthropogenic noise. *PLoS ONE* 7:e32681. doi: 10.1371/journal.pone.0032681

Mesoudi, A., Chang, L., Dall, S. R. X., and Thornton, A. (2016). The evolution of individual and cultural variation in social learning. *Trends Ecol. Evol.* 31, 1–11. doi: 10.1016/j.tree.2015.12.012

Moore, M., Early, G., Touhey, K., Barco, S., Gulland, F., and Wells, R. (2007). Rehabilitation and release of marine mammals in the United States: risks and benefits. *Mar. Mammal Sci.* 23, 731–750. doi: 10.1111/j.1748-7692.2007.00146.x

Moore, S. E., and Huntington, H. P. (2008). Arctic marine mammals and climate change: impacts and resilience. *Ecol. Appl.* 18, S157–S165. doi: 10.1890/06-0571.1

Morissette, L., Christensen, V., and Pauly, D. (2012). Marine mammal impacts in exploited ecosystems: would large scale culling benefit fisheries? *PLoS ONE* 7:e43966. doi: 10.1371/journal.pone.0043966

NOAA (2015). *North Atlantic Right Whale (Eubalaena glacialis): Western Atlantic Stock. Available online at: http://nefsc.noaa.gov/publications/tm/tm231/7_rightwhale_F2014July.pdf (Accessed February* 26, 2016).

Noad, M. J., Cato, D. H., Bryden, M. M., Jenner, M.-N., and Jenner, K. C. S. (2000). Cultural revolution in whale songs. *Nature* 408, 537–538. doi: 10.1038/35046199

Osborne, R. W. (1999). *A Historical Ecology of SALISH SEA "Resident" Killer Whales (Orcinus orca): with Implications for Management*. Ph.D., dissertation.

Pace, D. S., Pulcini, M., and Triossi, F. (2011). Anthropogenic food patches and association patterns of *Tursiops truncatus* at Lampedusa island, Italy. *Behav. Ecol.* 23, 254–264. doi: 10.1093/beheco/arr180

Parsons, E., Baulch, S., Bechshoft, T., Bellazzi, G., Bouchet, P., Cosentino, A., et al. (2015). Key research questions of global importance for cetacean conservation. *Endanger. Species Res.* 27, 113–118. doi: 10.3354/esr00655

Parsons, E. C. M., Wright, A. J., and Gore, M. A. (2008). The nature of humpback whale (*Megaptera Novaeangliae*) song. *J. Mar. Anim. Their Ecol.* 1, 21–30. doi: 10.3354/esr00655

Pennock, D. S., and Dimmick, W. W. (1997). Critique of the evolutionarily significant unit as a definition for "distinct population segments" under the U.S. Endangered species Act. *Conserv. Biol.* 11, 611–619. doi: 10.1046/j.1523-1739.1997.96109.x

Pitman, R. L., Durban, J. W., Greenfelder, M., Guinet, C., Jorgensen, M., Olson, P. A., et al. (2010). Observations of a distinctive morphotype of killer whale (*Orcinus orca*), type D, from subantarctic waters. *Polar Biol.* 34, 303–306. doi: 10.1007/s00300-010-0871-3

Prins, H. T., and Gordon, I. J. (2014). *Invasion Biology and Ecological Theory: Insights from a Continent in Transformation*. Cambridge: Cambridge University Press.

Rendell, L., Mesnick, S. L., Dalebout, M. L., Burtenshaw, J., and Whitehead, H. (2012). Can genetic differences explain vocal dialect variation in sperm whales, *Physeter macrocephalus*? *Behav. Genet.* 42, 332–343. doi: 10.1007/s10519-011-9513-y

Rendell, L., and Whitehead, H. (2001). Culture in whales and dolphins. *Behav. Brain Sci.* 24, 309–382. doi: 10.1017/S0140525X0100396X

Riesch, R., Barrett-Lennard, L. G., Ellis, G. M., Ford, J. K. B., and Deecke, V. B. (2012). Cultural traditions and the evolution of reproductive isolation: ecological speciation in killer whales? *Biol. J. Linn. Soc.* 106, 1–17. doi: 10.1111/j.1095-8312.2012.01872.x

Rode, K. D., Regehr, E. V., Douglas, D. C., Durner, G., Derocher, A. E., Thiemann, G. W., et al. (2014). Variation in the response of an Arctic top predator experiencing habitat loss: Feeding and reproductive ecology of two polar bear populations. *Glob. Chang. Biol.* 20, 76–88. doi: 10.1111/gcb.12339

Roman, J., and Palumbi, S. R. (2003). Whales before whaling in the North Atlantic. *Science* 301, 508–510. doi: 10.1126/science.1084524

Schaeff, C. M., Kraus, S. D., Brown, M. W., Perkins, J. S., Payne, R., and White, B. N. (1997). Comparison of genetic variability of North and South Atlantic right whales (*Eubalaena*), using DNA fingerprinting. *Can. J. Zool.* 75, 1073–1080. doi: 10.1139/z97-129

Schakner, Z. A., and Blumstein, D. T. (2013). Behavioral biology of marine mammal deterrents: a review and prospectus. *Biol. Conserv.* 167, 380–389. doi: 10.1016/j.biocon.2013.08.024

Schaurich, M. D. N., Lopes, V., Ricardo, F., and de Oliveira, L. R. (2012). Hybridization phenomenon in cetacean and pinniped species. *Neotrop. Biol. Conserv.* 7, 199–209. doi: 10.4013/nbc.2012.73.06

Sharp, S. M., Harry, C. T., Hoppe, J. M., Moore, K. M., Niemeyer, M. E., Robinson, I., et al. (2016). A comparison of postrelease survival parameters between single and mass stranded delphinids from Cape Cod, Massachusetts, U.S.A. *Mar. Mammal Sci.* 32, 161–180. doi: 10.1111/mms.12255

Sih, A., Bell, A. M., Johnson, J. C., and Ziemba, R. E. (2004). Behavioral syndromes: an integrative overview. *Q. Rev. Biol.* 79, 241–177. doi: 10.1086/422893

Sih, A., Ferrari, M. C. O., and Harris, D. J. (2011). Evolution and behavioural responses to human-induced rapid environmental change. *Evol. Appl.* 4, 367–387. doi: 10.1111/j.1752-4571.2010.00166.x

Simmonds, M. P. (2012). Cetaceans and marine debris: the great unknown. *J. Mar. Biol.* 2012, 1–8. doi: 10.1155/2012/684279

Simon, M., Hanson, M. B., Murrey, L., Tougaard, J., and Ugarte, F. (2009). From captivity to the wild and back: an attempt to release Keiko the killer whale. *Mar. Mammal Sci.* 25, 693–705. doi: 10.1111/j.1748-7692.2009.00287.x

Small, R. J., and Demaster, D. P. (1995). Survival of five species of captive marine mammals. *Mar. Mammal Sci.* 11, 209–226. doi: 10.1111/j.1748-7692.1995.tb00519.x

Sobel, J. M., Chen, G. F., Watt, L. R., and Schemske, D. W. (2010). The biology of speciation. *Evolution (N.Y).* 64, 295–315. doi: 10.1111/j.1558-5646.2009.00877.x

Stephens, P. A., Sutherland, W. J., and Freckleton, R. P. (1999). What is the Allee effect ? *Oikos* 87, 185–190. doi: 10.2307/3547011

Stirling, I., and Derocher, A. E. (2012). Effects of climate warming on polar bears: a review of the evidence. *Glob. Chang. Biol.* 18, 2694–2706. doi: 10.1111/j.1365-2486.2012.02753.x

Sutherland, W. (1998). The importance of behavioural studies in conservation biology. *Anim. Behav.* 56, 801–809. doi: 10.1006/anbe.1998.0896

Sutherland, W. J. (1995). *From Individual Behaviour to Population Ecology*. Oxford: Oxford University Press.

Sutherland, W. J. (1996). Predicting the consequences of habitat loss for migratory populations. *Proc. R. Soc. B Biol. Sci.* 263, 1325–1327. doi: 10.1098/rspb.1996.0194

Tablado, Z., and Jenni, L. (2015). Determinants of uncertainty in wildlife responses to human disturbance. *Biol. Rev.* doi: 10.1111/brv.12224. [Epub ahead of print].

Thode, A., Mathias, D., Straley, J., Connell, V. O., Behnken, L., Falvey, D., et al. (2015). Cues, creaks and decoys: using passive acoustic monitoring as a tool for studying sperm whale depredation. *ICES J. Mar. Sci.* 72, 1621–1636. doi: 10.1093/icesjms/fsv024

Thornton, A., and Clutton-Brock, T. (2011). Social learning and the development of individual and group behaviour in mammal societies. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 366, 978–987. doi: 10.1098/rstb.2010.0312

Tinker, M. T., Bentall, G., and Estes, J. A. (2008). Food limitation leads to behavioral diversification and dietary specialization in sea otters. *Proc. Natl. Acad. Sci. U.S.A.* 105, 560–565. doi: 10.1073/pnas.0709263105

Tixier, P., Gasco, N., Duhamel, G., and Guinet, C. (2015). Habituation to an acoustic harassment device (AHD) by killer whales depredating demersal longlines. *ICES J. Mar. Sci.* 72, 1673–1681. doi: 10.1093/icesjms/fsu166

Twiss, S. D., Cairns, C., Culloch, R. M., Richards, S. A., and Pomeroy, P. P. (2012). Variation in female grey seal (*Halichoerus grypus*) reproductive performance correlates to proactive-reactive behavioural types. *PLoS ONE* 7:e49598. doi: 10.1371/journal.pone.0049598

UNESCO (2016). *What is Intangible Cultural Heritage*? Available online at: http://www.unesco.org/culture/ich/en/what-is-intangible-heritage-00003 (Accessed February 24, 2016).

UNFPA (2011). *The World at Seven Billion. UNFPA - United Nations Fund Popul. Act.* Available online at: http://www.unfpa.org/sites/default/files/resource-pdf/7B_fact_sheets_en.pdf (Accessed February 24, 2016).

Veirs, S., Veirs, V., and Wood, J. (2015). Ship noise extends to frequencies used for echolocation by endangered killer whales. *Peer J. Prepr.* 4:e1657. doi: 10.7717/peerj.1657

Wade, P. R., Reeves, R. R., and Mesnick, S. L. (2012). Social and Behavioural factors in cetacean responses to overexploitation: are odontocetes less "resilient" than mysticetes? *J. Mar. Biol.* 2012, 1–15. doi: 10.1155/2012/567276

Waldick, R. C., Kraus, S., Brown, M., and White, B. N. (2002). Evaluating the effects of historic bottleneck events: an assessment of microsatellite variability in the endangered, North Atlantic right whale. *Mol. Ecol.* 11, 2241–2250. doi: 10.1046/j.1365-294X.2002.01605.x

Waters, C. N., Zalasiewicz, J., Summerhayes, C., Barnosky, A. D., Poirier, C., Ga, A., et al. (2016). The anthropocene is functionally and stratigraphically distinct from the Holocene. *Science* 351, aad2622-1–aad2622-10. doi: 10.1126/science.aad2622

Weber, D. S., Stewart, B. S., Schienman, J., and Lehman, N. (2004). Major histocompatibility complex variation at three class II loci in the northern elephant seal. *Mol. Ecol.* 13, 711–718. doi: 10.1111/j.1365-294X.2004.02095.x

Whitehead, H. (1994). Delayed competitive breeding in roving males. *J. Theor. Biol.* 166, 127–133. doi: 10.1006/jtbi.1994.1011

Whitehead, H. (2003). *Sperm Whales: Social Evolution in the Ocean*. Chicago, IL: University of Chicago Press.

Whitehead, H. (2010). Conserving and managing animals that learn socially and share cultures. *Learn. Behav.* 38, 329–336. doi: 10.3758/LB.38.3.329

Whitehead, H., Antunes, R., Gero, S., Wong, S. N. P., Engelhaupt, D., and Rendell, L. (2012). Multilevel societies of female sperm whales (*Physeter Macrocephalus*) in the Atlantic and Pacific: why are they so different? *Int. J. Primatol.* 33, 1142–1164. doi: 10.1007/s10764-012-9598-z

Whitehead, H., Christal, J., and Dufault, S. (1997). Past and distant whaling and the rapid decline of sperm whales off the Galapagos Islands. *Conserv. Biol.* 11, 1387–1396. doi: 10.1046/j.1523-1739.1997.96246.x

Whitehead, H., and Hope, P. L. (1991). Sperm whalers off the Galapagos Islands and in the Western North Pacific, 1830-1850: Ideal free whalers? *Ethol. Sociobiol.* 12, 147–161. doi: 10.1016/0162-3095(91)90018-L

Whitehead, H., and Rendell, L. (2015). *The Cultural Lives of Whales and Dolphins. University of Chicago Press.* Available online at: https://books.google.com/books?id=GeBXBQAAQBAJ&pgis=1 (Accessed September 21, 2015).

Whitehead, H., Rendell, L., Osborne, R. W., and Würsig, B. (2004). Culture and conservation of non-humans with reference to whales and dolphins: review and new directions. *Biol. Conserv.* 120, 427–437. doi: 10.1016/j.biocon.2004.03.017

Williams, R., Erbe, C., Ashe, E., and Clark, C. W. (2015). Quiet(er) marine protected areas. *Mar. Pollut. Bull.* 100, 154–161. doi: 10.1016/j.marpolbul.2015.09.012

Williams, R., and Lusseau, D. (2006). A killer whale social network is vulnerable to targeted removals. *Biol. Lett.* 2, 497–500. doi: 10.1098/rsbl.2006.0510

Wirsing, A. J., and Heithaus, M. R. (2012). Behavioural transition probabilities in dugongs change with habitat and predator presence: implications for sirenian conservation. *Mar. Freshw. Res.* 63, 1069–1076. doi: 10.1071/MF12074

Wolf, M., and Weissing, F. J. (2012). Animal personalities: consequences for ecology and evolution. *Trends Ecol. Evol.* 27, 452–461. doi: 10.1016/j.tree.2012.05.001

Yack, T. M., Barlow, J., Calambokidis, J., Southall, B., and Coates, S. (2013). Passive acoustic monitoring using a towed hydrophone array results in identification of a previously unknown beaked whale habitat. *J. Acoust. Soc. Am.* 134, 2589–2595. doi: 10.1121/1.4816585

Yodzis, P. (2001). Culling predators to protect fisheries: a case of accumulating uncertainty. *Trends Ecol. Evol.* 16, 282–283. doi: 10.1016/S0169-5347(01)02159-0

Zhan, X., Li, M., Zhang, Z., Goossens, B., Chen, Y., Wang, H., et al. (2006). Molecular censusing doubles giant panda population estimate in a key nature reserve. *Curr. Biol.* 16, R451–R452. doi: 10.1016/j.cub.2006.05.042


**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.

frontiers in Marine Science

BOOK REVIEW
published: 20 June 2016
doi: 10.3389/fmars.2016.00098

# Book Review: The Cultural Lives of Whales and Dolphins

*Erich Hoyt* [1,2]*

[1] Whale and Dolphin Conservation, Chippenham, UK, [2] IUCN SSC-WCPA Marine Mammal Protected Areas Task Force, Bridport, UK

**Keywords: dolphins, whales, culture, behavior, animal, conservation**

**A book review on**
**The Cultural Lives of Whales and Dolphins**

Hal Whitehead and Luke Rendell, Chicago; London: The University of Chicago Press, 2015

In the early 1980s, Hal Whitehead and other budding whale biologists set their sails across the Indian Ocean in search of whales. The International Whaling Commission had just declared the Indian Ocean as a giant no-whaling sanctuary. Whitehead and crew's post-whaling reconnaissance aimed to see what was left. Near Sri Lanka, they encountered sperm whales, groups of intensely social females and calves, surprisingly shy and incessantly clicking. That and subsequent sailing expeditions meeting sperm whale groups in the Pacific and Atlantic oceans, as well as humpback and other whale work, set Whitehead on a path leading to *The Cultural Lives of Whales and Dolphins* (Whitehead and Rendell, 2015).

Co-author Luke Rendell began collaborating with Whitehead in the 1990s, focusing on sperm whale social behavior and acoustics. They started thinking about exploring the idea of culture in whales and dolphins. Their review paper in *Behavioral and Brain Sciences* (Rendell and Whitehead, 2001) entitled "Culture in Whales and Dolphins" and a 2001 workshop at the Society for Marine Mammalogy biennial conference in Vancouver, B.C., helped launch things. For the book reviewed here, they gathered hundreds of fundamental papers based on long-term photo-ID and acoustic work on sperm, killer, humpback and blue whales, and bottlenose and other dolphins. A number of books set the stage, too, including *Among the Whales* (Payne, 1995), *Sperm Whales: Social Evolution in the Ocean* (Whitehead, 2003), and *Cetacean Societies: Field Studies of Dolphins and Whales* (Mann et al., 2000), among others. *The Cultural Lives of Whales and Dolphins* thus synthesizes much of the past work from over four decades and effectively launches a new field of enquiry in a comprehensive volume that does justice to the boldness of the title.

The first 44 pages are mostly devoted to defining the term "culture" in order to build a "not-too-leaky vessel" before examining the behavior of wild whales and dolphins. After looking at anthropocentric interpretations of culture from various disciplines that, by definition, exclude non-humans, the authors settle on a concise and clear definition of culture as "information or behavior—shared within a community—which is acquired from conspecifics through some form of social learning." Of course, much of the information that animals pass along has a genetic basis and this has dominated the way behavioral ecologists think about the biology of most animal species. But, in Whitehead and Rendell's words, culture is another method of moving information from animal to animal. And the more that is learned about cetacean social behavior, the more the evidence stands out.

Two of the main kinds of cultural transmission that Whitehead and Rendell examine are acoustic behavior and feeding behavior. Dipping a hydrophone into the ocean reveals that tropical oceans throb with humpback whale songs arranged in complex, evolving refrains. The Arctic has bowhead songs, while 14 different regional blue whale songs occupy the lowest

OPEN ACCESS

**Edited by:**
Mark Peter Simmonds,
University of Bristol, UK

**Reviewed by:**
Elisabeth Slooten,
University of Otago, New Zealand
Andrew Butterworth,
University of Bristol, UK

***Correspondence:**
Erich Hoyt
erich.hoyt@mac.com

**Specialty section:**
This article was submitted to Marine Affairs and Policy, a section of the journal Frontiers in Marine Science

**Received:** 19 May 2016
**Accepted:** 02 June 2016
**Published:** 20 June 2016

**Citation:**
Hoyt E (2016) Book Review: The Cultural Lives of Whales and Dolphins. Front. Mar. Sci. 3:98. doi: 10.3389/fmars.2016.00098

register and rumble out from the corners of the world where this endangered species yet persists. Killer whales with their dialects are more localized.

For feeding behavior, the various ecotypes of killer whales specialize on prey that they learn to eat as calves. Techniques such as rolling up on beaches in Patagonia to catch sea lions are practiced in the offseason by observing mothers or other older pod members. Culture can also be seen in the spread of dolphin behavior such as tail-walking and using bits of sponge to protect their beaks to probe in the sand, while humpbacks slap their flukes to enhance bubble-cloud feeding, and killer whales go beach-rubbing. Many shared behaviors probably started with an individual learning something and then passing it around.

How does culture affect biological fitness? The varying reproductive success in sperm whales of different oceans may indicate more successful transmission of specific pieces of information or behavior. Yet bottlenose dolphins who have learned to accept food hand-outs and human attention in Western Australia, have been less successful at taking care of their young than the dolphins staying offshore, so this cultural trait may be counter-productive and unlikely to persist.

The authors make numerous comparisons to culture in primates and humans that are instructive and entertaining. To suggest a few decades ago that culture was driving behavior outside of *Homo sapiens* would have been outside of the behavioral ecology line of research that has dominated cetacean work but, as Whitehead and Rendell explain, behavioral ecologists now accept that culture is part of the story. Of course, how much of behavior is due to social learning and how much due to genetics or environmental correlation, is up for further study and elucidation. The anthropologists and psychologists, meanwhile, mostly refuse to accept the notion of whale or chimpanzee culture (Tyack, 2001). It will take more evidence—and acceptance of a more up-to-date definition of culture—to persuade them.

Meanwhile, the acknowledgment that cetaceans have cultural lives is already having an impact on whale conservation. In 2014, the Convention on Migratory Species (CMS) passed a resolution calling on members to investigate the conservation implications of cetacean culture (CMS, 2014). The IUCN Marine Mammal Protected Areas Task Force has recognized unique cultural features as a criterion for selection as an Important Marine Mammal Area (IMMA) (Hoyt and Notarbartolo di Sciara, 2014).

*The Cultural Lives of Whales and Dolphins* is well written, carefully edited and accessible to a wide readership without sacrificing authoritativeness. The backmatter with notes and bibliography alone extends to 92 pages and there is a 19-page double-column index. The book could serve as reading material in biology or conservation courses, or a delightful provocation in anthropology or psychology courses. It can be anticipated that new editions will be able to chart the further implications of culture and add to the body of evidence. Those of us studying whales are fortunate to have seen our studies go from zero to an extraordinary flowering of research results uncovering highly diverse behavior, life history and population biology. We can now also enrich ourselves with the cultural lives of wild whales and dolphins.

## AUTHOR CONTRIBUTIONS

The author confirms that he is the sole contributor of this work and has approved it for publication.

## REFERENCES

Convention on Migratory Species (CMS) (2014). "UNEP/CMS/Resolution 11.23. conservation implications of cetacean culture," in *Adopted by the Conference of the Parties at its 11th Meeting* (Quito). Available online at http://www.cms.int/sites/default/files/document/Res_11_23_Implications_of_Cetacean_Culture_E.pdf

Hoyt, E., and Notarbartolo di Sciara, G. (eds.). (2014). *Report of the Workshop for the Development of Important Marine Mammal Area (IMMA) Criteria*. Marseille: IUCN Marine Mammal Protected Areas Task Force and International Committee on Marine Mammal Protected Areas.

Mann, J., Connor, R. C., Tyack, P. L., and Whitehead, H. (eds.). (2000). *Cetacean Societies: Field Studies of Dolphins and Whales*. Chicago; London: The University of Chicago Press.

Payne, R. (1995). *Among the Whales*. New York, NY: Scribner.

Rendell, L., and Whitehead, H. (2001). Culture in whales and dolphins. *Behav. Brain Sci.* 24, 2, 309–324. doi: 10.1017/S0140525X0100396X

Tyack, P. L. (2001). Cetacean culture: humans of the sea? *Behav. Brain Sci.* 24, 358–370. doi: 10.1017/S0140525X01593966

Whitehead, H. (2003). *Sperm Whales: Social Evolution in the Ocean*. Chicago; London: The University of Chicago Press.

Whitehead, H., and Rendell, L. (2015). *The Cultural Lives of Whales and Dolphins*. Chicago; London: The University of Chicago Press.

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

frontiers in Marine Science

ORIGINAL RESEARCH
published: 23 August 2016
doi: 10.3389/fmars.2016.00142

CrossMark

# Does the Seal Licensing System in Scotland Have a Negative Impact on Seal Welfare?

**Laetitia Nunny[1]*, Fritha Langford[2] and Mark P. Simmonds[3]**

[1] Royal (Dick) School of Veterinary Studies, The University of Edinburgh, Edinburgh, UK, [2] Animal and Veterinary Sciences, Scotland's Rural College, Edinburgh, UK, [3] School of Veterinary Sciences, University of Bristol, Bristol, UK

This study examined the licensing system that permits seal shooting in Scotland, which was established under Part 6 Conservation of Seals of the Marine (Scotland) Act 2010. Four approaches were used: data were collated and analyzed from both the Scottish Government and Scottish Marine Animal Stranding Scheme; a survey was sent to current license holders and informal interviews were conducted with key stakeholder types. Between February 2011 and the end of October 2015, 1229 gray seals, and 275 common seals were reported shot under license to the Scottish Government. The numbers of seals reported as shot has reduced year-on-year since the licensing system was put in place. While some license holders, notably fish farms, were using some non-lethal forms of deterrent to reduce seal-related damage, these were often used alongside seal shooting. Of the seals reported as shot to the Scottish Government, only a small percentage were also reported to the Scottish Marine Animal Stranding Scheme, despite this being a licensing requirement. Only 2.3% of the shot gray seals and 4.5% of the shot common seals were necropsied. There is evidence from these necropsies that some seals had not died instantly or had not been shot in the manner recommended by the Scottish Seal Management Code of Practice. These preliminary results show that more carcasses need to be recovered and necropsied if the welfare implications of current seal shooting practice are to be properly assessed. The current legislation does not specify closed seasons to protect breeding seals and 35% of necropsied seals were pregnant gray seals. Seals have also been shot during their lactation periods when pups are dependent on their mothers. This raises significant welfare concerns. The re-introduction of closed seasons specific to each species of seal is recommended along with greater effort to deploy non-lethal methods. Independent assessment of the number of seals being killed would also improve the credibility of the system.

**Keywords: gray seal, common seal, harbor seal, seal management, fish farm, fishery, welfare, aquaculture**



***Edited by:***
*Rob Harcourt, Macquarie University, Australia*

***Reviewed by:***
*Clive Reginald McMahon, Sydney Institute of Marine Science, Australia*
*Mary George, University of Malaya, Malaysia*
*Christian T. K.-H. Standtlander, Independent Researcher, St. Paul, USA*

***Correspondence:***
*Laetitia Nunny*
*laetitia.nunny@mac.com*

***Specialty section:***
*This article was submitted to Marine Affairs and Policy, a section of the journal Frontiers in Marine Science*

***Received:*** *18 March 2016*
***Accepted:*** *27 July 2016*
***Published:*** *23 August 2016*

***Citation:***
*Nunny L, Langford F and Simmonds MP (2016) Does the Seal Licensing System in Scotland Have a Negative Impact on Seal Welfare? Front. Mar. Sci. 3:142. doi: 10.3389/fmars.2016.00142*

## INTRODUCTION

Scotland has a large and growing aquaculture industry and is the third largest producer of Atlantic salmon (*Salmo salar*) in the world (Scotland's Aquaculture, 2016). In addition, Scottish waters are famed for their fishing, drawing anglers from across the world (Marine Scotland, 2016a). Gray seals (*Halichoerus grypus*) and common seals (*Phoca vitulina*) have long been viewed as in conflict with the Atlantic salmon and sea trout (*Salmo trutta*) fisheries (Butler et al., 2011). Seals prey on the fish and, potentially, affect the number available for capture as well as interfering with fishing activities and damaging nets and fish (Butler et al., 2011). Seals also predate on salmon at fish farms and are present at 81% of aquaculture sites in Scotland (Quick et al., 2004). Most damage at fish farms is reported as being caused by gray seals (Northridge et al., 2010).

Many Scottish rod fisheries and netting stations believe that seals have a significant impact on fish stocks and catches (Butler et al., 2011). A survey of such stakeholders from the Moray Firth in Scotland found that 77% believed that all seals are the problem and 47% thought that culling to reduce the overall seal population was desirable (Butler et al., 2011). Conversely, most fish farm managers believe that "rogue" individuals acting in a way that is not typical of all seals are responsible for most of the damage caused and that removing an individual seal means that attacks stop for a period (Northridge et al., 2010). Studies have been undertaken to ascertain whether certain seals do, in fact, behave differently to the majority of the population. A study in the Moray Firth observed that only a small number of gray and common seals were using rivers (Graham et al., 2011). Digestive tract samples taken from eight shot seals and one live-caught seal found in rivers were compared to 182 scat samples collected at haul-out sites (Graham et al., 2011). It was concluded that there are individual "rogue" seals that eat more salmonids than the general seal population (Graham et al., 2011). A study in the Baltic Sea also suggested that certain individual gray seals specialize in raiding fishing gear; even returning to the same fish traps over two seasons (Königson et al., 2013). These specialist fish trap-raiding seals accounted for only 1% of the local seal population (Königson et al., 2013).

The Moray Firth Seal Management Plan (MFSMP), which aimed to specifically target such "rogue" seals, was successfully implemented in 2005 and led to the introduction of a new seal licensing system throughout Scotland under Part 6 Conservation of Seals of the Marine (Scotland) Act 2010 (The Stationery Office, 2010; Butler et al., 2011). Prior to this, seals had been managed in Scotland under the Conservation of Seals Act 1970. This Act provided some protection for seals through the implementation of closed seasons although it still permitted the killing of seals in closed seasons under certain circumstances, for example to prevent a seal from damaging a fishing net, fishing tackle or a fish caught in a net (The Stationery Office, 1970). Although the Conservation of Seals Act 1970 was repealed in Scotland when the Marine (Scotland) Act 2010 was introduced, it still applies to England and Wales (The Stationery Office, 1970, 2010).

The first licenses to shoot seals under the new system were issued on 31 January 2011 (Marine Scotland, 2015). Scottish Ministers can grant licenses allowing the killing or taking of seals for various reasons including "to protect the health and welfare of farmed fish" and "to prevent serious damage to fisheries or fish farms" (The Stationery Office, 2010). The Marine (Scotland) Act 2010 requires that seal licenses impose conditions including the type of firearm used, the area and circumstances in which a seal can be shot, the species to be killed, periods when seals cannot be taken and regarding the recovery of carcasses (The Stationery Office, 2010).

License applicants request permission to shoot a certain number of seals and Marine Scotland (the department of the Scottish Government which is responsible for marine and fisheries issues) grants the quota deemed appropriate taking into account the number applied for and using a Potential Biological Removal (PBR) approach which determines, hypothetically, the number of seals that can be removed from a population without causing the population to decline (Marine Scotland, 2016b). The PBR is calculated by the Sea Mammal Research Unit (SMRU) at the University of St Andrews using a minimum population estimate, the population growth rate and a recovery factor (Thompson et al., 2014; Marine Scotland, 2016b). This is intended to ensure that Scottish seal populations are maintained at a "favorable" conservation status as required by the European Union Habitats Directive (Council of the European Union, 1992).

As well as concern for the conservation status of managed seal populations, the potential impact on the welfare of individual animals deserves consideration. Some authors advocate that if high standards of welfare are important in production animal husbandry then, for consistency, the same welfare standards should be ensured for wildlife that are affected by human activity (Sainsbury et al., 1995). Wherever wild animals are killed by humans, for example the shooting of seals to protect fisheries and fish farms, there is potential for these animals to experience pain and distress (Littin and Mellor, 2005). Warburton and Norton (2009) express the view that "nuisance" animals must be killed in a way that can be justified and as part of a management program with clear aims and which is carefully monitored. Gregory (2003) makes recommendations for improved humaneness in pest control including the increased use of deterrents rather than lethal methods and the assessment of killing methods based on how the animals die.

A variety of methods to deter seals from predating at fish farms and fisheries exist. The Royal Society for the Prevention of Cruelty to Animals (RSPCA) recommends that fish farms should use non-lethal methods which aim to physically exclude predators from fish enclosures (RSPCA, 2015). The use of appropriately tensioned enclosure nets, predator nets and Acoustic Deterrent Devices (ADDs) are recommended as well as the regular removal of dead fish (RSPCA, 2015). Fisheries may try methods such as lifting gear frequently, moving to other fishing grounds and changing the type of materials used in nets and traps as well as modified net and trap design (Hemmingsson et al., 2008). In river fisheries, non-lethal deterrence methods have not been extensively developed (Graham et al., 2009) and lethal control of seals continues to play a part in seal management in both fisheries and fish farms throughout Scotland.

Where seal killing is concerned, much of the research into welfare has focused on the commercial harp seal (*Pagophilus groenlandiscus*) hunt which takes place in Canada (Daoust and Caraguel, 2012). This hunt, clearly, has different aims, killing methods and outcomes to the seal killing that happens in Scotland. However, for comparison, it is noted that the Canadian commercial seal hunt requires seals to be killed in a three-step process: stunning, followed by external palpation of the skull (to ensure it is crushed), and bleeding out (Minister of Justice Canada, 2011). Seals killed for management reasons in Scotland are killed in a one-step process as they should be shot with "a rifle using ammunition with a muzzle energy not less than 600 foot pounds and a bullet weighing not less than 45 grains" (Marine Scotland, 2011). The Scottish Seal Management Code of Practice recommends a shot to the head noting that "the brain of a seal is a very small target" (Marine Scotland, 2011). Centerfire rifles with expanding bullets should be used for public safety and animal welfare reasons (Marine Scotland, 2011).

In addition to the welfare of the shot individual, the killing of one wild animal may indirectly affect the welfare of another. For example, the possibility of shooting a female who has dependent young is an important issue when assessing the humaneness of shooting an animal (Macdonald et al., 2000). In the case of seals, it is possible that the shot animal could be pregnant or lactating causing potential suffering to the unborn fetus or the neonate pup. Seals other than the target seal which are present in the immediate area when shooting takes place may also experience a negative impact on their welfare (Bonner, 1993).

The present study uses a mixed methods (quantitative-qualitative) approach to try to answer the following overarching questions:

1. Is there a difference in the proportion of seals shot of each species?
2. Are the numbers of seals being shot changing over time?
3. Does the Seal Management Area where the fishery or fish farm is located affect the number of seals granted and the number shot?
4. Does seal shooting activity differ over the seasons and is this likely to be related to the physiological status of the seals?
5. Does the type of establishment (e.g., fish farm or fishery) affect the way in which problems with seals are dealt with?
6. Do necropsied seals give any indication that the welfare of shot seals is being negatively impacted?
7. Is there evidence that the welfare of non-target seals is being negatively impacted?

In addition, gaps in research and knowledge are assessed and recommendations are made as to how to improve seal welfare.

## MATERIALS AND METHODS

This study was carried out in part fulfillment of the MSc International Animal Welfare, Ethics and Law at the University of Edinburgh. It was approved by the Veterinary Ethics Committee at the Royal (Dick) School of Veterinary Studies, University of Edinburgh. Four approaches were used to gather quantitative and qualitative data.

### Approach 1—Official Data Available to the Public

Although licenses can be issued for a number of reasons the main two license types that are issued by Marine Scotland and for which details are given on the Marine Scotland website, are the "License to Shoot Seals to Protect the Health and Welfare of Farmed Fish in Scotland" and the "License to Shoot Seals to Prevent Serious Damage to Fisheries in Scotland" (Marine Scotland, 2016b).

From the "Licenses and Returns" section of the Marine Scotland website, data for 2011–2014 were collected for both gray and common seals including the total population, the PBR, the number of seals applied for, the number of seals granted and the number of seals reported as shot. For 2015, the PBR, number of seals applied for, granted and reported as shot for the first 3 quarters of the year were taken from the "Seal Licensing" homepage of the Marine Scotland website (http://www.gov.scot/Topics/marine/Licensing/SealLicensing). Data are presented according to Seal Management Area without identifying individual sites.

The numbers summarizing how many seals were shot by fish farms and by fisheries or netting stations from 2011 to 2014 were extracted from the Annexes of the Report of the Inaugural Quinquennial Review of the Operation of Seal Licensing System Under the Marine (Scotland) Act 2010 which is available from the Marine Scotland "Seal Licensing" homepage (Marine Scotland, 2015).

### Approach 2—Necropsy Data

The Scottish Marine Animal Stranding Scheme (SMASS) at Scotland's Rural College (SRUC) Wildlife Unit reports to Marine Scotland annually describing the seal management cases that have been reported to them and any necropsies that they or the staff at SMRU have carried out. Completed reports were available for 2012–2014 from the Seal Licensing Team at Marine Scotland (SRUC Wildlife Unit, 2012; Brownlow and Davison, 2013, 2014).

The details of necropsied seals shot under the licensing system were extracted from the reports including how many seals of which species were necropsied, whether or not the animals had died instantaneously from their wounds and whether or not the female seals were pregnant. Details of seals which had not been reported to SMASS under the seal licensing system but which were considered (from post-mortem examination) to have been shot were also collected.

In addition to the reports, the lead author discussed the project with the SRUC Wildlife Unit in order to fully appreciate the reporting procedures and to acquire data relating to seal management cases which were necropsied in 2011 and which had not been written up in a formal report.

The data from these reports and discussions were tabulated to show the species, sex and reproductive state of shot seals necropsied by SMASS and SMRU by Seal Management Area and to allow comparison with seals reported as shot to Marine Scotland and the number of seal carcasses recovered and/or reported to SMASS.

### Approach 3—License Holder Survey

A questionnaire was sent to seal license holders. The questions were developed based on the requirements outlined in the Marine (Scotland) Act 2010, the Scottish Seal Management Code of Practice and the application forms that license applicants are required to complete (The Stationery Office, 2010; Marine Scotland, 2011, 2016c).

The names of license holders were obtained from downloaded excel spreadsheets available from the "Licenses and Returns" section of the Marine Scotland website. As only the company or organization name was available, searches were then conducted online for postal addresses. In November 2014 the survey was posted to 52 seal license holders accompanied by a letter of explanation and a pre-paid return envelope. License holders were also given the option of completing the survey online at: https://www.surveymonkey.com/s/seal_management.

License holders were asked to complete and return the survey before 16th January 2015. In early January 2015, follow-up e-mails were sent to the license holders whose e-mail address had been found during the online searches. The e-mail thanked the license holders for participating in the survey and reminded them that they could still complete the survey if they had not already done so.

The following questions were presented in the survey:

Question 1. *What problems have you experienced with seals? Tick all that apply.* Optional answers were "Seals kill/eat fish," "Seals injure/damage fish," "Presence of seals affects fish behavior," "Seals cause fish to escape from nets/net pens," "Seals damage equipment e.g., nets," "Other (please specify)."
Question 2. *Do you use or have you used Acoustic Deterrent Devices (ADDs) also known as pingers or seal scarers?* Optional answers were "Yes" and "No." Those who responded "No" to Question 2 were asked to go directly to Question 4.
Question 3. *Did the device deter seals from entering the target areas?* Optional answers were "Yes, the device was effective," "Sometimes," and "No, the device did not seem to have any effect."
Question 4. *Have you used other methods to deter seals? (Tick all that apply).* Optional answers were "Floats or buoys," "Predator nets," "Tensioned or false-bottom nets to exclude seals," "Removal of dead fish from dead-fish basket," "Screening blinds," "Shooting seals," and "Other (please specify)."
Question 5. Has shooting individual seals helped deter other seals from approaching or entering the fishery/fish farm? Optional answers were "Yes," "No," and "Don't know."
Question 6. *Have you injured (but not killed) any seals and therefore had to locate them and humanely dispatch them afterwards?* Optional answers were "Yes" and "No." If the response was "Yes" they were asked to specify how many seals.
Question 7. *Have you recovered the carcasses of any shot seals?* Optional answers were "Yes, all shot seals have been recovered," "Yes, some shot seals have been recovered," "No, no shot seals have been recovered," and "No, we have not shot any seals."
Question 8. *How many carcasses have you recovered?* Respondents were required to give a number.
Question 9. *What did you do with the recovered carcass(es)? (Tick all that apply).* Optional answers were "Reported it to the Scottish Agricultural College/SRUC," "Reported it to Marine Scotland," "Photographed it (please specify what you did with photo)," "Left it without reporting it," and "Other (please specify)."
Question 10. *If you answered "no" or "some" to Question 7, what has prevented you from recovering the carcasses? (Tick all that apply).* Optional answers were "Bad weather," "Bad sea conditions," "Seal sank after it was shot," "Seal swam away after it was shot," "It was too dangerous for the marksman to reach the seal," "We didn't know that we were supposed to recover seal carcasses," and "Other (please specify)."
Question 11. *Details of license holder. Please indicate whether you are:* Optional answers were "A fish farm," "A fishery," "An academic institution," and "Other (please specify)."
Question 12. *Please indicate which Seal Management Area(s) you hold or have held a license for:* Optional answers were "East Coast," "Moray Firth," "Orkney and North Coast," "Shetland," "South West Scotland," "West Scotland," and "Western Isles."

### Approach 4—Interviews

A field visit was made to the West Scotland and Moray Firth Seal Management Areas in April 2015. Informal semi-structured interviews were conducted with three people involved in seal management including a fish farm manager, a bag net fisherman, and the head bailiff of a fishery board. These visits provided qualitative data on the situation as experienced by a representative of each different industry reliant on salmon that may come into conflict with seals.

The fish farm manager was introduced to us via an academic contact who put us in touch with one of the largest fish farm companies in Scotland who, in turn, recommended that we visit this specific fish farm. The bag net fisherman responded to the survey and sent an e-mail offering to help with any further information that we might require. A fishery board director enclosed a letter with the completed survey also offering assistance with further information and, later, arranged the meeting with the head bailiff.

### Statistical Analysis

The data collected and collated for this paper come from either (a) a variety of publicly available sources or (b) questionnaire or interview data collected by the authors. As such, only a limited inferential statistical analysis can take place. Where comparisons have been possible, the data from the questionnaire have been analyzed using Fisher's Exact tests. For comparisons made between data from the license reports, first all percentage data were transformed using the ArcSine transformation to approximate the normal distribution. Where data were not normally distributed, Mann-Whitney and Kruskal Walis tests were used. Where equal variance were achieved, the data were analyzed using General Linear Model adding in the "year" as a repeated measure and using Tukey Test for *post-hoc* analysis. The post-mortem analysis were carried out using the Freeman-Halton extension of Fisher's exact test in a $2 \times 3$ contingency table. All data were analyzed in Minitab 17.

## RESULTS

### Approach 1—Official Data Available to the Public

When applying for a license, applicants indicate the maximum number of each species of seal that they are seeking permission to shoot in the next license year. **Table 1** shows the total population for each species, the PBR, how many seals have been applied for, how many have been granted by Marine Scotland and how many have been reported as shot for each year as well as showing the percentages that the reported shot seals represent of the total population and the allocation of granted seals.

## Seals Granted by Marine Scotland

For both gray and common seals, although the PBR and the number of seals applied for annually has fluctuated, the numbers granted by Marine Scotland have been decreasing each year (see **Table 1**). How do the numbers of seals granted relate to the total populations and the PBRs?

Between the years 2011 and 2015 a significantly higher percentage of the total population of common seals (median 1.3% IQR 1.1–1.5%) were granted to be shot in comparison to gray seals (median 0.8% IQR 0.7–0.9%) ($W = 15.0$, $P < 0.05$).

The number of seals granted by Marine Scotland to license holders is always fewer than the PBR for each Seal Management Area. The percentage of the gray seal PBR figures granted to be shot differed according to Seal Management Area. When the data across years 2011 to 2014 is combined (accounting for the difference between years as a repeated measure), it can be seen that Shetland (57.4 ± 7.6%) was granted the highest percentage of its PBR and that this percentage is statistically significantly different from the percentage granted to the Western Isles (32.2 ± 1.5%) and Orkney and North Coast areas (24.2 ± 5.2%) [$F = 5.44_{(6, 21)}$, $P < 0.01$].

The percentage of the common seal PBR granted to be shot also differed depending on Seal Management Area. After combining the data across years 2011 to 2014 (accounting for the difference between years as a repeated measure), it can be seen that Moray Firth (83.7 ± 8.5%) and South West Scotland (83.6 ± 3.17%) were granted the highest percentage of the PBR and that this percentage is statistically significantly different from the percentage of common seals granted to the Orkney and North Coast (39.8 ± 5.6%), West Scotland (39.5 ± 2.6%), and Shetland (37.5 ± 6.2%) areas [$F = 22.89_{(6, 21)}$, $P < 0.001$].

## Seals Reported as Shot under License to Marine Scotland

It is important to note that the numbers reported shot are based exclusively on returns received from license holders and there is no independent assessment of numbers. Since the start of the licensing system in 2011 and up to the end of October 2015, a total of 1229 gray seals and 275 common seals were reported as shot to Marine Scotland (Marine Scotland, 2016b).

Each year the number of gray seals reported as shot has declined. The percentage of the total gray seal population reported as shot has not exceeded 0.36% (the percentage for 2012). The number of common seals reported as shot has varied according to year but, generally, appears to be decreasing. In 2011, 0.46% of the common seal population was reported as shot under the license system. This is the highest percentage recorded so far. The numbers of seals reported as shot as a percentage of the total population of the species did not differ by species (median for common seals: 0.2% IQR 0.1–0.4%; median for gray seals: 0.2% IQR 0.1–0.3%; $P > 0.05$).

The numbers of seals reported as shot as a percentage of the numbers granted by the Scottish Government did not differ significantly between the two species. However, there was a weak tendency for a higher percentage of the gray seals granted to be reported as shot (median 30.7% IQR 18.4–38.3%) compared to the common seals (median 17.1% IQR 14.3–27.6%) ($P < 0.1$).

## Location of Seals Reported as Shot under License to Marine Scotland

The distribution of reported seal shootings by Seal Management Area is shown in **Figure 1** and **Tables 2, 3**. Most reported shot gray seals were killed in the Orkney and North Coast Seal Management Area (497 gray seals representing 40.4% of shot gray seals) while the majority of common seals have been reported

**TABLE 1 | Gray seal and common seal total populations, Potential Biological Removal (PBR), numbers of seals applied for, granted and reported as shot, the percentage of the total population reported as shot and the percentage of the granted seals reported as shot in Scotland 2011–2015 (Marine Scotland, 2016b).**

| Year | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Gray seals | Common seals | Gray seals | Common seals | Gray seals | Common seals | Gray seals | Common seals | Gray seals | Common seals |
| Total population | 108,000 | 20,400 | 100,000 | 20,500 | 100,000 | 20,500 | 100,000 | 20,500 | 101,000 | 20,700 |
| PBR | 2301 | 593 | 2301 | 589 | 3002 | 617 | 3002 | 617 | 2830 | 627 |
| No. of seals applied for | 1706 | 794 | 3008 | 812 | 1347 | 602 | 1327 | 547 | 1047 | 484 |
| No. of seals granted | 1025 | 314 | 878 | 289 | 774 | 265 | 765 | 240 | 662 | 197 |
| No. of seals reported shot | 366 | 93 | 359 | 74 | 238 | 36 | 164 | 41 | 102* | 31* |
| Percentage of total population reported as shot (%) | 0.34 | 0.46 | 0.36 | 0.36 | 0.24 | 0.18 | 0.16 | 0.20 | 0.1* | 0.15* |
| Percentage of seals granted reported as shot (%) | 35.7 | 29.6 | 40.9 | 25.6 | 30.7 | 13.6 | 21.4 | 17.1 | 15.4* | 15.7* |

**Refers to the first three quarters (1st February–31st October) of 2015 only.*


**FIGURE 1 | Map of Seal Management Areas where gray and common seals were reported shot to Marine Scotland February 2011–end of October 2015.** For detailed data description see **Tables 2, 3**. (Adapted from a map available from Scottish Government [Marine Scotland] at https://marinescotland.atkinsgeospatial.com/nmpi/default.aspx?layers=115 Open Government License: www.nationalarchives.gov.uk/doc/open-government-licence/version/3/).

shot in West Scotland (191 common seals representing 69.5% of the shot common seals).

The percentage of granted gray seals that were reported as shot differed depending on Seal Management Area. When combining the data across years 2011 to 2014 (accounting for the difference between years as a repeated measure), it can be seen that Shetland (50.6 ± 8.6%) reported shot the highest percentage of the granted gray seals and that this percentage is statistically significantly different from the West Scotland (17.5 ± 2.3%), Western Isles (16.7 ± 3.6%), and South West Scotland (7.1 ± 3.1%) areas [$F = 7.88_{(6,\ 21)}$, $P < 0.001$].

There was no significant statistical evidence for a difference between areas in the percentage of the granted common seals reported as shot [$F = 2.07_{(5,\ 18)}$, $P > 0.1$].

## Time of Year When Seals Reported as Shot under License to Marine Scotland

To consider whether seals are more likely to be shot at particular times of the year, the numbers of seals reported shot in each quarter for the years 2011–2014 are presented in **Tables 4, 5** (2015 is not included as data are not yet available for the whole licensing year).

**TABLE 2 | Gray seals applied for, PBR, gray seals granted, the percentage of PBR granted, gray seals reported shot and percentage of granted seals reported shot by Seal Management Area 2011–2015.**

| | 2011 | | | | | 2012 | | | | | 2013 | | | | | 2014 | | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Applied | PBR | Granted (% of PBR) | Reported shot | % of granted seals shot | Applied | PBR | Granted (% of PBR) | Reported shot | % of granted seals shot | Applied | PBR | Granted (% of PBR) | Reported shot | % of granted seals shot | Applied | PBR | Granted (% of PBR) | Reported shot | % of granted seals shot | Applied | PBR | Granted (% of PBR) | Reported shot * |
| East Coast | 246 | 277 | 132 (48) | 46 | 35 | 849 | 277 | 114 (41) | 42 | 37 | 142 | 314 | 82 (26) | 28 | 34 | 128 | 314 | 74 (24) | 11 | 15 | 92 | 297 | 66 (22) | 5 |
| Moray Firth | 85 | 152 | 75 (49) | 16 | 21 | 836 | 152 | 100 (66) | 43 | 43 | 145 | 174 | 90 (52) | 43 | 48 | 239 | 174 | 90 (52) | 25 | 28 | 120 | 201 | 70 (35) | 22 |
| Orkney/N Coast | 461 | 959 | 349 (36) | 167 | 48 | 475 | 959 | 280 (29) | 140 | 50 | 355 | 1448 | 220 (15) | 87 | 40 | 330 | 1448 | 232 (16) | 64 | 28 | 315 | 1240 | 220 (18) | 39 |
| Shetland | 384 | 163 | 120 (74) | 69 | 58 | 341 | 163 | 109 (67) | 73 | 67 | 240 | 236 | 105 (45) | 54 | 51 | 198 | 236 | 105 (45) | 28 | 27 | 89 | 235 | 82 (35) | 8 |
| SW Scotland | 115 | 45 | 31 (69) | 4 | 13 | 63 | 45 | 26 (58) | 3 | 12 | 63 | 57 | 26 (46) | 1 | 4 | 66 | 57 | 25 (44) | 0 | 0 | 65 | 57 | 15 (26) | 1 |
| West Scotland | 206 | 297 | 170 (57) | 36 | 21 | 206 | 297 | 126 (42) | 27 | 21 | 204 | 386 | 126 (33) | 15 | 12 | 188 | 386 | 123 (32) | 19 | 15 | 183 | 414 | 120 (29) | 17 |
| Western Isles | 209 | 408 | 148 (36) | 28 | 19 | 238 | 408 | 123 (30) | 31 | 25 | 198 | 387 | 125 (32) | 10 | 8 | 188 | 387 | 116 (30) | 17 | 15 | 183 | 386 | 89 (23) | 10 |
| TOTAL | 1706 | 2301 | 1025 (45) | 366 | 36 | 3008 | 2301 | 878 (38) | 359 | 41 | 1347 | 3002 | 774 (26) | 238 | 31 | 1337 | 3002 | 765 (26) | 164 | 21 | 1047 | 2830 | 662 (23) | 102 |

*Refers to the first three quarters (1st February–31st October) of 2015 only.

**TABLE 3 | Common seals applied for, PBR, common seals granted, the percentage of PBR granted, common seals reported shot and percentage of granted seals reported shot by Seal Management Area 2011–2015.**

| | 2011 | | | | | 2012 | | | | | 2013 | | | | | 2014 | | | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Applied | PBR | Granted (% of PBR) | Reported shot | % of granted seals shot | Applied | PBR | Granted (% of PBR) | Reported shot | % of granted seals shot | Applied | PBR | Granted (% of PBR) | Reported shot | % of granted seals shot | Applied | PBR | Granted (% of PBR) | Reported shot | % of granted seals shot | Applied | PBR | Granted (% of PBR) | Reported shot *** |
| East Coast | 92 | 3 | 0 (0) | 0 | – | 106 | 2 | 0 (0) | 0 | – | 54 | 2 | 0 (0) | 0 | – | 39 | 2 | 0 (0) | 0 | – | 14 | 1 | 0 (0) | 0 |
| Moray Firth | 52 | 23 | 20 (87) | 6* | 30 | 82 | 20 | 19 (95) | 10 | 53 | 34 | 17 | 16 (94) | 3 | 19 | 24 | 17 | 10 (59) | 6 | 60 | 15 | 16 | 5 (31) | 4 |
| Orkney/N Coast | 53 | 18 | 10 (56) | 4 | 40 | 58 | 18 | 7 (39) | 3 | 43 | 37 | 17 | 5 (29) | 1 | 20 | 39 | 17 | 6 (35) | 1 | 17 | 37 | 11 | 0 (0) | 0 |
| Shetland | 47 | 18 | 10 (56) | 2 | 20 | 32 | 18 | 6 (33) | 1 | 17 | 23 | 18 | 6 (33) | 3 | 50 | 17 | 18 | 5 (28) | 1 | 20 | 5 | 18 | 3 (17) | 0 |
| SW Scotland | 153 | 35 | 31 (89) | 12 | 39 | 104 | 35 | 30 (86) | 8 | 27 | 88 | 35 | 30 (86) | 0 | 0 | 91 | 35 | 26 (74) | 3 | 12 | 82 | 35 | 18 (51) | 0 |
| West Scotland | 296 | 442 | 203 (46) | 58 | 29 | 310 | 442 | 184 (42) | 50 | 27 | 291 | 446 | 163 (37) | 28 | 17 | 266 | 446 | 152 (34) | 29 | 19 | 260 | 464 | 137 (30) | 26 |
| Western Isles | 101 | 54 | 40 (74) | 11** | 28 | 120 | 54 | 43 (80) | 2 | 5 | 75 | 82 | 45 (55) | 1 | 2 | 71 | 82 | 41 (50) | 1 | 2 | 71 | 82 | 34 (42) | 1 |
| TOTAL | 794 | 593 | 314 (53) | 93 | 30 | 812 | 589 | 289 (49) | 74 | 26 | 602 | 617 | 265 (43) | 36 | 14 | 547 | 617 | 240 (39) | 41 | 17 | 484 | 627 | 197 (31) | 31 |

*Includes one unidentified seal counted as a common seal.*
***Includes three unidentified seals counted as common seals.*
****Refers to the first two quarters (1st February–31st October) of 2015 only.*

**TABLE 4 | Gray seals reported shot in Scotland 2011–2014 by quarter (Marine Scotland, 2015, 2016b).**

| | 2011 | 2012 | 2013 | 2014 | Total | % of total shot in each quarter | Mean shot in each quarter |
|---|---|---|---|---|---|---|---|
| 1st quarter (Feb, Mar, Apr) | 62 | 86 | 77 | 25 | 250 | 22.2 | 62.5 |
| 2nd quarter (May, Jun, Jul) | 117 | 115 | 90 | 72 | 394 | 35 | 98.5 |
| 3rd quarter (Aug, Sep, Oct) | 115 | 87 | 49 | 36 | 287 | 25.5 | 71.8 |
| 4th quarter (Nov, Dec, Jan) | 72 | 71 | 22 | 31 | 196 | 17.4 | 49.0 |

**TABLE 5 | Common seals reported shot in Scotland 2011–2014 by quarter (Marine Scotland, 2015, 2016b).**

| | 2011 | 2012 | 2013 | 2014 | Total | % of total shot in each quarter | Mean shot in each quarter |
|---|---|---|---|---|---|---|---|
| 1st quarter (Feb, Mar, Apr) | 20 | 29 | 8 | 10 | 67 | 27.5 | 16.8 |
| 2nd quarter (May, Jun, Jul) | 17 | 12 | 5 | 9 | 43 | 17.6 | 10.8 |
| 3rd quarter (Aug, Sep, Oct) | 30 | 22 | 12 | 6 | 70 | 28.7 | 17.5 |
| 4th quarter (Nov, Dec, Jan) | 26 | 11 | 11 | 16 | 64 | 26.2 | 16.0 |

There was a difference in the time of year when gray seals were shot. The second quarter of the year (May, June, and July) had the highest mean percentage of animals shot (36.4 $\pm$ 2.8%) and this was significantly higher than the means in the first (February, March, and April: 22.1 $\pm$ 3.9%) and fourth (November, December, and January: 16.9 $\pm$ 2.6%) quarters [$F = 7.71_{(3,12)}$, $P < 0.01$]. The fourth quarter is when the fewest gray seals were shot.

Twenty eight point seven per cent of common seals reported as shot were killed in the third quarter (August, September, and October) making it the quarter when the majority of common seal shootings took place. The mean number of common seals shot in that quarter is 17.5. The quarter when the fewest common seals have been reported as shot is the second (May, June, July) which accounts for 17.6% of shot common seals (a mean of 10.8 seals per year for that quarter). However, there is no statistical evidence for a difference in the percentage of common seals shot in each quarter.

## Establishment Types Responsible for Shooting

In September 2015, Marine Scotland published a review of the first 4 complete years of seal licensing. From this report it is possible to see that more seals have been reported as shot by river fisheries and netting stations (737 seals) than by fish farms (634 seals) (see **Table 6**). Fish farms have reported fewer shot seals each successive year. In 2014, 39% of reported shot seals were shot at fish farms and 61% were shot at fisheries and netting stations.

## Approach 2—Necropsy Data

The majority of the seal management cases necropsied at Scotland's Rural College (SRUC) Wildlife Unit were found to have been shot effectively with a single shot destroying the cranial vault (SRUC Wildlife Unit, 2012; Brownlow and Davison, 2013, 2014). However, each seal management case study report highlights at least one case of concern. In 2012 two seals (out of the 21 examined) showed signs of multiple gunshot wounds and blood aspiration which suggested that they had not been killed by the first shot (SRUC Wildlife Unit, 2012). In 2013, one seal (out of the seven examined) had been shot in the neck and, in 2014, one (out of the six examined) had been shot through the mandible (Brownlow and Davison, 2013, 2014).

**Table 7** shows the species, sex and reproductive state of shot seals necropsied by SMASS and SMRU between 2011 and 2014. Thirty-seven seals were necropsied in total; 26 gray seals and 11 common seals. Thirteen of them were pregnant gray seals, 11 of which were necropsied in 2012. They were reported between 11th May and 20th August (SRUC Wildlife Unit, 2012). One pregnant gray seal was necropsied in 2013 and another in 2014, both were reported in June (Brownlow and Davison, 2013, 2014). The pups of the pregnant females necropsied by SMASS were in various stages of gestation (Brownlow A., 2015, pers. comm.).

The two species differed significantly in the distribution of sex and physiological status of necropsied seals (Fisher's Exact Test, $P = 0.006$). To see where the difference lay, further tests were carried out. The distribution of males and females did not differ between species. The distribution of pregnant and non-pregnant females did differ by species (Fisher's Exact Test, $P = 0.02$) with all of the necropsied pregnant seals being grays.

**Table 8** compares the number of cases reported to SMASS (some of which were recovered for necropsy) with the number of animals reported as shot to Marine Scotland. For the years 2011–2014, only 5.1% of gray seals and 3.7% of common seals reported as shot to Marine Scotland were also reported to SMASS. Two unidentified carcasses were also reported to SMASS in 2012 but, even if they were included, the percentages would not be much higher (5.3% if they were both gray or 4.5% if they were both common). The actual necropsies of shot seals carried out by SMASS and SMRU accounted for 2.3% of the gray seals reported shot and 4.5% of the common seals reported as shot[1].

**TABLE 6 | Number of gray and common seals reported shot by fish farms and river fisheries and netting stations 2011–2014 (Marine Scotland, 2015).**

| Year | Fish farms | | River fisheries/Netting stations | | Total |
|---|---|---|---|---|---|
| | Seals reported as shot | Percentage of total | Seals reported as shot | Percentage of total | |
| 2011 | 241 | 52.5 | 218 | 47.5 | 459 |
| 2012 | 208 | 48 | 225 | 52 | 433 |
| 2013 | 105 | 38 | 169 | 62 | 274 |
| 2014 | 80 | 39 | 125 | 61 | 205 |
| Total | 634 | 46.2 | 737 | 53.8 | 1371 |

## Approach 3—License Holder Survey

All returned surveys were received anonymously except where the license holder chose to give their contact details. Of the 52 surveys sent out 31% ($n = 16$) were returned. Two surveys were filled in on-line and 14 paper surveys were returned. The responses received are presented here.

### Responses

*Question 1: What problems have you experienced with seals?*

It can be seen in the responses to Question 1, as shown in **Figure 2**, that a greater number of respondents felt that seals were killing or causing severe damage as compared to less severe damage resulting in the escape of fish or the damage to equipment.

*Question 2: Do you use or have you used Acoustic Deterrent Devices (ADDs) also known as pingers or seal scarers?*

56% of respondents ($n = 9$) answered "Yes," that they use ADDs.

*Question 3: Did the device deter seals from entering the target area?*

Of the nine respondents that use ADDs, two said that the device was effective in deterring seals from entering the target area; four said the device was sometimes effective in deterring seals; two ticked "yes" and "sometimes" (one of them specifying that it was effective on the coast and sometimes effective in-river); one respondent ticked "yes," "sometimes," and "no" then specified that it was effective for the first 3 years, was only effective sometimes in the third and fourth year of use and had ceased to be effective in the fifth year of use.

*Question 4: Have you used other methods to deter seals?*

None of the respondents use floats or buoys to deter seals. Four of them use predator nets and seven use tensioned or false-bottom nets to exclude seals. Dead fish are removed from the dead-fish basket by four of the respondents and 2 respondents use screening blinds. Thirteen respondents shoot seals to deter attacks. Other methods used included the use of poison (prior to 1970) and using boats to chase the seals away.

*Question 5: Has shooting individual seals helped deter other seals from approaching or entering the fishery/fish farm?*

Six respondents (37.5%) said that shooting individual seals had helped deter other seals. One said it had not deterred other seals. Nine respondents did not know whether it had deterred other seals or not.

*Question 6: Have you injured (but not killed) any seals and therefore had to locate them and humanely dispatch them afterwards?*

All 16 respondents said they had not injured any seals and had to locate and dispatch them afterwards.

[1]The apparent discrepancy in the percentage of common seals reported to SMASS and the number necropsied is because, in 2014, no common seals were reported to SMASS by seal license holders and yet two stranded seals were diagnosed as shot at necropsy.

**TABLE 7 | Species, sex, and reproductive state of shot seals necropsied by Scottish Marine Animal Stranding Scheme (SMASS) and Sea Mammal Research Unit (SMRU) by Seal Management Area 2011–2014 (SRUC Wildlife Unit, 2012; Brownlow and Davison, 2013, 2014; Davison N., 2015, pers. comm.).**

| | Gray seals | | | Common seals | | | |
|---|---|---|---|---|---|---|---|
| | **Male** | **Pregnant female** | **Non-pregnant female** | **Male** | **Pregnant female** | **Non-pregnant female** | **Total** |
| East Coast | 1 | 1 | 2 | | | | 4 |
| Moray Firth | 5 | 12 | 1 | 4 | | 1 | 23 |
| Orkney/N Coast | | | | | | 1 | 1 |
| Shetland | | | | | | 1 | 1 |
| Southwest Scotland | | | 2 | 1 | | | 3 |
| West Scotland | | | 1 | 2 | | 1 | 4 |
| Western Isles | 1 | | | | | | 1 |
| Total | 7 | 13 | 6 | 7 | 0 | 4 | 37 |

*Question 7: Have you recovered the carcasses of any shot seals?*
No respondents have recovered all of the seals they have shot and only four of them have recovered some of the shot seals. 62.5% ($n = 10$) of respondents had not recovered any of the seals that they have shot and two respondents replied that they have not shot any seals yet. Therefore, of the respondents that have shot seals, 71% of them have not recovered any carcasses and the remainder had only recovered some (not all) of the seals they had shot.

*Question 8: How many carcasses have you recovered?*
Of the four respondents who have recovered some carcasses, two said they had each recovered 1 carcass. Another said they had recovered 20% and the other said they had recovered "most" shot seals.

*Question 9: What did you do with the recovered carcass(es)?*
Of the four respondents who have recovered some carcasses, two said they reported it to the Scottish Agricultural College/SRUC. One of these also reported it to Marine Scotland. One of the other respondents also reported their carcass to Marine Scotland. One respondent ticked "other" and specified that they had reported it to SMRU.

*Question 10: If you answered "no" or "some" to question 7, what has prevented you from recovering the carcasses?*
See **Table 9** for responses.

*Question 11: Please indicate whether you are a fish farm, fishery, academic institution or other.*
Twelve survey respondents were fisheries and four were fish farms.

*Question 12: Please indicate which Seal Management Area(s) you hold or have held a license for.*
See **Table 10** for responses.

### Analysis of License Holder Survey Results

Using the data gathered from the license holder survey, a number of statistical tests were carried out.

There was no statistically significant evidence that fish farms and fisheries were different in their use of Acoustic Deterrent Devices (ADDs). However, there is a weak tendency, suggesting that if there had been more respondents, it may have been shown that fisheries were less likely to use ADDs than fish farms (Fisher's exact test, $P < 0.09$).

There was no statistical evidence that the response to question 3 (did the device deter seals from entering the target area?) differed between establishment type. Neither fisheries nor fish farms had differing opinions on how well ADDs work (Fisher's exact test, $P > 0.4$).

When asked about methods of deterring seals other than ADDs, there was a significant difference found between license holder types. Fisheries were more likely than fish farms to rely on shooting seals rather than other non-lethal methods to deter seals (Fisher's exact test, $P < 0.02$).

The answers to question five showed no statistical evidence of a difference in opinion between fish farms and fisheries on whether seal shooting was effective at deterring other seals (Fisher's exact test, $P > 0.4$).

There was no statistical evidence showing that fisheries or fish farms were more or less likely to recover carcasses (Fisher's exact test, $P = 1$).

## Approach 4—Interviews

Relevant information gathered during the informal interviews held with seal management stakeholders is presented here in three case studies.

### Case Study 1—Fish Farm Manager, West Scotland Seal Management Area

The fish farm manager explained that in the past, the fish farm had experienced problems with seals attacking salmon at their net pens. They had, therefore, relied on a local marksman to shoot the seals that he identified as being responsible for the attacks. The manager reported that for the last 4 or 5 years they have been using an Airmar dB Plus II Acoustic Deterrent System. Since installing it they have not had any problems with seal attacks and have not had to resort to lethal methods. The ADD is switched on all the time and is checked regularly. The pingers are positioned around the perimeter of the site and the System alternates which pinger sounds at any time.

**TABLE 8** | Gray and common seals reported as shot to Marine Scotland, seal carcasses recovered and/or reported to Scottish Marine Animal Stranding Scheme (SMASS), shot seals necropsied by SMASS and Sea Mammal Research Unit (SMRU) and the percentages these represent of the seals reported as shot 2011–2014 (SRUC Wildlife Unit, 2012; Brownlow and Davison, 2013, 2014; Marine Scotland, 2015; Davison N., 2015, pers. comm.).

| | Gray seals | | | | | Common seals | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Reported to Marine Scotland | Recovered and/or reported to SMASS | % of seals reported shot to Marine Scotland that were reported to SMASS | Necropsies carried out by SMASS or SMRU | % of seals reported shot to Marine Scotland that were necropsied | Reported to Marine Scotland | Recovered and/or reported to SMASS | % of seals reported shot to Marine Scotland that were reported to SMASS | Necropsies carried out by SMASS or SMRU | % of seals reported shot to Marine Scotland that were necropsied |
| 2011 | 366 | 2 | 0.5 | 1 | 0.3 | 93 | 2 | 2.2 | 2 | 2.2 |
| 2012* | 359 | 32 | 8.9 | 16 | 4.5 | 74 | 5 | 6.8 | 5 | 6.8 |
| 2013 | 238 | 21 | 8.8 | 5 | 2.1 | 36 | 2 | 5.6 | 2 | 5.6 |
| 2014 | 164 | 3 | 1.8 | 4 | 2.4 | 41 | 0** | 0 | 2** | 4.9 |
| Total | 1127 | 58 | 5.1 | 26 | 2.3 | 244 | 9 | 3.7 | 11 | 4.5 |

*Two unidentified seals were also reported to SMASS in 2012 but they are not included in this table.
**No common seals were reported to SMASS in 2014, however 2 stranded seals were diagnosed as shot at necropsy.

## Case Study 2—Bag Net Fisherman, Moray Firth Seal Management Area

The fisherman described the problems he has with seals entering his nets to eat trapped salmon and also attacking the fish from outside the nets. Damaged fish cannot be sold. When his nets are in use he empties them a few times each day. If a seal is in the net, he will shoot it as he believes there is no safe way to release the seal from the net. He commented that seals have sharp teeth and strong jaws and pose a danger to a fisherman who tries to handle them. He has shot seals around his nets too. He uses a Rugar. 243 rifle and shoots the seal from his boat. He always tries to recover the carcass and said that this is relatively easy if the seal is shot in the net. He explained how he ties the carcass to a buoy before reporting it to SMASS. In recent years he has worked alongside SMRU to trial ADDs including the Lofitech ADD. In order to undertake these studies he has had to apply to Marine Scotland for a License to Disturb Marine Species which is granted under regulation 44(2)(g) of the Conservation (Natural Habitats,&c.) Regulations 1994. It authorizes him to disturb the European protected species of Harbor Porpoise (*Phocoena phocoena*) and Bottlenose Dolphin (*Tursiops truncatus*) subject to various conditions. The fisherman reported that using ADDs has helped tackle the problem to some extent but that some individual seals do not seem to be deterred by them. When the seal licensing system was first introduced, the fisherman applied for his own, individual license. He has since joined with a group of other fisheries and they apply together for one license but with various individuals named as authorized marksmen.

## Case Study 3—Fishery Board Head Bailiff, Moray Firth Seal Management Area

The head bailiff explained that he shoots seals, when necessary, within the river or at the mouth of the river and the stretch of coast next to the estuary. He uses a .223 caliber rifle with a 62 grain head/bullet or a .270 caliber rifle with a 120 grain bullet. He described how he always tries to recover the carcasses but as the river is very fast flowing this is not always possible as the carcasses quickly get washed away. After a shooting, the bailiff will attempt to locate the carcass in the following days; sometimes they are found at the mouth of the river on the beach. The bailiff believes that the seals which enter the river to feed on salmon are mainly old, ill or juvenile seals. Most of the problem seals are grays. When asked about whether it is possible to identify a seal's sex before shooting it, he said that, in his opinion, it is not possible because the seals are shot in the water with only the head visible.

The bailiff referred to the busy nature of the river and the bay where the river meets the sea (it is a popular spot for tourists, dog walkers, bird watchers etc.,) and how it means that there are many times when it is inappropriate or dangerous to shoot a seal especially during the summer months. Therefore, at times, the bailiff has to refrain from shooting a seal which he would prefer to remove. The bailiff believes that alternative means of seal control such as ADDs are not, so far, appropriate for seal control in the area as it is a constantly changing environment and, therefore, where to position an ADD is not clear. There is no electricity supply and monitoring battery-operated devices might be difficult.

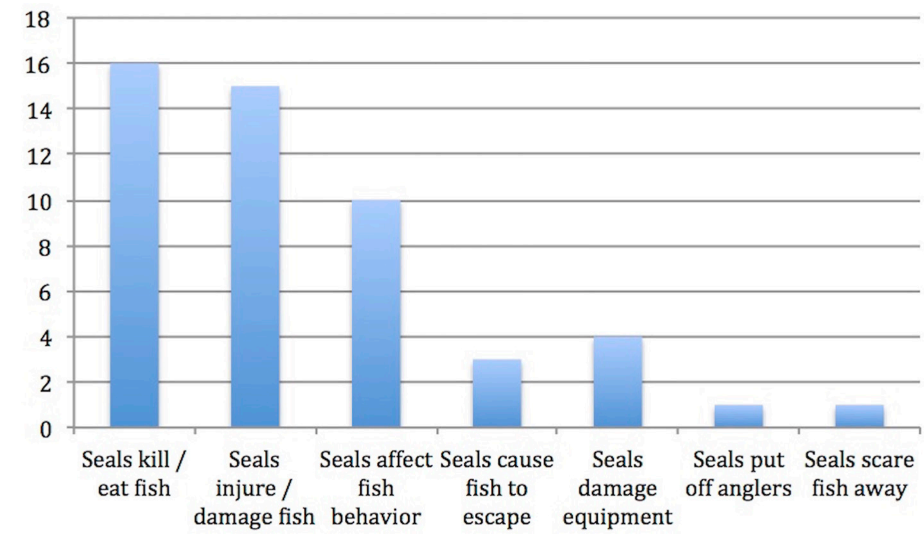


**FIGURE 2 | Responses to Question 1 of License Holder Survey "What problems have you experienced with seals?."**

# DISCUSSION

## Number of Seals Shot under License in Scotland

The data gathered by Marine Scotland and presented on their website relies on accurate reporting from license holders. These data are not independently verified and are, potentially, subject to error (for example in the numbers reported and species identification). The numbers themselves do not give information on whether the welfare of the shot seals is being negatively impacted but, when considered along with other available information, they show that there is cause for concern (see section on Monitoring the Welfare of Shot Seals).

The main findings from approach 1 show that a higher percentage of the total common seal population is allowed to be shot each year compared to the percentage of the gray seal population. As common seal populations around Scotland have been declining rapidly in recent years (Jensen et al., 2015) and are less numerous around Scotland than gray seals, this may seem counter-intuitive. However, the percentage of granted gray seals reported as shot shows a weak tendency to be higher than that of common seals. This difference in the numbers allocated and reported shot means that the percentage of the total population that are reported as shot each year is very similar between the two species.

The number of seals reported as shot has declined over time. In 2011, 366 grays and 93 commons were reported as shot. By 2014 (the last year for which the complete year's data is available) this had fallen to 164 gray seals and 41 common seals.

License holders in Shetland not only were granted a high percentage of the PBR of gray seals but also shot the highest percentage of the allocated number. License holders in Orkney and the North Coast were granted the lowest percentage of the gray seal PBR and yet reported shot a high percentage of this quota. License holders in South West Scotland were granted a high percentage of the PBR of gray seals in their area and yet reported that they shot the lowest percentage of this allowance.

In the Moray Firth and South West Scotland, high percentages of the PBR of common seals for each area were granted to license holders. The Moray Firth common seal population had been declining but is now considered stable (Jensen et al., 2015). However, it is possible that the additional pressure placed on a population by granting a high percentage of the PBR needs rethinking if the population is to be maintained at a favorable conservation status.

For gray seals, significantly more animals are shot in the second quarter (May-July) than in the first and fourth quarters (the period covering November–April). This could be because seals have higher nutritional demands during this period for some reason and, therefore, are more likely to come into conflict with fisheries and fish farms. For female gray seals in Scotland this is the period when they are approaching advanced pregnancy. However, in Canada it was found that female grays have higher energy requirements during the period after the breeding season due to their need to recover the body mass lost during lactation and which is needed to support pregnancy (Beck et al., 2007). In Scotland, the post-breeding period is October to January/February which coincides with when fewer seals are being shot. Perhaps the times when more seals are shot relates, not to the feeding requirements of the seals, but to periods when the weather is better and therefore seals are more likely to be sighted by license holders and when marksmen can shoot safely. In the case of fisheries, some are not operational in the winter and, therefore, have no cause to shoot seals during those months.

## Use of Non-lethal Methods

The Scottish Seal Management Code of Practice recommends that seals should only be shot as a last resort (Marine Scotland, 2011). However, what constitutes a "last resort" is not specified. It may be that under certain circumstances, such as when a seal

TABLE 9 | Responses to Question 10 of License Holder Survey.

| Reason for not recovering carcass | Response |
|---|---|
| Bad weather | 1 |
| Bad sea conditions | 1 |
| Seal sank after it was shot | 12 |
| Seal swam away after it was shot | 0 |
| It was too dangerous for the marksman to reach the seal | 7 |
| We didn't know that we were supposed to recover seal carcasses | 0 |
| Other (please specify) | 1 (1: H & S reasons, disposal issues, fish welfare, staff welfare, distance to SAC[a]) |

[a]*It is assumed that H & S means "Health and Safety" and that SAC means "Special Area of Conservation," although the survey respondent did not specify this.*

TABLE 10 | Responses to Question 12 of License Holder Survey.

| Seal management area | Response* |
|---|---|
| East Coast | 3 |
| Moray Firth | 5 |
| Orkney and North Coast | 0 |
| Shetland | 2 |
| South West Scotland | 2 |
| West Scotland | 4 |
| Western Isles | 2 |

**Some license holders have establishments in more than one Seal Management Area.*

is trapped inside a bag net, as described in Case Study 2, seal shooting is unavoidable, but these scenarios should, ideally, be exceptional.

From the survey carried out for this study, it appears that fisheries are more likely to resort to shooting than fish farms, rather than using non-lethal methods. This could be because there are more means of deterring seals from fish farms than fisheries. Indeed, in the questionnaire, some of the non-lethal methods listed were specific to fish farms. However, some methods are available to fisheries. Trials by Harris et al. (2014) concluded that ADDs can be an effective way to reduce seal predation from fishing nets. However, the license holder survey showed a weak tendency that fisheries are less likely to use ADDs than fish farms. Although the river bailiff interviewed for this study (Case Study 3) suggested that the river he manages may not be a suitable site for ADDs, experiments carried out by Graham et al. (2009) found that the use of ADDs reduced the likelihood of a seal being spotted upstream of the ADD by one half in their study river. Responses to the license holder survey suggested that ADDs are less effective in some locations and that they lose efficacy over time. These are issues that merit further research especially as it appears that more seals are being shot by fisheries than by fish farms and, therefore, fisheries need effective deterrence methods to reduce the number of seals they are shooting.

The results of the license holder survey and the interviews clearly demonstrated that fisheries and fish farms are concerned about seals killing and injuring salmon. As well as being of economic importance for these stakeholders it is also a fish welfare issue especially for the farmed salmon which are directly under human protection. Hence, whichever methods of seal deterrence are employed by fish farms and fisheries, they will be chosen, partly, because they do not have a negative impact on fish welfare.

Before granting a seal license, Marine Scotland must "have regard to any information they have about the effectiveness of non-lethal alternative methods of preventing seal damage to the fishery or fish farm concerned" (The Stationery Office, 2010). Such information should be provided to Marine Scotland via the application forms submitted by license applicants.

## Monitoring the Welfare of Shot Seals

A seal license must impose conditions about the recovery of carcasses (The Stationery Office, 2010). However, the license holder survey found that 71% of respondents who had shot seals had not recovered any carcasses. This result is supported by the information collected from SMASS (see **Table 8**) which shows that very small percentages of shot seals are reported to them and, therefore, few carcasses are recovered for necropsy. The number of shot seals actually necropsied between 2011 and 2014 represents only 2.7% of the total number of seals reported as shot to Marine Scotland.

SMASS suggests that cases submitted for necropsy are not representative of all seals shot under license (SRUC Wildlife Unit, 2012; Brownlow and Davison, 2013). Marksmen may choose to only recover seals that have been shot well. Seals that were shot badly may dive or swim away with their injuries. These seals are not available for necropsy. Seal carcasses that wash up and are subsequently found by landowners or members of the public go some way to alleviating this bias but these cases are few and far between and, often, are not in a good condition for study.

Of the license holders that had shot seals but failed to recover them, 85.7% gave the seal sinking as a reason. Butler et al. (2008) reported that most shot animals sink immediately. During the pilot Moray Firth Seal Management Plan, 12% of seals killed at netting stations were recovered and only 5% of those shot in rivers (Butler et al., 2008). According to the North Atlantic Marine Mammal Commission (NAMMCO) the nutritional state of a seal affects its buoyancy: fat animals float and thin animals sink (NAMMCO, 2006). For harp seals in Greenland this is considered to be a seasonal issue relating to breeding periods and the condition of the seals' prey (NAMMCO, 2006). If more carcasses are to be recovered in Scotland, the likelihood of whether shot gray and common seals will float or sink during particular periods of the year could be investigated.

By consulting with license holders, it may be possible to determine what other factors are contributing to so few seals being collected and to explore ways of increasing the number of recoveries. Forty-four percent of respondents to the survey said it was too dangerous for the marksman to retrieve the carcass. As no specific details about what dangers are involved were given, this needs further investigation. The possibility of photographing carcasses or tagging them in order to associate seal management cases with carcasses which subsequently wash up could be considered. The use of independent witnesses or assessors to monitor seal shooting incidents could allow the practicalities of carcass retrieval in differing circumstances to be assessed.

Despite the low numbers of shot seals being necropsied, there is clear evidence of seals being shot in ways that do not follow the Scottish Seal Management Code of Practice guidelines and which could negatively impact on the welfare of the seals being shot. The seals that were shot in the mandible and neck and the others which had multiple gunshot wounds as detailed in the Seal Management Cases reports for 2012, 2013, and 2014 show that there is cause for concern. If a greater number of carcasses were recovered for necropsy, then a more detailed picture of how seal welfare is being impacted by the licensing system would emerge.

One survey respondent ticked that "bad weather" was a reason for not recovering a carcass. Another indicated that "bad sea conditions" had prevented them from retrieving the carcass. The European Food Safety Authority (EFSA) concluded that shooting seals in bad weather and on bad habitat means there is a reduced chance of an effective hit and that greater suffering is, therefore, "likely" to occur (EFSA, 2007). As the Scottish Seal Management Code of Practice clearly states that shooting should only take place "in suitable weather conditions when there is sufficient visibility and sea conditions are such as to allow a clear shot" (Marine Scotland, 2011), it is of concern that some license holders are not following this guidance. The introduction of refresher training courses for nominated marksmen could help to ensure that the Code of Practice is being properly adhered to.

The welfare implications of using firearms (and other hunting methods) to stun seals was assessed by EFSA (2007). They concluded that, when used correctly, it was "very likely" to "likely" that a seal would be effectively shot and that suffering would be "negligible". It was considered "unlikely" that a seal would be ineffectively shot or killed but that suffering would be "high" if that did happen. Sainsbury et al. (1995) state that human actions that cause instantaneous deaths do not negatively impact on welfare because there is no fear, distress, or pain. Therefore, if carried out properly, shooting should not have a negative impact on seal welfare.

The concern is for seals which are ineffectively shot and which subsequently suffer (EFSA, 2007). How does the Marine (Scotland) Act 2010 provide for this possibility? In Section 112 (1) (b), the Act states that a seal license should specify what to do if a seal is injured during an attempt to kill it "in order to reduce the risk of it suffering unnecessarily" (The Stationery Office, 2010). The Scottish Seal Management Code of Practice states that steps should be taken to prevent a "prolonged and painful death" by finding and humanely killing any injured animals (Marine Scotland, 2011). No details are given about how to achieve this, though it is something that marksmen are trained in during completion of the Seal Management Professional Development Award (SQA, 2011). The checking of seal consciousness by palpation of the skull, as recommended in Canada, may not be appropriate or possible in Scotland where seals are always shot in the water (Marine Scotland, 2015). This, in itself, is also a cause for concern. Burdon et al. (2001) state that "shooting seals in open water can never be humane" and the Independent Veterinarians' Working Group on the Canadian Harp Seal Hunt recommended that seals should not be shot in water because of the potential for wounded animals to be lost (Smith, 2005). Daoust and Caraguel (2012) reported that, in Canada, shooting a seal in the water meant a 30% chance of a poor welfare outcome compared to a 2.6% risk for seals shot on ice.

According to the responses to the license holder survey, none of the respondents had had to locate and humanely dispatch an injured seal and none of them said that a seal had swum away after being shot. However, SMASS have had two cases of seal carcasses showing multiple gunshot wounds that had not been killed rapidly and so, clearly, there are cases of seals being injured and not killed instantly (SRUC Wildlife Unit, 2012). This has clear negative implications for seal welfare.

With so few carcasses being recovered, it is impossible to know how many seals need to be shot more than once and whether some seals are escaping or sinking and drowning after being hit, but not killed, by an initial shot. Though a quick death is the objective according to the Scottish Seal Management Code of Practice, there is no specific mention of what is an acceptable Time to Death (TTD) for a shot seal. This is something that deserves consideration as a criterion for the future monitoring of seal shooting incidents.

## Welfare of Non-target Seals

### Pregnant and Lactating Seals

The Marine (Scotland) Act 2010 and the Scottish Seal Management Code of Practice do not specify closed seasons and do not detail how to ensure that pregnant females are not targeted (The Stationery Office, 2010; Marine Scotland, 2011). Thirty-five per cent of the shot seals necropsied by SMASS during 2011–2014 were pregnant and it is likely that other, unrecovered, shot seals were also pregnant. The legislation states that a seal license may specify periods when seals may not be killed such as when females are likely to be in an advanced state of pregnancy (The Stationery Office, 2010).

After impregnation, gray seals in the North East Atlantic have a period of suspended development of ~104 days, followed by an active gestation of 246 days (Yunker et al., 2005). The delayed implantation in common seals in Alaska lasts ~77 days with an active gestation of about 252 days and it is assumed that common seals in Scotland have a similar period of active gestation (Pitcher and Calkins, 1979). Advanced gestation is considered to be the latter half of the third trimester (Brownlow A., 2015, pers. comm.) and, therefore, for both gray and common seals could be considered to be, roughly, the last 40 days before parturition. In Scotland the majority of gray seal pups are born between September and late November/early December (Russell et al., 2013; SMRU, 2014). Therefore, female gray seals will be in a state of advanced pregnancy from late July. In 2012, pregnant gray seals were shot in this period in Scotland (SRUC Wildlife Unit, 2012). **Table 4** shows that the majority of gray seals were shot in the period May–July, significantly more than in two of the other quarters. Many of these could have been pregnant females. Common seals give birth to their pups from late May to early July

(SMRU, 2014; Duck, 2010) and, therefore, their advanced stage of gestation starts in mid-April. Common seals have been shot during these periods. If pregnant seals are not to be targeted, then closed seasons need to be implemented.

Some authors assert that the ability of fetuses to experience pain *in utero* has been overestimated (Mellor et al., 2007). Mellor and Diesch (2006) state that for an animal to suffer it must be sentient and conscious and that, until at least halfway through pregnancy, fetuses are not sentient. Even once the fetus is capable of sentience, it remains unconscious and, therefore, does not perceive the sensory input that it receives (Mellor and Diesch, 2006). This suggests that, even in late pregnancy, the fetus is incapable of suffering. These conclusions are based on observations of fetuses and new-born farmed ungulates (Mellor and Diesch, 2006). Whether or not these results are applicable to all other mammals, including marine mammals is unclear. However, if it is the case that seal fetuses are incapable of suffering, then the shooting of pregnant seals in Scotland is not a welfare issue for the fetuses, though it is, of course, still necessary for the mother seal to be shot accurately to ensure that she experiences a quick death.

The Marine (Scotland) Act 2010 states that licenses may specify that female seals cannot be shot when they have dependent pups (The Stationery Office, 2010). Gray seal pups suckle from their mothers for between 16 and 23 days, while lactation lasts for between 4 and 6 weeks in common seals (Atkinson, 1997; Duck, 2010; SMRU, 2014). Marine Scotland (2014) notes that lactating females often leave their pups alone while they go foraging at sea. It is therefore, possible for a lactating mother to be targeted under the licensing system and for her dependent pup to be left to starve to death. **Tables 4, 5** show that gray and common seals are being shot during the periods when pups are born and are dependent on their mothers.

A review of sick and injured gray seal pups which were presented for rehabilitation in South-west England found that 91% of the unweaned pups had been separated from their mothers and that they would have become malnourished if they had not been rescued (Barnett et al., 2000). Anderson et al. (1979) found that in over 50% of gray seal pup deaths, the main cause of death was failure of or disturbance to the mother-pup bond. If the pup loses contact with its mother during the lactation period then its chances of survival are very low (Anderson et al., 1979). Osinga et al. (2012) observed that orphaned common seal pups in the Wadden Sea, Netherlands were never taken care of or allowed to suckle by other mothers in the area. Therefore, the shooting of any females that have dependent young will, most likely, result in two deaths: the death of the mother and the starvation of the pup.

Is it possible for a marksman to know whether an adult female seal has a dependent pup? Osinga et al. (2012) found that common seal mothers and pups stay close together on land and in the water. In their study the mothers were not seen to leave their pups in order to go foraging but this may be because the geography of the Wadden Sea means there is nowhere safe for a mother to leave her pup while she forages. The authors state that whether or not females leave their pups differs according to different populations. Indeed, studies in Sable Island, Canada and Maine, USA found that mother common seals did not fast during the lactation period and were reliant on foraging in order to produce enough milk to feed their pups (Boness et al., 1994; Skinner, 2006). A study of common seals in the Moray Firth, Scotland found that females do not feed much immediately after parturition and during the early stages of lactation but that they do resume foraging before the pups are weaned (Thompson et al., 1994). The radio-tagged females in the study stayed close to haul-out sites for the first 2 weeks after pupping before spending more time at sea. It was not clear whether pups accompanied their mothers on feeding trips although some of the studied females changed their haul-out site when they started foraging suggesting that pups moved to the new haul-out site with their mothers. There are fewer studies of foraging in lactating gray seals, but that of Lydersen et al. (1994) suggests that at least some lactating female gray seals are actively foraging prior to weaning their pups.

To avoid the shooting of a mother seal with a dependent pup, it is clear that a mother should never be shot when a pup is visible, including if the pup is swimming. As feeding mothers may not be possible to differentiate from other seals, closed seasons would be the best way to prevent mothers with dependent pups from being targeted.

### Other Non-target Seals

Six respondents (37.5%) to the License Holder Survey thought that shooting seals deterred other seals from approaching the area. Rifle shots can disturb non-target seals (Bonner, 1993) and, if they are on land and flee to the sea over rocky shores, they could be injured (Simmonds and Robotham, 2015). Human-caused disturbance of hauled-out seals can also lead to pups becoming separated from their mothers (Osinga et al., 2012) and this is, potentially, another negative welfare impact of seal shooting. To assess whether this is an issue for seals in Scotland, it is necessary to find out whether seals are being shot near breeding sites where pups could be disturbed.

## A Note on the Approaches Used

Although each of the approaches used in this study has its own limitations and our investigations can be considered preliminary, by combining and comparing the approaches, the issue of seal welfare under the licensing system can be considered. By comparing the number of seal management cases reported to SMASS to the number reported to Marine Scotland, it is clear that there is a huge discrepancy and that the reporting and carcass recovery system requires significant improvement.

The data from the survey and the interviews have highlighted some of the issues affecting some license holders. However, it must be noted that the majority (75%) of respondents were fisheries or fishery boards. Only four replies came from fish farms. The fish farms represented areas in Shetland, South West Scotland, West Scotland, and the Western Isles. Unfortunately no replies came from Orkney which is the Seal Management Area where the greatest number of gray seals have been reported shot to Marine Scotland (see **Figure 1**).

Inconsistencies in the answers given to the survey questions may have impacted on the results. For example, it is noted that one respondent did not answer question 4 to say which methods other than ADDs they used to deter seals but then, subsequently, gave answers to questions 5, 7, 8, and 10 indicating that they had shot seals.

Those license holders who completed the survey may not be representative of all license holders. Those who responded might have wanted to contribute to register their views of the current licensing system. The respondents may have wanted to demonstrate that the licensing system is transparent and that they have nothing to hide especially if they are not shooting any or many seals. Unanswered surveys may be due to a concern that their survey responses would paint them in a bad light. License holders who shoot a lot of seals may have chosen not to reply because they are worried about reprisals from activist groups. It is recognized by many that the issue of seal shooting is a sensitive subject. Some people may, simply, not have had the time or inclination to complete the survey.

## CONCLUSION

The results presented here represent the first independent assessment of seal shooting in Scotland under the current legislation. From the data available, it can be seen that the number of seals reported as shot has reduced year-on-year since the licensing system was introduced. An independent assessment of the numbers being killed could improve the accuracy and reliability of the data. As only very low numbers of gray and common seal carcasses are being recovered after they have been shot by fish farms and fisheries it is difficult to assess welfare implications but, despite this, there is evidence that some seals are having their welfare negatively impacted because marksmen are failing to follow the guidance in the Marine (Scotland) Act 2010 and the Scottish Seal Management Code of Practice. Regular or refresher training courses for license holders and/or marksmen could improve adherence to the legislative requirements. Effective enforcement of the law is necessary to guarantee improved seal welfare and, in some areas, the Marine (Scotland) Act 2010 would benefit from some amendments. In particular, if the legislation aims to protect the welfare of seal fetuses and dependent pups, closed seasons need to be introduced to eliminate the shooting of pregnant and lactating females because, to date, a large proportion of the gray seals which have been necropsied were pregnant.

To make improved recommendations for ensuring that the seal licensing system does not negatively impact seal welfare, more data are required. A significant increase in the number of shot seal carcasses that are recovered and presented for necropsy would be a good place to start. We have shown that fish farms seem to be using non-lethal methods of seal deterrent more than fisheries and netting stations. More research and knowledge transfer about the availability and use of non-lethal deterrents should be a priority to enable all types of license holders to maintain fish stocks and fish welfare without having to employ the "last resort" method of shooting a seal.

## AUTHOR CONTRIBUTIONS

LN researched this topic for the MSc International Animal Welfare, Ethics and Law at the University of Edinburgh and wrote the bulk of the paper. MS and FL offered guidance, editing and critical comment on the subject matter and relevance of results. FL carried out statistical analysis of the data.

## FUNDING

The study was funded and completed by LN as part of her MSc at the University of Edinburgh. This project was awarded a stipend from the Humane Society International. Travel and postage expenses were covered by the University of Edinburgh. Authors FL and MS acted as supervisors and thus received no funding for this research.

## ACKNOWLEDGMENTS

The first author carried out this project in part fulfillment of the MSc International Animal Welfare, Ethics and Law at the University of Edinburgh. The authors thank the Humane Society International and the University of Edinburgh for supporting this project. Thanks also go to Andrew Brownlow and Nicholas Davison at SRUC and to the fish farm manager, bag net fisherman and the fishery board head bailiff for their help. Thank you to the Seal Licensing Team at Marine Scotland for answering our queries and the license holders who responded to the survey. The opinions presented here are those of the authors and do not necessarily reflect those of the organizations with which they are affiliated.

## REFERENCES

Anderson, S. S., Baker, J. R., Prime, J. H., and Baird, A. (1979). Mortality in Grey seal pups: incidence and causes. *J. Zool.* 189, 407–417. doi: 10.1111/j.1469-7998.1979.tb03972.x

Atkinson, S. (1997). Reproductive biology of seals. *Rev. Reprod.* 2, 175–194. doi: 10.1530/ror.0.0020175

Barnett, J. E. F., Woodley, A. J., Hill, T. J., and Turner, L. (2000). Conditions in grey seal pups (*Halichoerus grypus*) presented for rehabilitation. *Vet. Rec.* 147, 98–104. doi: 10.1136/vr.147.4.98

Beck, C. A., Iverson, S. J., Bowen, D., and Blanchard, W. (2007). Sex differences in grey seal diet reflect seasonal variation in foraging behavior and reproductive expenditure: evidence from quantitative fatty acid signature analysis. *J. Anim. Ecol.* 76, 490–502. doi: 10.1111/j.1365-2656.2007.01215.x

Boness, D. J., Bowen, W. D., and Oftedal, O. T. (1994). Evidence of a maternal foraging cycle resembling that of otariid seals in a small phocid, the harbor seal. *Behav. Ecol. Sociobiol.* 34, 95–104. doi: 10.1007/BF00164180

Bonner, W. N. (1993). "Killing methods," in *Antarctic Seals: Research Methods and Techniques,* ed R. M. Laws (Cambridge, UK: Cambridge University Press), 155–160.

Brownlow, A., and Davison, N. (2013). *Seal Management Cases 1 January to 31 December 2013 for Marine Scotland,* Scottish Government. Scottish Marine Animal Stranding Scheme.

Brownlow, A., and Davison, N. (2014). *Seal Management Cases 1 January to 31 December 2014 for Marine Scotland,* Scottish Government. Scottish Marine Animal Stranding Scheme.

Burdon, R. L., Gripper, J., Longair, J. A., Robinson, I., Ruehlmann, D., and Fielder, J. (2001). *Veterinary Report Canadian Commercial Seal Hunt Prince Edward*

*Island March 2001. IFAW. 36pp.* Available online at: http://www.ifaw.org/sites/default/files/2001_Veterinary%20Report%20Canadian%20Commercial%20seal%20hunt.pdf (Accessed February 22, 2016).

Butler, J. R. A., Middlemas, S. J., Graham, I. M., and Harris, R. N. (2011). Perceptions and costs of seal impacts on Atlantic salmon fisheries in the Moray Firth, Scotland: implications for the adaptive co-management of seal-fishery conflict. *Mar Policy* 35, 317–323. doi: 10.1016/j.marpol.2010.10.011

Butler, J. R. A., Middlemas, S. J., McKelvey, S. A., McMyn, I., Leyshon, B., Walker, I., et al. (2008). The Moray Firth Seal Management Plan: an adaptive framework for balancing the conservation of seals, salmon, fisheries and wildlife tourism in the UK. *Aquat. Conserv.* 18, 1025–1038. doi: 10.1002/aqc.923

Council of the European Union (1992). *Council Directive 92/43/Eec Of 21 May 1992 on the Conservation of Natural Habitats and of Wild Fauna And Flora*. Available online at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0043 (Accessed October 28, 2015).

Daoust, P.-Y., and Caraguel, C. (2012). The Canadian harp seal hunt: observations on the effectiveness of procedures to avoid poor animal welfare outcomes. *Anim. Welf.* 21, 455–455. doi: 10.7120/09627286.21.4.445

Duck, C. (2010). "Section 3.5: Seals," in *UK Marine Monitoring and Assessment Strategy. Charting Progress 2 Healthy and Biological Diverse Seas Feeder Report,* eds M. Frost and J. Hawridge (London; Department for Environment Food and Rural Affairs on behalf of UKMMAS), 506–539.

EFSA [European Food Safety Authority] (2007). Scientific Opinion of the Panel on Animal Health and Welfare on a request from the Commission on the Animal Welfare aspects of the killing and skinning of seals. *EFSA J.* 610, 1–122. doi: 10.2903/j.efsa.2007.610

Graham, I. M., Harris, R. N., Denny, B., Fowden, D., and Pullan, D. (2009). Testing the effectiveness of an acoustic deterrent device for excluding seals from Atlantic salmon rivers in Scotland. *Int. Counc. Explor. Sea J.* 66, 860–864. doi: 10.1093/icesjms/fsp111

Graham, I. M., Harris, R. N., Matejusová, I., and Middlemas, S. J. (2011). Do 'rogue' seals exist? Implications for seal conservation in the UK. *Anim. Conserv.* 14, 587–598. doi: 10.1111/j.1469-1795.2011.00469.x

Gregory, N. (2003). "Assessing the humaneness of pest control methods. In: Solutions for achieving humane vertebrate pest control," in *Proceedings of the 2003 RSPCA Australia Scientific Seminar, Telstra Theatre, Australian War Memorial,* ed B. Jones (Canberra, CA).

Harris, R. N., Harris, C. M., Duck, C. D., and Boyd, I. L. (2014). The effectiveness of a seal scarer at a wild salmon net fishery. *ICES J. Mar. Sci.* 71, 1913–1920. doi: 10.1093/icesjms/fst216

Hemmingsson, M., Fjälling, A., and Lunneryd, S.-G. (2008). The pontoon trap: description and function of a seal-safe trap-net. *Fish. Res.* 93, 357–359. doi: 10.1016/j.fishres.2008.06.013

Jensen, S.-K., Lacaze, J.-P., Hermann, G., Kershaw, J., Brownlow, A., Turner, A., et al. (2015). Detection and effects of harmful algal toxins in Scottish harbor seals and potential links to population decline. *Toxicon* 97, 1–14. doi: 10.1016/j.toxicon.2015.02.002

Königson, S., Fjälling, A., Berglind, M., and Lunneryd, S.-G. (2013). Male gray seals specialize in raiding salmon traps. *Fish. Res.* 148, 117–123. doi: 10.1016/j.fishres.2013.07.014

Littin, K. E., and Mellor, D. J. (2005). Strategic animal welfare issues: ethical and animal welfare issues arising from the killing of wildlife for disease control and environmental reasons. *Rev. Sci. Tech.* 24, 767–782. doi: 10.20506/rst.24.2.1611

Lydersen, C., Hammill, M. O., and Kovacs, K. M. (1994). Activity of lactating ice-breeding grey seals, *Halichoerus grypus,* from the Gulf of St Lawrence, Canada. *Anim. Behav.* 48, 1417–1425. doi: 10.1006/anbe.1994.1377

Macdonald, D. W., Tattersall, F. H., Johnson, P. J., Carbone, C., Reynolds, J., Langbein, J., et al. (2000). *Managing British Mammals: Case Studies from the Hunting Debate.* Oxford, UK: Wildlife Conservation Research Unit.

Marine Scotland (2011). *Scottish Seal Management Code of Practice. Marine (Scotland) Act 2010: Part 6 – Conservation of Seals 2011*. Available online at: http://www.scotland.gov.uk/Resource/Doc/295194/0121503.pdf (Accessed February 18, 2016).

Marine Scotland (2014). *Guidance on the Offence of Harassment at Seal Haul-out Sites*. Available online at: http://www.gov.scot/Resource/0045/00452869.pdf (Accessed February 10, 2016).

Marine Scotland (2015). *Report of the Inaugural Quinquennial Review of the Operation of Seal Licensing System under the Marine (Scotland) Act 2010. Available* online http://www.gov.scot/Resource/0048/00484588.pdf (Accessed February 18, 2016).

Marine Scotland (2016a). *Salmon and Recreational Fisheries*. Available online at: http://www.gov.scot/Topics/marine/Salmon-Trout-Coarse (Accessed February 19, 2016).

Marine Scotland (2016b). *Seal Licensing*. Available online at: http://www.gov.scot/Topics/marine/Licensing/SealLicensing (Accessed February 18, 2016).

Marine Scotland (2016c). *How to Apply for a Licence*. Available online at: http://www.gov.scot/Topics/marine/Licensing/SealLicensing/applications (Accessed February 18, 2016).

Mellor, D. J., and Diesch, T. J. (2006). Onset of sentience: the potential for suffering in fetal and newborn farm animals. *Appl. Anim. Behav. Sci.* 100, 48–57. doi: 10.1016/j.applanim.2006.04.012

Mellor, D. J., Diesch, T. J., Gunn, A. J., and Bennet, L. (2007). "Fetal 'awareness' and 'pain': What precautions should be taken to safeguard fetal welfare during experiments?" in *Proceedings 6th World Congress on Alternatives and Animal Use in the Life Sciences* (Tokyo). AATEX 14, Special Issue: 79–83.

Minister of Justice Canada (2011). *Marine Mammal Regulations (SOR/93-56). Last Amended on February 10, 2011.* Available online at: http://laws-lois.justice.gc.ca/PDF/SOR-93-56.pdf (Accessed February18, 2016).

NAMMCO [North Atlantic Marine Mammal Commission] (2006). *Report of the NAMMCO Workshop to Address the Problems of "Struck and Lost" in Seal, Walrus and Whale Hunting*. North Atlantic House, Copenhagen, Denmark. 14–16 November 2006.

Northridge, S. P., Gordon, J. G., Booth, C., Calderan, S., Cargill, A., Coram, A., et al. (2010). *Assessment of the Impacts and Utility of Acoustic Deterrent Devices. Final Report to the Scottish Aquaculture Research Forum, Project Code SARF044. 34pp*. Available online at: http://www.sarf.org.uk/reports/ (Accessed February 19, 2016).

Osinga, N., Nussbaum, S. B., Brakefield, P. M., and Udo de Haes, H. A. (2012). Response of common seals (*Phoca vitulina*) to human disturbances in the Dollard estuary of the Wadden Sea. *Mamm. Biol.* 77, 281–287. doi: 10.1016/j.mambio.2012.02.005

Pitcher, K. W., and Calkins, D. G. (1979). *Biology of the Harbor Seal, Phoca vitulina richardsi in the Gulf of Alaska. Final Report Outer Continental Shelf Environmental Assessment Program Research Unit 229, Contract Number 03-5-002-69*. Alaska Department of Fish and Game. 231–208.

Quick, N. J., Middlemas, S. J., and Armstrong, J. D. (2004). A survey of antipredator controls at marine salmon farms in Scotland. *Aquaculture* 230, 169–180. doi: 10.1016/S0044-8486(03)00428-9

RSPCA [Royal Society for the Prevention of Cruelty to Animals] (2015). *RSPCA Welfare Standards for Farmed Atlantic Salmon*. Available online at: http://science.rspca.org.uk/sciencegroup/farmanimals/standards/salmon (Accessed February 13, 2016).

Russell, D. J. F., McConnell, B., Thompson, D., Duck, C., Morris, C., Harwood, J., et al. (2013). Uncovering the links between foraging and breeding regions in a highly mobile mammal. *J. Appl. Ecol.* 50, 499–509. doi: 10.1111/1365-2664.12048

Sainsbury, A. W., Bennett, P. M., and Kirkwood, J. K. (1995). The welfare of free-living wild animals in Europe: harm caused by human activities. *Anim. Welf.* 4, 183–206.

Scotland's Aquaculture (2016). *Scotland's Aquaculture*. Available online at: http://aquaculture.scotland.gov.uk/our_aquaculture/our_aquaculture.aspx (Accessed February 18, 2016)

Simmonds, M. P., and Robotham, R. (2015). The Grey Seals of Bardsey. *British Wildl.* 27, 2–9.

Skinner, J. P. (2006). *Physical and Behavioral Development of Nursing Harbor Seal (Phoca vitulina) Pups in Maine*. Thesis, B.S. Colorado State University.

Smith, B. (2005). *Improving Humane Practice in the Canadian Harp Seal Hunt. A Report of the Independent Veterinarians' Working Group on the Canadian Harp Seal Hunt*. Available online at: http://www.thesealfishery.com/files/IVWGReportAug2005.pdf (Accessed February 22, 2016).

SMRU [Sea Mammal Research Unit] (2014). *Scientific Advice on Matters Related to the Management of Seal Populations: 2014*. Available online at: http://www.smru.st-and.ac.uk/documents/2259.pdf (Accessed March 18, 2016).

SQA [Scottish Qualifications Authority] (2011). *Arrangements for: Professional Development Award (PDA): Seal Management at SCQF level 6. SQA*. Available online at: http://www.sqa.org.uk/sqa/files_ccc/ArrangementsSealManagement.pdf (Accessed February 10, 2016).

SRUC Wildlife Unit [Scotland's Rural College Wildlife Unit] (2012). *Scottish Marine Animal Stranding Scheme*. Seal Management Cases 1 January to 31 December 2012 for Marine Scotland, Scottish Government.

The Stationery Office (1970). *Conservation of Seals Act 1970 (c.30). London*. Available online at: http://www.legislation.gov.uk/ukpga/1970/30/contents (Accessed March 18, 2016).

The Stationery Office (2010). *Marine (Scotland) Act 2010 (asp 5). UK*. Available online at: http://www.legislation.gov.uk/asp/2010/5/contents (Accessed March 18, 2016).

Thompson, D., Morris, C. D., and Duck, C. D. (2014). *Provisional Regional PBR values for Scottish seals in 2015. Seal Mammal Research Unit. SCOS – BP 14/05. P144-151 in Scientific Advice on Matters Related to the Management of Seal Populations: 2014*. Available online at: http://www.smru.st-and.ac.uk/documents/2589.pdf (Accessed November 18, 2015).

Thompson, P. M., Miller, D., Cooper, R., and Hammond, P. S. (1994). Changes in the distribution and activity of female harbour seals during the breeding season: implications for their lactation strategy and mating patterns. *J. Anim. Ecol.* 63, 24–30. doi: 10.2307/5579

Warburton, B., and Norton, B. G. (2009). Towards a knowledge-based ethic for lethal control of nuisance wildlife. *J. Wildl. Manage.* 73, 158–164. doi: 10.2193/2007-313

Yunker, G. B., Hammill, M. O., Gosselin, J.-F., Dion, D. M., and Schreer, J. F. (2005). Foetal growth in north-west Atlantic grey seals (*Halichoerus grypus*). *J. Zool.* 265, 411–419. doi: 10.1017/S0952836905006503

**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.

frontiers in Marine Science

ORIGINAL RESEARCH
published: 21 September 2016
doi: 10.3389/fmars.2016.00178

# Under Pressure: Cetaceans and Fisheries Co-occurrence off the Coasts of Ghana and Côte d'Ivoire (Gulf of Guinea)

*Marijke N. de Boer*[1,2]*, *James T. Saulino*[1], *Koen Van Waerebeek*[3] *and Geert Aarts*[2]

[1] Seven Seas Marine Consultancy, Amsterdam, Netherlands, [2] Wageningen UR, Wageningen Marine Research, Den Helder, Netherlands, [3] Peruvian Centre for Cetacean Research, Centro Peruano de Estudios Cetológicos, Museo de Delfines, Lima, Peru

Within the Gulf of Guinea high levels of fisheries-related cetacean mortality (bycatch and direct-capture) has been documented. For locally rare species such removals could potentially lead to significant population level effects. However, information on the cetacean abundance and distribution is scarce. Similarly, it remains largely unreported where fishing fleets operate offshore. A cetacean survey took place during geophysical surveys (2013–2014) along the coasts of Ghana and Côte d'Ivoire. This provided a unique opportunity to study both offshore cetacean and fishing communities. Due to large group-sizes, melon-headed whales were the most abundant (0.34 animals $km^{-1}$) followed by Fraser's dolphins and short-finned pilot whales. Range state records were confirmed for melon-headed whale and Fraser's dolphin in Ivoirian waters and ten further species represented first at-sea sightings. The artisanal fishing canoe was most abundant (92% of all vessels) and recorded up to 99.5 km from the Ghanaian coast. Asian trawlers operated over shelf areas and tuna purse-seine vessels in deep oceanic and slope waters. Fraser's dolphins, melon-headed whales, pantropical spotted dolphins, bottlenose dolphins, and pilot whales were recorded in areas with the highest fishing densities. Melon-headed whales, pilot whales, and rough-toothed dolphins were observed in vicinity of trawlers; bottlenose dolphins, pantropical spotted dolphins, and pilot whales in vicinity of canoes. Some notable differences were found in the species composition between the present surveys and port-based surveys of landed cetaceans (bycatch/direct-captures). These may be explained by (1) feeding strategies (nocturnal vs. diurnal; surface vs. deep water); (2) different attractions to vessels/fishing gear; (3) variable body sizes; and (4) difficulty to positively identify species. Despite these differences, both cetaceans and fishing vessels predominantly occurred in shelf and slope waters (< 1000 m depth contour), making fishery-related mortality likely. The poor knowledge on population trends of cetaceans in this unique upwelling region, together with a high demand for cetacean products for human consumption (as "marine bushmeat") may lead to a potential decline of some species that may go unnoticed. These new insights can provide a foundation for the urgently required risk assessments of cetacean mortality in fisheries within the northern Gulf of Guinea.

**Keywords: cetacean mortality, fisheries, drift gillnet, anthropogenic impact, cetacean distribution, population decline, Gulf of Guinea, seismic survey**



***Edited by:***
*Andrew Butterworth, University of Bristol, UK*

***Reviewed by:***
*Mark Peter Simmonds, University of Bristol, UK*
*Catherine Sarah Longo, Marine Stewardship Council, UK*

****Correspondence:***
*Marijke N. de Boer*
*marijkedeboer@sevenseasmarine.nl*

***Specialty section:***
*This article was submitted to Marine Affairs and Policy, a section of the journal Frontiers in Marine Science*

***Received:*** *12 March 2016*
***Accepted:*** *05 September 2016*
***Published:*** *21 September 2016*

***Citation:***
*de Boer MN, Saulino JT, Van Waerebeek K and Aarts G (2016) Under Pressure: Cetaceans and Fisheries Co-occurrence off the Coasts of Ghana and Côte d'Ivoire (Gulf of Guinea). Front. Mar. Sci. 3:178. doi: 10.3389/fmars.2016.00178*

## INTRODUCTION

Fisheries bycatch (entanglement in fishing gear) is a key threat to cetacean species along the coast of West Africa. The current lack of information regarding the impact on cetacean abundance and population structure hinders assessments of the sustainability of mortality levels (Van Waerebeek and Ofori-Danson, 1999; Van Waerebeek et al., 2000, 2003; Ofori-Danson et al., 2003; Clapham and Van Waerebeek, 2007; Weir and Pierce, 2012). The capture locations and thus the type of habitat (neritic, slope, pelagic) where cetacean mortality occurs remain unreported as fishermen may operate both shoreward and offshore of the continental shelf and at considerable distance from the fishing ports where they land their catches.

Within the Gulf of Guinea [extending from Cape Palmas in Liberia to Cape Lopez in Gabon; International Hydrographic Organization (IHO), 1953], dedicated port-based research on the exploitation of cetaceans in Ghanaian waters has been carried out intermittently since 1995 using specimens and photographic evidence obtained from bycatch in fisheries, directed takes and several strandings (Ofori-Danson and Odei, 1997; Van Waerebeek and Ofori-Danson, 1999; Debrah, 2000; Ofori-Danson et al., 2003; Van Waerebeek et al., 2009, 2014; Debrah et al., 2010). Recent data originating from captured specimens landed at fishing ports, as well as strandings, provided a fully validated list of 18 cetacean species for Ghana (Van Waerebeek et al., 2009). Similarly, using data originating from strandings, captures, bycatch, whaling, and a few at-sea records has provided a list of 16 cetacean species in Côte d'Ivoire (Weir, 2010; Perrin and Van Waerebeek, 2012; Weir et al., 2013a,b).

A longitudinal set of landings data on cetaceans are available from a few fishing villages in southern Ghana (Ofori-Danson et al., 2003; Debrah et al., 2010; Van Waerebeek et al., 2014; **Table 3**). The Dixcove village holds a large community of drift-gillnet fishermen in the Ahanta district in the Western Region on Ghana's coast, where cetacean landings are highest. During the latest port-based survey in Dixcove, results indicated that daily cetacean landings in a single fishing port may have increased from 0.74 animals per day in 2001–2003 (Debrah et al., 2010) to 2.82 animals per day in 2013–2014 (Van Waerebeek et al., 2014). Generally, cetacean carcasses are often used as bait in shark fisheries but most captured animals seem to be landed, butchered and sold for human consumption, the co-called trade in marine bushmeat (Alfaro-Shigueto and Van Waerebeek, 2001; Ofori-Danson et al., 2003; Clapham and Van Waerebeek, 2007). In Ghana, as well as in the neighboring countries (Togo, Benin, and Côte d'Ivoire), cetaceans are protected species, although at Ghanaian ports cetaceans are landed and sold without impediment (Debrah et al., 2010; Segniagbeto and Van Waerebeek, 2010; Sohou et al., 2013; Segniagbeto et al., 2014). Aquatic mammals are protected by Ghana's 1971 Wildlife Conservation Regulation (Debrah et al., 2010), so direct captures of cetaceans are illegal in Ghana. However, there exists no legislation that we are aware of that outlaws landings of incidentally captured animals (by-catch). In recent years it has become apparent that considerable numbers of dolphins are being directly targeted in the gillnet fisheries or are harpooned or lanced at close quarters (Van Waerebeek et al., 2009). The latter is evident by the deep piercing dorsal wounds in a number of specimens landed at the fishing port of Dixcove and confirmed through fishermen's accounts (Debrah, 2000; Ofori-Danson et al., 2003; Van Waerebeek et al., 2009). Prices paid for dolphins are as high as those for similarly-sized billfishes, such as sailfish, marlin, and swordfish (Debrah et al., 2010). A decline in fish stocks together with a rapidly growing human population has turned formerly less attractive marine resources such as cetaceans and sea turtles into marine bushmeat (Ofori-Danson et al., 2003; Clapham and Van Waerebeek, 2007). This causal relationship was frequently cited by Ghanaian fishermen when interviewed and asked to explain their increasing captures of dolphins and sea turtles (Van Waerebeek et al., 2009). The combination of an increased number of fishermen per boat and overall reduced catch levels per boat, already apparent since 2001, highlights the decline of this sector as a source of gainful employment (Atta-Mills et al., 2004). This explains the increasing pressure upon local communities to exploit all possible marine resources, including cetaceans and turtles.

Along the West African coasts no systematic monitoring of cetacean mortality occurs outside of some ports in Ghana and, more recently, Mauritania (Weir and Pierce, 2012; Mullié et al., 2013). As there are no abundance estimates for cetaceans within the region and no operational national management plans, the levels of exploitations are of great concern, particularly for species such as the Clymene dolphin (*Stenella clymene)* which accounted for a third of all the captured cetaceans landed between 2013 and 2014 at one Ghanaian fishing village (Van Waerebeek et al., 2014). The International Union for Conservation of Nature (IUCN) recently classified Clymene dolphins as a Data Deficient species (Hammond et al., 2010). However, the documented high mortality of the species in Ghanaian fisheries (Ofori-Danson et al., 2003; Van Waerebeek et al., 2009; Debrah et al., 2010) led to the addition of the eastern tropical Atlantic (ETA) Clymene dolphin to the Conservation of Migratory Species (CMS) of Wild Animals Appendix II in 2008, as a migratory species that needs, or would significantly benefit from, international cooperation (Van Waerebeek and Perrin, 2012).

In the Ivoirian/Ghanaian part of the Gulf of Guinea, the fisheries sector can broadly be categorized into three subsections: Small scale (or artisanal); semi-industrial (or coastal); and industrial fisheries. The artisanal fisheries category, where large dug-out wooden canoes are most commonly used, is the most important with over 11,200 canoes operating actively from over 300 landing sites located along the entire 550 km length of the coastline of Ghana (Aheto et al., 2012). Drift gillnets are used offshore to exploit mainly large pelagic species such as, e.g., blue sharks (*Prionace glauca),* hammerhead sharks (*Sphyrna* spp.), yellowfin tuna (*Thunnus albacares),* skipjack tuna (*Katsuwonus pelamis*), Atlantic sailfish (*Istiophorus albicans*), and swordfish (*Xiphias gladius*) [Food and Agriculture Organization (FAO), 2007]. The semi-industrial fleet operates as purse seiners targeting mainly small pelagic fish during the upwelling periods, and switching to bottom trawling for the rest of the year [Food and Agriculture Organization (FAO), 2007]. The industrial fleet is made up of trawlers and shrimpers exploiting demersal and semi-pelagic species whilst the tuna fishing vessels target mainly yellowfin, skipjack, and bigeyetuna [*Thunnus obesus*; Food and Agriculture Organization (FAO), 2007].

Here we report on a marine mammal survey that took place from a geophysical seismic survey vessel during two subsequent years along the coasts of Ghana and Côte d'Ivoire. The objective of this study was to gather new information on the poorly monitored local cetacean populations in order to understand the threat posed by interactions with fisheries either due to unintended bycatch (entanglement) or direct capture. The information presented provides (a) a valuable insight into the occurrence, relative abundance, and at-sea distribution of cetaceans; (b) an overview of the distribution of fishing activities; (c) information on those areas where fishing density levels were at their highest; and (d) an indication as to which cetacean species appear to be under the greatest fishing pressure. As such, these findings provide new directions for future assessments of fishing pressure on cetaceans through incidental catches and directed takes.

# METHODS

## Study Area

The Republic of Ghana has borders with the Republic of Côte d'Ivoire to the west and the Republic of Togo to the east. There are two seasonal periods of coastal upwelling per year (major and minor), with differing duration and intensities. During the upwelling season the sea surface temperature (SST) drops whilst the surface salinity levels increase and the dissolved oxygen levels decrease (Koranteng, 2001). The major upwelling of nutrient-rich water (the "long cold season") occurs between July and September when the SST falls below 25°C. The minor upwelling (the "short cold season") normally lasts for only about 3 weeks, occurring anytime between December and March. In between the cold seasons are warm seasons during which SST is high (27–29°C) and during which a strong thermocline is formed in continental shelf waters (Koranteng, 2001). The main local surface flow is dominated by the eastward Guinea Current, accompanied by a westward undercurrent (Adamec and O'Brien, 1978).

## Survey Design

Effort-corrected cetacean observations (i.e., number of sightings per unit of effort, whereby effort is defined as distance surveyed) were carried out in Ghanaian waters (18 April–31 May 2013) and Ghanaian/Ivoirian waters (13 February–25 May 2014) during a geophysical seismic survey onboard the *Geco Eagle* (94.8 m) and *Geco Triton* (82.7 m). The distribution of survey effort was determined by parallel survey transects designed for the geophysical activities and the vessels did not divert from the track-line when sightings were made. The *Geco Eagle* left Takoradi, Ghana on 18 April 2013 and transited to the study area (04°33′N, 002°53′W) which was located 38–67 km (range) from the Ghanaian coast. The *Geco Triton* left Takoradi on 12 February 2014 and transited to the study area (04°34′N, 003°09′W) which was located 43–76 km (range) from the Côte d'Ivoire/Ghana border (**Figure 1**). There were three different survey periods (18 April–31 May 2013; 13 February–25 March 2014; 26 March–25 May 2014) utilizing different teams of observers. The survey area covered in 2013 comprised of water depths between 1200 and 3600 m and the survey area covered in 2014 was located in both Ivoirian and Ghanaian waters situated slightly further West (water depths of 67–3650 m; **Figure 1**).

Both vessels operated with a speed over ground of ca. 4 knots. Observations were carried out during all weather conditions following guidelines for minimizing the risk of injury and disturbance to marine mammals from seismic surveys (JNCC, 2010) and this took place during all daylight hours (06:00-18:45 UTC). Whilst one observer carried out a 2 h observation watch the other observer was on break. Observational effort was conducted from the bridge wings and foredeck at 18 m height (*Geco Eagle*) and 14 m height (*Geco Triton*) with occasional watches carried out from the higher decks (20 m and 18 m respectively). The observers scanned the sea predominately ahead of the vessel with the naked eye and also used binoculars (8 × 43 and 10 × 42) for searching the horizon, aiding species identification, and group-size estimations. When a sighting was made the radial sighting distance was determined using person-specific range-sticks (Heinemann, 1981). The bearing to the sighted animals and their heading were estimated using the ship's mounted compasses which were positioned on both the starboard and portside bridge wings (*Geco Eagle*) or center console (*Geco Triton*). Sightings data included the time (UTC), GPS position, water depth, species identification, group size, and the presence of calves and/or sub-adults. DSLR cameras were used to aid species identification, confirm group-sizes and the presence of calves. Zoom lenses (e.g., Canon 7D and Canon EOS 5D Mark II with a 200 mm f2.8 lens and 1.4xconverter; a NIKON D7000 with a 70–300 mm f5.6 lens and a Canon EOS550D with a 100–400 mm f4.5–5.6 lens) were used. Environmental observations were also collected and included wind speed and direction, swell height (low < 2 m, medium 2–4 m, and large > 4 m), and visibility (estimated by eye: Poor < 1 km, moderate 1–5 km, and good > 5 km), glare intensity (strong, weak, variable, or no glare), and Beaufort sea state (BSS). Water depth and SST were routinely measured throughout the survey period (Acoustic Doppler Current Profiler data). A GPSMAP76CSx (Garmin GPS) was used to log the ship's position every minute of the survey. GPS, speed, and course data were not continuously logged by the observers during the second leg; however, this information was provided by the ship's navigators. All the observers had previous experience of conducting cetacean surveys in tropical waters.

## Species Categories

Baleen whales located too distant from the vessel to allow definite identification (>1 km) were classified as "balaenopterid" (i.e., large rorqual with vertical blow) or "Bryde's/Sei whale" (i.e., large rorquals with prominent, upright, and falcate dorsal fin). Depending on the sighting distance and glare intensities apparent, dolphins which could not be positively identified were classified as follows: *Stenella/Delphinus* sp. (definitely one of the five *Stenella* species and/or *Delphinus* species); "*Stenella* sp." (i.e., definitely a *Stenella* species with a mid-length beak); "spinner/Delphinus" (i.e., dolphins with a very long thin beak);

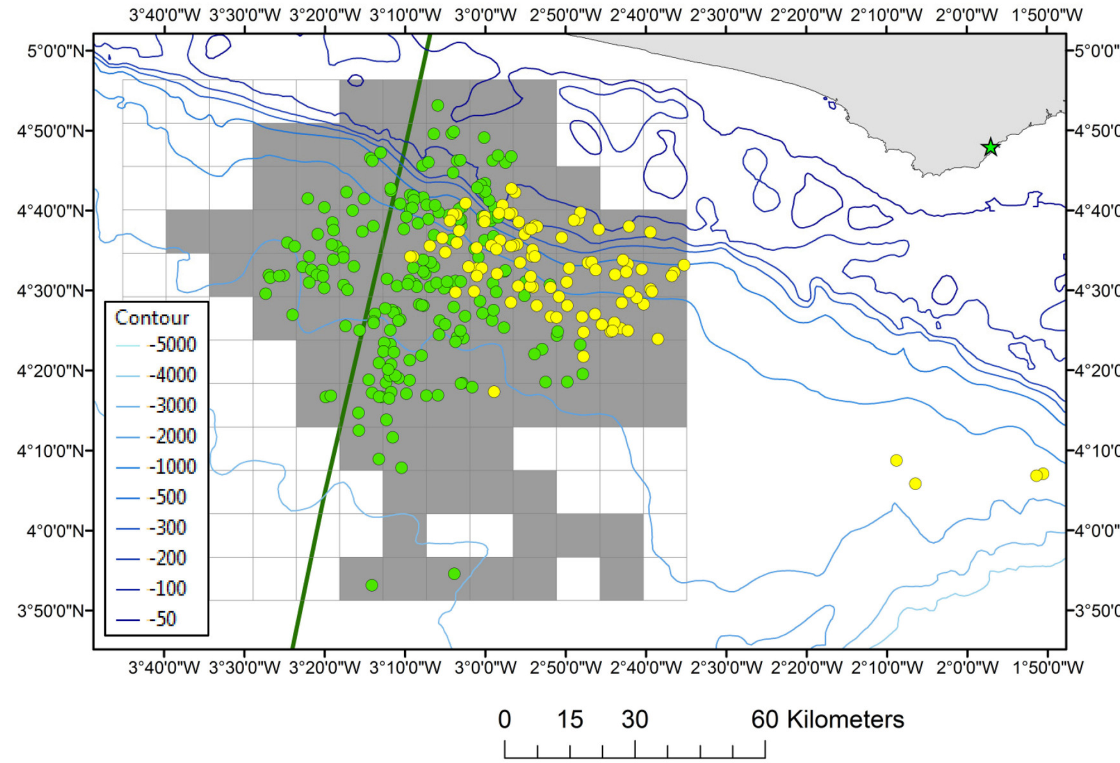


**FIGURE 1 | The location of the study area.** Grid cells are shaded gray where survey effort (2013 + 2014) took place in the (gridded) survey area. The positions of cetaceans observed in both survey years are depicted as yellow dots (2013) and green dots (2014). The EEZ border between Côte d'Ivoire and Ghana is also shown (green thick line). The position of Dixcove fishing port is presented by a green asterix. Depth contours are displayed from 50 to 5000 m water depth.

"spinner/clymene sp." (i.e., small active dolphins seen "spinning" and likely to be one of these two species); "small blackfish sp." (i.e., melon-headed whale *Peponocephala electra* or pygmy killer whale *Feresa attenuata*); or "large blackfish sp." (i.e., killer whale *Orcinus orca*, pilot whale, or false killer whale *Pseudorca crassidens*). All other unidentified animals were classed as "dolphin sp."; "large dolphin sp." or "whale sp."

## Fisheries

The following information was collected on fishing vessels in Ghanaian waters: Date, time of initial observation (UTC), and vessel type: Fishing canoe, trawler, or tuna purse-seiners. During 2013 systematic scans were carried out to record the number of fishing vessels visible to the naked eye. These systematic counts took place early morning (08:00-09:00) and afternoon (14:00-15:00), counting all fishing vessels ($\leq$5 km) around the vessel (360°). As such, these systematic scans could be used to estimate fishing vessel density (i.e., the number of vessels per unit of area). In 2014, only the location of fishing vessels was recorded, and the area surveyed was unknown. Hence, fishing vessel density could not be directly estimated. The survey in 2014 was initiated by different observers and these were informed by the client representatives that information regarding fishing vessels was to be collected by two support/chase vessels which were operating ahead of the survey vessel. These support vessels were tasked with guiding the fishing vessels away from the intended track of the seismic survey vessel. Fishing vessels were therefore treated as point observations (i.e., geographic location, date/time, and vessel type). Given the lack of effort-corrected fishing vessel data in 2014, it was assumed that all vessels within half a nautical mile on either side of the seismic survey vessel were recorded.

## Data Analysis (Effort-Corrected)

It is extremely unlikely that all animals within a surveyed area are sighted. The ability of the observer to sight a marine mammal is negatively affected by poor weather conditions. Prevailing weather conditions such as sea state, swell height and visibility were therefore considered and only cetacean data collected in "good" conditions, i.e., Beaufort Sea States (BSS 0 to 4), good visibility ($\geq$5 km) and low swells ($<$2 m) were used for data analysis. The remaining effort data collected in poor conditions were removed and classified as "off-effort." Associated sightings were downgraded to off-effort (incidental) status and not included in further analysis. Sightings collected during transits were also downgraded to incidental status as they were made outside of the main survey area.

The bearing and distance to cetacean sightings were used to estimate the position of each sighting taking into account the location of the vessel at the time of the sighting and the observation eye-height. All GPS records were converted to the following coordinate system (from now on referred to as Ghana Projection): Transverse_Mercator; Central_Meridian: −2.9875; Latitude of Origin: +4.5780; Linear Unit: Meter; Geographic Coordinate System: GCS_WGS_1984.

A grid with a resolution of 10 × 10 km was created and the latitude and longitude were assigned to the center of each grid cell when determining the mean water depth. The position of all fishing vessels (2013 and 2014) and cetaceans were imported into GIS (ArcMap 10.2.1). The relative abundance of cetaceans was then measured as the number of animals $km^{-1}$ (BSS 0–4, Swell < 2 m, visibility ≥ 5 km).

We employed statistical tests using the statistical package PASW for windows (SPSS, Inc., version 18) and the program R (version 3.2.2.) in order to adequately answer the following basic questions: (1) were there significant differences in cetacean data collected between the two surveys and, if not, could these datasets be pooled; (2) did cetacean abundance vary over different depth categories; (3) were fishing vessels heterogeneously distributed; and (4) did the spatial distribution of cetaceans overlap with the distribution of fishing vessels.

Firstly, we studied if there were potentially interannual differences occurring due to changes in survey methods or actual changes in cetacean distribution. We used a pairwise Mann–Whitney's (non-parametric) test to study potential differences between the two surveys by segregation of the relative abundance per grid cell by survey year.

Secondly, water depth is a factor that is known to influence the distribution and abundance of cetaceans (e.g., Cañadas et al., 2002). Cetaceans have shown depth-related trends in their occurrence in the waters off Angola and elsewhere in the wider Gulf of Guinea (Weir, 2011). It is therefore of interest to investigate at which depths the cetacean abundance was peaking within the present study area. We computed the indices of cetacean abundance per grid cell for different water depth categories defined as < 100 m; 100 to 200 m; 200 to 500 m; 500 to 1000 m; 1000 to 2000 m; 2000 to 3000 m and > 3000 m. We then used Kruskal–Wallis to check if the cetacean abundance was uniform distributed over the depth categories. As this was not the case we next carried out pairwise Mann–Whitney's (non-parametric) tests to study in which depth categories the indices of cetacean abundance significantly differed.

Thirdly, in order to investigate whether fishing vessels were heterogeneously distributed in space, and to map their distribution and density within the survey area we fitted a spatial model to the data. Although we could have used other methods (e.g., ordinary kriging or linear interpolation) to map the spatial distribution of fishing vessels, the advantage of fitting a spatial model is that it takes into account the uncertainty in the data, distribution of the response variable (e.g., counts) and only estimates spatial heterogeneity when there is sufficient support in the data to do so.

Because of the difference in (fishing vessel) data collection methods between the 2 years we could not pool the data and therefore modeled the fishing vessels for each year. For 2013, data on fishing vessels consisted of the number of fishing vessels counted during effort-corrected scans. All types of fishing vessels were pooled (fishing canoes, trawlers, Asian trawlers, and tuna vessels). The counts were assumed to follow a negative binomial error distribution, which allows for over-dispersion or clustering in the number of vessels observed. These counts were modeled as a function of a tensor product smooth of latitude and longitude, using a Generalized Additive Model (GAM; Wood 2006). This technique models spatial autocorrelation in the data and a significant spatial smooth implies non-uniform distribution of fishing vessels. This model was subsequently used to make a spatial prediction of the expected number of sighted fishing vessels, which was subsequently divided by the area of the scans (i.e., $\pi\, r^2$, where $r = 5$ km is the maximum sighting distance) to arrive at absolute fishing vessel density.

In 2014, the fishing vessel data consisted only of the registered location of fishing vessels. These data appeared more erroneous, with spurious spatial coordinates and lack of observations in Ivorian waters. Furthermore, the data were not effort-corrected, and only consisted of presences. Therefore, the 2014 data were modeled as a spatial inhomogeneous Poisson point process (IPP), where the distribution of individual vessels was compared with each 5 min point along the entire survey track, with a response value of 1 for the fishing vessels and a response value of 0 for the effort points (e.g., Aarts et al., 2012). Similar to 2013, these response data were modeled as smooth function of latitude and longitude using a GAM (Wood, 2006). The exponent of the linear predictor is proportional to fishing vessel density. This relative fishing vessel density was subsequently multiplied by the total number of vessels observed, divided by the total survey effort (assuming an effective survey strip of the chase vessels of 1 nautical mile) and the average predicted relative density. Under the assumption that all fishing vessels were registered within half a nautical mile of the seismic survey vessel, this leads to an absolute density of fishing vessels.

Finally, because of the poor data quality on the distribution of fishing vessels (particularly 2014), and the likely long-term effects of seismic noise on the distribution of cetaceans no statistical tests were performed to test if cetacean density significantly correlated with the density of fishing vessels. Instead, we visually evaluated the degree of overlap, and thus likely interaction frequency between fisheries and cetaceans, based on the computed fishing vessel density and the index of cetacean abundance.

## RESULTS

The total survey effort consisted of 548 h of visual observations in 2013 and 1218 h of visual observations in 2014. Survey effort was concentrated in the eastern half of the study area in 2013, whilst during 2014 survey effort expanded toward deeper waters and into Ivoirian waters as well as along the shelf into both Ghanaian and Ivoirian waters (**Figure 1**). The start of the survey in 2014 coincided shortly after the minor upwelling season in the Ivoirian/Ghanaian part of the Gulf of Guinea (December–March) although the SSTs never dropped below 25°C (data not shown). The Beaufort sea state (BSS) during the observations in both 2013 and 2014 ranged from 1 to 6. The observation effort was split across BSS 0 (1%), BSS 1 (7.5%), BSS 2 (26.1%), 3

(38.6%), and 4 (24.9%), with only 2% of effort occurring during BSS $\geq$ 5. Effort-corrected observations (data collected during good conditions) totaled 466 h along 3645 km in 2013 and 1101 h along 8273 km in 2014. A total of 705 h of observations (45%) occurred during seismic operations and 862 h during non-seismic operations (55%).

## Cetacean Occurrence, (Relative) Abundance, and Distribution

A significant difference in the relative abundance of cetaceans was detected between the 2 years (Mann–Whitney's $U = 9883{,}000$, $p = 0.006$). However, when only comparing the abundance of cetaceans within those areas where survey effort from both years overlapped this was no longer significant (Mann–Whitney's $U = 143{,}000$; $p > 0.05$). Therefore, in order to increase sample size it was decided to pool the two data sets for analysis. During effort-corrected observations, approximately 11,181 individual cetaceans were seen in 306 groups during 2013 and 2014 (**Table 1**); the majority of groups (61.8%) were observed when there were no seismic operations. The highest numbers of cetaceans were seen in Ghanaian waters where the most effort also took place (**Figure 1**).

The relative abundance of cetaceans (all species) were not distributed uniformly through all classes of depth ($\chi 2 = 14.57$, df $= 6$, $p = 0.02$). The abundance index in 2013 was significantly higher for waters of 200–500 m depth and 500–1000 m depth ($p < 0.05$; **Figure 2A**). In 2013, the cetacean abundance was significantly higher for waters of 500–1000 m depth (2.6 animals km$^{-1}$) compared to the abundance measured in 2014 (0.5 animals km$^{-1}$; $p = 0.009$; **Figure 2A**). The sample sizes for the relative abundance for the first three depth classes in 2014 and class 200–500 m in 2013 were low ($\leq$3).

## Species Accounts

Seven cetacean species were documented in 2013 and 12 species in 2014, totaling 12 species during both surveys (**Table 1**; **Figures 3–5**). There were 18 confirmed records of mixed-species groups. At least five species were observed in mixed-species groups. Most mixed-species groups ($n = 16$ records) comprised of two species but there were two groups comprising three species. Mixed-species groups mainly involved melon-headed whales and Fraser's dolphins (*Lagenodelphis hosei;* $n = 6$) or short-finned pilot whales and common bottlenose dolphins (*Tursiops truncatus*; $n = 5$). Short-finned pilot whales were also observed associating with Fraser's dolphins ($n = 3$), and rough-toothed dolphins (*Steno bredanensis*) were observed associating with Fraser's dolphin ($n = 2$) and melon-headed whales ($n = 1$). The interspecific associations involving groups of three species comprised of at least 500 melon-headed whales, 8 Fraser's dolphins and 4 rough-toothed dolphins and another record included at least 150 melon-headed whales, 5 rough-toothed dolphins, and 5 unidentified dolphins. Further details on species accounts (e.g., group-sizes, water depths, sea surface temperature, and behaviors) are described in the Supplements (Data Sheet 1 and associated Supplementary Figures 1–6).

## Distribution and Density of Fishing Vessels

The artisanal small-scale fishery was the most frequently recorded with many small wooden canoes present throughout the study area expanding well offshore (**Table 2**; **Figure 6**). At times aggregations of up to 25 canoes were recorded. The majority of fishing canoes were engaged with fishing activities (fishing, hauling and setting) mainly recorded between 06:00-08:00 and 15:00-19:00 UTC (Local Time). The most distant fishing canoe was recorded in 2586 m water depth and at a distance of 99.5 km from the Ghanaian coast. Similarly, the farthest canoe in Ivoirian waters was documented 89.8 km from the coast. Asian trawlers were mainly recorded over the shelf area in both Ivorian and Ghanaian waters but commercial trawlers were also recorded in slope waters (**Figure 6**). The tuna purse seine vessels and Fish Aggregation Devices (FADs) were generally recorded in deeper oceanic waters in the southern part of the study area (Ghanaian waters) (**Figure 6**).

Although fishing vessels occurred throughout the survey area, at least in 2013, the highest density of fishing vessels was measured for the eastern side of the study area (**Figure 7**) and specifically in deeper waters (**Figure 2B**). Since the spatial smooth of the GAM was significant (Chi$^2$ $= 32.54$, $p$-value $= 0.00031$), the distribution of fishing vessels was indeed not uniform in space. In 2013 the cetaceans occurred mainly in areas with a fishing vessel density of $\geq 0.04$ vessels km$^{-2}$ and in 2014 this was between 0.01 and 0.02 vessels km$^{-2}$ (**Figure 7**; diagnostic plots are shown in Supplementary Figure 7).

## Interactions between Cetaceans and Fisheries

For safety reasons, the chase vessels would frequently request fishing vessels to move well away from the intended track of the seismic survey vessel, and normally this occurred well before the arrival of the seismic survey vessel. Hence any interactions between cetaceans and fisheries were difficult to observe due to the distances involved. Nevertheless, some interactions were witnessed and these sightings occurred during those times when the fishing vessels were engaged in deploying, soaking or hauling gear (e.g., early morning or late afternoon). On two occasions, short-finned pilot whales were recorded in an area with at least 14 fishing canoes present. On one occasion a group of eight adults and one calf was seen in an area with an operating trawler and two fishing canoes. On 5 May 2013, in an area where one trawler and two fishing canoes (one hauling nets) were operating, a freshly dead melon-headed whale was recorded floating in the water. It seems likely that this animal was bycaught in fishing gear and subsequently lost or discarded at sea. On one other occasion a group of 300 melon-headed whales was seen in the vicinity of an operating trawler. Rough-toothed dolphins were recorded on one occasion in the vicinity of an operating trawler involving a group of 16 adults and two juveniles (water depth: 371 m). On 26 May 2013 (water depth 1280 m), a group of common bottlenose dolphins was observed in close vicinity of a fishing canoe with one dolphin surfacing directly alongside the canoe which was hauling an artisanal drift gillnet. One group of approximately 200 pantropical spotted dolphins, including at least 10 juveniles and

**TABLE 1 | Summary of cetacean sightings, individuals (ind), and indices of abundance (the number of individuals per km effort) for the 2 survey years (3,644.9 km effort in 2013 and 8,273.2 km in 2014) and pooled (11,918.1 km: 2013 + 2014).**

| Species | Number of group sightings | | | Number of individuals | | | Relative abundance index (Ind/km) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2013 | 2014 | 2013 + 2014 | 2013 | 2014 | 2013 + 2014 | 2013 | 2014 | 2013 + 2014 |
| Sperm whale | 0 | 9 | 9 | 0 | 25 | 25 | 0 | 0.003 | 0.002 |
| Balaenopterid | 1 | 14 | 15 | 1 | 17 | 18 | 0.000 | 0.002 | 0.002 |
| Bryde's whale | 0 | 3 | 3 | 0 | 4 | 4 | 0 | 0.001 | 0.000 |
| Bryde's/sei whale | 0 | 5 | 5 | 0 | 6 | 6 | 0 | 0.001 | 0.001 |
| Short-finned pilot whale | 31 | 57 | 88 | 377 | 784 | 1161 | 0.103 | 0.095 | 0.097 |
| Melon-headed whale | 10 | 11 | 21 | 2240 | 1790 | 4030 | 0.615 | 0.216 | 0.338 |
| Bottlenose dolphin | 4 | 3 | 7 | 24 | 20 | 44 | 0.007 | 0.002 | 0.004 |
| Rough-toothed dolphin | 1 | 5 | 6 | 18 | 51 | 69 | 0.005 | 0.006 | 0.006 |
| Spinner dolphin | 0 | 5 | 5 | 0 | 230 | 230 | 0 | 0.028 | 0.019 |
| Clymene dolphin | 0 | 3 | 3 | 0 | 130 | 130 | 0 | 0.016 | 0.011 |
| *Delphinus* sp. | 3 | 4 | 7 | 67 | 248 | 315 | 0.018 | 0.03 | 0.026 |
| Spinner/Clymene | 1 | 1 | 2 | 40 | 25 | 65 | 0.011 | 0.003 | 0.005 |
| Spinner/*Delphinus* sp. | 1 | 2 | 3 | 5 | 200 | 205 | 0.001 | 0.024 | 0.017 |
| Atlantic spotted dolphin* | 0 | 1* | 1* | 0 | 50* | 50* | n/a | n/a | n/a |
| Pantropical spotted dolphin | 3 | 4 | 7 | 238 | 130 | 368 | 0.065 | 0.016 | 0.031 |
| Fraser's dolphin | 6 | 8 | 14 | 980 | 598 | 1578 | 0.269 | 0.072 | 0.132 |
| *Stenella* sp. | 0 | 7 | 7 | 0 | 306 | 306 | 0 | 0.037 | 0.026 |
| Small blackfish sp. | 2 | 7 | 9 | 5 | 288 | 293 | 0.001 | 0.035 | 0.025 |
| Large blackfish sp. | 2 | 2 | 4 | 9 | 11 | 20 | 0.002 | 0.001 | 0.002 |
| *Delphinus/Stenella* sp. | 0 | 2 | 2 | 0 | 70 | 70 | 0 | 0.008 | 0.006 |
| Large dolphin sp. | 7 | 4 | 11 | 53 | 40 | 93 | 0.015 | 0.005 | 0.008 |
| Dolphin sp. | 24 | 38 | 62 | 576 | 884 | 1460 | 0.158 | 0.107 | 0.123 |
| Whale sp. | 2 | 4 | 6 | 2 | 6 | 8 | 0.001 | 0.001 | 0.001 |
| Total | 98 | 198 | 296 | 4635 | 5863 | 10,498 | 1.272 | 0.709 | 0.881 |

**Incidental sighting.*

three calves, was recorded in the presence of a canoe (water depth 989 m).

In 2013, Fraser's dolphins and melon-headed whales were recorded in the areas with the highest fishing densities (0.09 and 0.08 vessels km$^{-2}$; **Table 3**) of which the majority were fishing canoes. Likewise in 2013, Pantropical spotted dolphins were also recorded in areas with a high density of fishing vessels (0.06 vessels km$^{-2}$; **Table 3**) closely followed by common bottlenose dolphin and pilot whales (0.05 vessels km$^{-2}$), common dolphin and rough-toothed dolphin (0.04 vessels km$^{-2}$; **Table 3**). In 2014, balaenopterids (including Bryde's whales *Balaenoptera brydei*) were most abundant in shelf waters where commercial trawlers also operated. Indeed, the areas where Bryde's whales were observed had a relative high fishing density (0.04 vessels km$^{-2}$; **Table 3**). In 2014, common bottlenose dolphins and common dolphin also occurred in areas with relatively high fishing vessel densities (0.02 vessels km$^{-2}$; **Table 3**) whilst Clymene dolphin, sperm whale and Fraser's dolphin occurred in areas where the fishing density was the lowest (**Table 3**).

## DISCUSSION

Melon-headed whales were found to be the most abundant cetacean and it is therefore not surprising that the species is also regularly landed in the fishing ports in Ghana (Debrah et al., 2010; Van Waerebeek et al., 2014). The Dixcove village in the Western Region is located approximately 70 km from the present study area (**Figure 1**). Because it can be expected that the Dixcove fishermen set their driftnets in, or in close vicinity of the present study area, it is of interest to compare the cetacean species composition of landings to that observed at sea in the present study during the same survey years. The cetacean species mainly landed at Dixcove between January 2013 and February 2014 included, in order of frequency, Clymene dolphin, pantropical spotted dolphin, melon-headed whale, rough-toothed dolphin, common bottlenose dolphin, spinner dolphin, pilot whale, and occasionally long-beaked common dolphin and pygmy killer whale (Van Waerebeek et al., 2014). There are some interesting differences when comparing the species composition of landings to that of the present survey (**Table 3**). Most strikingly, Clymene dolphins were rarely identified at sea (1.3% of all sightings) yet they were the most frequently landed cetacean at Dixcove between 2013 and 2014 (32.1%; Van Waerebeek et al., 2014; **Table 3**). On the other hand Fraser's dolphins were encountered regularly offshore (4.8% of all sightings) and often in large groups (13.6% of all individuals counted offshore) yet were rarely landed at Dixcove (Debrah et al., 2010; Van Waerebeek et al., 2014; **Table 3**).

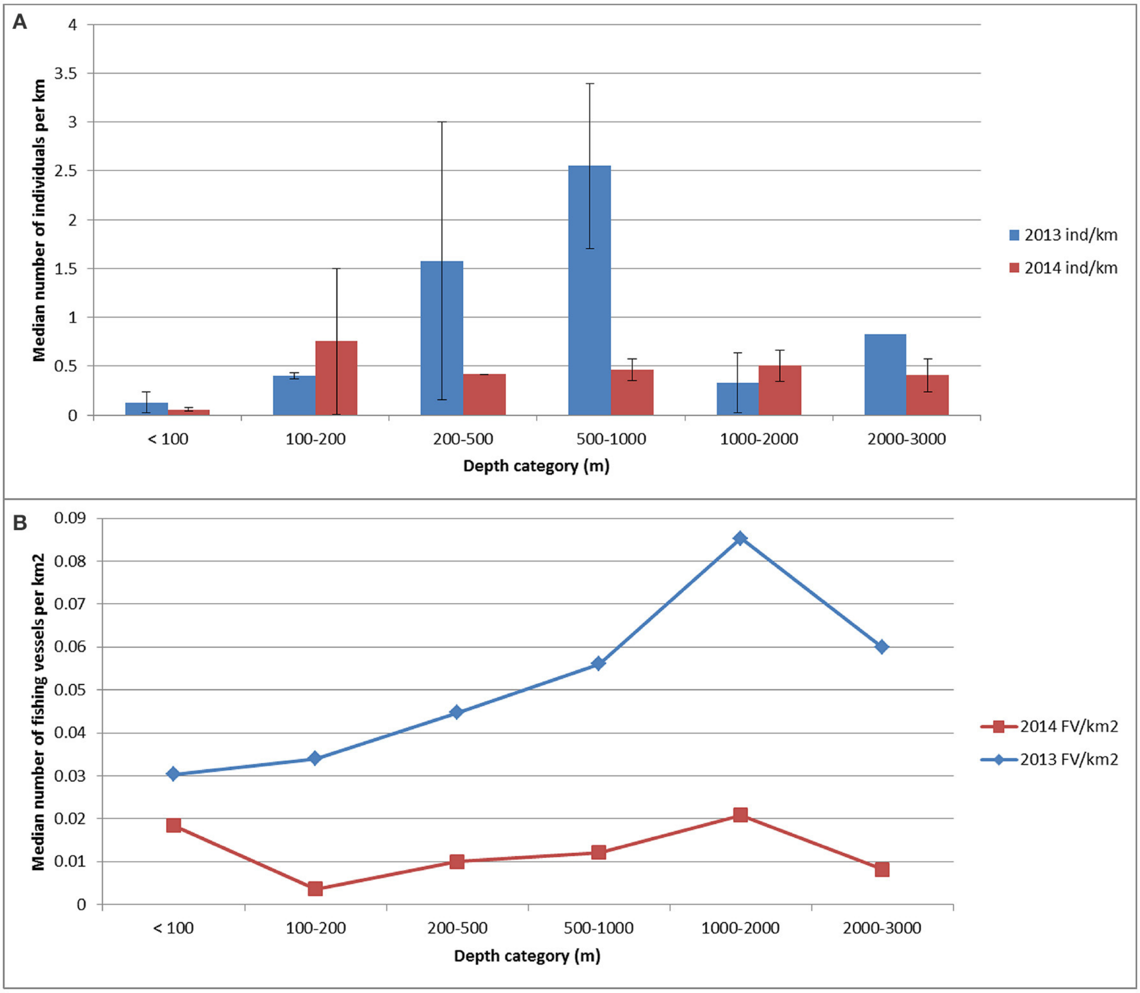


**FIGURE 2 | The (median) indices of abundance for cetaceans (number of animals km$^{-1}$ of search effort) computed for the following water depth categories: <100 m; 100–200 m; 200–500 m; 1000–2000 m and 2000–3000 m water depth for each survey year (A).** The density for fishing vessels (number of fishing vessels km$^{-2}$) for each depth category is also shown (number of vessels km$^{-2}$) for each survey year **(B)**.

## Species Accounts and Vulnerability to Fishing Mortality

We next discuss our findings for each species and confirm new species records for Ghana and Côte d'Ivoire. In addition, and based on our findings, we evaluate the species' vulnerability to fishing mortality through entanglement or direct capture in fishing gear in these waters.

### Bryde's Whales

Bryde's whales occurred mainly in shelf waters. It seems likely that the start of the 2014 survey may have been influenced by the tail of the upwelling season which created feeding opportunities for the Bryde's whales in these shelf waters consisting of small pelagic fish (e.g., sardines, *Sardinella* spp. and European anchovy, *Engraulis crassicolus*). Indeed, balaenopterids have been reported to show a close relationship with SST in areas with recently upwelled water (e.g., Gill et al., 2011). Bryde's whales have only previously been documented during the 1970s whaling activities (Best, 1996) and a stranded individual has been confirmed from Togo (Segniagbeto et al., 2014). Our records therefore present the first confirmed at-sea sightings for Ghanaian waters. Bryde's whales occurred in areas where trawlers and fishing canoes were operating (0.04 vessels km$^{-2}$; **Table 3**). Large balaenopterids, such as Bryde's whales, are known to occasionally become entangled in fishing gear, but due to their large size they do not appear to be especially susceptible (Reilly et al., 2008). We opine that overall there is a low risk of entanglement/capture in fisheries in Ghana with the higher chance of entanglement in drift gillnets in shelf waters, particularly involving smaller Bryde's whales.

### Sperm Whales

Sperm whales with juveniles were recorded in the present study and these nursing groups probably occur year-round. The historical "Coast of Africa" sperm whaling ground between latitudes 03–23°S (Townsend, 1935) combined with

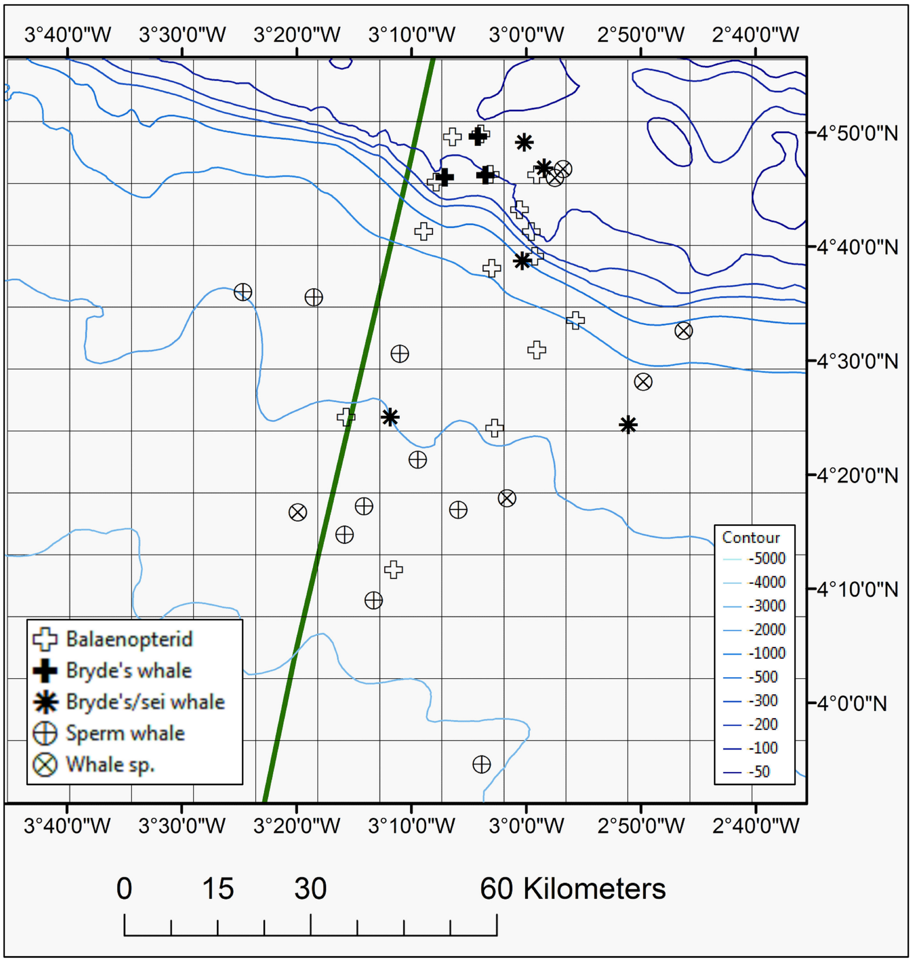


**FIGURE 3 | Map showing positions of whales species seen during the 2013 and 2014 surveys, including Bryde's whale, Bryde's/sei whale, sperm whale, unidentified balaenopterid species, or unidentified whale species.** The EEZ border between Côte d'Ivoire and Ghana is also shown (green thick line).

authenticated specimens ($n = 5$) from Benin, Ghana, and Togo suggests that this stock is also present in the northern Gulf of Guinea (Sohou et al., 2013). While confirmed at-sea sightings in offshore Ivoirian waters have previously been reported by Best (1974), our records present the first confirmed at-sea sightings in Ghanaian waters. Of the large cetaceans, the sperm whale is the most affected by entanglement in drift net fishing gear in the Mediterranean Sea (Reeves and Notarbartolo di Sciara, 2006). The deliberate capture of a small sperm whale by the crew of a large fishing canoe was previously reported in Ghanaian waters (Debrah et al., 2010). The only authenticated case of a sperm whale entangled in artisanal fishing gear within the region is an animal flensed at Bakingili, Cameroon (Ayissi et al., 2011). Other well documented interactions between sperm whales and fisheries include long-line fishing gear. In the equatorial waters of the Gulf of Guinea, and further south, long-line fishermen targeting tuna and sharks report regular predation of hooked fish by sperm whales (Van Waerebeek et al., 2009). We opine that there is a low risk of entanglement/capture in fisheries of sperm whales in Ghana although smaller whales may form an occasional target for deliberate capture.

## Short-Finned Pilot Whales

Short-finned pilot whales have been sighted off Côte d'Ivoire (Cadenat, 1959) and landed in Ghana (Ofori-Danson et al., 2003; Van Waerebeek et al., 2009, 2014; Debrah et al., 2010), Togo (Segniagbeto et al., 2014), and Benin (Sohou et al., 2013). Our records present the first confirmed at-sea sightings in Ghanaian waters. Despite their large size and deep-water foraging habits they do infrequently become entangled in artisanal fishing gear (5.5–10.3% since 1999; Van Waerebeek et al., 2014 **Table 3**). Interactions with other fisheries within tropical and sub-tropical zones involve pelagic long-liners that target tuna (*Thunnus* spp.) and swordfish (*Xiphiius gladius*) which, in other regions, are often depredated not only by killer whales (*O. orca*) and false killer whales (*P. crassidens*), but also short-finned pilot whales (Dalla Rosa and Secchi, 2007; Hernandez-Milian et al., 2008). However, during the present survey, commercial boats targeting tuna were only recorded on four occasions all of which occurred in deep

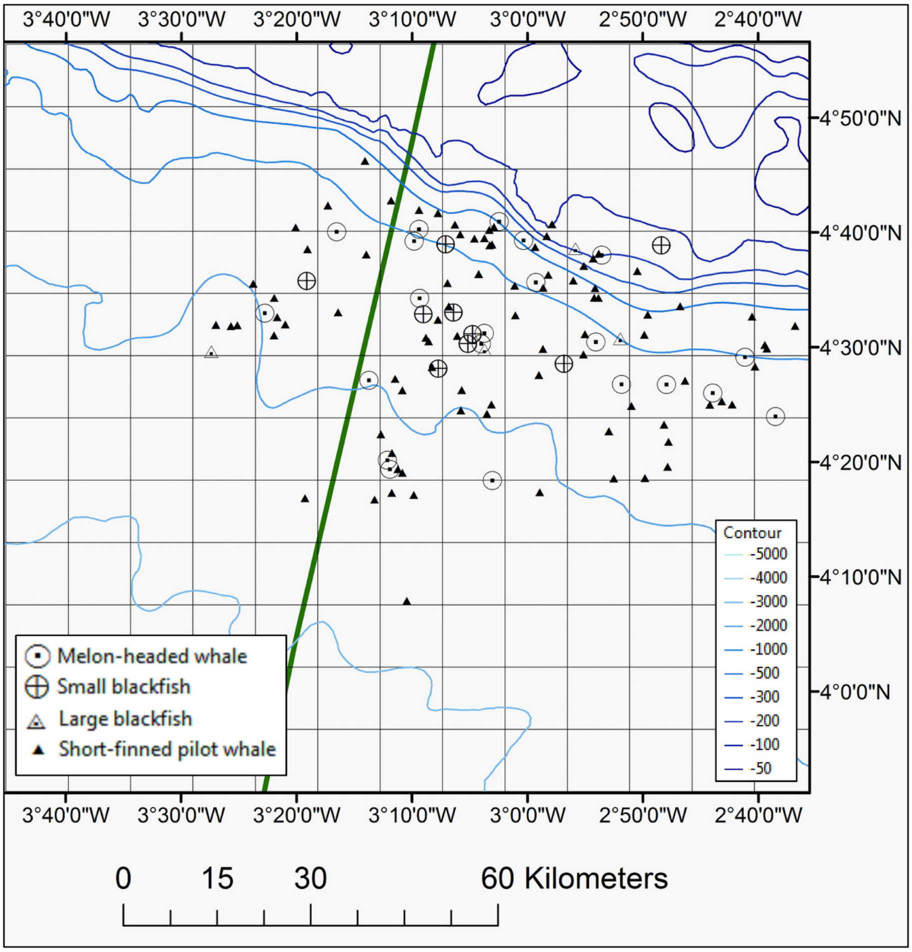


**FIGURE 4 | Map showing positions of blackfish species seen during the 2013 and 2014 surveys, including short-finned pilot whale, melon-headed whale, small, and large blackfish species.** The EEZ border between Côte d'Ivoire and Ghana is also shown (green thick line).

waters. We opine that there is a moderate risk of entanglement or capture of pilot whales in Ghana. Pilot whales were encountered in areas with a comparably high fishing vessel density (in 2013: 0.05 vessels $km^{-2}$; **Table 3**). The species is common in these waters and particularly immature pilot whales may become entangled in artisanal gillnets.

## Melon-Headed Whales

Melon-headed whales have not previously been recorded off Côte d'Ivoire (Perrin and Van Waerebeek, 2012). Two of our records occurred in Ivoirian waters (April) and present a new range state record for Côte d'Ivoire with the remainder presenting first confirmed at-sea sightings for Ghanaian waters. Melon-headed whales were observed associating with Fraser's dolphins on multiple occasions probably during multi-species feeding frenzies. Indeed, the two species are known to occur in mixed-species groups elsewhere in the tropical Atlantic [e.g., International Fund for Animal Welfare (IFAW), 1996; de Boer, 2015]. In comparison, melon-headed whales were observed to be less abundant further south and only occasionally encountered during surveys off Angola and Gabon (de Boer, 2010a; Weir, 2011). The melon-headed whale is the third most frequently captured cetacean in artisanal fishing gear (13.5–14.7% since 1999 in Dixcove landings; Van Waerebeek et al., 2014) and these figures match our observations where the species was found to be the most abundant of all cetaceans (**Table 3**). We opine that there is a high risk of melon-headed whales to become entangled or captured in fisheries in Ghana. They commonly occurred in areas with a high fishing vessel density (in 2013: 0.08 vessels km-2; **Table 3**). In addition, due to their large group formations, melon-headed whales are at risk of becoming entangled as a group ("group entanglement") rather than single individuals. Such simultaneous or group entanglement of genetically related dolphins (mother-offspring or related/reproductive pairs) in fishing gear has been reported for the Franciscana (*Pontoporia blainvillei*) in Argentina, and this might exacerbate the demographic consequences of bycatch, and the loss of groups of relatives means that significant components of genetic diversity could be lost together (Mendez et al., 2010).

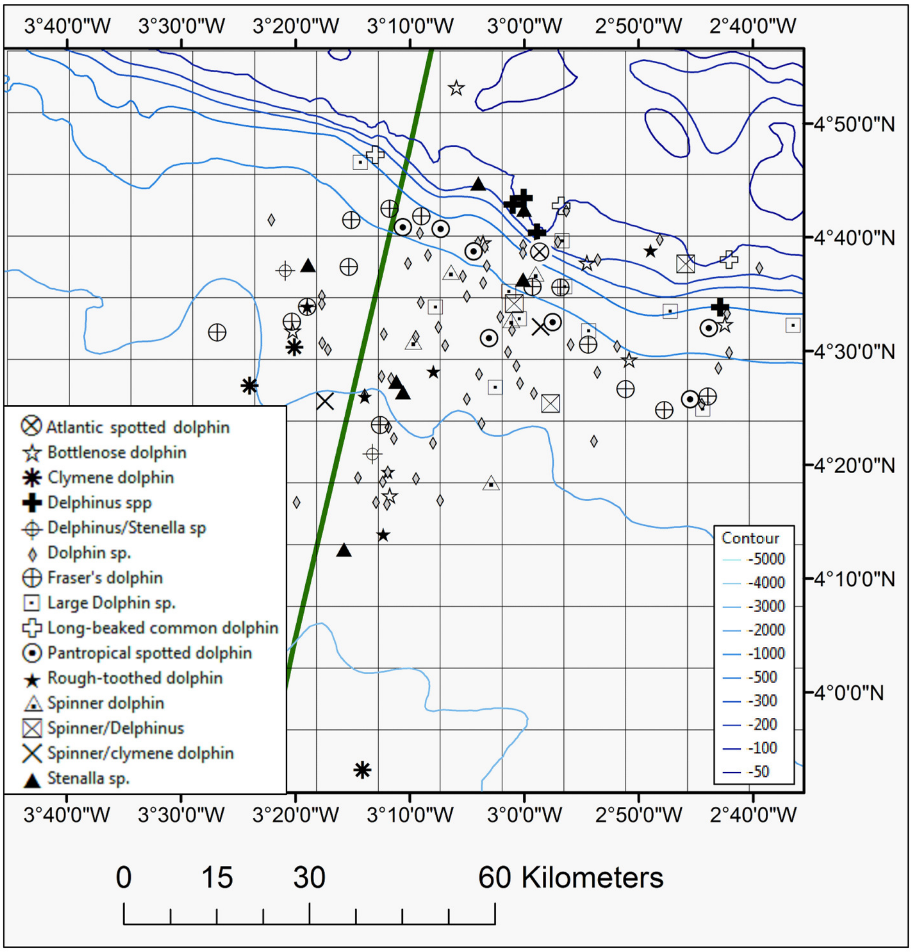


**FIGURE 5 | Map showing positions of all dolphin species seen during the 2013 and 2014 surveys, including Atlantic spotted, bottlenose, Clymene, *Delphinus* spp., long-beaked common, pantropical spotted, rough-toothed, Fraser's, and spinner dolphins.** The EEZ border between Côte d'Ivoire and Ghana is also shown (green thick line).

### Rough-Toothed Dolphins

Rough-toothed dolphins were recorded on six occasions during the present survey (2.2% of all sightings; **Table 3**) which is slightly higher compared to offshore surveys in Angola (0.6%; Weir, 2011) and Gabon (1.2%; de Boer, 2010a). Relatively little is known regarding rough-toothed dolphins along the West African coast but a few records are known for Mauritania, Senegal, Cape Verde, Gabon, Angola, and St Helena (Van Waerebeek et al., 2000; Findlay et al., 2006; MacLeod and Bennett, 2007; de Boer, 2010a; Weir, 2010). The species has been previously described for both Gabon and Côte d'Ivoire: (1) two sightings in 1972 at sea off Ghana; (2) reported landed in Ghana (e.g., Van Waerebeek et al., 2009, 2014); and (3) three specimens were captured in 1958 off Abidjan, Côte d'Ivoire (Cadenat, 1959). An increase in rough-toothed dolphins caught in artisanal fishing gear (from 3.2 to 12.8%) was reported from Dixcove (Debrah et al., 2010; Van Waerebeek et al., 2014; **Table 3**). Rough-toothed dolphins are known to interact with trawl fishing gear off West Africa (Addink and Smeenk, 2001) and FADs (de Boer, 2010b). We opine that the risk of entanglement or direct capture of rough-toothed dolphins in Ghana is quite high. Particularly, the tendency to interact with fisheries together with the relatively high mortality levels confirms that rough-toothed dolphins are particularly susceptible to bycatch. They also regularly form large groups of (multi-species) feeding associations which enhance the risk of group-entanglement. Finally, because of their attraction to boats they also are an easy target for direct capture.

### Common Bottlenose Dolphins

Common bottlenose dolphins were observed associating with pilot whales on five occasions. This association has also been previously described in Angolan waters (Weir, 2008a) and Northwest African waters (Djiba et al., 2015). The species is known to occur in both the inshore and offshore waters of Angola (Weir, 2011) however in Ghana most landed bottlenose dolphins are thought to belong to an offshore stock (Van Waerebeek et al., 2009). While the inshore stock of bottlenose dolphins are thought to be largely depleted in Ghanaian waters, they still

**TABLE 2 | Summary of fishing vessels for the 2 survey years and pooled (2013 + 2014).**

| Fishing vessel type | 2013 | 2014 | 2013 + 2014 |
|---|---|---|---|
| Chinese trawler | 0 | 4 | 4 |
| Trawler | 15 | 37 | 52 |
| Fishing canoe | 373 | 380 | 753 |
| Large canoe | 1 | 1 | 2 |
| FAD | 2 | 2 | 4 |
| Fishing gear | 0 | 2 | 2 |
| Tuna | 0 | 4 | 4 |
| Total | 391 | 430 | 821 |

*FAD, Fishing Aggregation Device.*

occur off Benin (Van Waerebeek et al., 2009; Sohou et al., 2013). The offshore numbers of bottlenose dolphins (2.5%; **Table 3**) are comparable to other offshore regions (Gabon: 3.6% and Angola: 2.1%; de Boer, 2010a; Weir, 2011). Three bottlenose dolphins were deliberately caught in Ivoirian waters in 1957–1958 (Cadenat and Lassarat, 1959). Our records present the first confirmed at-sea sightings in Ghanaian waters. At Dixcove, between 6.4 and 9.0% of small cetaceans landed consisted of common bottlenose dolphin during the 1999–2014 port monitoring period (Debrah et al., 2010; Van Waerebeek et al., 2014; **Table 3**). During this study, an observation was made involving a small group of bottlenose dolphins foraging in the direct vicinity of artisanal fishing gear and a similar interaction was recently reported from near-shore waters in Benin (Van Waerebeek et al., 2009; Sohou et al., 2013). We opine that there is a moderate to high risk of bottlenose dolphins to become entangled or captured in fisheries in Ghana. Although, their coastal tendency makes this species particularly susceptible to entanglement in fishing gear they only infrequently become entangled. However, their readiness to approach boats makes them an easy target for capture. Furthermore, there is a risk of group-entanglement.

## Pantropical Spotted Dolphins

Pantropical spotted dolphins accounted for 2.2% of all offshore sightings (**Table 3**) which is higher than recorded during offshore surveys off Angola (0.24%) and Gabon (1.2%; de Boer, 2010a; Weir, 2011). They were recorded in waters over the shelf edge and indeed further offshore which is consistent with records elsewhere in deep tropical waters specifically off Ghana, Gabon, and Angola (Picanço et al., 2009; Weir, 2010; de Boer, 2010a; Perrin and Van Waerebeek, 2012). Published group sizes of pantropical spotted dolphins within the region are mostly in the range of 50–150 animals which matched our observations (MacLeod and Bennett, 2007; Weir, 2007; de Boer, 2010a). The species has previously been reported in Ghanaian offshore waters, albeit non-authenticated (Jefferson et al., 1997) but its occurrence in Côte d'Ivoire remains unconfirmed (Weir, 2011). Pantropical spotted dolphins occurred in areas where there was a high fishing vessel density (in 2013: 0.06 vessels $km^{-2}$; **Table 3**). An increase in the landings of pantropical spotted dolphins from 10.9% in 2010 to 17.4% in 2014, was reported at Dixcove (Van Waerebeek et al., 2014; **Table 3**), making this the second most commonly landed cetacean. It is unclear whether the species is also captured in tuna purse seine fisheries in the tropical Atlantic. In the eastern tropical Pacific (ETP) seiners target pantropical spotted dolphin and spinner dolphin in order to locate and catch yellowfin and skipjack tuna (Culik, 2010a). We opine that the risk of entanglement or capture in fisheries of pantropical spotted dolphins in Ghana is high. The species frequently interacts with vessels and together with a tendency of interacting with fishing gear makes it particularly susceptible to bycatch in fishing gear within the region. These dolphins also form an easy target for direct capture and because of their formation into large groups there is a risk of group-entanglement.

## Atlantic Spotted Dolphins

Atlantic spotted dolphins (*Stenella frontalis*) were recorded once during the offshore surveys and this is reflected in their very occasional presence among landings at Dixcove (Van Waerebeek et al., 2014; **Table 3**) or other Ghanaian fishing ports (Debrah et al., 2010). The species is more abundant further south in Gabon (3.6% of all sightings) and Angola (3.2%; de Boer, 2010a; Weir, 2011). Two Atlantic spotted dolphins were captured for research in Côte d'Ivoire (Cadenat, 1959) and our record presents a first confirmed at-sea sighting for Ghanaian waters. It seems that there is a low risk of entanglement or capture in fisheries in Ghana. This is mainly based on the rare occurrence of this species in these waters. Because of the species' readiness to approach vessels they do form an easy target for direct capture but considering small group sizes (typically <20 off NW Africa; Djiba et al., 2015) the risk of group-entanglement seems limited.

## Spinner Dolphins

Spinner dolphins have previously been recorded on three occasions in the offshore waters of Ghana, all occurring in deep waters (> 3500 m) and in groups of 20–200 animals (Weir, 2011). Skulls of specimens originating from Côte d'Ivoire have been described by van Bree (1971) but at-sea sightings remain unconfirmed. Spinner dolphins are infrequently captured at Dixcove, i.e., 2.6–5.5% of landings in, respectively, 1999–2010 (Debrah et al., 2010) and 2013–2014 (Van Waerebeek et al., 2014; **Table 3**) similar to the percentage of pilot whale landings. This is not reflected in the offshore survey where spinner dolphins comprised 1.6% of all sightings whereas pilot whales comprised 29.4% (**Table 3**). Elsewhere, they are known to rest during the day and feed at night on mesopelagic fish, squids, and shrimps (Dolar et al., 2003). Spinner dolphins are also well-documented as bycatch in the tuna fishery in the ETP [Inter-American Tropical Tuna Commission (IATTC), 2009] however there is a lack of information on the bycatch of dolphins in the industrial tuna purse-seine fisheries within the Gulf of Guinea (Maigret, 1981; Van Waerebeek and Perrin, 2012). Because of their infrequent occurrence in Ghanaian waters we opine that the risk of entanglement or capture in fisheries of spinner dolphins in Ghana is moderate. Their presumed nocturnal foraging activities would make them particularly vulnerable to entanglement in night-time operated artisanal fishing gear. These dolphins readily approach vessels to bow-ride and they are an easy target for direct

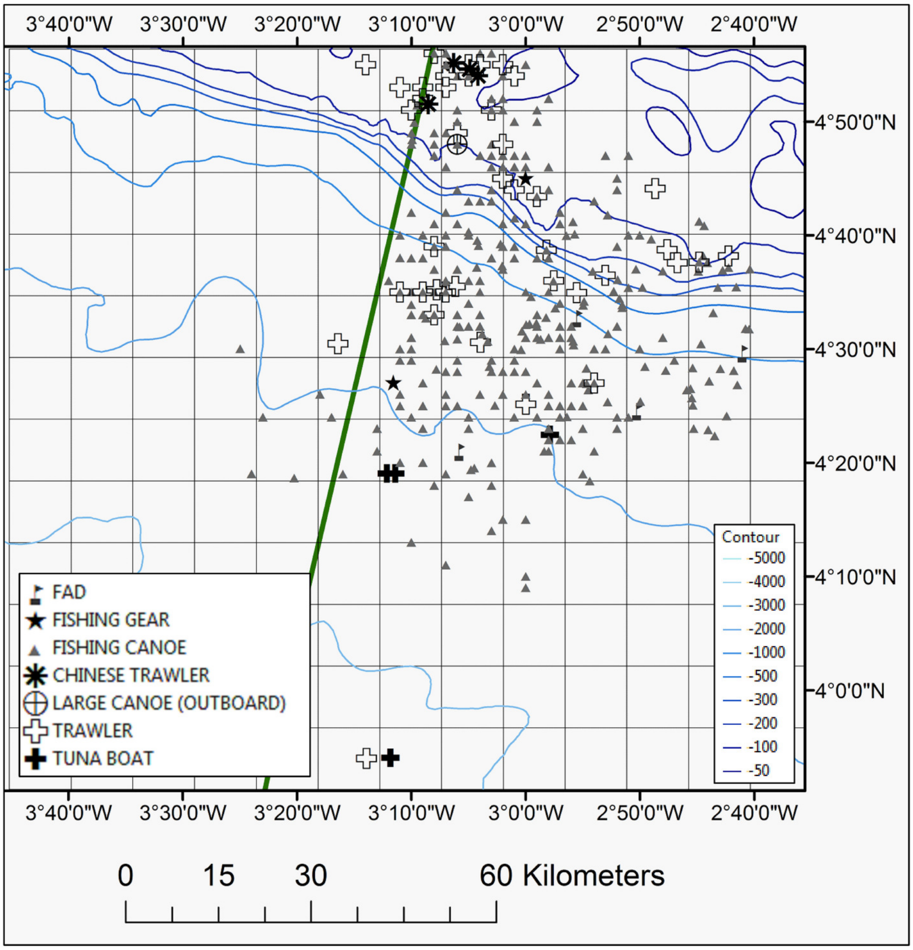


**FIGURE 6 | Map showing sighting position of different fishing vessels and fishing gear plotted during the 2013 and 2014 surveys.** The EEZ border between Côte d'Ivoire and Ghana is also shown (green thick line).

capture. Because of their formation into large groups (hundreds) the risk of group-entanglement is enhanced.

## Clymene Dolphins

Clymene dolphins have been recorded in Ghanaian offshore waters in 1972 (Perrin et al., 1981). The first documented record of a Clymene dolphin in Ghana was a bycaught specimen from Keta in 1956 (Van Waerebeek et al., 2009). Recent Clymene dolphin records from Côte d'Ivoire and Ghana all occurred in waters > 1999 m depth but off Angola and Gabon the species was also recorded in continental slope waters of 466 and 684 m depth (Weir et al., 2014). The Clymene dolphin is the most common cetacean landed at Ghanaian fishing ports (1998–2000, 34.5%; Ofori-Danson et al., 2003). This is consistent with the larger and more recent samples at Dixcove alone, where Clymene dolphins represented 30.1 and 32.1% of landed cetaceans occurring year-round (Debrah et al., 2010; Van Waerebeek et al., 2014; **Table 3**). This is however not reflected in the offshore survey where Clymene dolphins comprised of only 1.3% of all sightings (**Table 3**). There was a large amount of sightings that were classified as unidentified during the present survey or were classified only to species group level (42% of all sightings; **Table 3**). Naturally, some of these "unidentified" dolphins may have involved species such as the Clymene dolphin which can be very difficult to identify (Weir et al., 2014). In the western Atlantic, Clymene dolphins are known to be nocturnal foragers for mesopelagic fish and squid (Fertl et al., 1997). There is a lack of information regarding the bycatch of dolphins in the industrial tuna purse-seine fisheries in the Gulf of Guinea (Maigret, 1981; Van Waerebeek and Perrin, 2012). The occurrence of Clymene dolphin bycatch is undocumented in those countries neighboring Ghana (Sohou et al., 2013; Segniagbeto et al., 2014) yet when taking into account the multiple sighting records recently confirmed for the area (Weir et al., 2014) then bycatch is likely to occur throughout the region. We opine that the risk of entanglement or capture in fisheries of Clymene dolphins in Ghana is high. Their nocturnal foraging activities particularly make them vulnerable to entanglement in night-time operated artisanal fishing gear. They are generally weary of boats (they do not readily bow-ride) and therefore the risk of direct capture is probably low. If our observed sighting rate of Clymene dolphins is unbiased and representative of Ghana waters, the landing rate

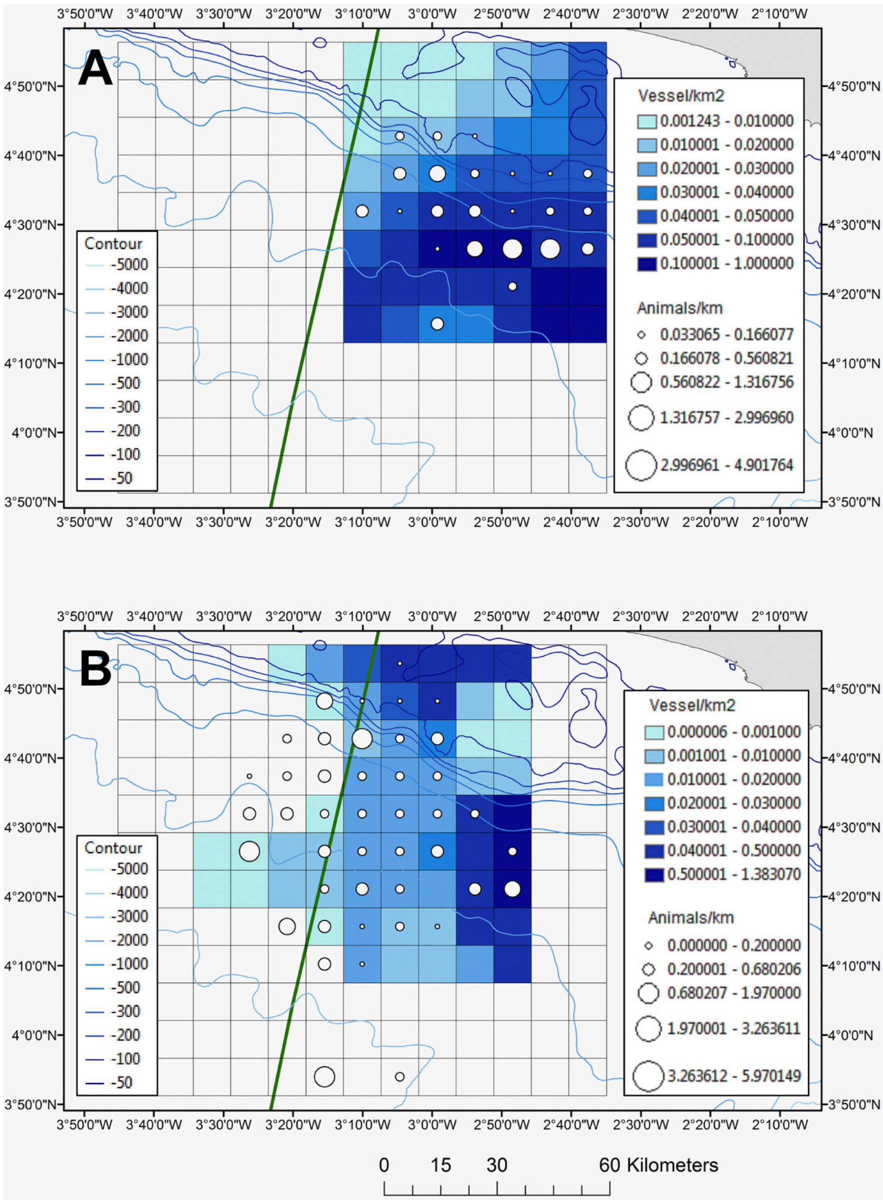


**FIGURE 7 | The relative abundance of all cetaceans (animals km$^{-1}$) together with the density of all fishing vessels (boats km$^{-2}$) for 2013 (A) and 2014 (B).** The EEZ border between Côte d'Ivoire and Ghana is also shown (green thick line).

(34.5%; Ofori-Danson et al., 2003) is very high compared to the population abundance. Hence, bycatch may have a negative influence on their population status.

## Long-Beaked Form of Common Dolphins

Long-beaked form of common dolphins (*Delphinus* sp.) comprised 2.2% of all sightings (**Table 3**). Specimens of "short-beaked" and "long-beaked" common dolphins have previously been described in Côte d'Ivoire (Cadenat, 1959; Van Bree and Purves, 1972; Van Waerebeek et al., 2009). Our records present the first confirmed at-sea sightings in both Ivoirian and Ghanaian waters. There has been a notable drop in the percentage of their landings at Dixcove (12.2–3.7%; Debrah et al., 2010; Van Waerebeek et al., 2014; **Table 3**). The continuation of at least occasional directed captures of this species has also been documented recently (Van Waerebeek et al., 2014). Bycatches of common dolphins have been reported in tuna purse-seine nets at the border between Liberia and Côte d'Ivoire (Simmons, 1968) and also off southern Africa (Best and Ross, 1977). Short-beaked common dolphins frequently become bycaught in trawl fisheries in the NE Atlantic (Morizur et al., 1999) and studies have shown that their relative abundance and group size were significantly higher in the presence of trawlers and that bycatch mostly occurred at night (de Boer et al., 2012). We opine that there is

**TABLE 3 | Species composition and summary of all cetacean sightings (S; during effort and off-effort search status) pooled from both survey years together with the percentage of all sightings (listed in order of frequency).**

| Species | Species composition offshore waters (this study) | | Predicted fishing density (offshore) Boats $km^{-2}$ | | Species composition landed specimens (port-based) | |
|---|---|---|---|---|---|---|
| | S effort + off-effort | % of S | 2013 | 2014 | % of landings in Dixcove 1999–2010[a] | % of landings in Dixcove Jan 2013–Feb 2014[b] |
| Short-finned pilot whale | 93 | 29.43 | 0.05 | 0.01 | **10.3** | 5.5 |
| Melon-headed whale | 24 | 7.59 | 0.08 | 0.01 | **13.5** | **14.7** |
| Fraser's dolphin | 15 | 4.75 | 0.09 | 0.002 | 0.6 | 0 |
| Sperm whale | 10 | 3.16 | | 0.001 | 0 | 0 |
| Common bottlenose dolphin | 8 | 2.53 | 0.05 | 0.02 | 9 | **6.4** |
| Pantropical spotted dolphin | 7 | 2.22 | 0.06 | 0.01 | **10.9** | **17.4** |
| Rough-toothed dolphin | 7 | 2.22 | 0.04 | 0.01 | 3.2 | **12.8** |
| *Delphinus* sp. | 7 | 2.22 | 0.04 | 0.02 | **12.2** | 3.7 |
| Spinner dolphin | 5 | 1.58 | | 0.01 | 2.6 | 5.5 |
| Clymene dolphin | 4 | 1.27 | | 0.0001 | **30.1** | **32.1** |
| Bryde's whale | 3 | 0.95 | | 0.04 | 0 | 0 |
| Atlantic spotted dolphin | 1 | 0.32 | | 0.01 | 0.6 | 0 |
| Pygmy killer whale | 0 | 0 | | | 0.6 | 1.8 |
| Risso's dolphin | 0 | 0 | | | 3.8 | 0 |
| *Kogia* sp. | 0 | 0 | | | 1.9 | 0 |
| False killer whale | 0 | 0 | | | 0.6 | 0 |
| Unidentified | 132 | 41.77 | | | n/a | n/a |
| All cetaceans | 316 | 100 | 0.06 | 0.01 | 100 | 100 |

*Also shown is the species composition and summary of the percentages of bycaught cetaceans (landings) in the fishing village of Dixcove during port-based studies between 1999–2010 and January 2013 to February 2014 (the highest five percentages are presented in bold type). The predicted (median) fishing vessel density (boats $km^{-2}$) for each species in Ghanaian waters is presented for each year (derived from GAM analysis).* [a]*Source: Debrah et al., 2010;* [b]*Source: Van Waerebeek et al., 2014.*

a high risk of entanglement or capture in fisheries of common dolphins in Ghana. Their tendencies to readily approach vessels to bow-ride and to interact with fisheries make them susceptible to bycatch and an easy target for direct capture. Furthermore, there is risk of group-entanglement.

### Fraser's Dolphins

Fraser's dolphins were common in the present study and with a high index of abundance (partly due to its formations into large group sizes). They are known to associate with other species (Dolar, 2002; Dolar et al., 2006) but, to our knowledge, this is the first documented case of an association between Fraser's dolphin and rough-toothed dolphin. There have been ten previous confirmed records of Fraser's dolphin in the ETA (from Senegal, Cabo Verde, Ghana, Angola, Gabon) and one further probable record off Nigeria (Debrah, 2000; Van Waerebeek et al., 2000, 2009; Ofori-Danson et al., 2003; Weir et al., 2008, 2013a; Torda et al., 2010). The previous records for Ghana involved specimens landed in Axim and Dixcove in 2000 (Debrah, 2000; Ofori-Danson et al., 2003). Our records contribute to the understanding of the geographical distribution range of this species by more than doubling the number of published records in West Africa and present the first verified at-sea sighting for Ghanaian waters and a new range state record for Côte d'Ivoire. Fraser's dolphins were recorded in deep waters of 942–2317 m depth and their affinity for foraging at night in deep waters can be explained by the type of prey they habitually target (mesopelagic fish, crustaceans, and cephalopods; Dolar et al., 2003). However, the feeding ecology of this species in the Gulf of Guinea is unknown. Fraser's dolphins were occurring in areas with the highest fishing vessel densities in 2013. Despite their common occurrence during the present survey, the species is rarely landed in Dixcove (0.6% of all landings between 1999–2010 and 0% between 2013–2014; Debrah et al., 2010; Van Waerebeek et al., 2014; **Table 3**). Fraser's dolphins are reported as bycatch in the tuna purse seine fishery in the ETP (Gerrodette and Wade, 1991) but the potential of bycatch in purse seine fisheries within the Gulf of Guinea remains to be assessed. Due to the fact that Fraser's dolphins were rarely landed in the Ghanaian fishing ports, but present in relative high abundance in our survey, we opine that there is a low risk of entanglement or capture in fisheries of Fraser's dolphins in Ghana. Fraser's dolphins do not readily approach vessels to bow-ride (Culik, 2010b) and therefore its shy nature together with its habitually deep diving foraging behavior (in spite of the fact that foraging takes place mainly at night) may help avoid entanglement in drift gillnets. Because of their formation into very large groups (often multi-species associations) there is however a risk of group-entanglement.

## Potential Sources of Bias

There was a marked difference in the fishing vessel density between both survey years which was probably caused partly by the difference in data-collection methods used. However, the differences in the two areas surveyed may also explain some of these differences as the area in 2014 covered a much wider region and expanded overall further westward. Furthermore, the fishing vessels in 2014 appeared more widely dispersed (and less aggregated) compared to those recorded in 2013. Nevertheless, caution is needed when comparing the fishing vessel densities between both years. In 2013, the data-collection method for fishing vessels was effort-corrected (unlike the data collected in 2014) and data were collected by the marine mammal observers onboard the seismic survey vessel. The 2013 fishing vessel data are therefore believed to be more accurate and the least biased, and therefore best represent the fishing vessel density for Ghanaian offshore waters.

Just under half of the survey effort was conducted during times when the seismic source was active (45%) and this is a lower percentage when compared to other seismic surveys (de Boer, 2010c, 2013, 2015). We highlight that caution is required when interpreting the results because overt responses to the seismic sound source by some cetaceans may have occurred. For example, responses to seismic by short-finned pilot whales, Atlantic spotted dolphins and pantropical spotted dolphins have been documented off West Africa (Weir, 2008a,b; Gray and Van Waerebeek, 2011). Avoidance of the area by some species in response to seismic sound levels may also have occurred as research on other marine mammals has shown (temporal) avoidance or a reduction in overall cetacean detection rates in response to loud noises (e.g., pile driving; Southall et al., 2007; Paiva et al., 2015). In addition, further disturbance to marine fauna was likely caused in 2014 by other seismic vessels that were operating nearby. With no information available regarding the detection rates of cetaceans within the region prior to/or after these seismic surveys it is not possible to assess if and how the distribution of cetaceans was affected or if there were significant overlaps between cetaceans and fisheries. Future surveys would benefit from a dedicated (line-transect) survey taking place prior to, and after, the geophysical seismic surveys in order to detect changes in detection rates and the distribution of cetaceans.

## CONCLUSIONS

The present survey provided a unique opportunity to study both the cetacean community and fishing activities in the poorly studied Ivoirian/Ghanaian part of the Gulf of Guinea. New insights into the occurrence of cetaceans were made with ten cetacean species representing first at-sea sightings and two species new range state records. Our findings confirmed that fishing occurred well offshore, including the small-scale artisanal fishery (**Figure 6**). However, it must be noted that near-shore areas were not surveyed. Both cetaceans and fishing vessels predominantly occurred in shelf and slope waters, specifically up to the 1000 m depth contour, and it is here where fishing activities are likely to be causing anthropogenic mortality through bycatch and direct captures. The gillnets of artisanal fishermen are most commonly soaked throughout the night and hauled in the early morning hours (E.A. Johnson, Dixcove fisheries officer, pers. comm. to K. Van Waerebeek) and at Dixcove, the landing of catches, including cetaceans, typically occurs during the morning (K. Van Waerebeek, pers. observations). This leads us to believe that most interactions between cetaceans and fisheries probably occurred during the hours of darkness. There are no indications that some species are more sought after than others (i.e., for consumption). The majority of cetaceans are landed freshly dead following entanglement, but occasionally if animals are alive when retrieved they are killed, with piercing lance-like metals, cutlasses, hand harpoons, or sticks (Debrah, 2000). No changes in the handling of landed cetaceans and commercial practices in Dixcove, in comparison with former years, were recently reported (Van Waerebeek et al., 2014). However, it is unknown whether the landings data based on one fishing village alone can be considered representative of broader fishing patterns for the entire region.

Some notable differences were found in the species composition between the present at-sea surveys and the port-based landings data (Ofori-Danson et al., 2003; Debrah et al., 2010; Van Waerebeek et al., 2014). The wide discrepancy between the comparatively large number of landed Clymene dolphins in Ghana and the fact that the species was rarely confirmed at sea, is at least partly explained by the difficulty to positively identify this smallish stenellid from a distance. Clymene dolphins were only observed in the absence of seismic operations and it is possible that these dolphins were either avoiding or keeping a greater distance to the vessel during operations. On the other hand, the wide discrepancy between the low number of landed Fraser's dolphins and the relatively high numbers encountered offshore cannot be explained by identification challenges as there are none. The differences in feeding strategies (nocturnal vs. diurnal; surface vs. deep water), different degrees of attraction to vessels and their gear as well as variable body sizes may influence the vulnerability of a species to become entangled or captured. Adult short-finned pilot whales and false killer whales may rarely be landed because they are more likely to break through nets, and escape, following entanglement but large species may also be difficult to retrieve from the nets and may subsequently be discarded at sea.

Based on our data on fishing density, cetacean (relative) abundance together with the previously reported information on cetacean landings we opine that in particular melon-headed whales, common dolphins, pantropical spotted dolphin, rough-toothed dolphin, common bottlenose dolphin, and Clymene dolphins are at high risk of entanglement or direct capture within these waters. This, together with the increase in the sale of cetacean products for human consumption as marine bushmeat in the Gulf of Guinea (e.g., Ofori-Danson et al., 2003; Van Waerebeek et al., 2015) may well contribute to a rapid and potentially localized decline of these species within this unique upwelling region. It is necessary to rapidly improve and implement feasible conservation measures directed to address this effectively unmanaged exploitation of small cetaceans in the Gulf of Guinea and the wider problem of an uncontrolled trade in marine bushmeat in western Africa.

Although our findings have given a new insight into the distribution of cetaceans and the problem of bycatch and direct takes in Ghanaian waters, it is clear that future risk assessments of fishing pressure on cetaceans through directed takes or incidental bycatch are urgently needed. Firstly, onboard observations are essential to study the dynamics of the catch process; while systematic studies of the ecology and natural history of all exploited species should also be undertaken. The lack of information on population status of cetacean species in this area hampers the understanding of which species-specific vulnerability characteristics drive the probability of a species to become entangled or captured in fishing gear, and this complicates future assessments of fishing pressure on cetaceans. There are also likely to be strong spatial and temporal (seasonal and inter-annual) variations in the distribution and abundance of both cetaceans and fisheries. Introducing biological factors into the analysis would lead to a clearer picture of how cetaceans use their habitat. This would not only improve our understanding of the ecology of the different species involved, but should also lead to more effective management and conservation measures.

## AUTHOR CONTRIBUTIONS

Conceived and designed the survey: Md, JS. Collected and analyzed the data: Md, JS, with contributions from KV, GA. Wrote the manuscript: Md, with textual contributions and re-drafting, critical review, and editorial input from JS, KV, GA.

## ACKNOWLEDGMENTS

Special thanks to observers Sue Travers, Andy Williams for their support and for providing contributing information. Of equal importance has been the support and goodwill of the crews, clients and the fisheries liaison officers of the Geco Eagle and Geco Trident. Special thanks to Tullow Ghana Limited and Dave Bolger and John Doherty from Tullow Oil for their support. Tullow Oil funded this project and GA has been partly funded by NWO-ZKO grant "Effects of underwater noise on marine mammals in the North Sea." Finally, we are grateful to Steve Geelhoed for reviewing an earlier draft of this manuscript.

## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fmars.2016.00178

## REFERENCES

Aarts, G., Fieberg, J., and Matthiopoulos, J. (2012). Comparative interpretation of count, presence-absence and point methods for species distribution models. *Methods Ecol. Evol.* 3, 177–187. doi: 10.1111/j.2041-210X.2011.00141.x

Adamec, D., and O'Brien, J. J. (1978). The seasonal upwelling in the Gulf of Guinea due to remote forcing. *J. Phys. Oceanogr.* 8, 1050–1060.

Addink, M. J., and Smeenk, C. (2001). Opportunistic feeding behaviour of rough-toothed dolphins *Steno bredanensis* off Mauritania. *Zool. Verh. Leiden* 334, 38–48.

Aheto, D. W., Asare, N. K., Quaynor, B., Tenkorang, E. Y., Asare, C., and Okyere, I. (2012). Profitability of small-scale fisheries in Elmina, Ghana. *Sustainability* 4, 2785–2794. doi: 10.3390/su4112785

Alfaro-Shigueto, J., and Van Waerebeek, K. (2001). "Drowning in a sea of silence: the bushmeat concept applied to marine wildlife," in *Zoos and Aquariums: Committing to Conservation, Symposium hosted by Brevard Zoo* (Orlando, FL), 16.

Atta-Mills, J., Alder, J., and Sumaila, U. R. (2004). The decline of a regional fishing nation: the case of Ghana and West Africa. *Nat. Resour. Forum* 28, 13–21. doi: 10.1111/j.0165-0203.2004.00068.x

Ayissi, I., Van Waerebeek, K., and Segniagbeto, G. (2011). "Report on the exploratory survey of cetaceans and their status in Cameroon," in *CMS Scientific Council UNEP/CMS/ScC17/Inf.10* (Bergen), 31.

Best, P. B. (1974). "The biology of the sperm whale as it relates to stock management," in *The Whale Problem: A Status Report*, ed W. E. Schevill (Cambridge: Harvard University Press), 257–293.

Best, P. B. (1996). Evidence of migration by Bryde's whales from the offshore population in the southeast Atlantic. *Rep. Int. Whal. Commn.* 46, 315–322.

Best, P. B., and Ross, G. J. B. (1977). Exploitation of small cetaceans off Southern Africa. *Rep. Int. Whal. Commn.* 34, 494–497.

Cadenat, J. (1959). Rapport sur les petits cétacés ouest-africaines. Résultats des recherches enterprises sur ces animaux jusqu'au mois de mars 1959. *Bull. IFAN* 21A, 1367–1440.

Cadenat, J., and Lassarat, A. (1959). Notes sur les Delphinidés ouest-africains. III. Notes complémentaires sur *Tursiops truncatus*. *Bull. IFAN* 21A, 416–419.

Cañadas, A., Sagarminaga, R., and Garcia-Tiscar, S. (2002). Cetacean distribution related with depth and slope in the Mediterranean waters off southern Spain. *Deep Sea Res. 1 Oceanogr. Res. Pap.* 49, 2053–2073. doi: 10.1016/S0967-0637(02)00123-1

Clapham, P., and Van Waerebeek, K. (2007). Bushmeat and bycatch: the sum of the parts. *Mol. Ecol.* 16, 2607–2609. doi: 10.1111/j.1365-294X.2007.03378.x

Culik, B. (2010a). *Odontocetes - The Toothed Whales: Stenella attenuata*. Bonn: UNEP/CMS Secretariat.

Culik, B. (2010b). *Odontocetes - The Toothed Whales: Lagenodelphis hosei*. Bonn: UNEP/CMS Secretariat.

Dalla Rosa, L., and Secchi, E. R. (2007). Killer whale (*Orcinus orca*) interactions with the tuna and swordfish longline fishery off southern and south-eastern Brazil: a comparison with shark interactions. *J. Mar. Biol. Assoc. U. K.* 87, 135–140. doi: 10.1017/S0025315407054306

de Boer, M. N. (2010a). Cetacean distribution and relative abundance in offshore Gabonese waters. *J. Mar. Biol. Assoc. U. K.* 90, 1613–1621. doi: 10.1017/S0025315410001165

de Boer, M. N. (2010b). First record of a white rough-toothed dolphin (*Steno bredanensis*) off West Africa including notes on rough-toothed dolphin surface behaviour. *Mar. Biodivers. Rec.* 3, e66. doi: 10.1017/S1755267210000539

de Boer, M. N. (2010c). Spring distribution and density of minke whale *Balaenoptera acutorostrata* along an offshore bank in the central North Sea. *Mar. Ecol. Prog. Ser.* 408, 265–274. doi: 10.3354/meps08598

de Boer, M. N. (2013). *Elusive Marine Mammals Explored - Charting Under-Recorded Areas to Study the Abundance and Distribution of Cetaceans using Multi-Method Approaches and Platforms of Opportunity*. Ph.D. thesis, Wageningen University, Wageningen.

de Boer, M. N. (2015). Cetaceans observed off Suriname and adjacent waters. *LAJAM* 10, 2–19. doi: 10.5597/lajam00189

de Boer, M. N., Saulino, J. T., Leopold, M. F., Reijnders, P. J. H., and Simmonds, M. P. (2012). Interactions between short-beaked common dolphin (*Delphinus delphis*) and the winter pelagic pair-trawl fishery off Southwest England (UK). *Int. J. Biodivers. Conserv.* 4, 481–499. doi: 10.5897/ijbc12.016

Debrah, J. A., Ofori-Danson, P. K., and Van Waerebeek, K. (2010). "An update on the catch composition and other aspects of cetacean exploitation in Ghana," in *International Whaling Commission SC/62/SM10* (Agadir), 8.

Debrah, J. S. (2000). *Taxonomy, Exploitation and Conservation of Dolphins in the Marine Waters of Ghana*. M.Phil. thesis (GH), University of Ghana.

Djiba, A., Bamy, I. L., Samba Ould Bilal, A., and Van Waerebeek, K. (2015). "Biodiversity of cetaceans in coastal waters of Northwest Africa: new insights through platform-of-opportunity visual surveying in 2011-2013," in *Oceanographic and Biological Features in the Canary Current Large Marine Ecosystem, IOC Technical Series, No. 115*, eds L. Valdés and I. Déniz-González (Paris: IOC-UNESCO), 283–297.

Dolar, M. L. L. (2002). "Fraser's dolphin, Lagenodelphis hosei," in *Encyclopedia of Marine Mammals*, eds W. F. Perrin, B. Würsig and J. G. M. Thewissen (San Diego, CA: Academic Press), 485–487.

Dolar, M. L. L., Perrin, W. F., Taylor, B. L., and Kooyman, G. L. (2006). Abundance and distributional ecology of cetaceans in the central Philippines. *J. Cet. Res. Manage.* 8, 93–111.

Dolar, M. L. L., Walker, W. A., Kooyman, G. L., and Perrin, W. F. (2003). Comparative feeding ecology of spinner dolphins (*Stenella longirostris*) and Fraser's dolphins (*Lagenodelphis hosei*) in the Sulu Sea. *Mar. Mammal Sci.* 19, 1–19. doi: 10.1111/j.1748-7692.2003.tb01089.x

Fertl, D., Schiro, A. J., and Peake, D. (1997). Coordinated feeding by clymene dolphins (*Stenella clymene*) in the Gulf of Mexico. *Aquat. Mamm.* 23, 111–112.

Findlay, K. P., Collins, T., and Rosenbaum, H. C. (2006). *Environmental Impact Assessment and Mitigation of Marine Hydrocarbon Exploration and Production in the Republic of Gabon*. New York, NY: Report of the Wildlife Conservation Society.

Food and Agriculture Organization (FAO) (2007). *Ghana Fishery Country Profile*. Rome: Food and Agriculture Organization of the United Nations.

Gerrodette, T., and Wade, P. R. (1991). Monitoring trends in dolphin abundance in the eastern Tropical Pacific: analysis of 1989 data. *Rep. Int. Whal. Commn.* 41, 511–515.

Gill, P. C., Morrice, M. G., Page, B., Pirzi, R., Levings, A. H., and Coyne, M. (2011). Blue whale habitat selection and within-season distribution in a regional upwelling system off southern Australia. *Mar. Ecol. Prog. Ser.* 421, 243–263. doi: 10.3354/meps08914

Gray, H., and Van Waerebeek, K. (2011). Postural instability and akinesia in a pantropical spotted dolphin, *Stenella attenuata*, in proximity to operating airguns of a geophysical seismic vessel. *J. Nat. Conserv.* 19, 363–367. doi: 10.1016/j.jnc.2011.06

Hammond, P. S., Bearzi, G., Bjørge, A., Forney, K., Karczmarski, L., Kasuya, T., et al. (2010). *Stenella clymene*. *IUCN Red List Threatened Species* 4, 1–5. doi: 10.2305/IUCN.UK.2012.RTLS.T20730A17840531.en

Heinemann, D. (1981). A range finder for pelagic birds censusing. *J. Wildl. Manage.* 45, 489–493.

Hernandez-Milian, G., Goetz, S., Varela-Dopico, C., Rodriguez-Gutierrez, J., Romon-Olea, J., Fuertes-Gamundi, J. R., et al. (2008). Results of a short study of interactions of cetaceans and longline fisheries in Atlantic waters: environmental correlates of catches and depredation events. *Hydrobiologia* 612, 251–268. doi: 10.1007/s10750-008-9501-2

Inter-American Tropical Tuna Commission (IATTC) (2009). *Report of the Inter-American Tropical Tuna Commission for the year 2007.* Annual Report. La Jolla, CA: IATTC.

International Fund for Animal Welfare (IFAW) (1996). *Cetacean field research conducted from Song of the Whale off Dominica and Grenada: Spring 1996 (Unpublished Report)*. London: IFAW.

International Hydrographic Organization (IHO) (1953). *Limits of Oceans and Seas. Special Publication 23, 3rd Edn*. Monaco: International Hydrographic Organization.

Jefferson, T. A., Curry, B. E., Leatherwood, S., and Powell, J. A. (1997). Dolphins and porpoises of West Africa: a review of records (Cetacea: Delphinidae, Phocoenidae). *Mammalia* 61, 87–108.

Joint Nature Conservation Committee (JNCC) (2010). *Guidelines for Minimising Acoustic Disturbance to Marine Mammals from Seismic Surveys*. Peterborough, ON: Joint Nature Conservation Committee.

Koranteng, K. A. (2001). Structure and dynamics of demersal assemblages on the continental shelf and upper slope off Ghana, West Africa. *Mar. Ecol. Progr. Ser.* 220, 1–12. doi: 10.3354/meps220001

MacLeod, C. D., and Bennett, E. (2007). Pan-tropical spotted dolphins (*Stenella attenuata*) and other cetaceans around St Helena. *J. Mar. Biol. Assoc. U. K.* 87, 339–344. doi: 10.1017/S0025315407052502

Maigret, J. (1981). Rapports entre les cétacés et la pêche thonière dans l'Atlantique tropical oriental. *Notes Afr.* 171, 75–84.

Mendez, M., Rosenbaum, H. C., Wells, R. S., Stamper, A., and Bordino, P. (2010). Genetic evidence highlights potential impacts of bycatch to cetaceans. *PLoS ONE* 5:e15550. doi: 10.1371/journal.pone.0015550

Morizur, Y., Berrow, S. D., Tregenza, N., Couperus, A. S., and Pouvreau, S. (1999). Incidental catches of marine mammals in pelagic trawl fisheries of the north-east Atlantic. *Fish. Res.* 41, 297–307.

Mullié, W. C., Wagne, M. M., Elmamy, C. A., Mint Yahya, F., Veen, J., and Van Waerebeek, K. (2013). "Large number of stranded harbour porpoises *Phocoena phocoena* as by-catch victims in Mauritania," in *International Whaling Commission SC/65a/HIM03* (Jeju), 5.

Ofori-Danson, P. K., and Odei, M. A. (1997). "Preliminary observations of the common dolphin, *Delphinus delphis,* (Order: Cetacea; fam: Delphinidae) in the Ghanaian coastal waters," in *International Whaling Commission SC/49/SM3* (Monaco), 8.

Ofori-Danson, P. K., Van Waerebeek, K., and Debrah, S. (2003). A survey for the conservation of dolphins in Ghanaian coastal waters. *J. Ghana Sci. Assoc.* 5, 45–54.

Paiva, E. G., Salgado Kent, C. P., Gagnon, M. M., McCauley, R., and Finn, H. (2015). Reduced detection of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in an inner harbour channel during pile driving activities. *Aquat. Mamm.* 41, 455–468. doi: 10.1578/AM.41.4.2015.455

Perrin, W. F., Mitchell, E. D., Mead, J. G., Caldwell, D. K., and van Bree, P. J. H. (1981). *Stenella clymene,* a rediscovered tropical dolphin of the Atlantic. *J. Mamm.* 62, 583–598.

Perrin, W. F., and Van Waerebeek, K. (2012). The small-cetacean fauna of the west coast of Africa and Macaronesia: diversity and distribution. *CMS Tech. Ser.* 26, 7–17.

Picanço, C., Carvalho, I., and Brito, C. (2009). Occurrence and distribution of cetaceans in São Tomé and Príncipe tropical archipelago and their relation to environmental variables. *J. Mar. Biol. Assoc. U. K.* 89, 1071–1076. Doi: 10.1017/S0025315409002379

Reeves, R., and Notarbartolo di Sciara, G. (2006). *The status and distribution of cetaceans in the Black Sea and Mediterranean Sea*. Malaga: IUCN Centre for Mediterranean Cooperation.

Reilly, S. B., Bannister, J. L., Best, P. B., Brown, M., Brownell, R. L. Jr., Butterworth, D. S., et al. (2008). *Balaenoptera edeni*. *IUCN Red List Threatened Species* 2014.3, 1–5. doi: 10.2305/IUCN.UK.2008.RLTS.T2476A94 45502.en

Segniagbeto, G. H., Van Waerebeek, K., Bowessidjaou, J. E., Ketoh, K., Kpatcha, T. K., Okoumassou, K., et al. (2014). Annotated checklist and fisheries interactions of cetaceans in Togo, with evidence of Antarctic minke whale in the Gulf of Guinea. *Integr. Zool.* 9, 1–13. doi: 10.1111/1749-4877.12011

Segniagbeto, G., and Van Waerebeek, K. (2010). "A note on the occurrence and status of cetaceans in Togo," in *International Whaling Commission SC/62/SM11* (Agadir), 8.

Simmons, D. C. (1968). Purse seining off Africa's west coast. *Commer. Fish. Rev.* 30, 21–22.

Sohou, Z., Dossou-Bodjrenou, J., Tchibozo, S., Chabi-Yaouré, F., Sinsin, B., and Van Waerebeek, K. (2013). Biodiversity and status of cetaceans in Benin, West Africa: an initial assessment. *WAJAE* 21, 121–134.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene, C. R. Jr., et al. (2007). Marine mammal noise exposure criteria: initial scientific recommendations. *Aquat. Mamm.* 33, 411–521. doi: 10.1080/09524622.2008.9753846

Torda, G., López Suárez, P., and López Jurado, L. F. (2010). First records of Fraser's dolphin *Lagenodelphis hosei* for the Cape Verde Islands. *Zool. Caboverdiana* 1, 71–73.

Townsend, C. H. (1935). The distribution of certain whales as shown by logbook records of American whale ships. *Zoologica* 19, 1–50.

van Bree, P. J. H. (1971). On skulls of *Stenella longirostris* (Gray, 1828) from the eastern Atlantic (Notes on Cetacea, Delphinoidea IV). *Beaufortia* 19, 21–25.

Van Bree, P. J. H., and Purves, P. E. (1972). Remarks on the validity of *Delphius bairdii* (Cetacea Delphininae). *J. Mamm.* 53, 372–374.

Van Waerebeek, K., Barnett, L., Camara, A., Cham, A., Diallo, M., Djiba, A., et al. (2003). *Conservation of Cetaceans in the Gambia and Senegal 1999-2001 and Status of the Atlantic Humpback Dolphin.* Bonn: WAFCET-2 Rep. CMS/UNEP. doi: 10.13140/RG.2.1.3917.9602

Van Waerebeek, K., Debrah, J., and Ofori-Danson, P. K. (2014). "Cetacean landings at the fisheries port of Dixcove, Ghana in 2013-14: a preliminary appraisal," in *International Whaling Commission SC/65b/SM17* (Bled), 4.

Van Waerebeek, K., Ndiaye, E., Djiba, A., Diallo, M., Murphy, P., Jallow, A., et al. (2000). *A Survey of the Conservation Status of Cetaceans in Senegal, The Gambia and Guinea-Bissau.* Bonn: WAFCET-1 Rep, CMS/UNEP. doi: 10.13140/RG.2.1.2538.6003

Van Waerebeek, K., and Ofori-Danson, P. K. (1999). "A first checklist of cetaceans of Ghana, Gulf of Guinea, and a shore-based survey of interactions with coastal fisheries," in *International Whaling Commission SC/51/SM35* (Grenada), 9.

Van Waerebeek, K., Ofori-Danson, P. K., and Debrah, J. (2009). The cetaceans of Ghana: a validated faunal checklist. *WAJAE* 15, 61–90. doi: 10.4314/wajae.v15i1.49428

Van Waerebeek, K., and Perrin, W. F. (2012). "Conservation status of the Clymene dolphin in West Africa," in *CMS Scientific Council CMS/ScC14/Doc.5* (Bonn), 9.

Van Waerebeek, K., Uwagbae, M., Segniagbeto, G., Bamy, I. L., and Ayissi, I. (2015). New records of Atlantic humpback dolphin in Guinea, Nigeria, Cameroon and Togo underscore fisheries pressure and generalised marine bushmeat demand. *BioRxiv*/2015/035337. doi: 10.1101/035337

Weir, C. R. (2007). Occurrence and distribution of cetaceans off northern Angola, 2004/05. *J. Cet. Res. Manage.* 9, 225–239.

Weir, C. R. (2008a). Overt responses of humpback whales (*Megaptera novaeangliae*), sperm whales (*Physeter macrocephalus*), and Atlantic spotted dolphins (*Stenella frontalis*) to seismic exploration off Angola. *Aquat. Mamm.* 34, 71–83. doi: 10.1578/AM.34.1.2008.71

Weir, C. R. (2008b). Short-finned pilot whales (*Globicephala macrorhynchus*) respond to an airgun ramp-up procedure off Gabon. *Aquat Mamm.* 34, 349–354. doi: 10.1578/AM.34.3.2008.349

Weir, C. R. (2010). A review of cetacean occurrence in West African waters from the Gulf of Guinea to Angola. *Mamm. Rev.* 40, 2–39. doi: 10.1111/j.1365-2907.2009.00153.x

Weir, C. R. (2011). *Ecology and Conservation of Cetaceans in the Waters between Angola and the Gulf of Guinea, with Focus on the Atlantic Humpback Dolphin* (*Sousa teuszii*). Ph.D. thesis (UK), University of Aberdeen.

Weir, C. R., Coles, P., Ferguson, A., May, D., Baines, M., Figueirdo, I., et al. (2014). Clymene dolphins (*Stenella clymene*) in the eastern tropical Atlantic: distribution, group size, and pigmentation pattern. *J. Mamm.* 95, 1289–1298. doi: 10.1644/14-MAMM-A-115

Weir, C. R., Collins, T., Cross, T., Gill, A., Elwen, S., Unwin, M., et al. (2013b). False killer whale (*Pseudorca crassidens*) sightings in continental shelf habitat off Gabon and Côte d'Ivoire (Africa). *Mar. Biodivers. Rec.* 6, e65. doi: 10.1017/S1755267213000389

Weir, C. R., Debrah, J., Ofori-Danson, P. K., Pierpont, C., and Van Waerebeek, K. (2008). Records of Fraser's dolphin *Lagenodelphis hosei* Fraser 1056 from the Gulf of Guinea and Angola. *Afr. J. Mar. Sci.* 30, 241–245. doi: 10.2989/AJMS.2008.30.2.4.554

Weir, C. R., Goncalves, L., and May, D. (2013a). New Gulf of Guinea (Africa) range state records for pygmy killer whale (*Feresa attenuata*) and Fraser's dolphin (*Lagenodelphis hosei*). *Mar. Biodivers. Rec.* 6, e35. doi: 10.1017/S1755267212001303

Weir, C. R., and Pierce, G. J. (2012). A review of the human activities impacting cetaceans in the eastern tropical Atlantic. *Mamm. Rev.* 43, 258–274. doi: 10.1111/j.1365-2907.2012.00222.x

Wood, S. N. (2006). *Generalized Additive Models: An Introduction with R*. London: Chapman and Hall.

**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.

The reviewer MS and handling Editor declared their shared affiliation, and the handling Editor states that the process nevertheless met the standards of a fair and objective review.

frontiers in Marine Science

MINI REVIEW
published: 16 September 2016
doi: 10.3389/fmars.2016.00163

# The Utilization of Aquatic Bushmeat from Small Cetaceans and Manatees in South America and West Africa

*A. Mel Cosentino[1]* and Sue Fisher[2]*

[1] Wild Earth Foundation, Puerto Pirámides, Argentina, [2] Department of Marine Wildlife, Animal Welfare Institute, Washington, DC, USA

Aquatic bushmeat can be defined as the products derived from wild aquatic megafauna (e.g., marine mammals) that are used for human consumption and non-food purposes, including traditional medicine. It is obtained through illegal or unregulated hunts as well as from stranded (dead or alive) and bycaught animals. In most South American and West African countries aquatic mammals are or have been taken for bushmeat, including 33 small cetaceans and all three manatee species. Of these, two cetacean species are listed in the IUCN red list as "near threatened," and one as "vulnerable," as are all manatee species. Additionally, 22 cetacean species are listed as "data deficient," hence some of these species may also be at risk. No reports (recent or otherwise) were found for some countries, caution is needed in concluding that aquatic bushmeat is not utilized in these nations. Moreover, although aquatic bushmeat is mostly obtained opportunistically and was likely originally taken only for local consumption, directed catches occur in most countries and may have reached unsustainable levels in some areas. For example, in Peru and Nigeria, thousands of small cetaceans are illegally hunted annually. Reliable, recent data and a better overall understanding of the drivers of aquatic bushmeat will be essential in the development of effective mitigation measures.

**Keywords: small cetaceans, manatees, hunting, bycatch, food, bait**

OPEN ACCESS

***Edited by:***
*Andrew Butterworth, University of Bristol, UK*

***Reviewed by:***
*Ruth Davis, University of Wollongong, Australia*
*Mark Peter Simmonds, University of Bristol, UK*

****Correspondence:***
*A. Mel Cosentino*
*orcinus.orca.1758@gmail.com*

***Specialty section:***
*This article was submitted to Marine Affairs and Policy, a section of the journal Frontiers in Marine Science*

***Received:*** *18 April 2016*
***Accepted:*** *24 August 2016*
***Published:*** *16 September 2016*

***Citation:***
*Cosentino AM and Fisher S (2016) The Utilization of Aquatic Bushmeat from Small Cetaceans and Manatees in South America and West Africa. Front. Mar. Sci. 3:163. doi: 10.3389/fmars.2016.00163*

## INTRODUCTION

Products derived from marine mammals, particularly cetaceans, that are used for food, bait or cash have been termed "marine bushmeat" by the scientific community (e.g., Alfaro and Van Waerebeek, 2001; Clapham and Van Waerebeek, 2007). Here, we adopt the term "aquatic bushmeat" as recently defined by the Convention on the Conservation of Migratory Species of Wild Animals (CMS) as the products sourced from wild aquatic megafauna (e.g., marine mammals, including riverine species) that are used for human consumption and other non-food purposes including traditional uses. Aquatic bushmeat is obtained through illegal or unregulated hunts as well as from stranded (dead or alive) and/or bycaught animals (CMS, 2016).

A thorough literature search of published and unpublished materials available online was conducted in English, Spanish, and French. The search included videos, news, and local organization websites. Additionally, the marine mammal community was approached via the mailing list MARMAM. Further information was also obtained by contacting individual authors and organizations.

Our findings suggest that aquatic mammal utilization as bushmeat is still common in many countries in America and Africa, reaching unsustainable levels in some areas. Here we present a brief literature review of the utilization of aquatic bushmeat from small cetaceans (dolphins, porpoises and beaked whales) and manatees in South America and West Africa.

## WEST AFRICA

There is no evidence of organized manatee exploitation in **Benin** although killing a manatee is an important event in a fisherman's life (Rihanath Olga and Tchibozo, 2008). Meat and body parts are used, *inter alia*, for food, therapeutic purposes and traditional ceremonies (Tchibozo, 2002; Dossou-Bodjrènou et al., 2004). Information on cetaceans in Benin is virtually non-existent. Sohou et al. (2013) is one of the only dedicated articles in the literature. The authors recorded the existence of at least nine cetacean species, some of which are occasionally consumed (Sohou et al., 2013).

The use of small cetaceans for human consumption and handicraft production in **Cape Verde** dates back several decades (Reiner et al., 1996). Products obtained opportunistically (e.g., from mass strandings) are used for food, handicrafts and decorations (Reiner et al., 1996; Hazevoet et al., 2010; Van Waerebeek et al., Unpublished). Recent reports indicate that the use of stranded and bycaught dolphin carcasses still occurs, although there is no current evidence of directed hunt (Brito and Carvalho, 2013).

Manatees are widely and illegally hunted by fishermen in **The Gambia** for food and traditional medicine (Powell, 1996; Jallow, 2008). Exploitation of small cetaceans may occur on a minor scale, mainly for food (Murphy et al., 1997; Alfaro and Van Waerebeek, 2001) but also for medicinal uses (Leeney et al., 2015).

Although the general public in **Ghana** did not consider dolphin meat edible until the late 1980s, that is no longer the case (Van Waerebeek and Ofori-Danson, 1999; Alfaro and Van Waerebeek, 2001). In fact, captures of cetaceans in Ghana are currently among the highest in West Africa, both in terms of animals landed and the number of species caught (e.g., Robards and Reeves, 2011). Small cetaceans were originally obtained as bycatch, however, direct catches now occur, at least in Apam, Dixcove, and Axim, where landing rates have greatly increased since the mid-1990s. For example, landings in Apam increased from 1.117 per month in the period 1995–1999, to 5.57 between 2001 and 2003 (Ofori-Danson et al., 2003; Debrah et al., 2010). Further, between January 2013 and February 2014, a minimum of 743 small cetaceans were landed at Dixcove alone, which represents an increase of almost 400% since 2003 (Debrah et al., 2010; Van Waerebeek et al., 2014). The entire animal, bones attached, is hacked into small, individual portions for sale, which explains the lack of bony remains on beaches (Van Waerebeek and Ofori-Danson, 1999). All body parts are used, including the internal organs, both for food and as bait (Ofori-Danson et al., 2003; Weir et al., 2008; Van Waerebeek et al., 2009, 2014; Debrah et al., 2010; Robards and Reeves, 2011; Weir and Pierce, 2013). Manatees hold different values between communities, some of which hunt them for food (Powell, 1996; Amlalo, 2008) while others kill them for bait (Ofori-Danson et al., 2008).

Some cultures in **Guinea** hunt manatees; their meat is typically consumed within the hunter's family, or shared between fishermen and hunters from the village, and their oil and bones are used for medicinal purposes (Powell, 1996; Keita, 2002; Richard et al., 2008). There is little evidence of small cetaceans being used as bushmeat (Van Waerebeek et al., 2004; Bamy et al., 2010).

Manatee hunting is probably declining in **Guinea-Bissau,** although incidental captures are currently the main threat (Sa et al., 2008). Products are used for food and other purposes (Powell, 1990; Silva et al., 1998; Silva and Araújo, 2001). Bycaught dolphins are also consumed locally and used in traditional ceremonies and for medicinal purposes (Leeney et al., 2015).

Manatees were heavily hunted in **Ivory Coast** in the 1980s and illegal hunting by specialized hunters continues (Powell, 1996; Perrin, 2001; Kouadio, 2008). Some communities hunt manatees for food. For example, the Ahizi consider manatee hunters heroes, although they are allowed to only kill three manatees during their lives. There are no recent reports of small cetaceans being used as bushmeat (Maigret, 1994).

Manatees have been hunted in **Liberia** for many decades, and probably to this day, using harpoons and guns (Robinson, 1971; Wiles and Makor, 2008).

In **Mali** manatees were hunted using a variety of methods for food and medicinal purposes, although hunting is currently uncommon (Powell, 1996; Perrin, 2001; Kienta et al., 2008).

There is little evidence for small cetacean bushmeat in **Mauritania** (Van Waerebeek et al., 2004) and no reports were found of the use of manatees as bushmeat.

Manatees are illegally hunted in **Niger**, along the Niger River, including for traditional ceremonies during the annual Sorko celebration. Their meat and other body parts are sold in markets (Malam Issa, 2008; Abbagana, 2013).

**Nigeria** appears to be one the largest consumers of small cetacean bushmeat in West Africa, with recent annual catches (both accidental and intentional) estimated at 10,000 dolphins (Lewison and Moore, 2012). Dolphins are captured using nets and, even when found alive, are butchered for human consumption (Uwagbae and Van Waerebeek, 2010). Manatee hunting was intensive in the past (Henshaw and Child, 1972; Sikes, 1974; Maigret, 1994; Angelici et al., 2001) and continues today for consumption and medicinal purposes despite a decline in the manatee population (Adeola, 1992; Maigret, 1994; Perrin, 2001; Oboto, 2002; Fa et al., 2006; Awobamise, 2008).

In **Senegal**, Atlantic humpback dolphins (*Sousa teuszii*) have been consumed opportunistically since the 1990s (Maigret, 1994; Van Waerebeek et al., 2004, 2008). Dolphin meat continues to be illegally traded as food and bait in the cephalopod fishery (Van Waerebeek et al., 1997a; Leeney et al., 2015). Manatees were caught historically (Maigret, 1994; Van Waerebeek et al., 1997a), on a scale that brought the population almost to extinction (Perrin, 2001). When incidental captures occur today, the meat is consumed and the oil used for medicinal purposes (Maigret, 1994; Powell, 1996; Van Waerebeek et al., 1997a; Diop, 2006; Ba et al., 2008).

Manatees have been hunted with nets and harpoons in **Sierra Leone** at least since the 1980s (Reeves et al., 1988), and exploitation likely continues (Siaffa and Jalloh, 2008). Additionally, rice farmers see manatees as pests and use traps to catch them (Reeves et al., 1988). Virtually the entire body is used (Maigret, 1994; Powell, 1996; Perrin, 2001; Siaffa and Jalloh, 2008). There is only little evidence of small cetacean bushmeat (Maigret, 1994).

In **Togo**, manatees are illegally hunted for their meat, which is sold and consumed locally and used in traditional medicine and ceremonies (Segniagbeto et al., 2008). Small cetaceans obtained from opportunistic and intentional captures are landed at Lomé harbor, where they are butchered and sent to other localities (Alfaro and Van Waerebeek, 2001; Segniagbeto et al., 2014).

## SOUTH AMERICA

In **Argentina**, bycaught porpoise and dolphin species were used for human consumption in the past (Crespo et al., 1994; Goodall et al., 1994; Ott et al., 2002; Robards and Reeves, 2011).

In **Bolivia,** botos are accidentally caught in fishing nets; their meat isused as bait or consumed by indigenous groups, and their oil used as medicine (Aliaga-Rossel, 2002; Trujillo et al., 2010, 2013; Robards and Reeves, 2011). No reports of manatee bushmeat were found.

Small cetaceans obtained opportunistically off the Atlantic coast of **Brazil** are used for food, bait, medicine and handicrafts (Siciliano, 1994; Ott et al., 2002; Alves and Rosa, 2008; Tosi et al., 2009; Oliveira de Meirelles et al., 2010; Trujillo et al., 2010). In the Brazilian Amazon River basin botos (*Inia* spp.) are illegally hunted for their meat to use as bait for fishing the scavenger catfish (*Calophysus macropterus*) known as *piracatinga* in Brazil, *mota* in Colombia, *simi* in Peru and *mapurite* in Venezuela (Flores et al., 2008; Gómez et al., 2008; Trujillo et al., 2010; Pinto de Sá Alves et al., 2012). The effect of these hunts is unknown as there are no available abundance estimates for river dolphins in their distribution range (Botero-Arias et al., 2014; Salinas et al., 2014). Evidence, however, suggests that some boto populations may be impacted; for example, da Silva et al. (2011) found a 10% annual reduction of boto abundance in a well-studied population, since 2000. It is estimated that 1650 dolphins are caught annually near Tefé alone (in Central Amazon), but a large number of other towns and villages in the Amazon target *piracatinga* using dolphin products as bait (da Silva and Martin, 2007; da Silva et al., 2011).

The West Indian (*Trichechus manatus*) and the Amazonian manatees (*Trichechus inunguis*) are present in Brazil (UNEP, 2010). They were hunted historically for their skin for making leather products (Domning, 1982). Today manatees are harvested for food and other uses (Lima et al., 1992; UNEP, 2010; Gómez et al., 2012; Franzini et al., 2013). At least 32 manatee hunters were active in 2014 (de Souza et al., 2014).

Over 7600 dolphins were killed for bait in the *centolla* King crab (*Lithodes santolla*) fishery in southern **Chile** between 1976 and 1979. Laws were adopted to protect dolphins but enforcement was poor (Cárdenas et al., 1987; Aguayo et al., 1998; Altieri and Rojas, 1999). The decline of crab abundance, the use alternative baits and other factors greatly reduced illegal hunts in the 1990s (Lescrauwaet and Gibbons, 1994; Van Waerebeek et al., 1997b). Small cetaceans were also killed in central Chile (Van Waerebeek et al., 1999) in the 1970s for bait in the longline fishery (Aguayo et al., 1998) and, although recent reports are scarce, in 2014 local fishermen were arrested for fileting a dolphin. Dolphins caught intentionally in Northern Chile in the 1970s–1980s were used for food and bait (see Aguayo et al., 1998).

In the **Colombian** Amazon, boto, and, rarely, tucuxi (*Sotalia fluviatilis*) dolphins have been hunted since the late 1980s at least (Beltrán and Trujillo, 1992). Body parts are used as aphrodisiacs and amulets, and their oil for medicinal uses (see Trujillo et al., 2010). However, the main use of botos is as bait to fish "*mota*" (Trujillo et al., 2011; Salinas et al., 2014). On the Pacific coast, hunts for dolphins for bait became common by 1990 (Vidal et al., 1994; Ávila et al., 2008). Mother-calf pairs were frequently targeted (Ávila et al., 2008). Evidence suggests directed hunts still occur (Flórez-González and Capella, 2010). West Indian manatees were heavily exploited in the 18th and 19th Centuries (Mancera Rodríguez and Reyes García, 2008), with bombs and nets used (Lima et al., 1992). Although directed hunts are uncommon, manatees are still targeted for food, for their leather to make whips, and for other purposes (Romero and Creswell, 2005; Arévalo-González et al., 2010; Cruz-Antía and Gómez, 2011; UNEP, 2010; Fundación Natütama, 2013; Kiszka, 2014).

In **Ecuador**, indigenous Amazonian tribes, such as the Siona, traditionally exploited Amazonian manatees for subsistence (Timm et al., 1986) and non-food uses. Recent reports suggest hunting still occurs (Denkinger, 2010; Brice, 2014). No reports of small cetacean bushmeat were found.

Native Americans in **French Guiana** historically hunted West Indian manatees for private consumption or for religious traditions (Spiegelberger, 2002), although the practice is now uncommon (Romero and Creswell, 2005; UNEP, 2010). Dolphins were occasionally harpooned for fish bait in the past (Vidal et al., 1994).

In **Guyana** there is probably no organized hunting of West Indian manatees, although they may be taken opportunistically (UNEP, 2010). No reports of small cetacean bushmeat were found.

The greatest exploitation of small cetaceans in South America occurs in **Peru**, where they have been intentionally and incidentally caught in fishing nets for several decades: an estimated 10,000 dolphins were landed annually in the 1980s (Read et al., 1988; Van Waerebeek and Reyes, 1990, 1994a). Harpooning was once opportunistic (Read et al., 1988), but became common toward the 1990s. Some fishermen also used dynamite to provoke dolphin "stampedes" into set gillnets (Van Waerebeek and Reyes, 1990). Dolphin meat was sold in local food markets, but most animals were shipped to Lima (Read et al., 1988).

Although hunting and trading of small cetaceans was banned in Peru in 1990, captures continued (Van Waerebeek et al., 1999, 2002; Majluf et al., 2002; Reyes et al., 2002; García-Godos,

**TABLE 1 | Small cetacean and manatee species that are or have been used as bushmeat in South America and West Africa.**

| Scientific name | Name | IUCN red list | CITES | CMS |
|---|---|---|---|---|
| **CETACEANS** | | | | |
| *Cephalorhynchus commersonii* | Commerson's dolphins | DD | II | |
| *Cephalorhynchus eutropia* | Chilean dolphin | NT | II | |
| *Delphinus capensis* | Long-beaked common dolphin | DD | II | |
| *Delphinus delphis* | Short-beaked common dolphins | LC | II | |
| *Feresa attenuata* | Pygmy killer whale | DD | II | |
| *Globicephala macrorhynchus* | Short-finned pilot whales | DD | II | |
| *Globicephala melas* | Long-finned pilot whales | DD | II | |
| *Grampus griseus* | Risso's dolphins | LC | II | |
| *Inia boliviensis* | Boto | DD | II | II |
| *Inia geoffrensis* | Boto | DD | II | II |
| *Kogia breviceps* | Pygmy sperm whale | DD | II | |
| *Kogia sima* | Dwarf sperm whale | DD | II | |
| *Lagenodelphis hosei* | Fraser's dolphin | LC | II | |
| *Lagenorhynchus australis* | Peale's dolphin | DD | II | II |
| *Lagenorhynchus obscurus* | Dusky dolphin | DD | II | II |
| *Lissodelphis peronii* | Southern right whale dolphins | DD | II | |
| *Mesoplodon europaeus* | Gervais' beaked whale | DD | II | |
| *Orcinus orca* | Killer whale | DD | II | |
| *Peponocephala electra* | Melon-headed whale | LC | II | |
| *Phocoena dioptrica* | Spectacle porpoise | DD | II | |
| *Phocoena spinipinnis* | Burmeister's porpoise | DD | II | II |
| *Pontoporia blainvillei* | Franciscana | VU | II | II |
| *Pseudorca crassidens* | False killer whale | DD | II | |
| *Sotalia fluviatilis* | Tucuxi | DD | I | II |
| *Sotalia guianensis* | Guiana dolphin | DD | I | II |
| *Stenella attenuata* | Spotted dolphin | NT | II | II |
| *Stenella clymene* | Clymene dolphin | DD | II | |
| *Stenella coeruleoalba* | Striped dolphin | LC | II | |
| *Stenella frontalis* | Atlantic spotted dolphins | DD | II | |
| *Stenella longirostris* | Spinner dolphin | DD | II | |
| *Steno bredanensis* | Rough-toothed dolphins | LC | II | |
| *Tursiops truncatus* | Bottlenose dolphin | LC | II | |
| *Ziphius cavirostris* | Cuvier's beaked whale | LC | II | |
| **SIRENIA** | | | | |
| *Trichechus inunguis* | Amazonian manatee | VU | I | II |
| *Trichechus manatus* | West Indian manatee | VU | I | I/II |
| *Trichechus senegalensis* | West African manatee | VU | I | I/II |

*VU, Vulnerable; DD, Data Deficient; NT, Near Threatened; LC, Least Concern; IUCN, International Union for Conservation of Nature; CMS, Convention on Migratory Species; CITES, Convention on International Trade of Endangered Species.*

2007; Mangel et al., 2010; Mangel, 2012) and by 1993 the annual estimated catch was 15,000–20,000 dolphins, exceeding the previous, legal, hunt (Van Waerebeek and Reyes, 1994b). In the late 1990s, dolphin products started to also be used as shark bait (Van Waerebeek et al., 1999). The annual catch estimate increased in the 2000s as products from harpooned and bycaught dolphins were also sold in local food markets and consumed onboard fishing vessels or at home. The use as bait has rapidly expanded and incidental and directed catches still occur (Tzika et al., 2010), as well as butchering of live stranded animals (García-Godos and Cardich, 2010).

Amazonian manatees are hunted in Peru to this day despite legal protection. Currently, however, they are mainly bycaught. Their meat is consumed (Reeves et al., 1996; Hidalgo Taricuarima, 2010) and skin, fat, and bones are occasionally used for medicinal purposes (Reeves et al., 1996; Elcacho Rovira, 2013; Silva et al., 2014). They are also captured alive to be "grown" for consumption, kept as pets, or even to be displayed in restaurants (Perea-Sicchar et al., 2011).

In **Venezuela**, the use of dolphins for bait and food has increased significantly since the 1970s (Vidal et al., 1994), with the Government even considering their commercial exploitation for food in the 1990s (Romero et al., 1997). Current removals (intentional and incidental) are estimated at 1000 animals annually (Robards and Reeves, 2011). Body parts are also used by some indigenous communities for religious events and medicinal purposes (Romero et al., 1997; Trujillo et al., 2010). West Indian manatees have been exploited for food, fuel, medicine, leather and cooking oil (PNUMA, 1995), since pre-Columbian times (Mondolfi, 1974; Romero and Creswell, 2005; UNEP, 2010) and manatee meat was found in markets until relatively recently (O'Shea et al., 1988). Some animals are also live captured for public display (UNEP, 2010).

## CONCLUSIONS

In most South American and West African countries aquatic mammals are or have been used as bushmeat, encompassing at least 33 small cetaceans and all manatee species. Although in most cases the practice likely began opportunistically for local consumption, in some countries it has evolved to include directed catches and may have expanded to unsustainable levels.

Of the 33 small cetacean species recorded in this study, two are listed in the International Union for Conservation of Nature (IUCN) red list as "near threatened" and two as "vulnerable," as are all manatee species. Additionally, 22 cetacean species are listed as "data deficient," therefore some may also be at risk. Moreover, many populations are considered threatened, while the species is not. All these species are listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) appendices signifying that their status could be compromised by trade of their products. However, as CITES regulates only international trade and aquatic bushmeat trade is typically domestic, the treaty offers little protection. Additionally, some species are included in the appendices of the Convention on the Conservation of Migratory Species of Wild Animals (CMS; **Table 1**) and most countries have domestic regulations that provide partial or full protection.

No recent information was found of the use of aquatic mammals for bushmeat in Uruguay, the Island of Saint Helena and São Tomé and Principe, after Robards and Reeves (2011). No reports were found for Suriname and Burkina Faso. The absence of information on aquatic bushmeat (recent or otherwise) is probably due to a lack of research and reporting rather than the non-existence of such use. A precautionary approach is recommended, and the absence of evidence should not be interpreted as evidence of absence. Moreover, despite legal protection, the use of small cetaceans and manatees for aquatic bushmeat appears to be growing.

Marine mammals are especially susceptible to exploitation due to low reproductive rates and the many other threats they face, including noise pollution and climate change (Perrin et al., 2009). An increase in knowledge and better understanding of the aquatic bushmeat issue is needed in order to implement local and international management programs for the effective monitoring and mitigation of unsustainable and illegal hunting and use of aquatic mammals. The work of the IWC Scientific Committee's Marine Bushmeat Intersessional Working Group, including holding dedicated regional workshops and formal liaison with other international bodies, such as CMS and the Convention on Biological Diversity (International Whaling Commission, 2016), is expected to provide a helpful contribution.

## AUTHOR CONTRIBUTIONS

AC was responsible for researching related literature and preparing a first draft. SF was responsible for the general idea and from the first draft on, she contributed to editing.

## REFERENCES


Abbagana, A. L. (2013). *Situation du lamantin au Niger.* Report to the Ministere de L'environnement, de la Salubrite Urbaine et du Developpement Durable, Direction de L'environnement et des Eaux et Forets, Direction de la Faune, de la Chasse et des Aires Protegees, Republique du Niger, 7.

Adeola, M. O. (1992). Importance of wild animals and their parts in the culture, religious festivals, and traditional medicine, of Nigeria. *Environ. Conserv.* 19, 125–134. doi: 10.1017/S0376892900030605

Aguayo, A., Navarro, D. T., and Ram, J. A. (1998). Los mamíferos marinos de Chile: 1. Cetacea. *Ser. Client. INACH* 48, 19–159.

Alfaro, J., and Van Waerebeek, K. (2001). "Drowning in a sea of silence: the bushmeat concept as applied to marine wildlife," in *Zoos and Aquariums: Committing to Conservation (ZACC)* (Orlando: ZACC), 16.

Aliaga-Rossel, E. (2002). Distribution and abundance of the river dolphin (*Inia geoffrensis*) in the Tijamuchi River, Beni, Bolivia. *Aq. Mamm.* 28, 312–323.

Altieri, M., and Rojas, A. (1999). La tragedia ecológica del "milagro" neoliberal chileno. *Pers. Soc. XIII* 1, 127–141.

Alves, R. R. N., and Rosa, I. L. (2008). Use of tucuxi dolphin *Sotalia fluvialilis* for medicinal and magic/religious purposes in North of Brazil. *Hum. Ecol.* 36, 443–447. doi: 10.1007/s10745-008-9174-5

Amlalo, M. (2008). "Ghana," in *Conservation Strategy for the West African Manatee,* eds T. Dodman, M. D. D. Ndiaye, and K. Sarr (Nairobi, Kenya and Wetlands International Africa; Dakar, Senegal: UNEP), 59–62.

Angelici, F. M., Egbide, B., and Akani, G. C. (2001). Some new mammal records from the rainforest of South-Eastern Nigeria. *Hystrix* 12, 37–43. doi: 10.4404/hystrix-12.1-4169

Arévalo-González, G. K., Castelblanco-Martínez, N., Sánchez-Palomino, P., and López-Arévalo, H. (2010). Uso de metodologías complementarias para la determinación del tamaño de la población de manatí (*Trichetus manatus*) en la Ciénaga de Pareces (Santander, Colombia). *Mem. Conf. Interna Med. Aprovech. Fauna Silv. Exot. Conv.* 6, 2.

Ávila, I. C., García, C., and Bastidas, J. C. (2008). A note on the use of dolphins as bait in the artisanal fisheries off Bahía Solano, Chocó, Colombia. *J. Cetacean Res. Manage.* 10, 179–182.

Awobamise, A. (2008). "Nigeria," in *Conservation Strategy for the West African Manatee*, eds T. Dodman, M. D. D. Ndiaye, and K. Sarr (Nairobi, Kenya and Wetlands International Africa; Dakar, Senegal: UNEP), 75–78.

Ba, E., Diop, M. D., Sarr, K., Mactar Niane, A., and Jaulin, M. (2008). "Senegal," in *Conservation Strategy for the West African Manatee*, eds T. Dodman, M. D. D. Ndiaye, and K. Sarr (Nairobi, Kenya and Wetlands International Africa; Dakar, Senegal: UNEP), 26–30.

Bamy, I. L., Van Waerebeek, K., Bah, S. S., Dia, M., Kaba, B., Keita, N., et al. (2010). Species occurrence of cetaceans in Guinea, including humpback whales with Southern Hemisphere seasonality. *Mar. Biod. Rec.* 3:e48. doi: 10.1017/S1755267210000436

Beltrán, S., and Trujillo, F. (1992). *Mortalidad Incidental y dirigida de Inia Geoffrensis y Sotalia fluviatilis, en la Amazonia y Orinoquie colombiana.*

*Abstract retrieved from Resúmenes, 5ta Reunión de Especialistas en Mamíferos Acuáticos de América del Sur,* Buenos Aires.

Botero-Arias, R., de Lima Franco, D., and Marmontel, M. (2014). *Caiman and Dolphin Mortality Associated to the Piracatinga Fishery in the Mid Solimões River Region - Amazonas, Brazil*. Report to the Ministry of Science, Technology and Innovation, Tefé, 60.

Brice, C. E. (2014). *The Detection of Amazonian Manatees (Trichechus inunguis) Using Side-Scan Sonar and the Effect of Oil Activities on their Habitats in Eastern Ecuador*. Master's thesis. Nova Southeastern University. Retrieved from NSUWorks, Oceanographic Center. Available online at: http://nsuworks.nova.edu/occ_stuetd/8

Brito, C., and Carvalho, I. (2013). "Blackfish off Cape Verde Islands: the need for future effort to assess distribution, abundance and interactions with human activities," in *Atas do colóquio Internacional Cabo Verde e Guiné-Bissau: Percursos do Saber e da Ciência*. Lisboa: Instituto de Investigação Científica Tropical.

Cárdenas, J. C., Gibbons, J., Oporto, J., and Stutzin, M. (1987). Impacto de la pesquería de centolla y centollón sobre las poblaciones de mamíferos marinos de Magallanes, Chile. *Amb. y Des.* 3, 111–119.

CMS (2016). *Aquatic Bushmeat*. UNEP/CMS/ScC-SC1/Doc.10.2.2. CMS.

Clapham, P., and Van Waerebeek, K. (2007). Bushmeat and bycatch: the sum of the parts. *Mol. Ecol.* 16, 2607–2609. doi: 10.1111/j.1365-294X.2007.03378.x

Crespo, E. A., Corcuera, J. F., and López Casorla, A. (1994). Interactions between marine mammals and fisheries in some coastal fishing areas of Argentina. *Rep. Int. Whal. Commn.* 15, 269–281.

Cruz-Antía, D., and Gómez, J. R. (2011). Aproximación al uso y tráfico de fauna silvestre en Puerto Carreño, Vichada, Colombia. *Amb. y Des.* 14, 63–94. Available online at: http://revistas.javeriana.edu.co/index.php/ambienteydesarrollo/article/view/1094

da Silva, V. M. F., and Martin, A. R. (2007). "Impact of human activities upon two species of dolphins in Amazonian flooded forest, Brazil," in *Abstract of the 17th Biennial Conference on the Biology of Marine Mammals* (Cape Town: Society for Marine Mammalogy).

da Silva, V. M. F., Martin, A. R., and Do Carmo, N. A. S. (2011). Amazonian fisheries pose threat to elusive dolphin species. *Species* 53, 10–11.

Debrah, J. S., Ofori-danson, P. K., and Van Waerebeek, K. (2010). *An Update on the Catch Composition and Other Aspects of Cetacean Exploitation in Ghana*. IWC SC/62/SM10.

Denkinger, J. (2010). Status of the Amazonian manatee (*Trichechus inunguis*) in the Cuyabeno Reserve, Ecuador. *Avances* 2, b29–b34.

de Souza, D. A., Ferreira da Silva, V. M., Fernandes da Silva, J. C., von Muhlen, E. M., Pinassi Antunes, A., and Rossoni Cardoso, F. (2014). Conservation prospects for the Amazonian manatee in the lower Purus River, Central Amazon, Brazil. *Sirenews* 62, 6–8.

Diop, M. D. (2006). *Conservation du Lamantin Ouest Africain Trichechus Senegalensis le Long du Littoral Ouest Africain: Enquête de Base Dans la Réserve de Biosphère du delta du Saloum (Sénégal) September 2005*. Wetlands International Report. Survey team of IUCN and Parc Nationale Delta du Saloum.

Domning, D. P. (1982). Commercial exploitation of manatees *Trichechus* in Brazil c. 1785–1973. *Biol. Conserv.* 22, 101–126.

Dossou-Bodjrènou, S. J., Sagbo, P., and Boko, J.-M. (2004). *Education, Conservation et Recherches sur le Lamantin d'Afrique Dans les Zones Humides du Sud-Benin*. Rapport d'Activité N° 002-PL-NT, Nature Tropicale, ONG, 28.

Elcacho Rovira, M. (2013). *Percepción Social Sobre el Manatí Amazónico, Trichechus Inunguis, en Iquitos (Perú)*. MSc. thesis, Barcelona: Instituto de Ciencia y Tecnología Ambiental (ICTA), Universidad Autónoma de Barcelona.

Fa, J. E., Seymour, S., Dupain, J., Amin, R., Albrechtsen, L., and Macdonald, D. (2006). Getting to grips with the magnitude of exploitation: Bushmeat in the Cross–Sanaga rivers region, Nigeria and Cameroon. *Biol. Conserv.* 129, 497–510. doi: 10.1016/j.biocon.2005.11.031

Flores, P. A. C., Trujillo, F., Rocha-Campos, C. C., Marini-Filho, O. J., Da Silva, V. M. F., Martin, A. R., et al. (2008). *The Status of "Piracatinga" Fishery using AMAZON Botos As Bait in South America*. IWC SC/60/SM17.

Flórez-González, L., and Capella, J. (2010). "Interacción pesquería-cetáceos: captura incidental en el Pacífico Sur de Colombia," in *Esfuerzos Para Mitigar el Impacto De Actividades Pesqueras en Cetáceos en Los Países del Pacífico Sudeste,* ed F. Félix (Guayaquil: CPPS), 14–20.

Franzini, A. M., Castelblanco-Martínez, D. N., Rosas, F. C. W., and da Silva, V. M. F. (2013). What do local people know about Amazonian manatees? Traditional ecological knowledge of *Trichechus inunguis* in the oil Province of Urucu, AM Brazil. *Nat. Conserv.* 11, 75–80. doi: 10.4322/natcon.2013.012

Fundación Natütama (2013). *Caminos Para la Conservación : Monitoreo y Manejo de la Fauna Acuática Con la Comunidad. Colombia*. Unpublished Report, 67.

García-Godos, I. (2007). "Revisión de las interacciones entre cetáceos y la pesquería marina peruana: perspectivas para la conservación de cetáceos en Perú," in *Memorias del Taller de Trabajo Sobre el Impacto de las Actividades Antropogénicas en Mamíferos Marinos en el Pacífico Sudeste,* ed F. F. Bogotá, (Colombia: CPPS/PNUMGuayaquil Ecuador, A), 77–82.

García-Godos, I., and Cardich, C. (2010). First mass stranding of Risso's dolphins (*Grampus griseus*) in Peru and its destiny as food and bait. *Mar. Biod. Rec.* 3, e3. doi: 10.1017/S1755267209991084

Gómez, A., Rodríguez, J., Jiménez, N., Cabezas, F., Rodríguez, J. E., and Matamoros, Y. (eds.). (2012). "Viabilidad de la población y el hábitat del manatí (*Trichechus Manatus Manatus*) en el Caribe," in *Estrategia para la conservación de la especie. Zoológico y Jardín Botánico Nacional Simón Bolívar*. UICN/SSC Conservation Breeding Specialist Group-Mesoamérica (San José: CBSG Mesoamérica).

Gómez, C., Trujillo, F., Diazgranados, M. C., and Alonso, J. (2008). "Capturas dirigidas de delfines de río en la Amazonia para la pesca de mota (*Calophysus macropterus*): una problemática regional de gran impacto," in *Fauna Acuática Amenazada en la Amazonia Colombiana. Análisis y Propuestas Para su Conservación,* eds F. Trujillo, J. C. Alonso, M. C. Diazgranados, and C. Gómez (Bogotá: Fundación Omacha, Fundación Natura, Instituto Sinchi y Corpoamazonia), 39–57.

Goodall, R. N. P., Schiavini, A. C. M., and Fermani, C. (1994). Net fisheries and net mortality of small cetaceans off Tierra del Fuego, Argentina. *Rep. Int. Whal. Commn,* 15, 295–306.

Hazevoet, C. J., Monteiro, V., López, P., Varo, N., Torda, G., Berrow, S., et al. (2010). Recent data on whales and dolphins (Mammalia: Cetacea) from the Cape Verde Islands, including records of four taxa new to the archipelago. *Zoologia Caboverdiana* 1, 75–99.

Henshaw, J., and Child, G. S. (1972). New attitudes in Nigeria. *Oryx* 11, 275–283.

Hidalgo Taricuarima, J. J. (2010). *Evaluación preliminar del "manatí" Amazónico Trichechus inunguis (Natterer, 1883) en el Río Lagartococha – Zona Reservada Güeppí, Loreto - Perú*. Report to Ministerio del Ambiente, 24.

International Whaling Commission (2016). *Report of the Scientific Committee.* IWC/66/Rep01, 136. Available online at: https://archive.iwc.int/pages/view.php?ref=6127&k

Jallow, A. (2008). "The Gambia," in *Conservation Strategy for the West African Manatee,* eds T. Dodman, M. D. D. Ndiaye, and K. Sarr (Nairobi, Kenya and Wetlands International Africa, Dakar: UNEP), 31–34.

Keita, N. (2002). *Inventaire du Lamantin d'Afrique (Trichechus senegalensis) en République de Guinée.* Unpublished Report, 10.

Kienta, M., Kone, B., and Timbo, S. (2008). "Mali," in *Conservation Strategy for the West African Manatee*, eds T. Dodman, M. D. D. Ndiaye, and K. Sarr (Nairobi, Kenya and Wetlands International Africa, Dakar: UNEP), 79–82.

Kiszka, J. (2014). *Bycatch Assessment of the West Indian Manatee (Trichechus Manatus) and Other Megafauna In Artisanal Fisheries of the Caribbean*. Report to SPAW-RAC, 41. Available online at: http://www.car-spaw-rac.org/?lang=en

Kouadio, A. (2008). "Côte D'ivoire/Ivory Coast," in *Conservation Strategy for the West African Manatee*, eds T. Dodman, M. D. D. Ndiaye, and K. Sarr (Nairobi, Kenya and Wetlands International Africa, Dakar: UNEP), 53–58.

Leeney, R. H., Dia, I. M., and Dia, M. (2015). Food, pharmacy, friend? Bycatch, direct take and consumption of dolphins in West Africa. *Hum. Ecol.* 43, 105–118. doi: 10.1007/s10745-015-9727-3

Lescrauwaet, A. C., and Gibbons, J. (1994). Mortality of small cetaceans and the crab bait fishery in the Magallanes Area of Chile since 1980. *Rep. Int. Whal. Commn.* 15, 485–494.

Lewison, R., and Moore, J. (2012). *Improving Interview-Based Assessments of Sea Turtle and Marine Mammal Bycatch in West Africa: Putting Fishing Activity into A Socio-Economic Context.* Project Report, San Diego State University and Southwest Fisheries Science Center, NOAA, 81.

Lima, R. P., Paludo, D., Soavinski, R. J., Silva, K. G., and Oliveira, E. M. A. (1992). Levantamento da distribuição, ocorrência e status de conservação do peixe-boi marinho (*Trichechus manatus*, Linnaeus, 1758) no litoral nordeste do Brasil. *Peixeboi* 1, 47–72.

Maigret, J. (1994). Marine mammals and fisheries along the West African coast. *Rep. Int. Whal. Commn.* 15, 307–316.

Majluf, P., Babcock, E. A., Riveros, J. C., Schreiber, M. A., and Alderete, W. (2002). Catch and bycatch of sea birds and marine mammals in the small-scale fishery of Punta San Juan, Peru. *Conserv. Biol.* 16, 1333–1343. doi: 10.1046/j.1523-1739.2002.00564.x

Malam Issa, A. (2008). "Niger," in *Conservation Strategy for the West African Manatee*, eds T. Dodman, M. D. D. Ndiaye, and K. Sarr (Nairobi, Kenya and Wetlands International Africa, Dakar: UNEP), 83–86.

Mancera Rodríguez, N. J., and Reyes García, O. (2008). Comercio de fauna silvestre en Colombia/Wildlife trade in Colombia. *Rev. Fac. Nal. Agr. Medellín* 61, 4618–4645. Available online at: http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0304-28472008000200015

Mangel, J. C., Alfaro-Shigueto, J., Van Waerebeek, K., Cáceres, C., Bearhop, S., Witt, M. J., et al. (2010). Small cetacean captures in Peruvian artisanal fisheries: high despite protective legislation. *Biol. Conserv.* 143, 136–143. doi: 10.1016/j.biocon.2009.09.017

Mangel, J. C. (2012). *Interactions of Peruvian Small Scale Fisheries with Threatened Marine Vertebrate Species*. PhD. thesis. Exeter, UK: University of Exeter.

Mondolfi, E. (1974). Taxonomy, distribution and status of the manatee in Venezuela. *Memorias de la Sociedad de Ciencias Naturales La Salle.* 34, 5–23.

Murphy, P. F., Van Waerebeek, K., and Jallow, A. O. (1997). *Cetacean in Gambian Waters*. IWC SC/49/SM11.

Oboto, E. (2002). *Manatee status in River Benue and River Niger (Nigeria)*. Unpublished Report, 89.

Ofori-Danson, P. K., Self-Sullivan, C., Mombu, V. M., and Yelibora, M. A. (2008). *Enhancing Conservation of the West African Manatee in Ghana (20pp).* Annual Report 2007. Nature Conservation Research Centre, Accra, 45.

Ofori-Danson, P. K., Van Waerebeek, K., and Debrah, S. (2003). A survey for the conservation of dolphins in Ghanaian coastal waters. *J. Ghana Sci. Assoc.* 5, 45–54.

Oliveira de Meirelles, A. C., Ribeiro, A. C., Silva, C. P. N., and Soares Filho, A. A. (2010). Records of Guiana dolphin, *Sotalia guianensis*, in the State of Ceará, northeastern Brazil. *Lat. Am. J. Aquat. Mamm.* 8, 97–102. doi: 10.5597/lajam00157

O'Shea, T. J., Correa-Viana, M., Ludlow, M. E., and Robinson, J. G. (1988). Distribution, status, and traditional significance of the West Indian manatee *Trichechus manatus* in Venezuela. *Biol. Conserv.* 46, 281–301. doi: 10.1016/0006-3207(88)90030-4

Ott, P. H., Secchi, E. R., Moreno, I. B., Danilewicz, D., Crespo, E. A., Bordino, P., et al. (2002). Report of the working group on fishery interactions. *Lat. Am. J. Aquat. Mamm.* 1, 55–64. doi: 10.5597/lajam00008

Perea-Sicchar, C. M., Velásquez-Varela, L. J., Sánchez-Babilonia, J., Espinoza-Azan, M., Lee-Richardson, D., and Sigler, L. (2011). Manejo y rehabilitación del manatí Amazónico (*Trichechus inunguis*) en cautiverio en el Perú. *Ciencia Amazónica (Iquitos)* 1, 104–113.

Perrin, W. F. (2001). Conservation status of the West African Manatee. *Sirenews* 36, 34–40.

Perrin, W. F., Würsig, B., and Thewissen, J. G. M. (2009). *Encyclopedia of Marine Mammals, 2nd Edn.*, San Diego, CA: Elsevier.

Pinto de Sá Alves, L. C., Antunes Zappes, C., and Andriolo, A. (2012). Conflicts between river dolphins (Cetacea: *Odontoceti*) and fisheries in the Central Amazon: a path toward tragedy? *Zoologia (Curitiba)* 29, 420–429. doi: 10.1590/S1984-46702012000500005

Powell, J. A. (1990). *Manatees in the Bijagos Archipelago: Recommendations for Their Conservation*. Cameroon: IUCN Wetland Programme, 30.

Powell, J. A. (1996). *The Distribution and Biology of the West African Manatee (Trichechus senegalensis Link, 1795)*. Nairobi, Kenya: United Nations Environment Programme, Regional Seas Programme, Oceans and Coastal Areas.

PNUMA (1995). Plan de Manejo Regional para el Manatí Antillano, Trichechus manatus. Technical Report to PAC No. 35. Programa Ambiental del Caribe del PNUMA, Kingston.

Read, A. J., Van Waerebeek, K., Reyes, J. C., McKinnon, J. S., and Lehman, L. C. (1988). The exploitation of small cetaceans in Coastal Peru. *Biol. Conserv.* 46, 53–70. doi: 10.1016/0006-3207(88)90108-5

Reeves, R. R., Leatherwood, S., Jefferson, T. A., Curry, B. E., and Henningsen, T. (1996). Amazonian manatees, *Trichechus inunguis*, in Peru: distribution, exploitation, and conservation status. *Interciencia* 21, 246–254.

Reeves, R. R., Tuboku-metzger, D., and Kapindi, R. A. (1988). Distribution and exploitation of manatees in Sierra Leone. *Oryx* 22, 75–84. doi: 10.1017/S0030605300027538

Reiner, F., dos Santos, M. E., and Wenzel, F. W. (1996). cetaceans of the Cape Verde archipelago. *Mar. Mamm. Sci.* 12, 434–443. doi: 10.1111/j.1748-7692.1996.tb00595.x

Reyes, J. C., Echegaray, M., and De Paz, N. (2002). "Distribución, comportamiento y conservación de cetáceos en el área Pisco-Paracas," in *Memorias I Jornada Científica. Bases Ecológicas y Socioeconómicas para el Manejo de los Recursos Vivos de la Reserva Nacional de Paracas.* eds J. Mendo and M. Wolf (Lima: Universidad Nacional Agraria La Molina), 136–144.

Richard, T., Ibrahima, C., Cécé Noel, K., Abdoulaye, D., Alhousséiny, D., and Cheick Ahmed Kassory, B. (2008). "Guinea," in *Conservation Strategy for the West African Manatee,* eds T. Dodman, M. D. D. Ndiaye, and K. Sarr (Nairobi, Kenya and Wetlands International Africa, Dakar: UNEP), 41–46.

Rihanath Olga, I., and Tchibozo, S. (2008). "Benin," in *Conservation strategy for the West African manatee,* eds T. Dodman, M. D. D. Ndiaye, and K. Sarr (Nairobi, Kenya and Wetlands International Africa, Dakar: UNEP), 71–74.

Robards, M. D., and Reeves, R. R. (2011). The global extent and character of marine mammal consumption by humans: 1970–2009. *Biol. Conserv.* 144, 2770–2786. doi: 10.1016/j.biocon.2011.07.034

Robinson, P. T. (1971). Wildlife trends in Liberia and Sierra Leone. *Oryx* 11, 117–122. doi: 10.1017/S0030605300009704

Romero, A., Agudo, A. I., and Green, S. M. (1997). *Exploitation of Cetaceans in Venezuela.* IWC SC/48/SM40.

Romero, A., and Creswell, J. (2005). "In the land of the mermaid: how culture, not ecology, influenced marine mammal exploitation in the South-eastern Caribbean," in *Environmental issues in Latin America and the Caribbean,* eds A. Romero, A., and S. E. West (New York, NY: Springer), 3–30.

Sa, J., Biai, J., da Cunha, L. R., da Silva Nagha, H., Djejo, F., Soares, J., et al. (2008). "Guinea-Bissau," in *Conservation Strategy for the West African Manatee*, eds T. Dodman, M. D. D. Ndiaye, and K. Sarr (Nairobi, Kenya and Wetlands International Africa, Dakar: UNEP), 35–40.

Salinas, C., Cubillos, J. C., Gómez, R., Trujillo, F., and Caballero, S. (2014). "Pig in a poke (gato por liebre)": The "mota" (*Calophysus macropterus*) fishery, molecular evidence of commercialization in Colombia and toxicological analyses. *Ecohealth* 11, 197–206. doi: 10.1007/s10393-013-0893-8

Segniagbeto, G. H., Akpamou, K. G., Tengue, K. T., Alassani, D., and Okoumassou, K. (2008). "Togo," in *Conservation Strategy for the West African Manatee*, eds T. Dodman, M. D. D. Ndiaye, and K. Sarr (Nairobi, Kenya and Wetlands International Africa, Dakar: UNEP), 63–70.

Segniagbeto, G. H., Van Waerebeek, K., Bowessidjaou, J. E., Ketoh, K., Kpatcha, T. K., Okoumassou, K., et al. (2014). Annotated checklist and fisheries interactions of cetaceans in Togo, with evidence of Antarctic minke whale in the Gulf of Guinea. *Integr. Zool.* 9, 1–13. doi: 10.1111/1749-4877.12011

Siaffa, D. D., and Jalloh, A. (2008). "Sierra Leone," in *Conservation Strategy for the West African Manatee*, eds T. Dodman, M. D. D. Ndiaye, and K. Sarr (Nairobi, Kenya and Wetlands International Africa, Dakar: UNEP), 47–50.

Siciliano, S. (1994). Review of small cetacean and fishery interactions in coastal waters of Brazil. *Rep. Int. Whal. Commn.* 15, 241–250.

Sikes, S. (1974). How to save the mermaids. *Oryx* 12, 465–470. doi: 10.1017/S0030605300012266

Silva, J., Montes, D., and Elías, R. (2014). Conocimientos, conservación y avistamiento del manatí Amazónico (*Trichechus inunguis*), según los pobladores de la cuenca del Río Ucayali (Loreto, Perú). *Salud Tecnol. Vet.* 2, 32–38. doi: 10.20453/stv.v2i1.2199

Silva, M. A., and Araújo, A. (2001). Distribution and current status of the West African manatee (*Trichechus senegalensis*) in Guinea-Bissau. *Mar. Mamm. Sci.* 17, 418–424. doi: 10.1111/j.1748-7692.2001.tb01285.x

Silva, M. A., Araújo, A., Djedjó, F., Gomes, L., and Monteiro, H. (1998). *Plano Nacional de Conservação do manatim Africano (Trichechus senegalensis)* *na Guiné-Bissau: Resultado do inquérito Nacional e recomendações para a conservação da população.* IUCN/ICN, 81.

Sohou, Z., Dossou-Bodjrenou, J., Tchibozo, S., Chabi-Yaoure, F., Sinsin, B., and Van Waerebeek, K. (2013). Biodiversity and status of cetaceans in Benin, West Africa: an initial assessment. *West Afr. J. Appl. Ecol.* 21, 121–134. Available online at: http://www.ajol.info/index.php/wajae/article/view/94736

Spiegelberger, T. (2002). *Analysis of a habitat used by Antillean manatee (Trichechus manatus manatus) in French Guiana*. Lehrstuhl für Vegetationsökologie. Technische Universität München.

Tchibozo, S. (2002). Etude pour la prospection des dernieres populations de lamantins (*Trichechus senegalensis*) dans la basse Vallee de l'oueme. *Rep. Benin Minister Environ.* 13.

Timm, R. M., Albuja, V. L., and Clauson, B. L. (1986). Ecology, distribution, Harvest, and conservation of the Amazonian Manatee *Trichechus inunguis* in Ecuador. *Biotropica* 18, 150–156. doi: 10.2307/2388757

Tosi, C. H., Magalhães, F. A., and Garri, R. G. (2009). Meat consumption of a Fraser's dolphin (*Lagenodelphis hosei*) stranded alive on the northern Brazilian coast. *Mar. Biod. Rec.* 2:e4. doi: 10.1017/S1755267208000043

Trujillo, F., Crespo, E., Van Damme, P. A., and Usma, J. S. (2010). *The Action Plan for South American River Dolphins 2010–2020.* WWF, Fundación Omacha, WDS, WDCS, Solamac, 249.

Trujillo, F., Diazgranados, M. C., Utreras, V., Aliaga-Rossel, E., and Rodríguez-Maldonado, M. V. (2011). *Delfines de río en Suramérica. Fundación Omacha, Serie de Especies Amenazadas* (Bogotá: Fundación Omacha), 64.

Trujillo, F., Gärtner, A., Caicedo, D., and Diazgranados, M. C., (eds.). (2013). *Diagnóstico del estado de conocimiento y conservación de los mamíferos acuáticos en Colombia*. Ministerio de Ambiente y Desarrollo Sostenible, Fundación Omacha, Conservación Internacional and WWF, 312.

Tzika, A. C., D'Amico, E., Alfaro-Shigueto, J., Mangel, J. C., Waerebeek, K., and Milinkovitch, M. C. (2010). Molecular identification of small cetacean samples from Peruvian fish markets. *Conserv. Gen.* 11, 2207–2218. doi: 10.1007/s10592-010-0106-8

UNEP (2010). *Regional Management Plan for The West Indian Manatee (Trichechus manatus). Compiled By Ester Quintana-Rizzo And John Reynolds, I. I. I.* CEP Technical Report No. 48. Kingston, Jamaica: UNEP Caribbean Environment Programme.

Uwagbae, M., and Van Waerebeek, K. (2010). *Initial Evidence of Dolphin Takes in the Niger Delta Region and a Review of Nigerian Cetaceans*. IWC SC/62/SM1.

Van Waerebeek, K., Barnett, L., Camara, A., Cham, A., Diallo, M., Djiba, A., et al. (2004). Distribution, status, and biology of the Atlantic humpback dolphin, *Sousa teuszii* (Kükenthal, 1892). *Aq. Mamm.* 30, 56–83. doi: 10.1578/AM.30.1.2004.56

Van Waerebeek, K. Bamy, I. L., Jiddou, A. M., and Campredon, P. (2008). *Indeterminate Status of West African Populations of Inshore Common Bottlenose Dolphins Tursiops truncatus Cautions Against Opportunistic Live-Capture Schemes*. Report to the Fondation Internationale du Banc d'Arguin, 9.

Van Waerebeek, K., Debrah, J. S., and Ofori-danson, P. K. (2014). *Cetacean Landings at the Fisheries Port of Dixcove, Ghana in 2013-14: A Preliminary Appraisal.* IWC SC/65/SM17.

Van Waerebeek, K., Diallo, M., Djiba, A., Ndiaye, P., and Ndiaye, E. (1997a). *Cetacean Research in Senegal 1995-97: An overview*. IWC SC/49/SM10.

Van Waerebeek, K., Montes, D., Onton, K., Santillan, L., Bressem, M., and Vega, D. (1997b). Las pesquerias de centolla y centollón y su interferencia con mamíferos marinos. *Amb. y Des. XIII* 4, 64–69.

Van Waerebeek, K., Montes, D., Onton, K., Santillan, L., Bressem, M., and Vega, D. (2002). *Fisheries Related Mortality of Small Cetaceans in Neritic Waters of Peru in 1999-2001*. IWC SC/54/SM10.

Van Waerebeek, K., and Ofori-Danson, P. K. (1999). *A First Checklist of Cetaceans of Ghana, Gulf of Guinea, and a Shore-Based Survey of Interactions with Coastal Fisheries.* IWC SC/51/SM35.

Van Waerebeek, K., Ofori-Danson, P. K., and Debrah, J. (2009). The cetaceans of Ghana, a validated faunal checklist. *West Afr. J. Appl. Ecol.* 15, 61–90. doi: 10.4314/wajae.v15i1.49428

Van Waerebeek, K., and Reyes, J. C. (1990). Catch of small cetaceans at Pucusana Port Central. *Biol. Conserv.* 51, 15–22.

Van Waerebeek, K., and Reyes, J. C. (1994a). Interactions between small cetaceans and Peruvian fisheries in 1998/1989 and analysis of trends. *Rep Int. Whal. Commn, Special Issue* 15, 495–502.

Van Waerebeek, K., and Reyes, J. C. (1994b). Post-Ban small cetacean takes off Peru: A review. *Rep Int. Whal. Commn* 15, 503–519.

Van Waerebeek, K., Van Bressem, M. F., Alfaro-shigueto, J., Sanino, G. P., Montes, D., and Ontón, K. (1999). *A Preliminary Analysis of Recent Captures of Small Cetaceans in Peru and Chile*. IWC SC/51/SM17.

Vidal, O., Van Waerebeek, K., and Findley, L. T. (1994). cetaceans and Gillnet Fisheries in Mexico, Central America and the Wider Caribbean: a preliminary review. *Rep. Int. Whal. Commn* 15, 221–236.

Weir, C., Debrah, J., Ofori-Danson, P., Pierpoint, C., and Van Waerebeek, K. (2008). Records of Fraser's dolphin *Lagenodelphis hosei* Fraser 1956 from the Gulf of Guinea and Angola. *Afr. J. Mar. Sci.* 30, 241–246. doi: 10.2989/AJMS.2008.30.2.4.554

Weir, C. R., and Pierce, G. J. (2013). A review of the human activities impacting cetaceans in the eastern tropical Atlantic. *Mamm. Rev.* 43, 258–274. doi: 10.1111/j.1365-2907.2012.00222.x

Wiles, D., and Makor, J. (2008). "Liberia," in *Conservation Strategy for the West African Manatee*, eds T. Dodman, M. D. D. Ndiaye, and K. Sarr (Nairobi, Kenya and Wetlands International Africa, Dakar: UNEP), 51–52.

**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.

The reviewer MPS and handling Editor declared their shared affiliation, and the handling Editor states that the process nevertheless met the standards of a fair and objective review.

frontiers in Marine Science

MINI REVIEW
published: 28 February 2017
doi: 10.3389/fmars.2017.00047

# Marine Mammals in Asian Societies; Trends in Consumption, Bait, and Traditional Use

*Lindsay Porter*[1]* *and Hong Yu Lai*[2]

[1] Sea Mammal Research Unit, Scottish Oceans Institute, University of St. Andrews, St. Andrews, UK, [2] SMRU Consulting Asia Pacific, Hong Kong, Hong Kong

In Asia many marine mammal species are consumed as food or for other purposes. The prevalence of this exploitation appears to increase from west to east. An escalating use of marine mammals and the emergence of commercialization of a trade in marine mammals is supported by:

- Regular documentation of both open and covert trade;
- A shift in focus in some diminishing traditional hunts to other marine mammal species;
- A possible revival in some targeted hunts, which had previously ceased;
- The recent implication of some cultures, which have little history of marine mammal consumption previously, in targeted hunts; and
- The growing importation of marine mammal parts from outside of Asia.

The factors that may drive marine mammal use include population reductions in species that have been traditionally targeted; diminishing returns from traditional fisheries; and an increase in market demand for marine mammal products. Lessons from similar studies in terrestrial wildlife trade will better focus future studies of marine mammal use in Asia.

**Keywords: Asia, marine mammals, hunting, bycatch, bait, consumption, medicine**

OPEN ACCESS

***Edited by:***
*Mark Peter Simmonds, University of Bristol, UK*

***Reviewed by:***
*Christian T. K.-H. Stadtlander, Independent Researcher, USA*
*Andrew John Wright, George Mason University, USA*
*Brendan John Godley, University of Exeter, UK*

****Correspondence:***
*Lindsay Porter*
*lp48@st-andrews.ac.uk*

***Specialty section:***
*This article was submitted to Marine Affairs and Policy, a section of the journal Frontiers in Marine Science*

***Received:*** *26 April 2016*
***Accepted:*** *09 February 2017*
***Published:*** *28 February 2017*

***Citation:***
*Porter L and Lai HY (2017) Marine Mammals in Asian Societies; Trends in Consumption, Bait, and Traditional Use. Front. Mar. Sci. 4:47. doi: 10.3389/fmars.2017.00047*

## INTRODUCTION

> "*Fisherman I knew in Hong Kong believed petty creatures like barnacles were too small to bother with (except in times of famine) and avoided sawfish, sturgeons, whales, and porpoises because these were "divine fish," tabooed by the gods. But elsewhere in China all of these have been used.*"
>
> (Andersen, 1988)

Localized beliefs, such as those described above by Anderson, can result in neighbors having profoundly different culinary cultures. These traditional preferences may, however, change over time as either environmental or social drivers change. For example, food item availability can alter, as can demand from a growing population and, likewise, trends in popular food culture. During the twentieth century, the hunting and harvesting of the oceans' animals increased dramatically with widespread and often indiscriminate industrial fishing practices being increasingly used. In addition, as human populations migrated to coastal areas, this also increased the need for aquatic resources (Jackson et al., 2001; O'Connor et al., 2011).

The increased hunting of terrestrial wildlife for food and other uses is of global concern and many studies have been conducted on the extent of consumption (e.g., Fa et al., 2002; Bowen-Jones et al., 2003; Lee et al., 2014) and the driving forces behind trade (e.g., Bowen-Jones and Pendry, 1999; Brashares et al., 2004; Rowcliffe et al., 2005; Lindsey et al., 2013).

Similar concerns have emerged for the utilization of marine mammals, and other aquatic species, for consumption, bait, and traditional use (Alfaro-Shigueto and Van Waerebeek, 2001; Clapham and Van Waerebeek, 2007; Costello and Baker, 2011). In 2011, a thorough review of existing literature, media reports, and local knowledge documented the global extent of marine mammal consumption (Robards and Reeves, 2011) and compared this information with earlier datasets (i.e., Mitchell, 1975a,b; Brownell et al., 1978). This review highlighted several key points:

i. That marine mammals caught unintentionally in fishing gear had been increasingly utilized for consumption;
ii. That diminished food resources in developing areas had led to both targeted hunting of marine mammals and the deliberate killing of bycaught individuals; and
iii. That there is a growing commercial trade in marine mammal meat.

This paper builds on the excellent work of Robards and Reeves (2011) using published information and other information gleaned since 2010 and aims to evaluate what is known of all marine mammal consumption for food and other uses in Asia. We also consider the factors that motivate this consumption.

## TRADITIONAL USE OF MARINE MAMMALS IN ASIA

There is a long written and spoken history in Asian societies about marine mammals. The Chinese character for "whale" was first printed as early as 179 BC (Le Blanc, 1985) and there are myriad myths throughout Asia that are based on the belief that most marine mammals bring good fortune and that harming them can bring bad luck (Perrin et al., 1996). However, not all cetacean species elicit the same good will. For example, according to Chinese mythology, the Baiji (*Lipotes vexillifer*), which is now extinct, is the reincarnation of a young maiden who had been forced to leap into the Yangtze River to escape her evil stepfather. The stepfather is subsequently turned into a finless porpoise (*Neophocaena phocaenoides*). It is claimed that reverence for the Baiji stemmed from this legendary act of courage. The species was not eaten and only parts from stranded or by-caught individuals were used in Traditional Chinese Medicine (TCM). By contrast, the dislike of the stepfather is manifested in disregard for the finless porpoise, which, is both historically and currently hunted and consumed (Wang, 1965; Zhou, 1991). In southern China, marine mammal bones can sometimes be found in the temples dedicated to *Tin Hau* or *Mā Zǔ* (媽祖), the favored goddess of the fishermen (Andersen, 2009). In particular, some fishermen consider the "Chinese white dolphin" (*Sousa chinensis*) divine as this species is often perceived as "paying homage" to the goddess as groups of dolphins often occur near the shores upon which her temples are built (Andersen, 1971). Festivals in honor of *Mā Zǔ* in Fujian Province traditionally culminated with the consumption of dolphin meat, although this practice is now prohibited (Huang et al., 1997). In Vietnam, whale temples occur along the entire coastline and the religion that stems from the worship of whales is still very much practiced (Lantz, 2009). Vietnamese people mourn the death of marine mammals and bury those found floating or stranded. After some years, the bones are exhumed and then placed in dedicated temples (Nguyen and Ruddle, 2010). In India, fishermen also revere marine mammals and believe that the presence of dolphins enhances fishing catches (D'Lima et al., 2014) and that some dolphins even chase fish into fishermen's nets (Bijukumar and Smrithy, 2012).

There is anecdotal information about the use of marine mammal parts in traditional medicines and tinctures. For example, in both Cambodia and Malaysia, dugong (*Dugong dugon*) tears are used in love potions (Perrin et al., 1996) but only in TCM pharmacopeia is there a comprehensive list of the use made of specific marine mammal parts. TCM originated over 5,000 years ago (Xie and Huang, 1984) and modern pharmacopeia include over 11,500 ingredients originating from animals, plants, and minerals (Chen, 2011; Alves et al., 2013). Several studies have investigated the active components of TCM and some (non-marine mammal) ingredients are now regularly incorporated into both western and veterinary medicine (Nadkarni, 1976; Jiang et al., 1979; Hagey et al., 1993; Normile, 2003). Derivatives from at least 20 marine mammal species are detailed in Chinese pharmacopeia and are recommended for a variety of maladies (Read, 1982; Zhai, 1989; Zhao, 1990; Han, 1992; Li and Lin, 1992; Bensky and Gamble, 1993). The most commonly listed ingredients derived from cetaceans are oil, pancreas, and liver. These are prescribed for intestinal disorders, inflammation, and a variety of skin conditions. Dugong oil and ground bone are believed to have haemostatic properties. Pinnipeds and mustilids are generally used as either an enhancer or suppressor of various human appetites. There is little information on how prevalent the current use of marine mammal parts are in TCM but an agreement between Canada and China in 2011[1], allowing the import of Canadian seal parts to China, plus a proposal to increase trade in 2015[2], indicates that a market certainly exists.

## RECENT USE OF MARINE MAMMALS IN ASIA

Over 60% of the world's population live in Asia[3] and, by its sheer mass and needs, the Asian population has a profound impact on global protein resources (Curran et al., 2002). The food needs of Asia puts extreme pressure on both agriculture and fisheries, exacerbated by the coastal location of most of Asia's mega cities (Hinrichsen, 1999; Tibbetts, 2002). Indeed, Asia's fishing fleet accounts for the majority of global fish landings (Watson and Pauly, 2013). Small-scale fishing in Asia is less well documented but certainly outweighs industrial fisheries (Kittinger, 2013). Global fish stocks are in rapid decline (Pauly

[1] http://www.economist.com/blogs/americasview/2012/02/canada-and-china (Accessed 2016 April, 25).
[2] http://www.vice.com/en_ca/read/proposal-could-see-newfoundland-selling-asia-a-bunch-of-seal-dicks (Accessed 2016 April, 25).
[3] United Nations Statistics Division standard geographical regions recommended for statistical use; Western Asia, Eastern Asia, South-Eastern Asia, Southern Asia (Accessed 2016 April, 25).

et al., 2005; Pauly and Zeller, 2016) and studies outside Asia indicate that as fisheries resources become reduced, efforts can shift to other protein sources, including terrestrial bushmeat (Brashares et al., 2004; Rowcliffe et al., 2005). Marine mammal consumption has already featured in most Asian cultures, with 24 Asian countries having a history of consuming marine mammals (e.g., Prematunga et al., 1985; Leatherwood and Reeves, 1989; Andersen and Kinze, 1995; Perrin et al., 1996, 2005; Mills et al., 1997; Rudolph et al., 1997; Baker et al., 2010; Acebes, 2014). Robards and Reeves' (2011) review revealed several new trends in the consumption of marine mammals in Asia and they concluded that the pressure to feed human populations where hunger and poverty prevail, is increasing both the deliberate and opportunistic utilization of marine mammals as food.

## Western Asia

In Western Asia (Turkey, Qatar, Saudi Arabia, United Arab Emirates, Oman, Bahrain, Yemen, and Georgia), all countries utilize individuals that are found opportunistically but only three countries (Turkey, Oman, and Yemen) record deliberate killing of such opportunistic finds. Only Oman reports directed catches of four species. The number taken per country per year is at most in the tens of individuals, but generally numbers <1 individual.

## South Asian

In South Asia (Nepal, Pakistan, India, Sri Lanka, and Bangladesh), only one country does not have directed hunts but it does utilize opportunistically found marine mammals, both live and deceased (Bangladesh). Two countries (Nepal and Pakistan) deliberately catch the occasional riverine dolphin, although this has not been reported in recent years. The remaining two countries have larger scale directed takes and these comprise at least 15 different species and total thousands of individuals per year (Sri Lanka and India).

## Southeast Asia

All the countries of Southeast Asia (Vietnam, Cambodia, Myanmar, Philippines, Indonesia, Malaysia, and Thailand) report directed hunts for marine mammals and most utilize individuals that are opportunistically found. Three countries (Cambodia, Thailand, and Vietnam) report that very limited numbers of individuals are taken, <10 per annum, of only 2–3 species. The remaining countries (Myanmar, Philippines, Indonesia, and Malaysia) document at least 23 species of marine mammals, which are consumed by the 100s–1,000s per annum in each country. Of these countries, only the Philippines used to conduct commercial whaling, although never at the scale of other Asian countries. The Philippines also reports imports and Malaysia reports exports of marine mammal products.

## East Asia

In East Asia (South Korea, Taiwan, Japan, and China) all four countries document directed takes, as well as utilizing opportunistically encountered live and dead marine mammals. All the countries previously hunted whales commercially and Japan currently allows regulated hunts within the jurisdiction of national waters. At least 32 species are utilized for consumption in East Asia. Data are not available for China but the other nations take tens to thousands of individuals each year. All of these countries also import marine mammal products. Overall, Robards and Reeves (2011) report that at least 38 cetacean species and four pinniped species are consumed across all Asian countries.

## Further Information

A review of recent publications and online media sources was conducted. For China, a short investigation of Chinese language social media, using a keyword search in the Chinese characters' equivalent of "marine," "mammal," and "food," resulted in 16 independent incidences of marine mammals for sale, both cooked and uncooked, in fish markets. That is, 16 different posts were noted with marine mammal parts clearly displayed in market settings. Several species were identified from these images and, as social media often contained location and date information, some fishing markets would appear to have had marine mammals for sale at different times.

In East Asia, the main use of marine mammals is for consumption and for traditional use, and some markets appear to be a focus for trade. Indonesia allows traditional hunting for sperm whales (*Physeter macrocephalus*), although this is largely restricted to two islands, Lamakera and Lamelera. One island no longer relies on this practice and in recent years, Lamelera islanders have increasingly targeted small cetaceans to supplement the diminishing catch of sperm whales (Mustika, 2006; Mustika et al., 2014). A detailed comparison of two culturally distinctive communities elsewhere in Indonesia (West Kalimantan and East Nusa Tenggara) showed that in one area, fishermen who incidentally caught marine mammals were more likely to discard them unused or pass them to others, whereas the second community kept nearly all individuals caught and utilized them within the community (Mustika et al., 2014). In another area of Indonesia (Bali), market and social surveys show that an open trade in dugong parts, from both opportunistic finds and deliberate hunting, is ongoing although this was largely for traditional or other use, and not for consumption (Lee and Nijman, 2015).

Opportunistic hunting was previously thought to be in decline in the Philippines (Dolar et al., 1994) but it now appears that, in some areas at least, marine mammals are increasingly and deliberately caught if they are sighted (Acebes, 2014). Communities in eastern Malaysia have always utilized marine mammal parts for traditional medicines and tinctures and the practice of consuming some species of salvaged marine mammals is ongoing (Ling and Porter, 2011), as is opportunistic hunting (Rajamani, 2013). Traditionally, Vietnamese people have revered cetaceans but there have been recent reports of Vietnamese fishermen catching marine mammals in Thailand's waters. It has been speculated that this is indicative of an increasing need for resources outweighing traditional practices (Pattaya Times, 2016a,b). In Southeast Asia, deliberate capture, both opportunistic and directed, occurs and, in some areas, marine mammals are increasingly targeted. Marine mammals are used for food, medicine, and ornaments and differing cultural attitudes may dictate specific uses.

The recent cessation of conflict in Sri Lankan has led to new fishing freedoms and social development and has thus, apparently, re-vitalized the traditional market for marine mammals. Recent observation of Sri Lankan fishing ports indicates that there is a clandestine trade in dolphins for bait in shark longlining fisheries and for consumption by people who live in non-coastal areas[4]. In both India and Pakistan, the deliberate capture of marine mammals still occurs although is reducing as these populations become smaller and law enforcement becomes stricter. Opportunistically found individuals are still utilized for food and bait and the oil is sometimes used to waterproof boat hulls (Sivakumar and Nair, 2013; Kiani and Van Waerebeek, 2015).

Information is summarized **Table 1**. In most Asian areas, little is known of either the number of individuals being removed or what impacts the loss of these individuals may have on populations. The scale of research required to quantify the prevalence of marine mammal use in Asia is daunting. However, as concerns mount, practical and rapid investigative tools must be utilized to elucidate this urgent issue more clearly and determine trends and impacts.

## LESSONS AND CONCLUSIONS FROM TERRESTRIAL WILDLIFE TRADE STUDIES

Emerging studies indicate that some forests in Asia, unlike in Africa, are becoming devoid of wildlife as a consequence of over-hunting rather than deforestation (Harrison et al., 2016). In a region where the bulk of the human population occupies coastal areas and relies heavily on aquatic resources, it can be assumed that this loss is likely being mirrored in the marine environment. Terrestrial studies that have focused on understanding wildlife use provide useful tools and techniques that may well increase our understanding of this issue in the aquatic realm.

Terrestrial bushmeat studies generally rely upon a multi-disciplinary, socio-economic approach that can either collect novel data or use existing socio-demographic information to understand what drives use (Bowen-Jones and Pendry, 1999; Wilkie et al., 2005). Spatial models and the novel application of production/commodity analyses have successfully identified key areas of concern and likely consumers (Bowen-Jones et al., 2003; Schlesinger et al., 2015). Economic sustainability models have also been utilized to target potential markets (Fa et al., 2002). The illicit nature of illegal wildlife use has led to the successful adaptation of rapid assessment techniques that maintain the participant's confidentiality while still capturing key information (Conteh et al., 2015). Focused ethnological studies appear useful in both understanding the drivers of wildlife use and also in providing a foundation for future conservation and education activities that aim to establish sustainable use through changes in human practices (Nekaris et al., 2010; Scheffers et al., 2012).

Gavin et al. (2010) provide a comprehensive review of socio-economic methodology based on 100 studies. This provides useful guidelines for the improvement of study accuracy and may help to address the lack of data common to illegal wildlife trade and use activities (Gavin et al., 2010). In general, these modeling tools do not rely on quantitative data and may be applied without the need to collect primary data from market surveys and community interviews. Modeling and mapping exercises may, therefore, be most useful in discerning potential locations of concern for marine mammal species where future, focused studies may be directed.

There are also a wide variety of forensic tools available that allow better identification and analyses of wildlife parts (e.g., Ogden et al., 2009; Alacs et al., 2010; Linacre and Tobe, 2011). Some of these have already been utilized to reveal discrepancies in reported marine mammal bycatch, to determine the magnitude of trade and to develop kits that rapidly identify marine mammal species *in situ* in Asian markets (Baker et al., 2006, 2007; Lukoschek et al., 2009; Lo et al., 2013). These tools, designed specifically for non-specialists, will allow quantitative data collection both on type and volume of marine mammal parts in Asian markets. Such information will reveal the extent of marine mammal trade in key markets and, thus, allow identification of populations that may be unsustainably impacted. The use of social and online media has also been remarkably successful as a tool in identifying and, by working with law enforcement agencies, obstructing illegal trade (Krishnasamy and Stoner, 2016). In addition, short online searches conducted for this mini-review resulted in new information on marine mammals for sale in markets. Comprehensive searches may reveal which markets or locations persistently trade marine mammal parts and help to focus on site studies.

In many countries, the use of marine mammals for any purpose is illegal but legislation appears inconsistent and a lack of public awareness of the relevant laws has likely contributed to the continued illegal use of some aquatic species. A clearer integration of old and new laws has been shown to reduce marine megafauna use (Humber et al., 2015). In the many developing countries of Asia, limited government resources are often focused on laws that relate more directly to humans than to wildlife. In some countries, however, and Malaysia in particular, wildlife task forces have been established that investigate wildlife trade chains and have already reduced the level of open trading, as well as making progress in uncovering illegal trade routes[5]. Empowerment of management authorities and clear guidance and education on wildlife law may also assist in the reduction of marine mammal trade and use.

Investigative tools and methods, ranging from on-site market testing to online data mining, will be useful in discerning the scope of marine mammal use and trade and the factors that drive it. What will be more challenging for the marine realm is establishing a better understanding of trade or exchange of marine mammals at sea rather than through centralized markets, which is thought to be a common practice in some areas.

[4]http://www.sundayobserver.lk/2016/03/20/fea08.asp (Accessed 2016 July, 13).

[5]http://www.nst.com.my/news/2016/07/158692/filipino-smugglers-found-19000-turtle-eggs-sabah-coast (Accessed 2016 September, 01).

**TABLE 1 | A summary of marine mammal species utilized in Asia for consumption, traditional or other uses.**

| Species | Common name | Consumed | Traditional | Hunted | Other[a] |
|---|---|---|---|---|---|
| *Eubalaena glacialis* | North Atlantic right whale | | Y | | |
| *Eubalaena japonica* | North Pacific right whale | Y | | Y | |
| *Eschrichtius robustus* | Gray whale | Y | Y | Y | |
| *Balaenoptera acutorostrata* | Minke | Y | Y | Y | |
| *Balaenoptera* spp. | Unspecified minke whale | Y | Y | Y | |
| *Balaenoptera bonaerensis* | Antarctic minke whale | Y | | Y | |
| *Balaenoptera borealis* | Sei whale | Y | Y | Y | |
| *Balaenoptera edeni* | Bryde's whale | Y | | Y | |
| *Balaenoptera musculus* | Blue whale | | Y | | |
| *Balaenoptera omurai* | Omura's whale | Y | | Y | |
| *Balaenoptera physalus* | Fin whale | Y | Y | Y | |
| *Megaptera novaeangliae* | Humpback whale | Y | Y | Y | |
| *N/A* | Blue/fin hybrid whale | Y | | Y | |
| *Physeter macrocephalus* | Sperm whale | Y | Y | Y | |
| *Kogia sima* | Dwarf sperm whale | Y | | Y | |
| *Berardius bairdii* | Baird's beaked whale | Y | | Y | |
| *Mesoplodon densirostris* | Blainville's beaked whale | Y | | Y | |
| *Mesoplodon ginkgodens* | Ginkgo-toothed beaked whale | Y | | Y | |
| *Ziphius cavirostris* | Cuvier's beaked whale | Y | | Y | |
| Family Platanistidae | South Asian river dolphin | Y | | Y | |
| *Lipotes vexillifer* | Baiji (Yangtze river dolphin) | | Y | | |
| *Delphinus delphis* | Common dolphin | Y | Y | Y | |
| *Feresa attenuata* | Pygmy sperm whale | Y | | Y | |
| *Globicephala macrorhynchus* | Short-finned pilot whale | Y | | Y | |
| *Grampus griseus* | Risso's dolphin | Y | | Y | |
| *Lagenodelphis hosei* | Fraser's dolphin | Y | | Y | |
| *Lagenorhynchus obliquidens* | Pacific white-sided dolphin | Y | | Y | |
| *Lissodelphis borealis* | Northern right whale dolphin | Y | | Y | |
| *Orcaella brevirostris* | Irrawaddy dolphin | Y | | Y | |
| *Orcinus orca* | Killer whale | Y | Y | Y | |
| *Peponocephala electra* | Melon-headed whale | Y | | Y | |
| *Sousa chinensis* | Indo-pacific humpback dolphin | Y | | Y | Y |
| *Stenella attenuata* | Pantropical spotted dolphin | Y | | Y | |
| *Stenella coeruleoalba* | Striped dolphin | Y | | Y | |
| *Stenella longirostris* | Spinner dolphin | Y | | Y | |
| *Steno bredanensis* | Rough-toothed dolphin | Y | | Y | |
| *Tursiop truncatus* | Bottlenose dolphin | Y | Y | Y | |
| *Pseudorca crassidens* | False killer whale | Y | | Y | |
| *Neophocaena phocaenoides* | Finless porpoise | Y | Y | Y | |
| *Phocoenoides dalli* | Dall's porpoise | Y | | Y | |
| *Phocoena phocoena* | Harbor porpoise | Y | Y | | |
| *Dugong dugon* | Dugong | Y | Y | Y | Y |
| *Cystophora cristata* | Hooded seal | | Y | | |
| *Erignathus barbatus* | Bearded seal | Y | | | |
| *Callorhinus ursinus* | Northern fur seal | | Y | | |
| *Halichoerus grypus* | Gray seal | Y | | Y | |
| *Histriophoca fasciata* | Ribbon seal | Y | | Y | |
| *Pagophilus groenlandicus* | Harp seal | Y | Y | Y | |
| *Phoca vitulina* | Harbor seal | | Y | | |

[a] *"Other" is souvenirs for tourists for the two species listed.*

Finally, and in conclusion, the available information indicates that social, economic, cultural, and ecological aspects of marine mammal use are intimately linked and should be considered together if a pathway is to be mapped toward sustainability in Asia. Lessons and tools developed for terrestrial bushmeat studies will assist in making progress in investigating marine mammal use for consumption, bait and other purposes and can help to direct studies and activities to areas where impact is likely to be unsustainable.

## AUTHOR CONTRIBUTIONS

LP reviewed and summarized all reference material and wrote the manuscript. HL conducted the literature search and the Chinese language online media review.

## FUNDING

LP and HL are supported by the University of St. Andrews via the university's office in Hong Kong SAR.

## REFERENCES


Acebes, J. M. V. (2014). "A history of whaling in the philippines: a glimpse of the past and current distribution of whales," in *Historical Perspectives of Fisheries Exploitation in the Indo-Pacific*, eds J. Christensen and M. Tull (Dordrecht: Springer), 83–105.

Alacs, E. A., Georges, A., FitzSimmons, N. N., and Robertson, J. (2010). DNA detective: a review of molecular approaches to wildlife forensics. *Forensic Sci. Med. Pathol.* 6, 180–194. doi: 10.1007/s12024-009-9131-7

Alfaro-Shigueto, J., and Van Waerebeek, K. (2001). "Drowning in the sea of silence: the bushmeat concept as applied to marine wildlife," in *Abstract in Zoos and Aquariums: Committing to Conservation*, ed B. Armstrong (Cocoa Beach, FL: Brevard Zoo), 16.

Alves, R. R. N., Rosa, I. L., Albuquerque, U. P., and Cunningham, A. B. (2013). "Medicine from the wild: an overview of the use and trade of animal products in traditional medicines," in *Animals in Traditional Folk Medicine,* eds R. R. Nóbrega Alves and I. L. Rosa (Berlin; Heidelberg: Springer), 25–42.

Andersen, E. (1971). "Essays on South China's Boat People," in *Asian Folklore and Social Life Monographs Volume XIX*, ed Lou Tsu-k'uang (Taipei: The Oriental Cultural Service), 93–131.

Andersen, E. (1988). *The Food of China*. New Haven, CT: Yale University Press.

Andersen, E. (2009). "Meeting the goddess: religion, morality and medicine in a fishing community in Hong Kong forty years ago," in *The Constant and Changing Faces of The Goddess*: *Goddess Traditions of Asia*, eds D. Shimkhada and P. K. Herman (Newcastle, UK: Cambridge Scholars Publishing), 122–133.

Andersen, M., and Kinze, C. C. (1995). Annotated checklist and identification key to the whales, dolphins and porpoises (Order *Cetacea*) of Thailand and adjacent waters. *Nat. Hist. Bull. Siam Soc.* 24, 17–24.

Baker, C. S., Cooke, J. G., Lavery, S., Dalebout, M. L., Ma, Y. U., Funahashi, N., et al. (2007). Estimating the number of whales entering trade using DNA profiling and capture—recapture analysis of market products. *Mol. Ecol.* 16, 2617–2626. doi: 10.1111/j.1365-294X.2007.03317.x

Baker, C. S., Lukoschek, V., Lavery, S., Dalebout, M. L., Yong-un, M., Endo, T., et al. (2006). Incomplete reporting of whale, dolphin and porpoise 'bycatch' revealed by molecular monitoring of Korean markets. *Anim. Conserv.* 9, 474–482. doi: 10.1111/j.1469-1795.2006.00062.x

Baker, C. S., Steel, D., Choi, Y., Lee, H., Kim, K. S., Choi, S. K., et al. (2010). Genetic evidence of illegal trade in protected whales links Japan with the US and South Korea. *Biol. Lett.* 6, 647–650. doi: 10.1098/rsbl.2010.0239

Bensky, D., and Gamble, A. (1993). *Chinese Herbal Medicine: Materia Medica*. Washington, DC: Eastland Press.

Bijukumar, A., and Smrithy, R. (2012). Behaviour of Indo-Pacific humpback dolphin, *Sousa chinensis* (Osbeck) in the Ashtamudi estuary, southwest coast of India. *J. Mar. Biol. Assoc. India* 54, 34. doi: 10.6024/jmbai.2012.54.2.01699-0x

Bowen-Jones, E., Brown, D., and Robinson, E. J. (2003). Economic commodity or environmental crisis? An interdisciplinary approach to analysing the bushmeat trade in central and West Africa. *Area* 35, 390–402. doi: 10.1111/j.0004-0894.2003.00189.x

Bowen-Jones, E., and Pendry, S. (1999). The threat to primates and other mammals from the bushmeat trade in Africa, and how this threat could be diminished 1. *Oryx* 33, 233–246. doi: 10.1046/j.1365-3008.1999.00066.x

Brashares, J. S., Arcese, P., Sam, M. K., Coppolillo, P. B., Sinclair, A. R., and Balmford, A. (2004). Bushmeat hunting, wildlife declines, and fish supply in West Africa. *Science* 306, 1180–1183. doi: 10.1126/science.1102425

Brownell, R., Schonewald, C., and Reeves, R. (1978). *Preliminary report on World Catches of Marine Mammals 1966-1975*. Final Report for MMC Contract MM6AC002. NTIS PB290 713.

Chen, C. Y. C. (2011). TCM Database@ Taiwan: the world's largest traditional Chinese medicine database for drug screening *in silico*. *PLoS ONE* 6:15939. doi: 10.1371/journal.pone.0015939

Clapham, P., and Van Waerebeek, K. (2007). Bushmeat and bycatch: the sum of the parts. *Mol. Ecol.* 16, 2607–2609. doi: 10.1111/j.1365-294X.2007.03378.x

Conteh, A., Gavin, M. C., and Solomon, J. (2015). Quantifying illegal hunting: a novel application of the quantitative randomised response technique. *Biol. Conserv*. 189, 16–23. doi: 10.1016/j.biocon.2015.02.002

Costello, M. J., and Baker, C. S. (2011). Who eats sea meat? Expanding human consumption of marine mammals. *Biol. Conserv*. 144, 2745–2746. doi: 10.1016/j.biocon.2011.10.015

Curran, S., Kumar, A., Lutz, W., and Williams, M. (2002). Interactions between coastal and marine ecosystems and human population systems: perspectives on how consumption mediates this interaction. *Ambio* 31, 264–268. doi: 10.1579/0044-7447-31.4.264

D'Lima, C., Marsh, H., Hamann, M., Sinha, A., and Arthur, R. (2014). Positive interactions between irrawaddy dolphins and artisanal fishers in the Chilika Lagoon of Eastern India are driven by ecology, socioeconomics, and culture. *Ambio* 43, 614–624. doi: 10.1007/s13280-013-0440-4

Dolar, M. L. L., Leatherwood, S., Wood, C., Alava, M. N. R., Hill, C., and Aragones, L. (1994). *Directed Fisheries for Cetaceans in the Philippines, Vol. 44.* Report of the International Whaling Commission, 439–449.

Fa, J. E., Peres, C. A., and Meeuwig, J. (2002). Bushmeat exploitation in tropical forests: an intercontinental comparison. *Conserv. Biol*. 16, 232–237. doi: 10.1046/j.1523-1739.2002.00275.x

Gavin, M. C., Solomon, J. N., and Blank, S. G. (2010). Measuring and monitoring illegal use of natural resources. *Conserv. Biol*. 24, 89–100. doi: 10.1111/j.1523-1739.2009.01387.x

Hagey, L. R., Crombie, D. L., Espinosa, E., Carey, M. C., Igimi, H., and Hofmann, A. F. (1993). Ursodeoxycholic acid in the Ursidae: biliary bile acids of bears, pandas, and related carnivores. *J. Lipid Res.* 34, 1911–1917.

Han, L. (1992). *A Glossary of Chinese-Latin-English Names of Animal Medicinal Materials*. Xiamen: Fujian Science and Technology Press.

Harrison, R., Sreekar, R., Brodie, J., Brooke, S., Luskin, M., O'Kelly, H., et al. (2016). Impacts of hunting and wildlife trade on Asian tropical forests. *Conserv. Biol.* 30, 972–981. doi: 10.1111/cobi.12785

Hinrichsen, D. (1999). *Coastal Waters of the World: Trends*, *Threats, and Strategies*. Washington, DC: Island Press.

Huang, Z. G., Liu, W. H., and Zheng, C. X. (1997). Chinese white dolphin (*Sousa chinensis*) in Xiamen Harbour. *J. Oceanogr. Taiwan Strait* 16, 473–479.

Humber, F., Andriamahefazafy, M., Godley, B. J., and Broderick, A. C. (2015). Endangered, essential and exploited: how extant laws are not enough to protect marine megafauna in Madagascar. *Mar. Policy* 60, 70–83. doi: 10.1016/j.marpol.2015.05.006

Jackson, J. B., Kirby, M. X., Berger, W. H., Bjorndal, K. A., Botsford, L. W., Bourque, B. J., et al. (2001). Historical overfishing and the recent collapse of coastal ecosystems. *Science* 293, 629–637. doi: 10.1126/science.1059199

Jiang, F., Deng, M., Gao, S., Zhang, Y., and Chen, E. (1979). *Compilation of Animals Used in Chinese Traditional Medicine*. Tianjin: Tianjin Science and Technology Press.

Kiani, M. S., and Van Waerebeek, K. (2015). Chapter eight-a review of the status of the Indian ocean Humpback Dolphin (*Sousa plumbea*) in Pakistan. *Adv. Mar. Biol.* 72, 201–228. doi: 10.1016/bs.amb.2015.09.002

Kittinger, J. N. (2013). Human dimensions of small-scale and traditional fisheries in the Asia-Pacific region. *Pac. Sci.* 67, 315–325. doi: 10.2984/67.3.1

Krishnasamy, K., and Stoner, S. (2016). *Trading Faces: A Rapid Assessment on the Use of Facebook to Trade Wildlife in Peninsular Malaysia.* Petaling Jaya: TRAFFIC.

Lantz, S. (2009). *Whale Worship in Vietnam*. Scientific studies of religion. The University of Gävle: Swedish Science Press. ISBN:978-91-975446-2-7.

Leatherwood, S., and Reeves, R. (1989). *Marine Mammal Research and Conservation in Sri Lanka, 1985–1986*. UNEP Marine Mammal Technical Report 1, 1–138.

Le Blanc, C. (1985). *Huai-Nan Tzu: Philosophical Synthesis in Early Han Thought* (*A Translation and Analysis of Chapter Six*). Hong Kong: Hong Kong University Press.

Lee, P., and Nijman, V. (2015). Trade in dugong parts in Southern Bali. *J. Mar. Biol. Assoc. U.K.* 95, 1717–1721. doi: 10.1017/S0025315415001423

Lee, T. M., Sigouin, A., Pinedo-Vasquez, M., and Nasi, R. (2014). *The Harvest of Wildlife for Bushmeat and Traditional Medicine in East, South and Southeast Asia: Current Knowledge Base, Challenges, Opportunities and Areas for Future Research.* Occasional Paper 115, Bogor, Indonesia: CIFOR.

Li, F., and Lin, J. Y. (1992). *Use of Marine Products in Medicine*. Nanjing: Nanjing University Press.

Linacre, A., and Tobe, S. S. (2011). An overview to the investigative approach to species testing in wildlife forensic science. *Investig. Genet.* 2:2. doi: 10.1186/2041-2223-2-2

Lindsey, P. A., Balme, G., Becker, M., Begg, C., Bento, C., Bocchino, C., et al. (2013). The bushmeat trade in African savannas: impacts, drivers, and possible solutions. *Biol. Conserv.* 160, 80–96. doi: 10.1016/j.biocon.2012.12.020

Ling, S. N., and Porter, L. J. (2011). Dolphin populations in the Kinabatangan: questionnaire survey of fishermen. *Report to LEAP,* 32.

Lo, C., Chin, L. T., Chu, C. S., Wang, Y. T., Chan, K. W., and Yang, W. C. (2013). Rapid immune colloidal gold strip for cetacean meat restraining illegal trade and consumption: implications for conservation and public health. *PLoS ONE* 8:e60704. doi: 10.1371/journal.pone.0060704

Lukoschek, V., Funahashi, N., Lavery, S., Dalebout, M. L., Cipriano, F., and Baker, C. S. (2009). High proportion of protected minke whales sold on Japanese markets is due to illegal, unreported or unregulated exploitation. *Anim. Conserv.* 12, 385–395. doi: 10.1111/j.1469-1795.2009.00302.x

Mills, J., Ishihara, A., and Sakaguchi, I. (1997). *Whale Meat Trade in East Asia: A Review of the Markets in 1997.* Hong Kong: TRAFFIC International.

Mitchell, E. (1975a). *Porpoise, Dolphin and Small Whale Fisheries of the World: Status and Problems.* IUCN Monograph No. 3.

Mitchell, E. (1975b). Review of biology and fisheries for smaller cetaceans. *J. Fish. Res. Board Can.* 32, 875–1242 doi: 10.1139/f75-114

Mustika, P. L. (2006). *Marine Mammals in the Savu Sea (Indonesia): Indigenous Knowledge, Threat Analysis and Management Options.* Doctoral thesis, James Cook University.

Mustika, P. L. K., Purnomo, F. S., and Northridge, S. (2014). *A Pilot Study to Identify the Extent of Small Cetacean Bycatch in Indonesia Using Fisher Interview and Stranding Data as Proxies.* Denpasar: Updated Report to the International Whaling Commission.

Nadkarni, A. K. (1976). *Revised and Enlarged Edition of Dr. K. M. Nadkarni's Indian Materia Medica II: 154*. Bombay: Popular Prakashan Press.

Nekaris, K. A., Shepherd, C. R., Starr, C. R., and Nijman, V. (2010). Exploring cultural drivers for wildlife trade via an ethnoprimatological approach: a case study of slender and slow lorises (Loris and Nycticebus) in South and Southeast Asia. *Am. J. Primatol.* 72, 877–886. doi: 10.1002/ajp.20842

Nguyen, D. T., and Ruddle, K., (2010). "Vietnam: The van chai system of social organization and fisheries community management," in *Managing Coastal and Inland Waters,* eds K. Ruddle and A. Satria (Dordrecht: Springer), 129–160.

Normile, D. (2003). The new face of traditional Chinese medicine. *Science* 299, 188–190. doi: 10.1126/science.299.5604.188

O'Connor, S., Ono, R., and Clarkson, C. (2011). Pelagic fishing at 42,000 years before the present and the maritime skills of modern humans. *Science* 334, 1117–1121. doi: 10.1126/science.1207703

Ogden, R., Dawnay, N., and McEwing, R. (2009). Wildlife DNA forensics—bridging the gap between conservation genetics and law enforcement. *Endanger. Species Res.* 9, 179–195. doi: 10.3354/esr00144

Pattaya Times (2016a, April 11). Navy Seizes Vietnamese fishing boat, Vol. XXIV. *Pattaya Times*.

Pattaya Times (2016b, April 15). Navy Seizes 5 more Vietnamese dolphin boat, Vol. XXIV. *Pattaya Times.*

Pauly, D., Watson, R., and Alder, J. (2005). Global trends in world fisheries: impacts on marine ecosystems and food security. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 360, 5–12. doi: 10.1098/rstb.2004.1574

Pauly, D., and Zeller, D. (2016). Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. *Nat. Commun.* 7:10244. doi: 10.1038/ncomms10244

Perrin, W. F., Dolar, M. L., and Alava, M. N. R. (1996). *Report of the Workshop on the Biology and Conservation of Small Cetaceans and Dugongs of Southeast Asia.* Dumaguete, UNEP (W)/EAS WG.1/2.

Perrin, W. F., Reeves, R. R., Dolar, M. L. L., Jefferson, T. A., Marsh, H., Wang, J. Y., et al. (eds.). (2005). *Report of the Second Workshop on the Biology and Conservation of Small Cetaceans and Dugongs of Southeast Asia.* Bonn: CMS Technical Series Publication No. 9, 161.

Prematunga, W. P., Alling, A., and Leatherwood, S. (1985). *Species Composition of Small Cetacean Bycatches in Gillnets off Trincomalee, Sri Lanka, January 1984 Through April 1985*. International Whaling Commission, SC/37/SM9.

Rajamani, L. (2013). Using community knowledge in data-deficient regions: conserving the Vulnerable Dugong dugong dugon in the Sulu Sea, Malaysia. *Oryx* 47, 173–176. doi: 10.1017/S0030605312000154

Read, B. E. (1982). *Chinese Materia Medica*. Taipei: Southern Materials Center.

Robards, M. D., and Reeves, R. R. (2011). The global extent and character of marine mammal consumption by humans: 1970–2009. *Biol. Conserv.* 144, 2770–2786. doi: 10.1016/j.biocon.2011.07.034

Rowcliffe, J. M., Milner-Gulland, E. J., and Cowlishaw, G. (2005). Do bushmeat consumers have other fish to fry? *Trends Ecol. Evol. (Amst).* 20, 274–276. doi: 10.1016/j.tree.2005.03.007

Rudolph, P., Smeenk, C., and Leatherwood, S. (1997). Preliminary of Cetacea in the Indonesian Archipelago and adjacent waters. *Zool. Verhandel.* 312, 1–48.

Scheffers, B. R., Corlett, R. T., Diesmos, A., and Laurance, W. F. (2012). Local demand drives a bushmeat industry in a Philippine forest preserve. *Trop. Conserv. Sci.* 5, 133–141. doi: 10.1177/194008291200500203

Schlesinger, J., Drescher, A., and Shackleton, C. M. (2015). Socio-spatial dynamics in the use of wild natural resources: evidence from six rapidly growing medium-sized cities in Africa. *Appl. Geogr.* 56, 107–115. doi: 10.1016/j.apgeog.2014.11.013

Sivakumar, K., and Nair, A. (2013). *Dugong Distribution, Habitat and Risks Due to Fisheries and Other Anthropogenic Activities in India*. Technical Report, Wildlife Institute of India.

Tibbetts, J. (2002). Coastal cities: living on the edge. *Environ. Health Perspect.* 110, 674–681. doi: 10.1289/ehp.110-a674

Wang, W. Y. (1965). Initial observation on the living habitats of the white dolphins in Xiamen Harbour. *Fujian Fish. Soc. Corres.* 3, 16–21.

Watson, R. A., and Pauly, D. (2013). The changing face of global fisheries—The 1950s vs. the 2000s. *Mar. Policy* 42, 1–4. doi: 10.1016/j.marpol.2013.01.022

Wilkie, D. S., Starkey, M., Abernethy, K., Effa, E. N., Telfer, P., and Godoy, R. (2005). Role of prices and wealth in consumer demand for bushmeat in Gabon, Central Africa. *Conserv. Biol.* 19, 268–274. doi: 10.1111/j.1523-1739.2005.00372.x

Xie, Z., and Huang, X. (1984). *Dictionary of Traditional Chinese Medicine*. Hong Kong: Commercial Press Ltd.

Zhai, Z. Q. (1989). *Chinese, English, Latin and Korean Collection of Animal Medicine Names*. Chang Chun: Chang Chun Publishing House.

Zhao, X. Z. (1990). The medicinal survey of marine animals in Fujian Province. *Chin. J. Mar. Med.* 90, 34–37.

Zhou, K. (1991). *Marine mammal studies in China*. International Marine Biological Institute Reports, 2, 11–33.

**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.

frontiers in Marine Science

OPINION
published: 22 June 2016
doi: 10.3389/fmars.2016.00102

CrossMark

# What Drives Japanese Whaling Policy?

*Christopher Butler-Stroud* *

*Whale and Dolphin Conservation, Chippenham, UK*

**Keywords: whaling, Japan, fisheries, science, politics**

## WHAT DRIVES JAPANESE WHALING POLICY?

The debates about whaling are reported to hinge around the issues of animal welfare (Brakes and Simmonds, 2011), science (Burnett, 2012) and clashes over differing cultural perspectives (Hirata, 2005). However, the dynamics that shape the hunting of the great whales managed through the International Whaling Commission (IWC), are much more complex. Stakeholders act under significant forces not always directly relevant to the conservation or exploitation of wildlife, or indeed, the marginal profits available from whaling. It is argued that it is domestic Japanese politics (Clapham et al., 2007) and attempts to create new norms in more economically important fisheries agreements that now drive the demand for continued whaling.

Japan is one of the few states in the world that assertively supports its claims to resume commercial whaling. The IWC enacted a moratorium on commercial whaling in 1982 but even before the zero catch quotas had come into force the Japanese Minister of Agriculture, Forestry and Fisheries, Moriyoshi Sato, stated,

> "*The government will do its utmost to find out ways to maintain the nation's whaling in the form of research or other forms*" (Cherfas, 1985).

Thus, began a sustained programme of "resistance" to the implementation of the IWC moratorium. This included launching a programme of "scientific" permit whaling, ostensibly allowed for under Article VIII of the International Convention for the Regulation of Whaling (ICRW). Indeed, Japan's extensive Antarctic whaling only paused when it was ruled illegal and "*not for the purposes of science*" by the International Court of Justice (ICJ) in its landmark 2014 ruling[1] However, in late 2015, despite failing to obtain IWC or scientific support, Japan's whaling fleet sailed to the Antarctic under a new permit (NEWREP-A)[2] with the intention of taking 333 minke whales. At the same time Japan signaled that it would not countenance any future challenges when it withdrew from the jurisdiction of the ICJ with respect to "*research on, or conservation, management or exploitation of, living resources of the sea*"[3]

But maybe this assertive move should not have come as a shock to observers of Japanese policy within the IWC.

The 1946 signing of the ICRW was an important jurisprudential step in establishing the principle of international regulation of a common property resource both in the high seas and national waters. However, since joining the IWC in 1951, Japan has actively sought to limit IWC jurisdiction, for example, increasingly asserting its sovereignty within its 200 mile Exclusive Economic Zone

[1] *Whaling in the Antarctic* (Australia vs. Japan: New Zealand intervening) Judgment of 31 March 2014: http://www.icj-cij.org/docket/index.php?p1=3&p2=1&case=148&p3=4.

[2] Government of Japan, NEWREP-A: Available online at: https://iwc.int/document_3550.

[3] Yoshikawa, M., Permanent Representative of Japan to the United Nations (6th October, 2015) International Court of Justice: Available online at: http://www.icj-cij.org/jurisdiction/?p1=5&p2=1&p3=3&code=JP.

OPEN ACCESS

**Edited by:**
*Andrew Butterworth, University of Bristol, UK*

**Reviewed by:**
*Mark Peter Simmonds, Humane Society International, UK*

***Correspondence:**
*Christopher Butler-Stroud*
*chris.butler-stroud@whales.org*

**Specialty section:**
*This article was submitted to Marine Affairs and Policy, a section of the journal Frontiers in Marine Science*

**Received:** 18 March 2016
**Accepted:** 06 June 2016
**Published:** 22 June 2016

**Citation:**
*Butler-Stroud C (2016) What Drives Japanese Whaling Policy? Front. Mar. Sci. 3:102. doi: 10.3389/fmars.2016.00102*

(EEZ) over the accepted norms of IWC control of whaling in "*all waters in which whaling is prosecuted*"[4] and subsequently arguing against IWC competency for small cetaceans (Morikawa, 2009).

The use of IWC objections procedures and the creative interpretation of Article VIII permits, appears to be a strategy to bring the IWC to an impasse, allowing Japan to claim that the IWC is "dysfunctional" (Kirby, 2006). Alongside procedural maneuvers Japan has encouraged social scientists to champion views that exemptions for Inuit whalers under Aboriginal Subsistence Whaling (ASW) should lead to a broader definition of "subsistence" that allows for a greater amount of commercial trade (Schieber, 1998)—a result that could directly benefit its coastal whaling operations for which Japan has consistently claimed similarities to ASW.

The recent decision by Japan to apparently disregard the IWC's scientific committee's critiques (Brierley and Clapham, 2016), and to withdraw from the jurisdiction of the ICJ appears to increasingly indicate that Japan's powerful Ministry of Fisheries seeks not be bound by international norms with respect to whaling and should be a warning bell for any nations engaged in any resource access debate with Japan. Indeed Clapham (2015) believes that the history of Japan in the IWC in *"deny[ing] the existence of population declines and the need for lower catch limits, exploitation of IWC procedures to block or delay progressive measures..."* has been a fundamental way of working for Japan since it joined.

Some authors have pointed to the incestuous relationships between the Japanese Government and those who profit from whaling. For example, Clapham (2015) notes the Institute of Cetacean Research (ICR), the "quasi-governmental" body that carries out "scientific" whaling, is funded by sales of whale meat and from direct subsidies, whilst the government relies on the "independence" of the ICR to claim scientific legitimacy of its continued use of an IWC loophole. Atsushi and Okubo (2007) go so far as to argue that this relationship is so institutionalized that Japan has been happy with the scientific whaling status quo.

Morikawa (2009) points to the policy of aging whaling proponents amongst the Ministry of Fisheries "retiring" into the fisheries conglomerates that financially benefit from Japan's continued whaling. Hirata (2005) argues that this domestic bubble of shared interests makes Japan almost impervious to external pressures when it comes to ending whaling.

Furthermore, some commentators remain cautious about Japan changing its position anytime soon. Clapham (2015) notes that Japan is intent on "*pursuing its long-term plan of attempting to obtain the votes necessary to lift the moratorium and reinstate commercial whaling.*"

Japan had announced as early as 1999 that it was giving aid to countries in the hope of changing the balance of votes at the Commission (Brown, 1999). The then Japanese Vice-Minister for Fisheries stated:

> "*We would like to utilise overseas development aid as a practical means to promote nations to join...which support Japan's claim*"

Like many nations, Japan had, post 1960, established a programme of using overseas development aid (ODA) to build its international reputation. In contrast to its behavior in the IWC, the Japanese ODA Blue Book calls for the "*establishment of the 'rule of law' in the international community*" (Japanese Diplomatic Blue Book, 2013). However, a 2012 review of Japanese ODA[5] states that "*it is necessary to grasp not only the development effect but also the diplomatic effect,*" of such aid,

> "*Developing mutual understanding concerning sustainable use of resources, without undue emphasis on conservation...' and, 'Supporting Japan's position on issues such as the use of marine resources, etc. in the international arena...*"

The withdraw of Japan from the jurisdiction of the ICJ and its preference for any future adjudication under other provisions of the United Nations Convention on the Law of the Sea (UNCLOS) may evidence an underlying strategy of increasingly militating against the effects of multilateral governance regimes when it inconveniences them.

But this is not a new strategy. In the 1970s Japan had fought against the creation of EEZs under the United Nations Convention on the Law of the Sea (UNCLOS). As Tarte (1998) notes,

> *"...Shock waves spread quickly through the Japanese fishing industry... Fishing access agreements became a necessity within Pacific nations' territorial waters, and it is in this context, that the catalyst for Japanese foreign aid to the region can be found".*

According to Tarte, the precedence of Japanese interests over the preferences of the recipients has remained a constant feature of Japan's aid programme to the region. Within these programmes Cosgriff (2001) notes, *"By keeping negotiations bilateral, Japan is able to exploit divisions between states to maximise its bargaining power."*

Thus, where possible, Japan has sought to maximize its fisheries opportunities outside of multilateral agreements. Its withdrawal from the jurisdiction of the ICJ should be viewed with some concern as it potentially significantly limits any future challenge to Japan's scientific whaling in an international court, or, indeed, with respect to *any fisheries issues*. Amor (2012) notes that the ICJ and the Law of the Sea Tribunal (ITLOS) "are serving a common goal of a mutually reinforcing corpus of international law" but also notes that the ITLOS has regularly referred to the judgments of the Court "with respect to questions of international law and procedure," and also that the Court enjoys a more "general and comprehensive jurisdiction than specialized judicial bodies." Becker (2015) develops this thought, noting that in seeking arbitration through UNCLOS any "claims to be litigated would need to concern the interpretation or application of a UNCLOS provision" and could not address the generality of Japan's actions with respect to the ICRW.

[4]ICRW (1946) Article 1(2): https://archive.iwc.int/pages/view.php?ref=3607&k=.

[5]Nomura Research Institute, Ltd. (2012) Evaluation of Grant Aid for Fisheries: http://www.mofa.go.jp/policy/oda/evaluation/FY2011/text-pdf/fisheries.pdf.

The domestic power of the whaling block within the Japanese Ministry of Fisheries should not be underestimated. Work by Strand and Truman (2009) suggests that the Fisheries Ministry has been the main beneficiary of an aggressive ODA policy, within the context of the Japanese Government solidifying its rhetoric around a distinctly nationalistic agenda.

Of growing concern to many external observers[6] is the rise of *Nippon Kaigi,* a nationalistic revisionist grouping within the Japanese Cabinet, Diet and Japanese society (Day, 2014). Historical issues have long colored Japan's relationships with its neighbors, particularly China and South Korea, but this new nationalism is seeking to redefine and reinforce whaling as part of the nationalist narrative. This nationalistic linkage to whaling goes back to at least 1982. The Liberal Democratic Party (LDP), then, as now, wishing to shore up its rural political support, including from fishing communities (Moreby, 1982), has been careful to back the establishment's whaling position. There is even an LDP Parliamentary League for Whaling.

This author suggests that the nationalistic rhetoric and accompanying spurious projection of Japan's problems as being caused by Euro-American aggression (Oh and Ishizawa-Grbić, 2000) helps us understand the way whaling is used as a symbol of "being Japanese" and of a Japan that is perceived to be under constant external pressure by foreigners.

[6]Congressional Research Service (2014) 'Japan-U.S. Relations: Issues for Congress (page 6), 24 February. Available online at: http://mansfieldfdn.org/mfdn2011/wp-content/uploads/2014/02/USJ.Feb14.RL33436.pdf.

It also allows us to contextualize the Japanese nationalist polemic that whaling is a Japanese "tradition" that has been subject to foreign attempts to control the "very soul of Japan." As noted by O'Dwyer (2013), *"While most Japanese today rarely eat whale meat, some defend pelagic whaling out of a belief that Japanese eating habitats should not be dictated to by foreign activists"*

Thus, it is argued here that Japanese whaling policy is a complex product of domestic political forces, an industry maintained by direct and indirect subsidies, and an increasing nationalistic whaling narrative. Maybe more worryingly, we should recognize that the debate within the IWC is not just about protecting whales, but is increasingly a testing ground for Japan in establishing new international norms for the exploitation of all marine species, and that the consequences of acquiescence to Japan's ambitions will have major repercussions for many other species in desperate need of international conservation.

## AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and approved it for publication.

## ACKNOWLEDGMENTS

My thanks to Nicola Hodgins, Vanesa Tossenberger, Vicki James, Jane Bryan, and Astrid Fuchs for reviewing early drafts.

## REFERENCES

Amor, B. S. (2012). "The International Court of Justice and the Law of the Sea," in *Universidad Nacional Autónoma de México-Instituto de Investigaciones Jurídicas*. Mexico: Anuario Mexicanode Derecho Internacional, Décimo Aniversario, 2–26. Available online at: http://www.corteidh.or.cr/tablas/r29686.pdf

Atsushi, I., and Okubo, A. (2007). An alternative explanation of Japan's Whaling Diplomacy in the Post-Moratorium Era. *J. Int. Wildlife Law Policy* 10, 55–87. doi: 10.1080/13880290701229911

Becker, M. J. (2015). *Japan's New Optional Clause Declaration at the ICJ: A Pre-Emptive Strike?* Blog of the European Journal of International Law. Available online at: http://www.ejiltalk.org/japans-new-optional-clause-declaration-at-the-icj-a-pre-emptive-strike/

Brakes, P., and Simmonds, M. P. (2011). *Whales and Dolphins, Cognition, Culture,Conservation and Human Perceptions*. London: Earthscan.

Brierley, A. S., and Clapham, P. J. (2016). Whaling permits: Japan's whaling is unscientific. *Nature* 529, 283. doi:10.1038/529283a

Brown, P. (1999). *Japan Admits Using Aid to Build Pro-Whaling Vote.* London: Guardian Newspaper. Available online at: http://www.theguardian.com/environment/1999/nov/11/whaling.internationalnews

Burnett, D. G. (2012). *The Sounding of the Whale, Science and Cetaceans in the Twentieth Century.* Chicago, IL: The University of Chicago Press.

Cherfas, J. (1985). More whales harpooned 'for science.' *New Scientist* 105:1044.

Clapham, P. J. (2015). Japan's whaling following the International Court of Justice ruling: brave New World – Or business as usual? *Mar. Policy* 51, 238–241. doi: 10.1016/j.marpol.2014.08.011

Clapham, P. J., Childerhouse, S., Gales, N. J., Rojas-Brancho, L., Tillman, M. F., and Brownell, R. L. (2007). The whaling issue: conservation, confusion, and casuistry. *Mar. Policy* 31, 314–319. doi: 10.1016/j.marpol.2006.09.004

Cosgriff, B. (2001). ODA: *Official Development Assistance or Opportunity, Duty and Agenda? A Comparative Analysis Of Japan And Australia As Foreign Aid Donors In The South Pacific 1976-2000*. MA Thesis. Canterbury: Univeristy of Canturbury.

Day, J. (2014). Blog: abe unifies far-right ideology in upper echelons of Japanese politics. *China News Agency*. Available online at: http://news.xinhuanet.com/english/world/2014-09/08/c_133628335.htm

Hirata, K. (2005). Why Japan supports whaling. *J. Int. Wildlife Law Policy* 8, 129–149. doi: 10.1080/13880290590965276

Japanese Diplomatic Blue Book (2013). *Japan's Foreign Policy in Major Diplomatic Fields*. 25–26. Available online at: http://www.mofa.go.jp/files/000019042.pdf

Kirby, A. (2006). Japan sets 2006 whaling ultimatum. *BBC News*. Available online at: http://news.bbc.co.uk/1/hi/sci/tech/3907415.stm

Moreby, C. (1982). What whaling means to the Japanese. *New Scientist* 31, 661–663.

Morikawa, J. (2009). *Whaling in Japan, Power, Politics and Diplomacy*. London: Hurst and Company.

O'Dwyer, S. (2013). A Japanese poet's whale elegy. *The Japan Times*. Available online at: http://www.japantimes.co.jp/opinion/2013/04/10/commentary/japan-commentary/a-japanese-poets-whale-elegy/#.VxirTJMrJE5

Oh, I., and Ishizawa-Grbić, D. (2000). Forgiving the culprits: Japanese historicalrevisionism in a post-cold war context. *Int. J. Peace Stud.* - 5:2.http://www.gmu.edu/programs/icar/ijps/vol5_2/oh_grbi.html

Schieber, H. N. (1998). Historical Memory, cultural claims, and environmental ethics in the jurisprudence of whaling regulation. *Ocean Coast. Manag.* 38, 5–40.

Strand, J., and Truman, J. (2009). *Japanese Foreign Aid to Microstates and Voting in the International Whaling Commission: Evidence from Latin America and the Caribbean*. Las Vegas: University of Nevada.

Tarte, S. (1998). *Japan's Aid Diplomacy and the Pacific Islands*. Canberra, ACT: Australian National University.

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

frontiers in Marine Science

PERSPECTIVE
published: 18 July 2016
doi: 10.3389/fmars.2016.00121

# Japanese Small Type Coastal Whaling

*Sue Fisher* *

*Animal Welfare Institute, Washington, DC, USA*

2016 marks the 70th anniversary of the International Convention for the Regulation of Whaling (ICRW) as well as the 30th anniversary of the International Whaling Commission's (IWC) moratorium on commercial whaling. It also marks three decades of effort by Japan to overturn this ban. Its strategy to circumvent the moratorium by issuing permits to kill protected whales for scientific research is famous—even the subject of a 2014 lawsuit at the International Court of Justice. Less well known is Japan's strategy to overturn the ban by persuading the Commission to authorize a category of commercial whaling known as Small Type Coastal Whaling (STCW) that is conducted on minke and other small whales in Japanese waters but has never been regulated, or even formally recognized, by the IWC. For three decades Japan has sought STCW catch limits for four communities which it claims are still suffering distress as a result of the moratorium. While the Commission has rejected each proposal, mainly citing concerns that the commercial nature and purpose of STCW violates the moratorium, Japan has persisted, exhibiting great flexibility in its approach. Its tactics changed significantly in 2014; it no longer denied (or defended) the commerciality of the hunt, but argued that it is irrelevant since it sought only a small exemption to the moratorium which would remain intact for all other populations. This is a perspective on Japan's evolving STCW strategy and the risk that lifting, or modifying, the moratorium would pose to the conservation of whales.

**Keywords: Japan, International Whaling Commission, moratorium**



***Edited by:***
*Mark Peter Simmonds, University of Bristol, UK*

***Reviewed by:***
*Peter Corkeron, National Oceanic and Atmospheric Administration, USA*
*Russell Christopher Leaper, University of Aberdeen, UK*

***Correspondence:**
*Sue Fisher*
*sue.fisher@balaena.org*

***Specialty section:***
*This article was submitted to Marine Affairs and Policy, a section of the journal Frontiers in Marine Science*

***Received:*** *18 March 2016*
***Accepted:*** *23 June 2016*
***Published:*** *18 July 2016*

***Citation:***
*Fisher S (2016) Japanese Small Type Coastal Whaling. Front. Mar. Sci. 3:121. doi: 10.3389/fmars.2016.00121*

## BACKGROUND

The devastation wreaked on whale populations by centuries of unregulated, and later poorly regulated, commercial whaling is renowned: 2.9 million whales were killed in the 1900s (Rocha et al., 2014). Targeted on an industrial scale for their oil and, more recently, for their meat, many of the 13 species of "great" whales (baleen whales plus the sperm whale) suffered catastrophic declines. Some populations were lost entirely, including the North Atlantic gray whale (Reilly et al., 2008). Others, including the North Atlantic right whale, survive only in the low hundreds today, even after decades of protection (Reilly et al., 2008).

The International Convention for the Regulation of Whaling (ICRW) (IWC, 1946a) was negotiated at the end of World War II by the leading whaling nations (with the exception of Japan which joined in 1951) in an attempt to bring order to the extreme competition that had long characterized commercial whaling. The ICRW established the International Whaling Commission (IWC or Commission) whose (now 88) contracting governments implement the ICRW's objective to "*provide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry.*" This is achieved through the adoption of legally binding regulations, including catch limits (also known as quotas), into a schedule (IWC, 2015a) that "*forms an integral part*" of the convention (IWC, 1946b).

Regrettably, for the next four decades the IWC continued to set unsustainable catch limits for many populations and, because the ICRW lacked any enforcement mechanisms, remained unable to prevent or punish extensive illegal hunting and mis- or non-reporting of catches. Nations also evaded regulations by conducting whaling for scientific research and by lodging objections that exempted them from the Commission's decisions. Both practices are allowed by the convention: Article VIII permits contracting governments to issue "*special permits*" authorizing whaling "*for purposes of scientific research,*" while Article V allows objections.

By the 1960s more than 70,000 whales were killed annually (Rocha et al., 2014). The IWC began to protect the most vulnerable species in 1966 but did not adopt a total ban on commercial whaling until 1982. Specifically, it agreed a new schedule paragraph 10(e) which set catch limits "*for the killing for commercial purposes of whales from all stocks*" to zero after a 4 year phase-in period (IWC, 1982). Around the same time its Scientific Committee began developing a more precautionary quota-setting model for future commercial whaling that would set all catch limits to zero by default until scientific evidence showed that sustainable catch limits could be set for a specific population. The Commission accepted the specifications of this Revised Management Procedure (RMP) in 1994 (IWC, 1994a) but will not adopt it into the schedule until it has established a Monitoring, Control and Surveillance (MCS) regime, as part of a Revised Management Scheme (RMS) (IWC, 1994a).

## JAPAN'S RESPONSE TO THE MORATORIUM

Although all other remaining commercial whaling nations (Brazil, Spain, Korea, Iceland and the Philippines) ceased whaling in accordance with the moratorium, Japan, Norway, Peru and the Soviet Union lodged objections (IWC, 1982). Threatened with exclusion from valuable fishing grounds and other sanctions, Japan—then the leading whaling nation—was persuaded by the United States to withdraw its objection in 1987 (ICJ, 2011) although the other major hunters, Norway and the Soviet Union, retained their objections (Peru removed its objection in 1983). However, Japan immediately announced its intention to use Article VIII to hunt hundreds of whales annually on their Antarctic feeding grounds in a "feasibility study" that in 1989 became the 12 year (but subsequently extended) Japanese Whale Research Program under Special Permit in the Antarctic (JARPA, later JARPA-II). In 1994, it launched the Japanese Whale Research Program under Special Permit in the North Pacific (JARPN, later JARPN-II) which uses the same factory fleet. Japan and others had issued special permits before but never on such a scale or so blatantly for commercial purposes. Article VIII states that whales taken shall be processed "*so far as possible*" and the "*proceeds*" dealt with in accordance with directions issued by the government concerned; Japan interprets this as a mandate to sell the whale products through existing commercial markets.

Japan's use of Article VIII to keep its pelagic fleet operative and producing thousands of tons of whale meat a year despite the moratorium is widely criticized: It is the topic of countless hours of debate at IWC meetings, 25 IWC resolutions calling on Japan to reconsider its programmes, multiple diplomatic complaints and the threat of trade sanctions[1]. Moreover, the International Court of Justice (ICJ) ruled in 2014 that JARPA-II "*is not for the purposes of science*" and should stop (ICJ, 2014a). (Japan modified the programme and resumed Antarctic whaling in late 2015). In contrast, its efforts over the last 30 years to persuade the IWC to allow its small-scale, near-shore whaling operation known as "Small Type Coastal Whaling (STCW)" to resume legal commercial hunting of minke whales in its coastal waters are far less well-known.

Yet, because the ultimate goal of Japan's STCW strategy is to overturn, rather than circumvent, the moratorium, it may ultimately be more damaging. Lifting the moratorium, or modifying it for specific stocks, would make commercial whaling legal for the first time in three decades, enabling Norway, which currently hunts minke whales under objection, and Iceland, which uses a reservation to the moratorium to hunt fin and minke whales, to finally avoid reproach for "abusing loopholes" (WDC, 2015[2]). It would also open opportunities for other nations which have a market for whale meat that is not currently satisfied. For example, the Republic of Korea has asserted that if Japan is given an STCW quota, it would issue a similar demand (IWC, 1994b).

Furthermore, the IWC's prohibitions on commercial whaling up to and including the moratorium were the impetus for CITES, the Convention on International Trade in Endangered Species of Wild Fauna and Flora, to place all great whales[3] on its Appendix I (CITES, 2016) which prohibits international trade for primarily commercial purposes. Although the remaining whaling nations already trade whale products with each other under CITES reservations, they seek greater market access, including for new products, such as health supplements, that they are developing from whales (WDCS, 2010) and Norway and Japan have repeatedly sought to "downlist" whales to Appendix II. While CITES Parties have so far rejected each of these attempts, instead recommending in 2000 that "*Parties agree not to issue any import or export permit... for any specimen of a species or stock protected from commercial whaling by the International Convention for the Regulation of Whaling*" (CITES, 2000), given that CITES follows the IWC's lead in managing whales, lifting the moratorium, even fractionally, is likely to revive demands to allow international commercial trade to resume.

## JAPAN'S STCW STRATEGY

STCW is a Japanese category of whaling, conducted in a handful of towns, that is characterized by the species targeted (mainly Baird's beaked whales, short-finned pilot whales and Risso's

[1]United States Presidents Reagan, Clinton and G.W. Bush have all contemplated trade sanctions against Japan under the Pelly Amendment to the Fishermen's Protective Act 22 U.S.C. §1978, as amended Pub. L. No. 95-376, 92 Stat. 714 (Sept. 18, 1978).
[2]WDC (2015). Available online at: http://us.whales.org/wdc-in-action/whaling
[3]With the exception of the West Greenland minke whale which remains on Appendix II.

**TABLE 1 | STCW requests, catches of small cetaceans by STCW operations and minke whale catches in JARPN/JARPN II since the moratorium came into effect.**

| Year | Annual STCW quota sought | Catches of small cetaceans | | | JARPN/JARPN II minke catches (coastal) |
|---|---|---|---|---|---|
| | | Baird's beaked whale | Pilot whales | Risso's dolphins | |
| 1986 | 210 minke whalesr | 40 | 62 | | |
| 1987 | No proposal | 40 | | | |
| 1988 | 210 minke whales | No data found | No data found | No data found | |
| 1989 | 320 minke whales | 54 | 58 | | |
| 1990 | 50 minke whales | 54 | 18 | 11 | |
| 1991 | 50 minke whales | 54 | 59 | 92 | |
| 1992 | 50 minke whales | 54 | 81 | 30 | |
| 1993 | 50 minke whales | 54 | 91 | | |
| 1994 | 50 minke whales | 54 | 55 | 20 | 21* |
| 1995 | 50 minke whales | No data found | No data found | No data found | 100* |
| 1996 | 50 minke whales | No data found | No data found | No data found | 77* |
| 1997 | 50 minke whales | 54 | 77 | 20 | 100* |
| 1998 | 50 minke whales | 54 | 84 | 20 | 100* |
| 1999 | 50 minke whales | 62 | 104 | 12 | 100* |
| 2000 | 50 minke whales | 62 | 106 | 20 | 40* |
| 2001 | 50 minke whales | 62 | 87 | 17 | 100* |
| 2002 | No proposal | 62 | 83 | 12 | 50 |
| 2003 | 150 minke whales | 62 | 69 | 19 | 50 |
| 2004 | 100 minke whales | 62 | 42 | 7 | 60 |
| 2005 | 150 minke whales 150 Bryde's whales withdrawn before vote | 66 | 47 | 8 | 121 |
| 2006 | 150 minke whales 150 Bryde's whales withdrawn before vote | 63 | 17 | 7 | 97 |
| 2007 | No number specified | 67 | 16 | 20 | 108 |
| 2008 | No number specified | 64 | 20 | | 112 |
| 2009 | No proposal | 67 | 22 | | 122 |
| 2010 | No proposal | No data found | No data found | No data found | 105 |
| 2011 | No proposal | 61 | | | 77 |
| 2012 | No proposal | 71 | 16 | | 110 |
| 2013 | No proposal | 62 | 10 | | 92 |
| 2014 | <17 minkes/year | Data not available | | | 81 |

**Pelagic hunt, no coastal component. Source: 1986–1996, 2010–2014: Japan's Progress Reports to the Scientific Committee. 1997–2009: Annex L: Report of the Sub-committee on small cetaceans. Appendix 2. j. cetacean res. manage. 13 (suppl.), 2012.*

dolphins in addition to minke whales; see **Table 1** for catches since the moratorium). Although these are smaller species, the "small" in STCW actually derives from the size (maximum 48 tons) and short range of the vessels used (Kalland and Moeran, 1997). STCW is not a category of whaling regulated, or even recognized, by the IWC which for 70 years has governed only commercial and special permit whaling as well as hunting by indigenous people for nutritional and cultural subsistence, known as Aboriginal Subsistence Whaling (ASW). Moreover, the IWC does not regulate the hunting of species other than the great whales (which includes the minke whale) due to disagreement over its legal competence to manage "small cetaceans"—small toothed whales, dolphins and porpoises including those targeted in STCW.

The 2014 ICJ decision confirmed there can be no categories of whaling falling outside Article VIII or the schedule provision regulating ASW that are exempt from the prohibition on commercial whaling in 10(e). Although the court did not directly consider STCW, it is clear from its decision that by authorizing STCW on a species protected by 10(e) the IWC would not only exceed the scope of the ICRW, it would "*undermine its object and purpose*" (ICJ, 2014b).

Japan first sought STCW catch limits for minke whales in 1986, the year the moratorium came into effect; it sought an annual quota of 210 to meet the needs of three coastal towns, Ayukawa, Kushiro, and Abashiri, that had, until then, hunted minke as well as Baird's beaked and pilot whales and sold surplus meat throughout their respective regions (IWC, 1986). At the time the IWC was considering how to regulate ASW in light of the moratorium and Japan asserted that denial of its request would have the same damaging impact on STCW communities as it would on indigenous subsistence whalers. Conflating ASW and STCW by claiming similarities in their nature, size and history, Japan stated that "*the tradition of whaling in the [STCW] community is a complex and deep-rooted socio-economic element based on the long history of religion, custom and social behaviour which have survived through the centuries to the present day, on which the solidarity of the entire community has been built*" (IWC, 1986).

While STCW does have a long tradition in parts of Japan and is different in nature and scale from modern commercial whaling, it is also quite distinct from whaling for the purpose of nutritional and cultural subsistence that is conducted by indigenous people in remote, and typically harsh, environments for their local consumption (IWC, 2015b). Indeed, the framers of the ICRW explicitly recognized the needs of such indigenous people in both the final act of the convention and its first schedule (Tillman, 2008), establishing a legal mandate for the regulation of ASW that the IWC has exercised ever since. The IWC was not persuaded that Japan's STCW hunt should be treated like ASW and exempted from the moratorium.

Then, and now, the main objection to STCW is that it is an inherently commercial enterprise and therefore prohibited by paragraph 10(e). Indeed, Japan's first accounts of its longstanding STCW operations described clear for-profit elements, including sales by 10 wholesalers and almost 300 retailers, and regional sales of surplus (IWC, 1986). Displaying a flexibility that has come to characterize its STCW strategy, in subsequent proposals Japan denied or de-emphasized the commercial nature of the whaling operation; for example, it claimed in its third proposal (IWC, 1988) that a significant proportion of whale meat was distributed through non-commercial channels such as gifting. It also began to place greater emphasis on the social and cultural importance of STCW, interchangeably calling it "community based whaling." The assertion that the moratorium caused "*socio-cultural, dietary, religious, occupational and psychological*" distress to its STCW communities, and that the IWC has a responsibility to mitigate those harms, has remained a consistent element in Japan's requests and the Commission has recognized the needs of the communities and committed to "*work expeditiously to alleviate the distress*" (for example, IWC, 1993). But it did so initially in response to an offer of "*formal assurances*" by Japan that meat taken in STCW "*shall not become the object of any commercial distribution*". With Japan's ongoing STCW operations continuing to be (and acknowledged by Japan to be) commercial in nature and purpose, the Commission does not have the legal option—as the ICJ confirmed—to grant "*relief*" that would violate the moratorium.

Apparently undeterred by the repeated rejections of its proposals—17 have been defeated and the rest were withdrawn or never put to a vote—Japan has persisted. For each concern raised by IWC Commissioners, a subsequent proposal has typically offered a rejoinder or taken a new approach. For example, in the mid-1990s, Japan tried to remove all commercial elements from several of the action plans that accompanied its requests; replacing "sales" with "levies" and "reimbursements," limiting processing to portions of less than 1 kg, and transferring legal ownership of hunted whales to management councils which would distribute meat to schools, nursing homes and to community festivals. It even proposed fixing the price of whale meat sold in guest houses to avoid profit-making (IWC, 1995). When this failed to convince the Commission, it reversed approach in 2003—instead embracing the commercial aspects of the hunt and seeking a higher catch limit to "*vitalise the local economy by promoting local processing industries and stimulating tourism*" (IWC, 2003).

Japan has taken a similarly adaptable approach to addressing MCS issues. For example, it responded to concerns about how products from minke whales taken for non-commercial purposes would be prevented from entering the well-developed and high value market for Baird's beaked whales that used the same vessels, crews, ports and processing facilities by incorporating elements of the RMS then being negotiated by the Commission such as global positioning systems on boats, local inspectors at ports, a DNA database of whale meat and penalties for unauthorized selling of whale products (IWC, 1995). The flexibility of its proposals has even extended to the communities seeking an STCW quota; while Japan initially sought catch limits to meet the needs of Kushiro, Abashiri and Ayukawa, it subsequently dropped Kushiro and added Taiji and Wada (IWC, 1990), only to reinstate Kushiro (where a new whaling station was to be built) in 2003 (IWC, 2003) after Japan began sub-contracting a coastal component of JARPN-II to STCW vessels.

However, the most variable element in STCW proposals has been the number, and even the species, of whales claimed to be needed by STCW communities in addition to meat from their ongoing—and relatively stable—small cetaceans takes. In the early years, Japan sought 210 (IWC, 1986) or 320 (IWC, 1989) minke whales a year to satisfy need, while from 1990 (when it offered to reduce its Baird's beaked whale quota) to 2003 it requested a more symbolic "*emergency relief quota*" of 50 whales a year (IWC, 1990). Its proposal expanded to 150 minke whales in 2003 (IWC, 2003), dropped to 100 in 2004 then, for 2 years, included an additional 150 Bryde's whales (IWC, 2005, 2006) although this is not a species traditionally hunted in STCW. Japan did not identify a number of whales in its 2007 and 2008 proposals, but sought advice directly from Scientific Committee on an appropriate catch limit (IWC, 2007). After pausing its requests between 2009 and 2012 when the IWC attempted to avoid controversial issues while it focused its discussions on its future, Japan most recently sought 17 minke whales in 2014 (IWC, 2014a).

Governments routinely express concern about the sustainability of the proposed hunt. Minke whales in the North Pacific comprise at least two and probably more genetically distinct stocks including a depleted population known as J-stock. J-stock whales mix at certain times of the year with the more populous O-stock and are vulnerable to both high levels of by-catch by Japan and South and North Korea and JARPN-II (Baker et al., 2000). Japan has responded in various ways to concerns about the potential impact of STCW on these stocks but most recently in 2014, it claimed the impact on the stocks would be negligible because it calculated the proposed catch limit "*in light of the RMP Implementation Review completed in 2013*" (IWC, 2014c). In fact the Scientific

Committee had determined that the experimental variant of the RMP used by Japan to generate a catch limit of 17 minke whales would be acceptable only with additional research and, overall, was one of the worst performing of 10 variants reviewed in 2013 (IWC, 2014b). In addition, Japan's 2014 proposal did not take into account the Commission's longstanding agreement (IWC, 2000) that whales killed in by-catch should be deducted from catch limits calculated by the RMP. Nor did it commit to reduce catches in proportion to the number of minke whales (up to 120 a year have been taken since 2002) in the coastal component of JARPN II conducted by STCW vessels and sold locally (Suisan Keizai News, 2005[4]). In contrast Japan offered to offset these takes in 2007 (IWC, 2007).

## 2014—A NEW APPROACH

Japan's approach changed significantly in 2014—the first time the Commission had met on a new biennial cycle and following the ICJ decision. Claiming that it had no wish to change or delete paragraph 10(e) which, it insisted, would remain in operation if its proposal was adopted, Japan proposed an exemption to the moratorium via a new paragraph that would apply "*notwithstanding*" 10(e)'s provisions (IWC, 2014d). Paragraph 10(f) would establish a 5 years block of catch limits for the single stock of minke whales in the western North Pacific on which it had tested a variant of the RMP. Although the proposal was rejected, Japan's Commissioner subsequently sought governments' input to a "consultative questionnaire" to "*identify remaining arguments and issues that need further discussion*" (Morishta, 2015[5]) and Japan has approached opposing governments during the intersessional period to discuss their concerns (Anon, 2016). These unprecedented attempts at outreach signal the importance of its STCW strategy to Japan, particularly in light of its acknowledgment that it must revise JARPN-II as well as its Antarctic programme "*in light of the ICJ ruling*" (Jiji News, 2016[6]) which likely means a reduction in special permit catches—and therefore meat—from the North Pacific.

The timing of this apparent increase in effort around STCW is particularly significant as Japan will assume the chairmanship of the Commission at the end of the 2016 meeting and its Commissioner will oversee the IWC's negotiation of new ASW catch limits in 2018. STCW may never rival special permit whaling for attention but, given the risks of lifting or modifying the moratorium, Commissioners should pay close attention to the STCW proposal that Japan is expected to bring to the next meeting.

## AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and approved it for publication.

## FUNDING

This research was supported by Animal Welfare Institute.

[4]Minke Whale Meat Arrives at Sendai Market for the First Time From Research Whaling off Sanriku. April 15th, 2005. Suisan Keizai News. Text on file with author.

[5]Letter Joji Morishta, 21 January 2015. Downloaded at https://iwc.int/stcw on 3 March 2016

[6]Scientific whaling in the northwest Pacific to be completely revised, new program to be created this fall. Jiji News, 22 April, 2016. Available online at: http://www.jiji.com/jc/article?k=2016042200349&g=eco

## REFERENCES


Anon (2016). *Confidential Personal Communication with IWC Commissioners*, Anon.

Baker, C. S., Lento, G. L., Cipriano, F., and Palumbi, S. R. (2000). Predicted decline of protected whales based on molecular genetic monitoring of Japanese and Korean markets. *Proc. R. Soc. Lond.* B 267, 1191–1199. doi: 10.1098/rspb.2000.1128

CITES (2000). "Conservation of cetaceans, trade in cetacean specimens and the relationship with the International Whaling Commission," in *Resolution Conf. 11.4 (Rev. CoP12)*. Available online at: https://cites.org/eng/res/11/11-04.php

CITES (2016). *Appendix I*. Available online at: https://cites.org/eng/app/appendices.php

ICJ (2011). *Memorial of Australia*, vol. I, P70–P76. Available online at: http://www.icj-cij.org/docket/index.php?p1=3&p2=3&k=64&case=148&code=aj&p3=1

ICJ (2014a). *Whaling in the Antarctic (Austl. v. Japan), 2014 I.C.J. 148*. Available online at: http://www.icj-cij.org/docket/index.php?p1=3&p2=3&k=64&case=148&code=aj&p3=3. 72

ICJ (2014b). *Whaling in the Antarctic (Austl. v. Japan), 2014 I.C.J. 148*. Available online at: http://www.icj-cij.org/docket/index.php?p1=3&p2=3&k=64&case=148&code=aj&p3=3. 66

IWC (1946a). *International Convention for the Regulation of Whaling*. Stat. 1716, 161 U.N.T.S. 72, IWC.

IWC (1946b). *International Convention for the Regulation of Whaling*. Art. I. 10, 62 Stat. 1716, 161 U.N.T.S. 72, IWC.

IWC (1982). *International Convention for the Regulation of Whaling, Schedule Art. III*, 10(e), 62 Stat. 1716, 161 U.N.T.S. 72, IWC.

IWC (1986). *Small Type Whaling in Japan's Coastal Seas*. Submitted by the Government of Japan. TC38/AS2. 26–27, IWC.

IWC (1988). *Chairman's Report of the 39th Annual Meeting*. Report of the International Whaling Commission 38. 22.

IWC (1989). *Chairman's Report of the 41st Annual Meeting*. Report of the International Whaling Commission 40, 1990. 27.

IWC (1990). *Chairman's Report of the 42nd annual meeting*. Report of the International Whaling Commission. 41, 1991. 33.

IWC (1993). "Resolution on Japanese Community-based Minke Whaling," in *Chairman's Report of the 46th Annual Meeting*. Report of the International Whaling Commission, 44, 1994. 31.

IWC (1994a). "IWC Resolution 1994-5. Resolution on the Revised Management Scheme," in *46th Annual Meeting, 1994*. Report of the International Whaling Commission, 45.

IWC (1994b). *Chairman's Report of the 46th Annual Meeting*. Report of the International Whaling Commission. 45. 1995. 18.

IWC (1995). *Action Plan for Japanese Community-Based Whaling (CBW) (Revised)*. Government of Japan, IWC/47/46.

IWC (2000). *Chairman's Report of the Fifty-Second Annual Meeting*. Annual Report of the International Whaling Commission, 2000. 33.

IWC (2003). *Chair's Report of the 55th Annual Meeting*. Report of the International Whaling Commission 2003. 28.

IWC (2005). *Chair's Report of the 57th Annual Meeting*. Report of the International Whaling Commission 2005. 35.

IWC (2006). *Chair's Report of the 58th Annual Meeting*. Report of the International Whaling Commission 2006. 28.

IWC (2007). *Chair's Report of the 59th Annual Meeting*. Report of the International Whaling Commission 2007. 33–37.

IWC (2014a). *Chair's Report of the 65th Meeting*. Report of the International Whaling Commission 2014, 12–13.

IWC (2014b). *Journal of Cetacean Research and Management*. 15 (suppl.), 2014. Report of the Scientific Committee, IWC, 11–15.

IWC (2014c). *Japan's Proposal and its Background for Schedule Amendment to Permit the Catching of Minke Whales from the Okhotsk Sea-West Pacific Stock by Small-Type Coastal Whaling Vessels*. IWC/65/09

IWC (2014d). *Additional Information to IWC/65/09 (Japan's Proposal and its Background for Schedule Amendment to Permit the Catching of Minke Whales from the Okhotsk Sea-West Pacific Stock by Small-Type Coastal Whaling Vessels),* IWC/65/21.

IWC (2015a). *Schedule As amended by the Commission at the 65th Meeting Portorož, Slovenia*. Available online at: https://iwc.int/convention

IWC (2015b). *Schedule As amended by the Commission at the 65th Meeting Portorož, Slovenia*. Paragraph 13 (b) (1), (2), (3), (4). Available online at: https://iwc.int/convention

Kalland, A., and Moeran, B. (1997). *Japanese Whaling: End of an Era?* London: Curzon Press.

Morishta, J. (2015). *Letter to Simon Brockington, Secretary of the IWC*. Available online at: https://iwc.int/stcw

Reilly, S. B., Bannister, J. L., Best, P. B., Brown, M., Brownell Jr., R. L., Butterworth, D. S., et al. (2008). *Eschrichtius robustus. The IUCN Red List of Threatened Species 2008: e.T8097A12885255*. Available online at: http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T8097A12885255.en. Downloaded on 16 March, 2016

Rocha, R. C., Clapham, P. J., and Ivashchenko, Y. V. (2014). Emptying the oceans: a summary of industrial whaling catches in the 20th century. *Marine Fish. Rev.* 76, 37–48.

Tillman, M. F. (2008). The international management of aboriginal whaling. *Rev. Fish. Sci.* 16, 437–444. doi: 10.1080/10641260802013932

WDCS (2010). *Reinventing the Whale*. Available online at: http://us.whales.org/reinventing-whale

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

frontiers in Marine Science

PERSPECTIVE
published: 28 June 2016
doi: 10.3389/fmars.2016.00110

# An Overview of Increasing Incidents of Bottlenose Dolphin Harassment in the Gulf of Mexico and Possible Solutions

*Courtney S. Vail* *

*Whale and Dolphin Conservation, Plymouth, MA, USA*

The panhandle region of the Gulf of Mexico is known by scientists, regulatory agencies and conservation organizations as a "hotbed" area of dolphin harassment. Interactions between humans and wild dolphins routinely occur through close vessel approaches or through direct contact associated with commercial or recreational fisheries, swim-with, or feeding activities. Such interactions are of serious concern for wild dolphin welfare and conservation under the U.S. Marine Mammal Protection Act, as well as for human safety. In recent years, an alarming number of dolphins in this region have been fatally wounded by gunshot, hunting arrows, or sharp tools (i.e., screwdriver). The potential to mitigate the detrimental impacts resulting from these human-dolphin encounters requires a comprehensive outreach strategy to address increasing incidents of harassment and vandalism, as well as an evaluation of the serious trends and challenges hampering dolphin protection in this region. In addition to the identification and conviction of perpetrators through the application of existing law, voluntary outreach programs offer real potential to educate and reform public attitudes and behaviors through community-based stewardship initiatives, which can foster dolphin protection in areas of high human-dolphin conflict. The development of these types of programs underlines the potential for non-regulatory approaches to serve as an effective means to reach and activate the public on some of the most pressing local and regional marine conservation issues. In tandem with regulations and enforcement, voluntary stewardship programs can provide stakeholders an opportunity to engage in local dolphin conservation efforts through a positive approach aimed to inspire accountability.

**Keywords: bottlenose dolphins, harassment, vandalism, Gulf of Mexico, human-dolphin interactions, law enforcement, regulations, US Marine Mammal Protection Act**



**Edited by:**
*Mark Peter Simmonds,*
*University of Bristol, UK*

**Reviewed by:**
*Christian T. K.-H. Stadtlander,*
*Independent Researcher, USA*
*Randall Wells,*
*Chicago Zoological Society, USA*

***Correspondence:**
*Courtney S. Vail*
*courtney.vail@whales.org*

**Specialty section:**
*This article was submitted to Marine Affairs and Policy, a section of the journal Frontiers in Marine Science*

***Received:*** *05 April 2016*
***Accepted:*** *13 June 2016*
***Published:*** *28 June 2016*

**Citation:**
*Vail CS (2016) An Overview of Increasing Incidents of Bottlenose Dolphin Harassment in the Gulf of Mexico and Possible Solutions. Front. Mar. Sci. 3:110. doi: 10.3389/fmars.2016.00110*

The harassment or "take" of bottlenose dolphins (*Tursiops truncatus*) resulting from increasing opportunities to encounter this species in the wild through commercial or recreational activities which put humans in close proximity to wild populations is of growing concern within the United States. The take of marine mammals, including harassment and feeding, is illegal under the U.S. Marine Mammal Protection Act of 1972 (MMPA), and concern is growing over human-dolphin interactions concentrated in certain coastal areas in the Gulf of Mexico where injuries or fatalities to bottlenose dolphins, specifically, have been documented. These encounters, which bear great potential and risk for injury to the public and to individual dolphins and populations, may take the form of interaction with recreational or commercial fishing vessels and gear (Wells et al., 1998; Powell and Wells, 2011), direct interaction with humans through feeding or swim-with activities (Colborn, 1999; Samuels and Bejder, 2004; Danil et al., 2005; Cunningham-Smith et al., 2006; Finn et al., 2008; Perrtree et al., 2014), or encounters with vessels during whale or dolphin viewing activities (Wells and Scott, 1997; Nowacek et al., 2001; Constantine et al., 2004; Goodwin and Cotton, 2004; Lusseau, 2006; Timmel et al., 2008). Impacts to wild dolphins from these activities include conditioning and alteration of normal foraging and resting behaviors; disturbance and ultimate dispersal of populations from preferred habitat; injury from vessel strikes or directed harm, and reduced reproductive success, all of which can threaten survival.

## REGIONAL CONCERNS

Marine mammal scientists, regulatory authorities and charitable organizations have expressed, through a significant body of scientific literature, targeted outreach programs, and advocacy campaigns heightened concerns over the conservation and welfare impacts associated with increasing human-dolphin encounters in the wild (**Figure 1**). Dangers to wild marine mammals include injury or death from development of unnatural behaviors such as begging; dependence on human provisioning; vessel strikes; intentional and directed violence and vandalism; ingestion of harmful items; commercial exploitation; and intrusion into critical habitats (Samuels and Bejder, 2004; Cunningham-Smith et al., 2006). Dangers to humans include serious injuries or worse from wild animals that have been illegally fed or chronically harassed (Frohoff and Packard, 1995; Seideman, 1997; Cunningham-Smith et al., 2006).


**FIGURE 1 | As part of its outreach to the public, NOAA/NMFS has posted signs in marinas and coastal areas to raise awareness to wild dolphin harassment issues (Image provided by NOAA/SERO).**

Federal authorities continue to seek information relating to what appears to be a pattern of violence against dolphins along the coastlines of Florida, Texas, Alabama, Mississippi and Louisiana (NOAA, 2014b). The recent increase in incidents of shooting or directed harm toward individual dolphins in the wild necessitates a review of possible regulatory and non-regulatory approaches to this serious conservation issue. Management becomes crucial in these areas of the southeastern U.S. where viewing and swim-with activities are popular with tourists, concentrated in small geographic areas, and potentially target small, resident populations of *Tursiops truncatus*.

Bottlenose dolphin stranding data maintained by the National Oceanic and Atmospheric Administration (NOAA) show an apparent increase in the number of dolphins stranding dead with evidence of a gunshot wound in the northern Gulf of Mexico. From 2003 to 2016, at least 20 dolphins have stranded with gunshot wounds, with 65% of those occurring since 2011 (**Table 1**). These incidents are cause for concern considering the potential trauma and suffering experienced by individual dolphins in these cases, and also total unknown impacts on wild populations. The numbers of individuals recovered may only represent a fraction of total numbers of animals that may never wash to shore, strand, or become available to recovery efforts (Williams et al., 2011; Peltier et al., 2012; Wells et al., 2015). For example, three cases of fishermen shooting at dolphins in the northern Gulf of Mexico were federally prosecuted but the carcasses were not found, and hence, not reflected in stranded animals shown in **Table 1** (DOJ, 2006, 2007, 2013). Furthermore, some of these individuals may be pregnant when wounded or killed, exacting a larger toll on wild populations than accounted for. For instance, a bottlenose dolphin found dead from a gunshot wound on Miramar Beach in the area of Destin, Florida in November 2014 was just weeks from giving birth (NOAA, 2014a).

Not included in **Table 1** are those dolphin fatalities resulting from other forms of directed violence (e.g., arrows, explosives, other sharp objects). Unfortunately, other types of vandalism are also occurring in this region. NOAA's Fisheries Service's Office of Law Enforcement is receiving increased reports of people taking extraordinary actions against dolphins including shooting, throwing cherry bombs, and pipe bombs (NOAA, 2009). In July 2014, a bottlenose dolphin in Cow Bayou, Texas was fatally shot by two brothers with a compound bow (DOJ, 2015). In November 2014, another dolphin was shot with a hunting bow in Orange Beach, Alabama and died approximately 5 days later from a secondary infection from the wound (NOAA, 2014b,c).

**TABLE 1 | NOAA National Marine Mammal Health and Stranding Response Database (previously unpublished data).**

| DEAD STRANDED BOTTLENOSE DOLPHINS WITH EVIDENCE OF GUNSHOT IN THE GULF OF MEXICO: 2003–2016 | | | |
|---|---|---|---|
| **YEAR** | **DATE** | **STATE** | **LOCATION** |
| 2016 | May 9 | FL | Okaloosa Island |
| 2014 | November 13 | FL | Miramar |
| 2014 | February 3 | LA | Port Sulphur |
| 2013 | April 5 | MS | Pass Christian |
| 2013 | January 13 | LA | Houma |
| 2013 | January 11 | LA | Grand Isle |
| 2012 | November 9 | MS | Ocean Springs |
| 2012 | September 22 | LA | Grand Isle |
| 2012 | January 1 | MS | Deer Island |
| 2011 | July 6 | LA | Dularge |
| 2011 | February 22 | LA | Grand Isle |
| 2011 | January 28 | LA | Grand Isle |
| 2011 | January 11 | LA | Grand Terre |
| 2007 | June 24 | TX | Corpus Christi |
| 2006 | December 22 | FL | Pensacola Beach |
| 2006 | April 15 | FL | Bradenton |
| 2004 | May 22 | LA | Grand Terre |
| 2004 | March 16 | TX | Matagorda |
| 2004 | March 8 | TX | San Jose Island |
| 2003 | April 13 | TX | Crystal Beach |

In June 2012 off Dupont Point, Alabama, a bottlenose dolphin was sighted alive with a screwdriver lodged in its head and then later found dead near the Florida-Alabama state line in Perdido Bay (NOAA, 2012).

The contributing causes to this general increase in violence toward bottlenose dolphins in the Gulf of Mexico are partially informed by some of the cases that have been successfully prosecuted to date and existing literature. In several instances, fishermen reportedly became irritated at dolphins trying to take bait and catch from fishing lines or trawl nets and shot or threw pipe bombs at the dolphins to keep them away from their gear and/or catch (DOJ, 2006, 2007, 2013; NOAA, 2009). Provisioning dolphins conditions them to approaching humans and boats for food where they may then attempt to aggressively prey on hooked bait and catches, creating conflicts with fishermen (Zollett and Read, 2006; Read, 2008). Depredation of both commercial and recreational fisheries is a growing problem globally (Noke and Odell, 2002; Brotons et al., 2008; Powell and Wells, 2011). In addition, activities that bring dolphins into close proximity with fishing gear have the potential to seriously injure or kill the animals through ingestion, entanglement, or even vessel strikes (Zollett and Read, 2006; Read, 2008; Wells et al., 2008; Barco et al., 2010; Powell and Wells, 2011; Stolen et al., 2013). As more people locate to coastal areas and participate in recreational activities, the chances for close encounters increase, making local populations susceptible to disturbance, harassment, or direct attack (Samuels and Bejder, 2004; Mattson et al., 2005; Cunningham-Smith et al., 2006; Zollett and Read, 2006). As a result, it is possible to suggest that a byproduct of dolphin conditioning to human interaction in the region, including activities to swim with or feed these animals, is resulting in closer proximity and access to wild dolphins, exposing them to directed harm and violence (Waring et al., 2015; NOAA, 2016). Finally, it is also possible that increasing awareness and publicity surrounding these events, in addition to expanding stranding response in the region due to Deepwater Horizon oil spill remediation and research efforts, may also be contributing factors toward the growing perception of an apparent increase in the occurrence of violent incidents through enhanced reporting of cases or recovery of carcasses.

## POSSIBLE SOLUTIONS

In response to increasing numbers of reports of cases of dolphin abuse and vandalism in this specific area, a variety of approaches have historically been implemented. Some are discussed below, suggesting that other measures may be required.

### Non-Regulatory Approaches

#### Protect Wild Dolphins Campaign

Aside from this more recent upsurge in dolphin fatalities, concerns over the feeding and harassment of wild dolphins by the public has a long history. In response to a general trend of increasing interactions between the public and wild dolphins, including swimming with and feeding wild dolphins which bear the potential for injury to both humans and dolphins, NOAA's National Marine Fisheries Service (NMFS) launched its "Protect Wild Dolphins" Campaign in the late 1990s[1]. With a focus on recreational activities in coastal waters, NMFS' campaign focused its messaging on the risks associated with close interactions with wild dolphins, harm to the health and welfare of individual dolphins and populations, and the potential illegality of these activities under the MMPA (Spradlin et al., 1999).

Various public outreach materials including brochures, signs, billboards, aerial banners, press releases[2], social media, and media articles have been produced to inform the public that feeding wild dolphins is illegal, and that recreational swim activities may cause disturbance to wild populations and be considered harassment under the protective provisions of the MMPA. This campaign continues to run in tandem with other public information and outreach initiatives relating to marine mammal protection within NOAA's NMFS[3].

#### Don't Feed Wild Dolphins Campaign

Building upon the "Protect Wild Dolphins" platform, this complementary campaign focused its messaging specifically on the problem of the public's provisioning of wild dolphins, its illegality, and detrimental consequences for both dolphins and humans alike. The initiative was spawned through the collaboration of NMFS and partners within the nonprofit,

[1]http://www.nmfs.noaa.gov/pr/education/protectdolphins.htm
[2]For example see: http://www.nmfs.noaa.gov/pr/pdfs/education/dolphin_press.pdf
[3]http://sero.nmfs.noaa.gov/protected_resources/outreach_and_education/index.html

scientific, and aquaria community to expand public messaging opportunities. In the form of a compelling and engaging Public Service Announcement and informational website[4], this campaign was designed to illustrate the serious health and welfare impacts associated with feeding wild dolphins, and provide recommendations for fishermen seeking to minimize depredation and conflict with "begging" bottlenose dolphins, especially in regional areas of high human-dolphin interactions.

As part of this campaign, educational materials addressing the problems associated with the discarding of fishing bait and bycatch have also been produced in order to educate the public about the hazards to wild dolphins associated with recreational and commercial fishing[5]. These guidelines are designed to prevent serious injuries to dolphins from fishing gear and boats, and offer recommendations relating to how to act if dolphins are present in the fishing area, how bait should be discarded, and what types of gear and tackle can be used to reduce hazards to dolphins.

### Dolphin SMART Program

Dolphin SMART is a voluntary recognition and education program for commercial businesses conducting dolphin watching tours. The program was established in 2007 through a multi-stakeholder engagement process that was convened initially to address the very real problem of dolphin feeding and harassment near Key West, Florida[6]. Within Key West, a very discrete population of resident dolphins is targeted by the commercial dolphin watching community in a very concentrated area (WDCS, 2008).

Currently being implemented in Florida and Hawaii, this stewardship program was developed to provide dolphin tour operators with an incentive program to minimize the disturbance of wild dolphin populations, educational materials for the public, and baseline field research to measure program outcomes. This incentive program requires operators to participate in annual trainings and follow certain viewing and advertising guidelines. These guidelines require adherence to best practices, such as a 50-yard approach distance, not promoting or allowing swim-with activities during a dolphin-watching excursion, and providing an on-board briefing about the program. Operators participating in the program are able to fly a flag that designates them as "Dolphin SMART" and that signals to the public that they contribute to dolphin conservation. Environmentally-conscious consumers, theoretically, would favor an operator that adheres to Dolphin SMART program guidelines and procedures (Cone, 2010).

Although the program has enjoyed some initial success in expanding to various locations in the southeastern U.S., and to three islands in Hawaii, it is challenged by a general lack of resources to fully implement and realize the benefits of this voluntary incentive program.

[4]http://www.dontfeedwilddolphins.org/
[5]http://www.dontfeedwilddolphins.org/brochure/dolphin_interaction_card.pdf
[6]www.dolphinsmart.org

## Regulatory Approaches

### Law Enforcement

Law enforcement efforts to prosecute the "take" of bottlenose dolphins are hampered by a general lack of agency resources, difficulty in documenting detrimental human-dolphin encounters, and competing agency priorities. However, more recent action in the courts against fishermen and other individuals in violation of the MMPA may be sending a strong message to the public that NMFS and the Department of Justice (DOJ) are taking these crimes seriously, which may eventually have a dampening effect on these activities in the wild.

In October 2006, a Panama City, Florida charter boat captain was sentenced for knowingly and unlawfully shooting at dolphins as they grabbed his hooked fish (DOJ, 2006). Similarly, in January 2007, an Orange Beach, Alabama charter boat captain was convicted for illegally shooting a dolphin that was approaching his charter fishing vessel (DOJ, 2007). In yet another case of harassment, in March 2009, a federal judge sentenced a Panama City, Florida boat captain to 2 years in prison, 3 years of supervised probation, and $125 special assessment for attempting to intentionally harm bottlenose dolphins with pipe bombs (NOAA, 2009). Two other cases have been successfully prosecuted, including a shrimper who was convicted of shooting at dolphins (DOJ, 2013) and two brothers found guilty for killing a dolphin with a compound arrow (DOJ, 2015). Additionally, NOAA's Office of Law Enforcement has successfully investigated cases of illegal feeding of wild dolphins resulting in multiple successful charges against individuals brought by NOAA's Office of General Counsel[7].

Bottlenose dolphins are protected under the MMPA. Harassing, harming, killing, or feeding wild dolphins is prohibited. Violations can be prosecuted either civilly or criminally and are punishable by up to $100,000 in fines and up to 1 year in jail per violation. Unfortunately, these penalties are not necessarily an overt deterrent to these types of activities, as evidenced by the more recent record of fatal incidents involving intentional harm to dolphins in the Gulf region (see **Table 1**).

### Federal Regulations Addressing Marine Mammal Harassment

In January 2002, NMFS published an Advanced Notice of Proposed Rulemaking (ANPR) regarding the issue of human harassment that threatens the health and welfare of marine mammals in the wild[8]. At the time, NMFS considered proposing regulations to protect marine mammals in the wild from directed human activities that have the potential to harass the animals. Some of these activities of concern included feeding wild marine mammals (subsequently included within MMPA implementing regulations), "swim-with" activities, vessel-based interactions, and land-based interactions. Although regulations were not proposed or finalized, this notice opened the possibility for evaluation of those activities encompassing the spectrum of human-dolphin interactions that bear significant potential to

[7]http://www.nmfs.noaa.gov/ole/slider_stories/2014/12_031214_dolphin_harassment.html; See also http://www.nmfs.noaa.gov/ole/slider_stories/2014/19_081914_panama_city_dolphin_harassment.html
[8]50 CFR Part 216; Docket No. 020103001-2001-01; I.D. 122001B; RIN: 0648AN43

harm or injure wild dolphins, including the operation of personal watercraft, swim encounters, and touching or petting marine mammals in the wild.

Currently, a proposed rule is pending that will specifically address the harassment of spinner dolphins in Hawaii. Scientific research has revealed the real impact that human activities are having on local spinner dolphin populations (Courbis and Timmel, 2009; Tyne et al., 2014). A proposed rule has been in the pipeline since an ANPR was issued by NMFS in December 2005 (NOAA, 2005). The proposed rule may include regulatory measures that will restrict human activities that bear the potential to disturb or harm spinner dolphins in Hawaii.

## DISCUSSION

Education and outreach programs are important mechanisms to inform stakeholders about protection of dolphins in the wild. With the advent of social media, messaging can be compelling, accessible, and rapidly distributed among networks of consumers, recreationalists, and tourists. However, more attention could be focused on engaging a critical class of stakeholders—the fishing community. Obtaining a better understanding of the dynamics between wild dolphins and fishing activities, the emergence and transmission of begging or depredation behavior in dolphins, and fishermen perceptions and attitudes toward dolphins may enlighten focused solutions.

However, voluntary education and outreach programs, no matter how sophisticated and on their own, may not be enough to reduce the types of take that have been documented in the Gulf Region, and cited within this article. Regulatory approaches may also be a necessary part of any solutions targeting the growing problem of dolphin harassment in the wild. Regulations to reduce harassment would provide an additional framework within which to identify specific activities that threaten the conservation and welfare of wild dolphin populations, while raising the profile of human-dolphin interactions. Such regulations would also empower law enforcement to proactively address these activities, while offering policymakers an enhanced toolkit of strategies to target activities that have the potential to cause harassment (i.e., area closures and other space or temporal restrictions). Finally, regulations could serve to complement existing education and outreach programs.

The difficulties in enforcing even the most egregious violations of the MMPA is evidenced by the increasing incidents of targeted shootings and other directed violence against dolphins in the Gulf of Mexico region in the United States. Of the at least 20 documented strandings of dolphins with evidence of gunshot wounds and other known intentional harm cases mentioned above (i.e., defined as “takes” under the MMPA) since 2003, just six have involved the identification or legal conviction of the perpetrators of these crimes. Further challenging the identification and conviction of perpetrators of these directed acts against dolphins is the fact that oftentimes a carcass is not available as evidence in a case; the determination of a cause of death is not possible for various reasons; or investigators are unable to conduct ballistics on certain types of bullets found in the carcass (i.e., buckshot).

In 2012, in response to the large number of dolphin shooting deaths over the period of just a few months, several conservation, animal welfare, and civic organizations established multiple monetary rewards requesting information leading to the identification, arrest, and conviction of the person or persons responsible for these illegal and cruel acts. These standing rewards are meant to assist ongoing and longer- term efforts to prosecute violations of the MMPA and support the continuing need for public informants to come forward with information to support law enforcement efforts in these types of crimes that sometimes only become visible when an animal washes ashore.

Although challenging to assemble and manage, monetary rewards have proven useful in encouraging the public to come forward with information aiding the identification of a perpetrator in at least one of these cases[9]. It is hoped that these outstanding[10] and future financial rewards will contribute to additional successful and high-profile prosecutions that will ultimately reduce the targeted harassment of dolphins in this region.

The increasing proximity and encouragement of direct interaction and close encounters with wild dolphins through commercial and recreational activities has had a profound effect on eroding the protective barriers that once existed between wild dolphins and the general public. Increasingly, as they are seen as less-than-wild animals, either through habitual interaction with fisheries or ocean-goers seeking to swim with or feed them, wild dolphins are increasingly at risk of targeted harassment and even violence. As coastal communities deal with the influx of tourists or locals who are eager for close dolphin encounters, they must also bear the responsibility of educating consumers about keeping a necessary and respectful distance from this vulnerable species.

## AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and approved it for publication.

## ACKNOWLEDGMENTS

The author acknowledges the assistance of individuals in the NMFS Southeast Region office (SERO) who provided support for this article, including unpublished dolphin stranding data for the Gulf of Mexico and details of past regional law enforcement efforts relating to dolphin take and harassment. With special thanks to Stacey Horstman for her editorial comments and review.

[9]Orange Beach, Alabama incident involving dolphin shot with an arrow. Multiple entities provided reward totaling $24,000. Reward was claimed. Here is story link: http://sero.nmfs.noaa.gov/news_room/press_releases/2014/tips_lead_to_break_in_the_case_of_a_dolphin_shot_with_a_hunting_arrow.pdf
[10]http://sero.nmfs.noaa.gov/news_room/press_releases/2012/la_dolphin_shot_sept_2012_final.pdf

## REFERENCES


Barco, S., D'Eri, L. R., Woodward, B. L., Winn, J. P., and Rotstein, D. S. (2010). Spectra fishing twine entanglement of a bottlenose dolphin: a case study and experimental modeling. *Mar. Pollut. Bull.* 60, 1477–1481. doi: 10.1016/j.marpolbul.2010.05.005

Brotons, J. M., Grau, A. M., and Rendell, L. (2008). Estimating the impact of interactions between bottlenose dolphins and artisanal fisheries around the Balearic Islands. *Mar. Mamm. Sci.* 24, 112–127. doi: 10.1111/j.1748-7692.2007.00164.x

Colborn, K. (1999). *Interactions Between Humans and Bottlenose Dolphins, Tursiops truncatus, near Panama City, Florida*. MS Thesis for Duke University, North Carolina, 45.

Cone, Inc. (2010). *Cone Cause Evolution Study*. Boston, MA: Cone, LLC. Available online at: http://ppqty.com/2010_Cone_Study.pdf

Constantine, R., Brunton, D. H., and Dennis, T. (2004). Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. *Biol. Conserv.* 117, 299–307. doi: 10.1016/j.biocon.2003.12.009

Courbis, S., and Timmel, G. (2009). Effects of vessels and swimmers on behavior of Hawaiian spinner dolphins (*Stenella longirostris*) in Kealake'akua, Honaunau, and Kauhako bays, Hawaii. *Mar. Mamm. Sci.* 25, 430–440. doi: 10.1111/j.1748-7692.2008.00254.x

Cunningham-Smith, P., Colbert, D. E., Wells, R. S., and Speakman, T. (2006). Evaluation of human interactions with a provisioned wild bottlenose dolphin (*Tursiops truncatus*) near Sarasota Bay, Florida, and efforts to curtail the interactions. *Aquat. Mamm.* 32, 346–356. doi: 10.1578/AM.32.3.2006.346

Danil, K., Maldini, D., and Marten, K. (2005). Patterns of use of Maku'a Beach, O'ahu, Hawai'I, by Spinner Dolphins (*Stenella longirostris*) and potential effects of swimmers on their behavior. *Aquat. Mamm.* 31, 403–412. doi: 10.1578/AM.31.4.2005.403

Department of Justice (DOJ) (2006). *Florida Charter Boat Captain Pleads Guilty to Shooting at Dolphins. Media Release*. Available online at: https://www.justice.gov/archive/opa/pr/2006/October/06_enrd_691.html

Department of Justice (DOJ) (2007). *Shooting of Dolphin Leads to Federal Charges. Media release*. Available online at: http://uk.whales.org/sites/default/files/doj_dolphin_shooting_prosecution_alabama_2007.pdf

Department of Justice (DOJ) (2013). *Media Release*. Available online at: https://www.justice.gov/opa/pr/alabama-shrimper-convicted-shooting-dolphin

Department of Justice (DOJ) (2015). *Orange County Brothers Guilty of Killing Bottlenose Dolphin in Cow Bayou. Media release*. Available online at: http://sero.nmfs.noaa.gov/news_room/press_releases/2015/edtx_environ_moseley_021815__1_.pdf

Finn, H., Donaldson, B., and Calver, M. (2008). Feeding flipper: a case study of human-dolphin interaction. *Pac. Conserv. Biol.* 14, 215–225. doi: 10.1071/PC080215

Frohoff, T. G., and Packard, J. M. (1995). Human interactions with free-ranging and captive bottlenose dolphins. *Anthrozoos* 8, 44–53. doi: 10.2752/089279395787156527

Goodwin, L., and Cotton, P. A. (2004). Effects of boat traffic on the behaviour of bottlenose dolphins (*Tursiops truncatus*). *Aquat. Mamm.* 30, 279–283. doi: 10.1578/AM.30.2.2004.279

Lusseau, D. (2006). The short-term behavioral reactions of bottlenose dolphins to interactions with boats in Doubtful Sound, New Zealand. *Mar. Mamm. Sci.* 22, 802–818. doi: 10.1111/j.1748-7692.2006.00052.x

Mattson, M. C., Thomas, J., and St. Aubin, D. (2005). Effects of boat activity on the behavior of bottlenose dolphins (*Tursiops truncatus*) in waters surrounding Hilton Head Island, South Carolina. *Aquat. Mamm.* 3, 133–140. doi: 10.1578/AM.31.1.2005.133

NOAA (2005). *Advanced Notice of Proposed Rulemaking. Protecting Spinner Dolphins in the Main Hawaiian Islands From Human Activities that Cause "Take," as Defined in the Marine Mammal Protection Act and Its Implementing Regulations, or To Otherwise Adversely Affect the Dolphins*. Available online at: http://www.fpir.noaa.gov/Library/PRD/Spinner%20Dolphin/ANPR.pdf

NOAA (2009). *Experts Worried More Dolphins Hurt by Guns and Explosives*. Available online at: http://sero.nmfs.noaa.gov/protected_resources/bottlenose_dolphins/guns_and_explosives/index.html

NOAA (2012). *NOAA Seeks Information on Dead Dolphin Found Off Dupont Point, Alabama. Media release*. Available online at: http://sero.nmfs.noaa.gov/news_room/press_releases/2012/perdido_dolphin_alert_june_22_2012_final_with_pics__1_.pdf

NOAA (2014a). *NOAA Seeks Information on Pregnant Dolphin Found Dead on Miramar Beach, Florida. Media release*. Available online at: http://sero.nmfs.noaa.gov/news_room/press_releases/2014/sero_final_20141120_destin_shot_dolphin_media_advisory_final__1_.pdf

NOAA (2014b). *Tips Lead to Break in the Case of Dolphin Found Dead, Shot with a Hunting Arrow in Northern Gulf of Mexico. Media release*. Available online at: http://sero.nmfs.noaa.gov/news_room/press_releases/2014/tips_lead_to_break_in_the_case_of_a_dolphin_shot_with_a_hunting_arrow.pdf

NOAA (2014c). *NOAA Seeks Tip on Dolphin Killed with Hunting Arrow in Orange Beach, Alabama. Media release*. Available online at: http://sero.nmfs.noaa.gov/news_room/press_releases/2014/news_advisory_noaa_seeks_tips_on_dolphin_killed_with_hunting_arrow_in_orange_beach.pdf

NOAA (2016). *Deepwater Horizon Oil Spill Final Programmatic Damage Assessment and Restoration Plan and Final Programmatic Environmental Impact Statement*. 289–308. Available online at: http://www.gulfspillrestoration.noaa.gov/wp-content/uploads/Chapter-5_Restoring-Natural-Resources_508.pdf

Noke, W. D., and Odell, D. K. (2002). Interactions between the Indian River Lagoon blue crab fishery and the bottlenose dolphin, *Tursiops truncatus*. *Mar. Mamm. Sci.* 18, 819–832. doi: 10.1111/j.1748-7692.2002.tb01075.x

Nowacek, S. M., Wells, R. S., and Solow, A. R. (2001). Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Mar. Mamm. Sci.* 17, 673–688. doi: 10.1111/j.1748-7692.2001.tb01292.x

Peltier, H., Dabin, W., Daniel, P., Van Canneyt, O., Dorémus, G., Huon, M., et al. (2012). The significance of stranding data as indicators of cetacean populations at sea: modelling the drift of cetacean carcasses. *Ecol. Indic.* 18, 278–290. doi: 10.1016/j.ecolind.2011.11.014

Perrtree, R., Kovacs, C. J., and Cox, T. (2014). Standardization and application of metrics to quantify human-interaction behaviors by the bottlenose dolphin (*Tursiops* spp.) *Mar. Mamm. Sci.* 30, 1320–1334. doi: 10.1111/mms.12114

Powell, J. R., and Wells, R. S. (2011). Recreational fishing depredation and associated behaviors involving common bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *Mar. Mamm. Sci.* 27, 111–129. doi: 10.1111/j.1748-7692.2010.00401.x

Read, A. J. (2008). The looming crisis: interactions between marine mammals and fisheries. *J. Mamm.* 89, 541–548. doi: 10.1644/07-MAMM-S-315R1.1

Samuels, A., and Bejder, L. (2004). Chronic interaction between humans and free-ranging bottlenose dolphins near Panama City Beach, Florida, USA. *J. Cetacean Res. Manage.* 6, 69–77. Available online at: http://researchrepository.murdoch.edu.au/3007/

Seideman, D. (1997). Swimming with trouble. *Audubon* 99, 76–82.

Spradlin, T. R., Drevenak, J. K., Terbush, A. D., and Nitta, E. T. (1999). "Interactions between the public and wild dolphins in the United States: biological concerns and the Marine Mammal Protection Act," in *Presented at the "Wild Dolphin Swim Program Workshop" Held in Conjunction with the 13th Biennial Conference on the Biology of Marine Mammals, November 28* (Maui, HI).

Stolen, M., Noke Durden, W., Mazza, T., Barros, N., and St. Leger, J. (2013). Effects of fishing gear on bottlenose dolphins (*Tursiops truncatus)* in the Indian River Lagoon system, Florida. *Mar. Mamm. Sci.* 29, 356–364. doi: 10.1111/j.1748-7692.2012.00575.x

Timmel, G., Courbis, S., Sargeant-Green, H., and Markowitz, H. (2008). Effects of human traffic on the movement patterns of Hawaiian spinner dolphins (*Stenella longirostris*) in Kealakekua Bay, Hawaii. *Aquat. Mamm.* 34, 402–411. doi: 10.1578/AM.34.4.2008.402

Tyne, J. A., Pollock, K. H., Johnston, D. W., and Bejder, L. (2014). Abundance and survival rates of the Hawaii Island associated spinner dolphin (*Stenella longirostris*) stock. *PLoS ONE* 9:e86132. doi: 10.1371/journal.pone.0086132

Waring, G. T., Josephson, E., Maze-Foley, K., and Rosel, P. E., (Eds.). (2015). *U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments-2014. (NOAA Tech Memo NMFS NE 231)*. Woods Hole, MA: NOAA, National Marine Fisheries Service, Northeast Fisheries Science Center.

WDCS, Whale and Dolphin Conservation Society (2008). *Dolphin SMART: Dolphin Tour Operator Education and Recognition Program in the Florida Keys*. Final Technical Report, October 31, 2008.

Wells, R. S., Allen, J. B., Gorzelany, J., Delynn, R. E., Fauquier, D. A., and Barros, N. B. (2015). Carcass-recovery rates for resident bottlenose dolphins in Sarasota Bay, Florida. *Mar. Mamm. Sci.* 31, 355–368. doi: 10.1111/mms.12142

Wells, R. S., Allen, J. B., Hofmann, S., Fauquier, D. A., and Scott, M. D. (2008). Consequences of injuries on survival and reproduction of common bottlenose dolphins (*Tursiops truncatus*) along the west coast of Florida. *Mar. Mamm. Sci.* 24, 774–794. doi: 10.1111/j.1748-7692.2008.00212.x

Wells, R. S., Hofmann, S., and Moors, T. L. (1998). Entanglement and mortality of bottlenose dolphins, *Tursiops truncatus*, in recreational fishing gear in Florida. *Fish. Bull.* 96, 647–650.

Wells, R. S., and Scott, M. D. (1997). Seasonal incidence of boat strikes on bottlenose dolphins near Sarasota, Florida. *Mar. Mamm. Sci.* 13, 475–480. doi: 10.1111/j.1748-7692.1997.tb00654.x

Williams, R., Gero, S., Bejder, L., Calambokidis, J., Kraus, S. D., Lusseau, D., et al. (2011). Underestimating the damage: interpreting cetacean carcass recoveries in the context of the Deepwater Horizon/BP incident. *Conserv. Lett.* 4, 228–233. doi: 10.1111/j.1755-263X.2011.00168.x

Zollett, E. A., and Read, A. J. (2006). Depredation of catch by bottlenose dolphins (*Tursiops truncatus*) in the Florida king mackerel (*Scomberomorus cavalla*) troll fishery. *Fish. Bull.* 104, 343–349. Available online at: http://aquaticcommons.org/8971/

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

frontiers in Marine Science

REVIEW
published: 18 August 2016
doi: 10.3389/fmars.2016.00149

CrossMark

# A Review of the Welfare Impact on Pinnipeds of Plastic Marine Debris

*Andy Butterworth**

*Clinical Veterinary Science, University of Bristol Veterinary School, Bristol, UK*

Uncounted, and usually unobserved, numbers of pinnipeds find themselves entangled in lost fishing gear, monofilament line, nets, rope, plastic packaging in the ocean or on the shoreline. These animals may carry debris wrapped around themselves for long periods, and often die as a result, sometimes from deep chronic wounds. The pinniped species most affected by this modern and manmade phenomenon are fur seals, monk seals, and California sea lions, and to a lesser extent gray, common, and monk seals. Entanglement rates described range up to 7.9% of local populations annually, and the common entangling materials; packing bands, fragments of lost net, rope, monofilament line, fishery flashers and lures, long-line fishing gear, hooks and line, and bait hooks are discussed. Awareness of this issue is increasing, and local action is reported to have made measurable differences in entanglement rates, however, plastic material in the ocean is likely to be long lived, and will leave many entangled pinnipeds unreported and result in a hidden and potentially significant effect on wild animal welfare.

**Keywords: welfare, pinnipedia, marine debris, seals, entanglement**

OPEN ACCESS

***Edited by:***
*Lyne Morissette,*
*M - Expertise Marine, Canada*

***Reviewed by:***
*Julia Ann Jabour,*
*University of Tasmania, Australia*
*Christian T. K.-H. Stadtlander,*
*Independent Researcher, USA*

****Correspondence:***
*Andy Butterworth*
*andy.butterworth@bris.ac.uk*

***Specialty section:***
*This article was submitted to Marine Affairs and Policy, a section of the journal Frontiers in Marine Science*

***Received:*** *06 April 2016*
***Accepted:*** *04 August 2016*
***Published:*** *18 August 2016*

***Citation:***
*Butterworth A (2016) A Review of the Welfare Impact on Pinnipeds of Plastic Marine Debris. Front. Mar. Sci. 3:149. doi: 10.3389/fmars.2016.00149*

## INTRODUCTION

Uncounted, and usually unobserved, numbers of the animals that live in the oceans find themselves snared, trapped, or entangled in lost fishing gear, monofilament line, nets, rope, plastic packaging, packing bands from crates, or become hooked on discarded fishing gear, or ingest human marine debris. Seals, sea lions, and walrus (the pinnipeds), seem particularly susceptible to entanglement in marine debris—perhaps their exploratory natures may make this more likely, or perhaps they come upon plastic waste and rope on the shoreline to a greater extent than the other fully aquatic mammals? Pinnipeds, meeting with plastic, either in the sea, or on the shoreline, may carry debris wrapped around themselves, for long periods, and often die as a result—sometimes from horrible, chronic wounds (Dau et al., 2009). Although a wide range of the global species of seals can be affected by marine debris, some species are much more significantly affected than others. Based on the available literature, the key seal species affected by entanglement are monk seals, fur seals and California sea lions. Seals which become entangled or who ingest marine debris may be subjected to distress, pain, trauma, infection, skin, and muscle lesions, and compromised ability to move, to feed, and to carry out normal behaviors. For these reasons marine debris has the capacity to present a significant and global issue with respect to animal welfare, as well as to the more immediately apparent concerns regarding habitats and the quality of the marine environment. At present, there is little directed focus on marine debris in relation to animal welfare. Marine debris can:

- cause direct harm and profound welfare impacts on wild animals directly through entanglement and ingestion
- smother the seabed and disturb habitats—causing altered behaviors and population changes

- can be a source of persistent chemical pollution in the ocean—particularly from plastics, which may result in direct toxicity effects in top predators if toxins accumulate in marine food
- marine debris can potentially transport invasive species between seas through flotation—and invasive species may alter the environment resulting in changed food and habitat availability

In this review published papers and reports are brought together which identify and describe entanglement and ingestion in seals and seal lions. Second, we assess the welfare impact on individual seal species of being entangled or of ingesting marine debris.

Marine debris is now found in all oceans of the globe, but its effects are not so uniformly spread, and the reporting of the effects of marine debris on animals is uneven, linked with the density of "observers" (including scientists), and also on the local cultural position with regard to interactions with marine animals. For this reason, there is almost no reporting of marine mammal entanglement in some parts of the world, but this may be a result of low reporting rates rather than low "incidence" rates. Harcourt et al. (1994) point out that most published entanglement incidence rates are likely to be conservative because they only register animals that come on shore, and do not account for those that die and are lost at sea. Moore et al. (2013) indicated that post-mortem examination of dead and live stranded pinnipeds can show the distribution of malicious human impacts, such as vessel collision, fishing gear entanglement and gunshot. These authors however, also note that delayed discovery, inaccessibility, logistics, and human safety concerns can limit accurate detection and reporting of the cause of death of "discovered" animals, and so under reporting of marine debris as a cause of death is likely to be an important factor in the estimation of the true numbers of animals affected.

There are significant variations in the geographical spread of research into the effects of marine debris on animals, and the Convention on Biological Diversity's 2012 report (CBD, 2012) highlights this imbalance by indicating the number of reports that it has reviewed regarding marine debris entanglement in a range of species (not just pinnipeds) from different regions: Americas (North and South (117), Australasia (56), Europe (52), Africa (12), Antarctic (7), Asia (6), Arctic (5). Some general comments on the variability of reporting of entanglement are made by Butterworth et al. (WSPA, 2012).

*Estimates based on published reports can reflect only the areas where the reports were carried out, and the level of research and interest is not uniformly spread across the globe.*

*Estimates of animal entanglement and ingestion generally rely on reports of animals seen alive (or recently deceased), and so are likely to seriously underestimate the scale of the problem. If animals are affected and die unseen (as is likely to be common), then they are not reported. As Cole et al. (2006) say—"Our greatest concern remains the number of animals we never saw."*

Even allowing for regional reporting biases, it is however apparent that some regions present a higher risk of entanglement and ingestion hazard, and so, it may well be that targeted action to reduce or ameliorate the local effects of marine debris on seals could focus resources in these areas. There are some apparent "hotspots" for seal entanglement; Western Coast USA—Fur seals, Sea lions; Eastern Coast Australia—Fur seals; Southern African coast—Fur seals; North sea—Gray seal.

## MARINE DEBRIS: BACKGROUND

Norwegian explorer Thor Heyerdahl crossed the Atlantic Ocean in 1970, and at this time, he was sufficiently concerned about the litter and waste that he saw on the oceans to submit a report to the United Nations Conference on the Human Environment, held in Stockholm in 1972. The United Nations Environment Programme defines marine litter as "any persistent, manufactured or processed solid material discarded, disposed or abandoned in the marine and coastal environment," and the 2005 United Nations Environment Programme estimated that about 6.4 million tons of "litter" are disposed of in the seas and oceans each year. Today, estimates for the amount of marine debris vary, but it is thought that up to 300,000 items of litter and debris can be found, on average, per sq km of ocean surface (NRC, 2008). Marine debris includes plastics, rubber, metal, and glass, however, plastic in a myriad of forms has come to dominate marine litter, due to its long lifespan. The top ten marine debris items from 103,247,609 items collected 1989–2007 (ICC, 2008):

*"Cigarettes/cigarette filters: 24.6%, Bags (paper and plastic): 9.4%, Caps/lids: 9.1%, Food wrappers/containers: 8.9%, Cups/plates/forks/knives/spoons: 7.2%, Plastic beverage bottles (less than 2 l): 5.5%, Glass beverage bottles: 4.8%, Beverage cans: 4.6%, Straws/stirrers: 4.4%, Rope: 2.1%"*

Wilcox et al. (2016) ranked the likely impact of different types of marine debris on marine mammals; *From highest rank (risk) to lowest rank;* Buoys/traps/pots; Monofilament; Fishing nets; plastic bags; Butts (cigarette butts); Plastic utensils; Balloons; Plastic caps; Food packaging; Plastic food lids; Straws/stirrers; Takeout containers; Hard plastic; Cans; Cups and plates; Glass bottles; Beverage bottles; Paper bags.

"Plastic" comprises synthetic or semi-synthetic organics polymers, polypropylene, nylon, polyesters, polyethylene terephthalate (PET), liquid crystal polymer (LCP), high-density polyethylene (HDPE), polyethylene Aramids and acrylics. Most rope and fishing gear, and much packaging, including packing straps, is now made from some form of braided or woven plastic, and this represent a potential to be a persistent type of marine debris. Because rope and net have been designed to withstand use in the sea, rope and net can have enormous breaking strength, and can be resistant to degradation by water, salt, and sunlight and abrasion. Many plastics are buoyant, or neutrally buoyant in seawater, and so either float at the surface, sink only very slowly in the sea, or are easily carried by currents. DuPont (E. I. du Pont de Nemours and Company, Delaware, USA) first sold nylon monofilament fishing line in 1938, and with each generation of development of these materials, the lines become stronger, less visible in water (low optical density), very strong, and very resistant to biting and chewing by trapped animals.

Fishing lines are very strong in relation to their thickness, and their thin diameter can cut into, and damage tissues readily if an animal becomes entangled. It is estimated that some plastic filaments will last in the sea for up to 600 years (polymers of this type were only first used widely for rope and line since 1935, and so their long term lifespan in the environment can only be estimated). For these reasons, lost or abandoned fishing gear; nets, lines, monofilament fishing line, traps, and floats are a significant source of marine debris, and of particular concern for animal welfare, due to the capacity of these strong and persistent lines to entangle and trap animals in the sea. In a related way to "rope," the strong and persistent "packing bands" used to wrap containers and packages which are made from polypropylene, polyester or nylon, sometimes reinforced with fibers of other types of "plastic"—are very strong, resistant to degradation and can persist in the marine environment for decades. One particular concern with packing bands is that they are commonly found as "loops" (their functional purpose was to surround containers) and looped structures are much more likely to trap animals, including pinnipeds, than "open ended" lines or ropes.

In the United Kingdom, debris from fishing including nets, buoys, line and floats is the second most common type of marine debris after visitors' litter on beaches (Marine Conservation Society [MCS], 2007). The United States National Marine Debris Monitoring Program (Sheavly, 2007) indicated that 17.7% of beach litter came from fishing activity, fishing line, net, rope, floats and buoys, fish baskets, and pots and traps.

Marine debris results from a wide range of human activity; from intentional and unintentional losses from shipping, including fishing vessels; from deliberate or accidental dumping of domestic, commercial, or industrial waste into the sea, and derived from the land; or from windblown waste which comes from the shore, or waste from boats and land-based debris which is passed into the sea through wind, storm or river floods.

The origin (manufacturing origin, not disposal location) of plastic objects and packaging can be determined using barcodes (digits in the barcode indicate the country where the object was manufactured) and Santos et al. (2005) reported the source of strandline debris found Brazilian beaches, and found the country of origin of plastic debris to be; *"USA 12.2%, Italy 7.6%, South Africa 6.4%, Argentina 6.0%, Germany 5.6%, United Kingdom 4.6%, Taiwan 4.4%, Singapore 3.6%, Spain 3.6%, Malaysia 3.1%, with others 35.2%, and unidentified 7.6%."* Tracing of barcodes on plastic debris has shown that marine plastic debris can originate in one country and be found 10 years later 10,000 km away (Barnes et al., 2009). Zalasiewicz et al. (2016) note that degraded plastic is so widely spread now in ocean sediments that plastics will become one of the key geological indicator of the Anthropocene (current time, time of mankind), a distinctive stratal layer.

Some debris that originated on land, rather than from boat activity, has traveled in currents, into the ocean gyres, the giant rotating ocean currents. Debris in the oceans slowly breaks down into small particles (like sand) and plastic particles are found in the water and the ocean floor sediments across the world's oceans. The Great Pacific Oceanic Gyre contains plastic and debris with an estimated mass of 100 million tons, and concentrated into an accumulation estimated to be as large as Spain and France combined (Sheavly, 2007). Before the 1980s, only very small amounts of marine litter had reached the Southern Ocean islands. Plastic debris has now moved into the entire southern hemisphere, with increasing rates of accumulation on remote shores and with debris moving toward the Antarctic (Barnes, 2005). Plastics degradation can be slow in the marine environment, and Wang et al. (2016) discuss how, with the effects of UV-B radiation in sunlight and exposure to oxygen, autocatalytic degradation can occur, however, in the relatively low temperatures of the sea, the rate of degradation of many plastics in the marine environment is slow when compared to the terrestrial environment.

Educational programmes have been identified as one way to reduce marine wildlife entanglement. Pearson et al. (2014) describe a survey used to assess the familiarity of Australians in coastal communities with an initiative called "Seal the Loop" aimed at protecting seals from marine waste. Many participants were familiar with the education programme, however 32% of the participants were unable to explain what the risks to wildlife were, and they under-estimated the impact on wildlife numbers. This study identified that *"learning something new, changed waste disposal behaviors."*

## PLASTIC WASTE IMPACTS ON ANIMAL WELFARE THROUGH THE ENTANGLEMENT OF PINNIPEDS

Many languages have a term for "welfare" as used in the context of animal welfare or wellbeing. For example: in German, *wohlbefinden*—well-being, wellness, physical comfort: in French, *bien-être*—well-being, a sense of wellbeing: in Spanish, *benestar*—state of health, prosperity.

In many considerations of animal welfare, the description of "good welfare" includes the animal being "well" and also having the potential for "wellbeing"—being at ease or, at least, not subject to distress. Many people consider disease or physiological or anatomical damage, injury, or trauma as providing challenges which mean that an animal is unlikely to experience high levels of animal welfare. Sandoe and Simonsen (1992) uses the term "cost of coping": that emotional distress, pain, or increased levels of physiological or disease related challenge have a cost, and if that cost is great, then the animal is less likely to cope, and that prolonged failure to cope will result in suffering. For wild animals, entanglement can result in altered feeding behaviors and altered food sources, altered social interactions and breeding patterns, altered migration, hunting or foraging patterns, altered breeding, and altered territorial or animal human interactions. For the individual entangled animal, the capacity to cope (or not) will depend on the severity of the restriction, whether the entanglement interferes with movement, and, in severe cases, whether the entanglement causes incisive wounds, trauma, skin lesions, or inability to swim, mate, or feed. Will the entanglement result in disease through skin or muscle lesions, or results in starvation inability to forage, hunt, and feed? The types of marine debris found in the environment of different pinnipeds are likely to profoundly influence whether entanglement happens, what the entanglement is with, how often and how severely the animal is affected, and the outcome. Entanglement may cause immediate and severe welfare problems such as asphyxiation, or trapping underwater, or may be "chronic" with prolonged periods of entanglement in rope or net, and where the welfare impacts may increase over time as infection, progressive tissue damage and weight loss start to act.

A large number of pinniped species have been recorded entangled, and a review of the literature shows the global nature of this problem. Entanglement has been noted in 58 per cent of all species of seals and sea lions (Boland and Donohue, 2003). The incidence rate of entanglement for seal and sea lion species is estimated to be in the range at 0.001–5% of the population annually, with a high incidence of up to 7.9% in Mexican California sea-lions (Harcourt et al., 1994). Williams et al. (2011), describe the entangled seal species found around the coast of British Columbia in Steller sea lion (*Eumetopias jubatus*), harbor seal (*Phoca vitulina*) and in northern elephant seals (*Mirounga angustirostris*), and a study by Derraik (2002), on Bering Sea northern fur seals, estimated that 40,000 seals a year were entanglement in and killed by plastic waste.

When seals become entangled, the "trapping" may involve a ring of packing strap, fishing net, monofilament line or net, which commonly forms a collar around the neck. The loop tightens as the animal grows or, may be trapped by the nature of the coat (which is flattened against the body in the direction of least water resistance), and in adult seals, the loop can incise the tissues of the neck or flipper and become firmly embedded in the skin, subcutaneous fat or the muscle, and even into bone. It is believed that, for many cases, the loop becomes deeply enmeshed or embedded in tissue and it becomes unlikely that the animal can remove it (Lawson et al., 2015). The majority of entanglements appear to be in young seals, which, it may be surmised, is because they are curious, exploratory, or naïve or inexperienced feeders, unfamiliar with the hazards of rope or fishing net fragments. Young seals find themselves wrapped up in rope, net or monofilament loops, and these become firmly fixed around the neck or the body close to the flipper, and this constriction may restrict feeding to the point of starvation. These rope and monofilament line ligatures can cause acute cutting damage and amputation of flippers, and can leave wounds which, because they contain a foreign body (rope or line), remain open to long term infection, reducing the likelihood of survival. The constriction may sever arteries, and finally cause death by strangulation. Because plastic is extremely durable in the marine environment, it is possible that, when the entangled animal dies, the debris or entangling rope or net may returned to the sea with the potential to entangle other animals (WSPA, 2012). Entangled pinnipeds will sometime require to increase their metabolism to compensate for the increased drag caused by the entangling objects during swimming (Boland and Donohue, 2003), and Derraik (2002) describe how Northern Fur Seals (*Callorhinus ursinus*) carrying net fragments of as little as 200 grams in weight had up to a four-fold increase in the quantity of food that was required to be consumed to compensate for drag caused by interference with water flow. This drag effect may produce large energetic burdens, and restrict movement and ultimately lead to exhaustion and drowning. Where pinnipeds including stellar sea lions (*E. jubatus*) in Alaska and British Columbia ingest fishing gear equipped with hooks, or lines with lures or fish flashers, these hooks and lines can lodge inside the animal and can damage the mouth and the lower digestive system, or reduce the animal's capacity to forage and feed effectively.

## Severity Scoring for Pinniped Interactions with Marine Debris

In human medicine, well established scoring scales for wounds are used to enable clinicians to communicate the severity of wounds and to guage how they are healing, and internationally, the Red Cross classification of war wounds is used to describe wounds based on their visual appearance (and is not based on what caused them; Coupland, 1992). In a related way, work has been initiated on assessment of the severity of entanglements in marine mammals, and the NOAA/NMFS Injury Technical Workshop, held in Seattle in 2007 (NOAA/NMFS, 2007), proposed a hierarchical descriptive scale for injuries to marine mammals. The following area of entanglement and injury related to human activity were categorized:

> ***"Serious**—gear-related injury; Ingestion of gear; Trailing gear (e.g., flasher or lure), when it has the potential to anchor or drag, or when it is wrapped around the animal; Gear attached to the body with the potential to wrap around flippers, body, or head; Foreign bodies penetrating into a body cavity; Multiple wraps around the body; Missing flippers—front and back flipper (serious), for both otariids or phocids; Deep external injuries.*
>
> ***Non-serious**—gear-related injuries; Hooked in the lip; Hooked in flipper, etc. with minimal trailing gear that does not have the potential to wrap around body parts, accumulate drag, or anchor; Freely swimming animals encircled by purse seine nets.*
>
> ***Gray area**—gear-related injuries (less clear how serious the welfare impact is): Hooked in head (serious injury could be assumed, but it depends on several factors, including where on the head the hooking took place, the depth of the hooking, the type of hook, etc.); animals stressed by being encircled or trapped (e.g., purse seine); Animals released without gear following entanglement (this designation depends on the extent of the injury or how long the animal was submerged, how long the gear was on the animal, and the degree of restraint).*
>
> ***Other impacts of interactions with humans:** Pinniped brought onto a vessel (this was considered in the report to be non serious, and the severity dependent on how the animal was brought up (e.g., in net or a roller, or through the power block)."*

Some examples of "serious scores" to illustrate the range of possible welfare insults causing severe welfare insults based on descriptions of observed seal entanglements from Spraker and Lander (2010); Severe impacts.

> *"Rope fragment wrapped around shoulder, strands had cut through muscles of right shoulder and halfway through the mid-portion of the humerus"*

*"Material wrapped around upper neck, line had cut through lower half of trachea."*

*"Line Wrapped around mid-neck, had cut through all dorsal muscles of neck exposing dorsal spinal processes of cervical vertebrae."*

In the following sections, a review of studies describing the impacts of entanglement on specific pinniped species is presented;

## Fur Seals

Hofmeyr et al. (2002) report 101 fur seals (*Arctocephalus* spp.) and five southern elephant seals (*Mirounga leonina*) which were entangled in debris at Marion Island in the Southern Ocean over a 10-year period. These authors describe how 67% of the entangling materials derived from the fishing industry. Polypropylene packaging straps and trawl netting were the most commonly found entangling debris. They also reported longline hooks seen embedded in animals, and also report that fishing line entanglements only started to be encountered in the waters around Marion Island after the start of longline fishing in 1996. These authors estimated that 0.24% of the population of fur seals were entangled annually. Hofmeyr et al. (2006) also made observations of Antarctic fur seals (*Arctocephalus gazella*) from 1996 to 2002 on the sub-antarctic island, Bouvetøya. They report entanglement rates of between 0.024 and 0.059%, and they conclude that these rates are comparatively low when compared to other pinniped populations, and surmise that this is because of the geographic isolation of the site. This study found that over two-thirds of entangling materials were derived from fisheries sources.

Spraker and Lander (2010) describe the causes of mortality in Northern Fur Seals (*C. ursinus*) on St. Paul Island, Alaska, and describe some of the horrible combinations of entanglement, asphyxiation and tissue trauma caused by net and packing band loops. In one case described, a living but heavily entangled animal is dragging a dead and decomposing seal in the same piece of net.

Lawson et al. (2015) describe sampling work carried out at Seal Rocks, Lady Julia Percy Island, Kanowna Island, Berry's Beach, Cowes jetty and Western Port in Southern Australia. These islands had at the time of the study an estimated Australian fur seal (*Arctocephalus pusillus doriferus*) populations of around 30,000 individuals. Over a period from 1997 to 2012, 138 entanglement items were collected and stored by the project. Fifty percent ($n = 69$) of the objects were made of plastic twine or rope (including trawl nets), 20% ($n = 27$) were made of other plastics such as plastic bags, packing straps, and balloon ribbon, 17% ($n = 24$) were monofilament line, including gill nets and 8% ($n = 11$) were comprised of rubber. The remaining 5% ($n = 7$) consisted of metal items (such as hooks and lures) and cotton (a baseball cap that resulted in a neck constriction). White plastic packaging strapping formed the majority (67%, $n = 6$) of the strap entanglements. These authors found that 61% ($n = 43$) of twine/rope entanglements involved green material, whereas gray and white colored rope items accounted for only 10% ($n = 7$) and 9% ($n = 6$) respectively, and that for monofilament line, more monofilament was clear or green in color (52 and 26%, respectively). The characteristics of the entangling material was also noted; type, color, overall size, mesh size, diameter, number of threads, whether the item was braided, twisted, knotted, if it was monofilament and number of strands for all entanglement items. Where available, information on the date and location, the age class of the seal (pup, juvenile, adult), and the severity of the injury (whether cutting deep or surface wound) was also collated. This data set showed that the overwhelming majority 94% ($n = 46$) of entanglements involved young juvenile or pup seals, with more pups (53%) than juveniles (41%) being entangled. McIntosh and others (McIntosh et al., 2015) working at Seal Rocks, South-Eastern Australia reported 359 entangled Australian fur seals, and showed that the most common entanglement materials were from commercial fisheries and that entanglements were most frequent in pups and juveniles. This study indicated that entanglement was more commonly observed from July to October, when the young animals approached weaning, and using a Generalized Additive Mixed Models (GAMMs) these authors estimated that 1.0% (CI = 0.6–1.7%) of the local population was entangled each year.

The loop diameters of entangling materials which entangled Antarctic fur seals from a study at Bird Island, South Georgia are described by Waluda and Staniland (2013). They reported material found entangling 90 animals, with loops from 11 to 69 cm in diameter (with a median diameter of 18 cm). These authors found that loop diameter was closely related to age class: very young animals commonly entangled in smaller loops (median = 15.5 cm): juveniles (18 cm) and adult females (17 cm) entangled in similar loop diameters. Adult males were more likely to be found with larger loops of median diameter 34 cm. These authors reported that juveniles were five times more likely to be entangled than adult females. They proposed that younger animals were more likely to entangle whilst interacting with debris through curiosity and play. Adult males were the least likely of the age classes to be entangled. This was proposed to be potentially a result of their broad muscular necks, their relatively lower numbers within the overall population, and also potentially due to behavioral differences. This report also noted that that if the entanglement was fatal prior to adulthood, then individuals prone to entanglement could have been selected from the population. This study also reported that there were more "very severe" entanglements during the winter than the summer. The authors speculate that this may be a reflection of changes in the ability to observe animals rather than a true alteration in entanglement rate, as the animals which are hauled out (on the shoreline) would been removed from ready observation (i.e., hauled out away from human occupation, or at sea) during the winter months. This report also identified a potential decline in the number of seals entangled in packaging bands at Bird Island over time. In 1988/99—58% of entanglements were with packing bands, between 1989 and 1994 this fell to 46%, and between 1994 and 2013 the proportion was 39%. These authors propose that the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) legislation to ban packaging bands, which was initiated in 1995 may have had a reducing (but not eliminating) effect on packing band entanglements. In the Antarctic, entanglement of Antarctic fur seals (*A. gazella*) reduced by 50% over the 5 years (1990–1994) after the introduction of MARPOL Annex V (MARPOL is the International Convention for the Prevention of Pollution from Ships[1] however, fishing net, polypropylene packing bands, and synthetic string and rope were still found as common debris items entangling seals across all years (Arnould and Croxall, 1995).

In New Zealand, Page et al. (2004) indicate that fur seals were found to be entangled in packing tape loops, and trawl net fragments, which were believed to have been derived from local rock lobster and trawl fisheries. These authors (Page et al., 2004) also reported entanglement for New Zealand fur seals and Australian sea lions: the Australian sea lion entanglement rate was estimated at 1.3% of the population annually, and the New Zealand Fur seal entanglement rate as 0.9%. Australian sea lions were most frequently entangled in monofilament line or net, which may have derived from the local shark fishery.

On St Paul Island, in the Alaskan Pribilof Islands, Northern fur seals (*C. ursinus*) were reported by Fowler (1987) with various objects around their necks, shoulders and flippers, with an estimated incidence rate amongst sub-adult males of about 0.4%. The majority of entanglements were trawler fishing net fragments and plastic packing bands. These authors noted that entanglement was more commonly seen in young animals, which were *"sometimes observed entangled together in groups attached to the same large items of debris."* Shaughnessy (1980) describes Cape fur seals (*Arctocephalus pusillus*), entangled between 1972 and 1979, with the majority of the entangling objects, being on the seals' necks. The highest incidence was recorded at the Cape Cross colony, at 0.56–0.66%, animals being entangled with string, rope, fishing net, plastic straps, monofilament line, rubber O-rings, and wire. Boren et al. (2006) reported that several thousand Antarctic fur seals from South Georgia were caught in lost fishing gear, with an estimated rate of entanglement of 0.4% of the population, and these authors estimated that 15,000 seal entanglements took place each year, of which they estimated 5700 would be likely to die as a result. Allen and Angliss (2014) describes entanglement of Northern fur seals at St. George Island, with mean entanglement rates of 0.06–0.08% for very young animals, and a seasonal variability and the a maximum rate occurring in October of up to 0.11% just before weaning. The rate of juvenile male entanglement reported in these studies was particularly high in 2005–2006, with between 0.15 and 0.35% of the population becoming entangled, based on observational studies.

New Zealand fur seals (*Arctocephalus forsteri*) from Kaikoura have a breeding area close to a busy tourist and fishing area, and are reported to become entangled in nets and plastic waste (Boren et al., 2006). Entanglement rates are described from 0.6 to 2.8% of the local population annually, with green trawl net fragments (42%), and plastic strapping (31%) noted as the most common entangling materials. Perhaps because of the high density of "observers" in this area, nearly half (43%) of the entangled seals described in this study were successfully treated and released. Post-release surveys showed that the probability of an entangled individual surviving after release was high, even after having suffered a significant wound from the entanglement.

Hanni and Pyle (2000) in studies from South East Farallon Island, in North California, between 1976 and 1998,describe 914 Northern Elephant Seals (*M. angustirostris*), Steller Sea Lions (*E. jubatus),* California Sea Lions (*Zalophus californianus*), Northern Fur Seals (*C. ursinus*), and Pacific Harbor Seals (*P. vitulina*), reported entangled. The materials that these authors report causing entanglement were *"monofilament line and net, heavy fishnet material, other net material, salmon fishing lure and line, fish hooks and line, packing straps, other miscellaneous marine debris, and 'constriction' (where no actual material was observed, presumed to be hidden in the fur or wound, but a circular indentation was present around the head, neck or torso)."*

## Sea Lions

In Australia, an estimated 1500 Australian sea lions (*Neophoca cinerea*) are estimated to die through entanglement, mostly from trapping in monofilament gillnet associated with the shark fishery local to the sea lion foraging area (Page et al., 2003).

In California, Dau et al. (2009) reported 1090 pinniped entanglements, of which 11.3% were linked to fishing gear, and with a high prevalence of fishing gear injury reported from the San Diego region. Zavala-González and Mellink (1997) describe entanglement rated for California sea lion (*Z. californianus*) from a population which extends from British Columbia to Mazatlan in Mexico, including populations in the Gulf of California. The population of sea lions in the Mexican part of this range is estimated at ∼74,500 individuals on the Pacific coast, and 28,220 animals from the Gulf of California, and the annual entanglement rate for these animals is estimated to be 2.24%.

A survey of 386 Steller sea lions (*E. jubatus*) reported an estimated incidence rate for entanglement of 0.26% of the population in northern British Columbia and Southeast Alaska (Raum-Suryan et al., 2009). These authors examined materials causing entanglement and found that: *"packing bands (54%) were most common, followed by large rubber bands (rubber packing bands; 30%), net (7%), rope (7%) and monofilament line (2%)."* This study also describes the types of fishing gear ingested or entangling these animals, and this included: *"salmon fishery flashers/lures (80%), long-line gear (12%), hooks and line (4%), spinners or spoons (2%), and bait hooks (2%)."* Raum-Suryan et al. also describe the local campaign called "Lose the Loop!" which promoted procedures such as cutting entangling loops of synthetic material and eliminating packing bands to help prevent entanglements. Work reported by the National Oceanic and Atmospheric Administration (NOAA, 2012) report that packing bands cause greater than 50% of neck entanglements seen in Steller sea lions (*E. jubatus*) in Alaska.

[1]MARPOL International Convention for the Prevention of Pollution from Ships (MARPOL) International Maritime Organization Retrieved 27/6/16; http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx

## Elephant Seals

The impact of entanglement on Southern Elephant Seals (*M. leonina*) is discussed by Campagna et al. (2007), and the characteristic wound around the neck caused by monofilament lines is described. In this study, entangled Elephant Seals were caught, and in the majority of cases the material which was removed was monofilament line typically 1.3–1.5 mm thick and tied in a circle with a knot. In some animals, this monofilament line had colored lures armed with hooks attached, a configuration typical of squid fishing gear. These authors estimate that the rate of entanglement was relatively low, 0.001%, however, they suggest this to be an underestimate since the observations they made were taken at a time when juveniles—in many seal species, the most commonly affected group—were not present in the population. These authors describe how the monofilament entanglement becomes a chronic wound, with infection and with debilitating consequences, and they describe how, based on assessment of the depth of the wounds, some entangled seals may have survived for months or years with monofilament line incising the skin and muscle tissues around the neck.

## Monk Seals

Donohue and Foley (2007) assessed the effects of weather and storms on monk seal entanglement rates in the North Pacific Ocean, and reported that in the 23 years leading up to the year 2007, monk seal entanglement increased during the times when the El Niño weather system was operating. They proposed that the oceanographic processes linked with El Niño contributed to changes in entanglement rates, perhaps as a result of introduction of new debris material along with the changes in ocean currents. The Hawaiian monk seal *(Monachus schauinslandi*) is an endangered species, limited to breeding on six small islands and atolls in North-West Hawaii. Between 1996 and 2000 a multi-agency initiative took place to reduce the amount of lost fishing gear and fishery derived material found in the reefs of these Hawaiian Islands. These reefs are close to the breeding sites for these seals, and were systematically cleaned up (Boland and Donohue, 2003) and 195 tons of abandoned, lost or otherwise discarded fishing gear (ALDFG) were removed from the area.

Karamanlidis (2000) found that ALDFG had a measurable effect on the monk seal (*Monachus monachus*) population in the Mediterranean, and this author argued that the use of gillnets threatened the small and endangered monk-seal colony which is found around the Desertas Islands, Madeira.

## Gray Seals and Common Seals

The type and rate of entanglement seen in gray seals (*Halichoerus grypus*) stranded on the Dutch coast, between 1985 and 2010, are described by Hekman and Osinga (2010). This study reports that entanglement was more common in gray seals than common seals (*P. vitulina*; about twice as common) and that for both species a larger proportion of the entangled seals were males and that entanglement was most frequent in juveniles. Discarded trawl nets and gillnets were the most common entangling material, and these authors indicate that the numbers seen and reported were probably only a small part of the true extent of animal lost to entanglement because it was assumed that most animals would be undetected and lost at sea.

Allen et al. (2012) discuss the physiological and anatomical effects of entanglement on gray seals (*H. grypus*) and describe how an important (and under reported) aspect of entanglement are the effects of increased drag through the resistance trailing material, and the increase in time spent foraging due to increased metabolic demands from drag. These authors also comment on the animal welfare impact of the injuries sustained, and the types of injuries sustained by the animals to be "constriction" (43%); "wound" (7%); "constriction and wound" (14%); "evident" (visible entanglement but wound type unclear; 36%). Allen et al. (2012) also describe how entangled seals form *"8.7% of the seals on the Cornish photo ID database (as of the end of 2011), and that of 58 seals on the database, 37 (64%) had injuries that were causing a constriction or had formed an open wound, or both."* They estimate entanglement rates in these seals from 5% of the population in 2004 to 3.1% in 2011.

# CONCLUSIONS

Pinnipeds are at the visible end of the spectrum of animals which become entangled, snared, trapped or caught in marine debris, particularly plastics in the form of net, rope, monofilament line and packing bands, with severe consequences, and the potential for acute welfare impacts on the individual animals. Plastic in the ocean is a "new" challenge to these animals, man-made and found only in any quantity in this century, and with an apparent dramatic rise in quantity, spread and effect in the last 20 years. Plastic is likely to be very long lived in a marine environment (we don't yet know how long in practice), as there are still plastic objects floating in the sea that were manufactured in the 1950s. The effects of marine debris, particularly of plastics, are not only aesthetic, they have the potential to cause significant, widespread and "mostly hidden and unreported" animal suffering, though constriction, wounding, drag, amputation, compromised feeding, and gut impaction or trauma if ingested. Studies reviewed here describe how entanglement lesions become chronic wounds, with infection and with debilitating consequences, and they describe how entangled pinnipeds may live for months or years with plastic line, or net, cutting into skin and muscle tissues.

The pinniped species most affected (**Table 1**; all species however can potentially be affected) through entanglement are: monk seals, fur seals and California sea lions, and to a lesser extent gray, common and monk seals. Entanglement rates described in the literature range up to 7.9% of local populations annually, and the literature refers repeatedly to the common entangling materials; packing bands, fragments of lost net, rope, monofilament line, fishery flashers and lures, long-line fishing gear, hooks and line, and bait hooks.

**TABLE 1 | Summary tabulation of reported entanglement rates for the pinniped species found in different ocean regions—the rate of entanglement (estimated % of population annually), and the net, plastic, and fishing line (% of reported entanglement cases for each category respectively), and the published source of the data.**

| Ocean region | Species/sub species | Rate of entanglement (%) | Net | Plastic | Fishing line | Published source |
|---|---|---|---|---|---|---|
| North East Pacific | Steller seal lion | 0.26 | 7 | 54 | 2 | Raum-Suryan et al., 2009 |
| | Northern fur seal | 0.4 | 65 | 19 | | Fowler, 1987 |
| | Northern fur seal | 0.08–0.35 | 39 | 37 | 9 | Allen and Angliss, 2014 |
| Eastern Central Pacific | Californian sea lion | 0.08–0.22 | 19 | 25 | 14 | Stewart and Yochem, 1987 |
| | Californian sea lion | 3.9–7.9 | 50 | | 33 | Harcourt et al., 1994 |
| | Northern elephant | 0.15 | 19 | 36 | 33 | Stewart and Yochem, 1987 |
| | Harbor seal | 0.09 | | 33 | | Stewart and Yochem, 1987 |
| | Northern fur seal | 0.24 | 50 | | | Stewart and Yochem, 1987 |
| | Steller seal lion | | 4 | | 4 | Hanni and Pyle, 2000 |
| Central Pacific | Hawaiian monk seal | 0.7 | 32 | 8 | 28 | Henderson, 2001 |
| South West Pacific | Kaikoura fur seal South | 0.6–2.8 | 42 | 31 | | Boren et al., 2006 |
| North West Atlantic | Gray seal | 3.1–5 | | | | Allen et al., 2012 |
| South East Atlantic | Antarctic fur seal | 0.024–0.059 | 48 | 18 | | Hofmeyr et al., 2002 |
| | Antarctic fur seal | 0.4 | | 46–52 | | Arnould and Croxall, 1995 |
| | Cape fur seal | 0.1–0.6 | | 50 | | Shaughnessy, 1980 |
| South West Atlantic | Southern elephant seal | 0.001–0.002 | | 36 | 64 | Campagna et al., 2007 |
| | Australian fur seal | 1.9 | 40 | 30 | | Pemberton et al., 1992 |
| | New Zealand fur seal | 0.9 | 29 | 30 | 3 | Page et al., 2004 |
| | Australian sea lion | 1.3 | 66 | 11 | 6 | Page et al., 2004 |
| Western Indian Ocean | Antarctic and Sub Antarctic fur seal | 0.24 | 17 | 41 | 10 | Hofmeyr et al., 2002 |

*Highlighted line (gray), indicates estimated annual entanglement rates of >1%.*

Awareness of the issue by the public, governments and industry is increasing, and local action is reported by some authors to have made measurable differences in entanglement rates. The spread of plastic material in the ocean will leave many seals unseen in their contortions to remove entangling material, and this is a hidden horror taking place in the ocean resulting from human activity which was not anticipated, but is having a significant effect on animal welfare and will be notable in future analysis of human effects on wild animals as a recognizable stage in the evolution of the interaction of wild animals and mankind.

## AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and approved it for publication.

## FUNDING

This review was carried out as a result of the individual academic interests of the author and was not funded by a specific funding body.

## REFERENCES

Allen, B. M., and Angliss R. P. (2014). *National Fur Seal (Callorhinus ursinus): Eastern Pacific Stock; Annual Human – Caused Mortality and Serious Injury National Oceanic and Atmospheric Administration.* Available online at: http://www.nmfs.noaa.gov/pr/sars/pdf/stocks/alaska/2014/ak2014_northernfurseal-cp.pdf

Allen, R., Jarvis, D., Sayer, S., and Mills, C. (2012). Entanglement of grey seals *Halichoerus grypus* at a haul out site in Cornwall, UK. *Mar. Pollut. Bull.* 64, 2815–2819. doi: 10.1016/j.marpolbul.2012.09.005

Arnould, J. P. Y., and Croxall, J. P. (1995). Trends in entanglement of Antarctic fur seals (*Arctocephalus gazella*) in man-made debris at South Georgia. *Mar. Pollut. Bull.* 30, 707–712.

Barnes, D. K. A. (2005). Remote islands reveal rapid rise of Southern Hemisphere sea debris. *ScientificWorldJournal* 5, 915–921. doi: 10.1100/tsw.2005.120

Barnes, D. K. A., Galgani, F., Thompson, R. C., and Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philos. Trans. R. Soc. B* 364, 1985–1998. doi: 10.1098/rstb.2008.0205

Boland, R. C., and Donohue, M. J. (2003). Marine debris accumulation in the nearshore marine habitat of the en- dangered Hawaiian monk seal, *Monachus schauinslandi* 1999-2001. *Mar. Pollut. Bull.* 46, 1385–1394. doi: 10.1016/S0025-326X(03)00291-1

Boren, L. J., Morrissey, M., Muller, C. G., and Gemmell, N. J. (2006). Entanglement of New Zealand fur seals in man-made debris at Kaikoura, New Zealand. *Mar. Pollut. Bull.* 52, 442–446. doi: 10.1016/j.marpolbul.2005.12.003

Campagna, C., Falabella, V., and Lewis, M. (2007). Entanglement of southern elephant seals in squid fishing gear. *Mar. Mamm. Sci.* 23, 414–418. doi: 10.1111/j.1748-7692.2007.00105.x

Cole, T., Hartley, D., and Garron, M. (2006). "Mortality and serious injury determinations for baleen whale stocks along the Eastern Seaboard of the United States, 2000-2004," in *Northeast Fisheries Science Center Reference Document, 06-04* (Woods Hole, MA: National Marine Fisheries Service), 18.

Convention on Biological Diversity (CBD) (2012). *Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel—GEF (2012).* Impacts of Marine Debris on Biodiversity: Current Status and Potential Solutions, Montreal, Technical Series No. 67. Available online at: https://www.cbd.int/doc/publications/cbd-ts-67-en.pdf

Coupland, R. M. (1992). The Red Cross classification of war wounds: the E.X.C.F.V.M. *scoring system. World J. Surg.* 16, 910–917. doi: 10.1007/BF02066991

Dau, B. K., Gilardi, K. V., Gulland, F. M., Higgins, A., Holcomb, J. B., Leger, J. S., et al. (2009). Fishing gear-related injury in California marine wildlife. *J. Wildl. Dis.* 45, 355–362. doi: 10.7589/0090-3558-45.2.355

Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: a review. *Mar. Pollut. Bull.* 44, 842–852. doi: 10.1016/S0025-326X(02)00220-5

Donohue, M. J., and Foley, D. G. (2007). Remote sensing reveals links among the endangered Hawaiian monk seal, marine debris, and El Niño. *Mar. Mamm. Sci.* 23, 468–473. doi: 10.1111/j.1748-7692.2007.00114.x

Fowler, C. W. (1987). Marine debris and northern fur seals: a case study. *Mar. Pollut. Bull.* 18, 326–335. doi: 10.1016/S0025-326X(87)80020-6

Hanni, K. D., and Pyle, P. (2000). Entanglement of Pinnipeds in Synthetic Materials at South-east Farallon Island, California, 1976-1998. *Mar. Pollut. Bull.* 40, 1076–1081. doi: 10.1016/S0025-326X(00)00050-3

Harcourt, R., Aurioles, D., and Sanchez, J. (1994). Entanglement of California sea lions at Los Islotes, Baja California Sur, Mexico. *Mar. Mamm. Sci.* 10, 122–125. doi: 10.1111/j.1748-7692.1994.tb00399.x

Hekman, R., and Osinga, N. (2010). *Stichting Zeehondencreche Lenie t' Hart 2010*. Available online at: http://www.zeehondencreche.nl/wb/pages/wetensch.-onderzoek/wetenschappelijke-publicaties.php (Accessed April 2, 2016).

Henderson, J. R. (2001). A pre- and post-MARPOL Annex V summary of Hawaiian monk seal entanglements and marine debris accumulation in the northwestern Hawaiian Islands, 1982–1998. *Mar. Pollut. Bull.* 42, 584–589. doi: 10.1016/S0025-326X(00)00204-6

Hofmeyr, G. J., Bester, M., Kirkman, S. P., Lydersen, C., and Kovacs, K. M. (2006). Entanglement of Antarctic fur seals at Bouvetøya, Southern Ocean. *Mar. Pollut. Bull.* 52, 1077–1080. doi: 10.1016/j.marpolbul.2006.05.003

Hofmeyr, G. J. G., De Maine, M., Bester, M. N., Kirkman, S. P., Pistorius, P. A., and Makhado, A. B. (2002). Entanglement of pinnipeds at Marion Island, Southern Ocean: 1991-2001. *Aust. Mammal.* 24, 141–146. doi: 10.1071/AM02141

International Coastal Cleanup (ICC) (2008). *Annual Report – Ocean Conservancy 2008*. Available online at: http://www.oceanconservancy.org/our-work/marine-debris/2016-data-release/2016-data-release-1.pdf (Accessed June 27, 2016).

Karamanlidis, A. A. (2000). *Monitoring Human and Mediterranean Monk Seal Activity in the National Marine Park of Alonnissos and Northern Sporades, Greece*. Monachus Guardian. Available online at: http://www.monachus-guardian.org

Lawson, T. J., Wilcox, C., Johns, K., Dann, P., and Hardesty, B. D. (2015). Characteristics of marine debris that entangle Australian fur seals (*Arctocephalus pusillus doriferus*) in southern Australia. *Mar. Pollut. Bull.* 98, 354–357. doi: 10.1016/j.marpolbul.2015.05.053

Marine Conservation Society (MCS) (2007). *Beachwatch 2006. The 14th Annual Beach Litter Survey Report. Marine Conservation Society, Ross on Wye.* Available online at: https://www.mcsuk.org/press/view/181 (Accessed April 6, 2016).

McIntosh, R. R., Kirkwood, R., Sutherland, D. R., and Dann, P. (2015). Drivers and annual estimates of marine wildlife entanglement rates: a long-term case study with Australian fur seals. *Mar. Pollut. Bull.* 101, 716–725. doi: 10.1016/j.marpolbul.2015.10.007

Moore, M. J., van der Hoop, J., and Barco, S. G. (2013). Criteria and case definitions for serious injury and death of pinnipeds and cetaceans caused by anthropogenic trauma. *Dis. Aquat. Organ.* 103, 229–232. doi: 10.3354/dao02566

NOAA (2012). *Marine Mammal Entanglement: Pinniped.* Available online at: https://alaskafisheries.noaa.gov/pr/pinniped-entanglement (Accessed July 12, 2016).

NOAA/NMFS (2007). *Serious Injury Technical Workshop, Seattle, 2007 Severity Indexes Page 7.* Available online at: http://www.nmfs.noaa.gov/pr/pdfs/interactions/serious_injury_techmemo2008.pdf (Accessed April 2, 2016).

NRC National Research Council (2008). *Tackling Marine Debris in the 21st Century. Committee on the Effectiveness of International and National Measures to Prevent and Reduce Marine Debris and its Impacts*. Available online at: http://docs.lib.noaa.gov/noaa_documents/NOAA_related_docs/marine_debris_2008.pdf (Accessed April 2, 2016).

Page, B., McKenzie, J., McIntosh, R., Baylis, A., Morrissey, A., Calvert, N., et al. (2004). Entanglement of Australian sea lions and New Zealand fur seals in lost fishing gear and other marine debris before and after Government and industry attempts to reduce the problem. *Mar. Pollut. Bull.* 49, 33–42. doi: 10.1016/j.marpolbul.2004.01.006

Page, B., Welling, A., Chambellant, M., Goldsworthy, S. D., Dorr, T., and van Veen, R. (2003). Population status and breeding season chronology of Heard Island fur seals. *Polar Biol.* 26, 219–224. doi: 10.1007/s00300-003-0478-z

Pearson, E., Mellish, S., Sanders, B., and Litchfield, C. (2014). Marine wildlife entanglement: assessing knowledge, attitudes, and relevant behaviour in the Australian community. *Mar. Pollut. Bull.* 89, 136–148. doi: 10.1016/j.marpolbul.2014.10.014

Pemberton, D., Brothers, N. P., and Kirkwood, R. (1992). Entanglement of Australian fur seals in man-made debris in Tasmanian waters. *Wildlife Res.* 19, 151–159. doi: 10.1071/WR9920151

Raum-Suryan, K. L., Jemison, L. A., and Pitcher, K. W. (2009). Entanglement of steller sea lions (*Eumetopias jubatus*) in marine debris: identifying causes and finding solutions. *Mar. Pollut. Bull.* 58, 1487–1495. doi: 10.1016/j.marpolbul.2009.06.004

Sandoe, P., and Simonsen, H. B. (1992). Assessing animal welfare: where does science end and philosophy begin? *Anim. Welfare* 1, 257–267.

Santos, I. R., Friedrich, A. C., and Barretto, F. P. (2005). Overseas garbage pollution on beaches of northeast Brazil. *Mar. Pollut. Bull.* 50, 782–786. doi: 10.1016/j.marpolbul.2005.04.044

Shaughnessy, P. D. (1980). Entanglement of Cape fur seals with man-made objects. *Mar. Pollut. Bull.* 11, 332–336. doi: 10.1016/0025-326X(80)90052-1

Sheavly, S. B. (2007). *National Marine Debris Monitoring Program*. Final Program Report, Data Analysis and Summary. Prepared for U.S. Environmental Protection Agency by Ocean Conservancy, Grant Number X830534 01-02, 76.

Spraker, T. R., and Lander, M. E. (2010). Causes of Mortality in Northern Fur Seals (*Callorhinus ursinus*), St. *Paul Island, Pribilof Islands, Alaska, 1986-2006. J. Wildl. Dis. 46,* 450–473. doi: 10.7589/0090-3558-46.2.450

Stewart, B. S., and Yochem, P. K. (1987). Entanglement of pinnipeds in synthetic debris and fishing net and line fragments at San Nicolas and San Miguel Islands, California, 1978–1986. *Mar. Pollut. Bull.* 18, 336–339. doi: 10.1016/S0025-326X(87)80021-8

Waluda, C. M., and Staniland, I. J. (2013). Entanglement of Antarctic fur seals at Bird Island, South Georgia. *Mar. Pollut. Bull.* 74, 244–252. doi: 10.1016/j.marpolbul.2013.06.050

Wang, J., Tan, Z., Peng, J., Qiu, Q., and Li, M. (2016). The behaviors of microplastics in the marine environment. *Mar. Environ. Res.* 113, 7–17. doi: 10.1016/j.marenvres.2015.10.014

Wilcox, C., Mallos, N. J., Leonard, G. H., Rodriguez, A., and Hardesty, B. D. (2016). Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife. *Mar. Policy* 65, 107–114. doi: 10.1016/j.marpol.2015.10.014

Williams, R., Ashe, E., and O'Hara, P. D. (2011). Marine mammals and debris in coastal waters of British Columbia, Canada. *Mar. Pollut. Bull.* 62, 1303–1316. doi: 10.1016/j.marpolbul.2011.02.029

World Society for the Protection of Animals (WSPA) (2012). *Marine Debris: A Global Picture of the Impact on Animal Welfare and of Animal-Focused Solutions*, eds A. Butterworth, I. Clegg, and C. Bass (London: WSPA

International). Available online at: http://oceansandplastics.info/wp-content/uploads/2015/07/REP_WSPA_2012.pdf (Accessed June 27, 2016).

Zalasiewicz, J., Waters, C. N., Ivar do Sul, J. A., Corcoran, P. L., Barnosky, A. D., Cearreta, A., et al. (2016). The geological cycle of plastics and their use as a stratigraphic indicator of the Anthropocene. *Anthropocene* 13, 4–17. doi: 10.1016/j.ancene.2016.01.002

Zavala-González, A., and Mellink, E. (1997). Entanglement of California sea lions, *Zalophus californianus* californianus, in fishing gear in the central-northern part of the Gulf of California, Mexico. *Fish. Bull.* 95, 180–184.

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

frontiers in Marine Science

MINI REVIEW
published: 31 August 2016
doi: 10.3389/fmars.2016.00158

CrossMark

# The International Whaling Commission—Beyond Whaling

*Andrew J. Wright[1]*, Mark P. Simmonds[2] and Barbara Galletti Vernazzani[3]*

[1] Department of Environmental Science and Policy, George Mason University, Fairfax, VA, USA, [2] School of Veterinary Sciences, University of Bristol, Bristol, UK, [3] Centro de Conservacion Cetacea, Santiago, Chile

Since its establishment in 1946 as the international body intended to manage whaling, the International Whaling Commission (IWC) has expanded its areas of interest to ensure the wider conservation of whales. Several key conservation topics have been taken forward under its auspices including climate change, chemical and noise pollution, marine debris and whale watching. Work on each of these topics at the IWC has grown substantially since the 1990s and remains ongoing. Important developments were the establishment of the Standing Working Group on Environmental Concerns in 1996 and the IWC's Conservation Committee in 2003. Trying to address this diverse set of issues is obviously a challenge, but will be necessary if the long term conservation of cetaceans is to be achieved. Through research, workshops, resolutions and collaboration with other organizations, the IWC has advanced both the understanding of the various issues and the means to manage them with increasing effectiveness. The IWC is likely to remain on the forefront of continuing efforts to address these, and other, conservation concerns and ensure the continued viability of cetacean populations around the globe.

**Keywords: International Whaling Commission, conservation, climate change, marine debris, ship strike, underwater noise pollution, Whale watching, chemical pollution**

OPEN ACCESS

***Edited by:***
*Rob Harcourt,*
*Macquarie University, Australia*

***Reviewed by:***
*Ruth Davis,*
*University of Wollongong, Australia*
*Karen Nadine Scott,*
*University of Canterbury, New Zealand*
*David John Slip,*
*Taronga Conservation Society Australia, Australia*

****Correspondence:***
*Andrew J. Wright*
*marinebrit@gmail.com*

***Specialty section:***
*This article was submitted to Marine Affairs and Policy, a section of the journal Frontiers in Marine Science*

***Received:*** *22 March 2016*
***Accepted:*** *19 August 2016*
***Published:*** *31 August 2016*

***Citation:***
*Wright AJ, Simmonds MP and Galletti Vernazzani B (2016) The International Whaling Commission—Beyond Whaling. Front. Mar. Sci. 3:158. doi: 10.3389/fmars.2016.00158*

## INTRODUCTION

The International Convention for the Regulation of Whaling established the International Whaling Commission (IWC) in 1946 with the stated purpose to "provide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry" (International Convention for the Regulation of Whaling, 1946). Over time, concern over impacts from non-whaling threats has expanded the topics under discussion at the IWC. Key expert opinion on subjects related to the conservation of all cetaceans is now frequently distilled in the IWC's Scientific Committee (IWCSC). This expansion led India's Commissioner to suggest that the IWC be re-named the International Whales Commission in 2012 (IWC, 2013c).

A critical step in this development was the creation of the "Environmental Concerns Standing Working Group (ESWG)" under the IWCSC in 1996 to "facilitate examination of the effects of environmental change on cetaceans," following Commission Resolution 1996–8 (IWC, 1997a). Two years later, the IWCSC placed environmental concerns centrally in their visual representation of their seven priority topic areas (Figure 1 in IWC, 1999a) and the Commission adopted a standing Agenda Item on "Environmental Concerns" (IWC, 1999b). The next major development was the 2003 establishment of the Conservation Committee to consider numerous emerging cetacean conservation issues (IWC, 2004c).

The evolving and expanding focus of the IWC is reflected in its Resolutions, as reviewed in the 2003 Annual Report (IWC, 2004c). Complementing that retrospective, this review provides a look back at the evolving role of the IWC in several topic areas over the last two decades.

## WHALE WATCHING

Despite noted educational (IFAW et al., 1997), cultural (Hoyt and Iñiguez, 2008), and direct and indirect economic (Hoyt and Iñiguez, 2008; O'Connor et al., 2009; Cisneros-Montemayor et al., 2010) benefits, concerns have arisen over the negative effects of whale watching on the targeted species and populations. The IWCSC first expressed concern about the commercial tourist operations in gray whale (*Eschrichtius robustus*) breeding lagoons in Mexico in the 1970s (IWC, 1975). The first IWC Resolution (1993-9) on whale watching came in 1993, establishing a Working Group and inviting IWC members to contribute scientific and economic information on this expanding tourist industry (IWC, 1994). The ongoing discussion of scientific, legal, socio-economic, and educational aspects of the issue by the scientists, governments, non-governmental organization (NGOs), tour operators and other stakeholders gathered at the IWC has since, among other things, produced a framework to assist coastal states in drafting whale watching guidelines and regulations (IWC, 2004a).

In 1998, the Whale Watching Sub-Committee (WWSC) was established (following Resolution 1996-2) under the IWCSC (IWC, 1997b). This Sub-Committee considers any relevant information pertaining to whale watching and swim-with programs. Since 1999 the WWSC has systematically compiled relevant regulations and guidelines from around the world (Carlson, 2013). The WWSC also held a workshop specifically to assess long-term effects of whale watching on cetaceans (IWC, 2001b).

Perhaps most notably, in 2007, Resolution 2007-3 recognized the "non-lethal use [of cetaceans] as a legitimate management strategy" and encouraged "member States to work constructively toward the incorporation of the needs of non-lethal users of whale resources in any future decisions and agreements" (IWC, 2008a). A 2008 IWCSC workshop followed to discuss strategic planning of large-scale whale watching research to improve long-term impact studies (IWC, 2009a).

The Conservation Committee established its own Working Group on Whale Watching in 2009, initially to produce a draft strategic plan. The IWC subsequently adopted the 5 year Strategic Plan 2010–2015 on whale watching, with elements that addressed science, management, and capacity building (IWC, 2011a). Among other things the Strategic Plan produced a web-based "living" handbook on whale watching (Carlson, 2013).

Operators were invited to the IWC to provide feedback on the Strategic Plan in 2013. They concluded the IWC should take a more active role in advising sustainable whale watching activities, especially in developing countries (IWC, 2013a). Relatedly, a process is underway to review progress on previous recommendations and find ways to improve resolution visibility and effectiveness, especially those concerning "highly endangered or isolated cetacean species/populations" (IWC, 2015a). Most recently, in February 2016, the IWC provided technical and logistic support for a workshop on whale watching held by the Indian Ocean Rim Association in Sri Lanka (Simmonds pers obs).

## CHEMICAL POLLUTION

A long-accepted environmental concern, it is perhaps unsurprising that chemical pollution has arguably received more attention than any other non-whaling issue at the IWC. Following the 1995 IWC Pollution Workshop (Reijnders et al., 1999), Commission Resolution 1997-7 initiated a multi-national, multi-disciplinary research programme to establish pollutant cause-effect relationships in cetaceans (IWC, 1998). Strongly endorsed by the Agreement on the Conservation of Small Cetaceans in the Baltic, North East Atlantic, Irish, and North Seas (ASCOBANS) and the International Council for the Exploration of the Sea (ICES) Working Group on Marine Mammal Habitats, the initial proposal was refined through three meetings (IWC, 2000b), ultimately becoming known as "POLLUTION 2000+," to focus on polychlorinated biphenyls (PCBs) in harbor porpoises (*Phocoena phocoena*) and bottlenose dolphins (*Tursiops* sp.; IWC, 2000b).

POLLUTION 2000+ Phase I objectives were to validate/calibrate methodology to: (a) determine changes in concentration of biomarkers of PCB exposure with post-mortem times; and (b) examine relationships between biopsy sample concentrations with those from other tissues only available from fresh carcasses (IWC, 2000b). Initially heavily supported by the SOWER (Southern Ocean Whale and Ecosystem Research) programme, POLLUTION 2000+ also drew considerable (although arguably insufficient) funding from the IWC and elsewhere (IWC, 2001a). Consequently, upon completion in 2006, the IWCSC agreed that Phase I had contributed to the Commission's request to give priority to research on effects of environmental changes on cetaceans (IWC, 2007b). The program had created the first individual-based model for a cetacean (the bottlenose dolphin) simulating PCB accumulation in a population, with modification of first-year calf survival based on maternal blubber PCB levels. Phase I had also laid the foundation for the use of incidentally caught animals in pollutant studies.

Phase II began in 2007 by concentrating on developing: (1) an integrated modeling framework to examine the effects of pollutants on cetacean populations; and (2) a protocol for validating the use of biopsy samples in pollution-related studies (IWC, 2008b). Experts in chemical contaminants, toxicology, cetacean biology, veterinary medicine, and biomarkers refined objectives over several years (IWC, 2011b,c) and the first elements of Phase II were ready for IWCSC review in 2011 and 2012 (IWC, 2012a, 2013b). Phase II efforts received IWCSC commendation, as "population-level consequences of pollutant exposure in cetaceans are extremely difficult to determine directly" (IWC, 2012a).

The IWC also continued discussion of contaminants outside POLLUTION 2000+. For example, Resolution 1999-4 called on "relevant countries to take measures to reduce pollution that may cause negative health effects from the consumption of cetacean products," among other things (IWC, 2000b). The inconclusive 2005–2011 Russian investigation into inedible "stinky" gray whales found in the Chukotkan aboriginal subsistence hunt has also been repeatedly discussed (Polyakova et al., 2012; IWC, 2013c).

More recently, the 2010 Deepwater Horizon oil spill has featured prominently, initially overshadowing POLLUTION 2000+. Discussions focused on the possible impacts of oil and dispersants, and the prolonged elevation of dolphin strandings in the Gulf of Mexico into 2013 (IWC, 2012a, 2013b, 2014a). Acknowledging the uncertainties, the Commission made a general statement in support of research on the wide impacts of contaminants on marine mammals and their environment with Resolution 2012-1 (IWC, 2013c).

By 2013, POLLUTION 2000 Phase II was approaching completion, having developed stochastic models of population-level impacts of contaminant bioaccumulation and offered a risk assessment (IWC, 2014a). The IWCSC thus established a steering group to plan Pollution 2020, in effect a POLLUTION 2000+ Phase III, which will focus on assessing the toxicity of microplastics and polycyclic aromatic hydrocarbons and dispersants in cetaceans (IWC, 2014a).

## CLIMATE CHANGE

The first climate change workshop took place in 1995 to review and consider potential threats to cetaceans posed by a changing climate following a 1993 call from the IWCSC (Ashford-Hodges and Simmonds, 2014). The workshop concluded that climate change would adversely affect cetaceans, with the most important impacts expected to be mediated via prey distribution changes. It also noted that current climate change models had predictive capability limitations and that considerable further research would be required to accurately predict impacts of climate change on cetaceans.

In 2002, the IWCSC designated high latitude climate change as a priority topic for future work for ESWG (IWC, 2003b). A special session on Southern Ocean climate change and cetaceans was held in 2003 (IWC, 2004c). However, a second climate change workshop was not convened until 2009 with the primary goal of determining how to improve conservation under the 4th Intergovernmental Panel on Climate Change (IPCC) Assessment on Climate Change scenarios (IPCC: Pachauri and Reisinger, 2007). Recommendations included developing more accurate models of cetacean responses to climate, with explicitly quantified uncertainties, and improving understanding of relationships between cetacean distribution and quantifiable climatic indices (e.g., sea surface temperature: IWC, 2010b). Commission Resolution 2009-1 followed, requesting Contracting Governments to both incorporate climate change considerations into existing conservation and management plans and take urgent action to reduce the rate and extent of climate change (IWC, 2010a).

Participants of a further workshop on the impacts of climate change on small cetaceans expressed particular concern for species with restricted habitats, stressing the importance of long-term datasets for assessing such impacts (IWC, 2012b). The IWCSC established a steering group in 2014 to provide recommendations on how to take work on this topic forward (IWC, 2015b).

## MARINE NOISE

Among increasing scientific concern, two overview papers submitted to ESWG initiated IWC discussions of noise in 1998. The IWCSC agreed at that time "attempting a major initiative on the impact of noise on cetaceans was not advisable" (IWC, 1999a) and the Commission accepted this conclusion (IWC, 1999c).

Regardless, ongoing discussions of impacts of noise continued, initially focusing on acoustic deterrent devices, or "pingers," whale watching vessels and seismic surveys (IWC, 2000a, 2002). The potential contributions of noise to habitat abandonment by humpback whales (*Megaptera novaeangliae*) in the Gulf of Paria and threatened Western North Pacific gray whales (*Eschrichtius robustus*) of their Piltun feeding ground (IWC, 2002) led to a joint WWSC-ESWG session on noise in 2002 (IWC, 2003a). Notably, this discussion represented one of the first international gatherings of scientists dedicated to the topic of underwater noise.

In 2003, the Commission used the term "noise pollution," the ESWG established noise as regular agenda item, and the IWCSC broadened its discussions to include windfarm construction and anthropogenic noise more generally (IWC, 2004b). A dedicated ESWG mini-symposium in 2004 commended Brazilian Government efforts to protect critical habitats from seismic survey noise, and strongly recommended similar protections elsewhere (IWC, 2005a). The Commission endorsed IWCSC findings that there was "now compelling evidence implicating military sonar has a direct impact on beaked whales in particular," and that "other sources... were cause for serious concern" (IWC, 2005a,b). IWCSC discussion of naval activity continued into 2006 following a mass stranding of beaked whales in Taiwan, while a workshop focusing on seismic impacts substantially expanded the body's acoustic expertise (IWC, 2007a). Workshop conclusions highlighted the need for better planning, reduced horizontal energy output, and additional well-designed long-term monitoring studies (IWC, 2007a).

By 2008, IWCSC observers were regularly reporting on external resolutions and recommendations (IWC, 2009a). Among other things, the IWCSC endorsed a call for shipping noise reductions "in the 10–300 Hz band by 3 dB in 10 years and by 10 dB in 30 years relative to current levels" (IWC, 2009a). An Agreement of Cooperation between the International Maritime Organization (IMO) and the IWC followed in 2009, granting the IWC observer status at the IMO. Immediately, the IWCSC strongly supported recommendations for ships to incorporate low-noise propulsion designs, among other measures (IWC, 2011b).

As information accumulated, the IWCSC concluded there was "considerable evidence that anthropogenic noise can affect beaked whales" (IWC, 2012a) and strongly recommend that "military exercises and seismic surveys should avoid areas of important habitat for beaked whales" (IWC, 2013b). In 2013, a joint ESWG-WWSC session further considered ship noise (IWC, 2014a) eliciting the IWCSC recommendation for additional examination of possible population-level effects from behavioral responses (IWC, 2015a). A joint IWC-IQOE (International Quiet Ocean Experiment) technical workshop on soundscape modeling followed (IWC, 2015a). While undoubtedly an excellent start, the limited geographical coverage of soundscape programs was noted, as was the need for standardization (IWC, 2015a).

Multi-beam echosounders entered discussions following implication in the 2008 Madagascar melon-headed whale (*Peponocephala electra*) mass stranding (Southall et al., 2013). The IWCSC responded by recommending high intensity multi-beam echosounder systems, like military sonars, be considered possible threats to cetacean populations (IWC, 2015a). More generally, the IWCSC stressed the importance of temporal and spatial management and recommended that Governments encourage commercial use of noise-reducing technologies (IWC, 2015a).

## MARINE DEBRIS

Increasing recognition of the near-ubiquitous presence of marine debris in the oceans, and the huge potential for wildlife impacts (e.g., NOAA Marine Debris Program, 2014; NOAA, 2015), led the IWC to hold two marine debris workshops in quick succession. The 2013 workshop focused on improving understanding of the threat posed by marine debris to cetaceans and discussed impacts from both macrodebris (e.g., fishing gear, plastic bags, and sheeting) and microplastics (e.g., plastic particles added to cosmetics and the pellet form of raw plastics). The IWCSC endorsed the recommendation for more research (IWC, 2014b). The IWCSC also agreed that: (1) legacy and contemporary marine debris have the potential to be persistent, bioaccumulative and lethal to cetaceans, and thus represent a global management challenge; and (2) entanglement in, and intake of, active fishing gear, ALDFG (abandoned, lost, or otherwise discarded fishing gear) and other marine debris have lethal and sub-lethal effects on cetaceans (IWC, 2015a).

The 2014 workshop gathered several key international bodies already engaged in marine debris principally to discuss a role for the IWC. It was agreed that the IWC's primary contribution should be to ensure that cetacean-related issues are adequately represented within existing initiatives and that its strong scientific expertise is made available in collaborative efforts (IWC, 2014d). Thus, these workshops likely represent merely the beginning of IWC work on this issue.

## SHIP STRIKES

Ship strikes rose to prominence at the IWC with Resolution 1998-2, which specified, for the first time, that collisions with ships and other sources of human-induced mortality should be counted toward total allowable removals (IWC, 1999c). Discussions continued into the new millennium, focusing on high-speed vessels, United States and Canadian right whale (*Eubalaena glacialis*) ship strike-reduction efforts, and disappointments with acoustic alarms (IWC, 2000b, 2001a). Meanwhile, early IWC Secretariat approaches to the IMO were rebuffed as the IWC did not have observer status at that time.

The Conservation Committee established the Ship Strikes Working Group (SSWG) in 2005 (IWC, 2006). Quickly the SSWG recommended a combination of four technical mitigation measures: detection and avoidance maneuvers; repulsion; protection; and training (IWC, 2007b), and initiated the IWC Global Ship Strikes Database, which had reached 763 records by 2008, mainly from published sources (IWC, 2009b).

Following the 2009 formal Agreement with the IMO, the IWC has contributed to IMO discussions on ship strikes (in addition to underwater noise), leading to the adoption of shipping lane changes in the Santa Barbara Channel and off San Francisco, California, USA, to reduce blue whale ship strikes, among other things (IMO, 2012). The Conservation Committee contributed greatly to this collaboration, while continuing to build the database and raise awareness globally. It also contributed to the 2010 joint IWC-ACCOBAMS (Agreement on the Conservation of Cetaceans in the Black Sea Mediterranean Sea and Contigous Atlantic Area) workshop on ship strikes in the Mediterranean Sea and the Canary Islands (IWC, 2010a).

Despite some regional progress, workshop participants noted the data necessary for carrying out full risk assessments and determining appropriate conservation actions were generally lacking, especially within the ACCOBAMS region (IWC, 2011d). Participants recommend additional data collection, increased reporting to the IWC database, and greater international collaboration on the issue (IWC, 2011d). These were echoed by both the IWCSC and Commission (IWC, 2012c).

In response, the Commission approved IWCSC, and subsequently Conservation Committee, recommendations to appoint a part-time dedicated ship strike data coordinator (IWC, 2012c, 2013c). The Commission also committed to contributing to three further workshops on disentanglement and ship strikes in the wider Caribbean in 2012-13 (IWC, 2013c).

A further IWC-endorsed workshop in Tenerife focused on management and mitigation of ship strikes (Tejedor et al., 2013). This highlighted the need to define and communicate "whale hotspots," for better advanced route planning, a subject to be pursued further by a subsequence workshop (IWC, 2014c).

## RESERVATIONS

While some have questioned IWC authority over non-whaling topics (especially when the Conservation Commission was created), the majority of member nations have supported the broadening focus (e.g., by passing resolutions). However, three countries have recently made specific statements indicating their belief that certain items are outside IWC jurisdiction. For example, in 2015 Japan, Iceland and Norway stated to the IWCSC their opposition to marketplace monitoring of whale meat products (e.g., DNA register systems) and Japan additionally opposed consideration of "whale watching" and "small cetaceans" (IWC, 2016). In practice scientists sent to the IWCSC by these nations do not take part in discussions on these topics, which still proceed. Japan also does not participate in the Conservation Committee.

## CONCLUSIONS

With increasing scientific acknowledgement that multiple stressors can produce cumulative impacts (e.g., Wright, 2009),

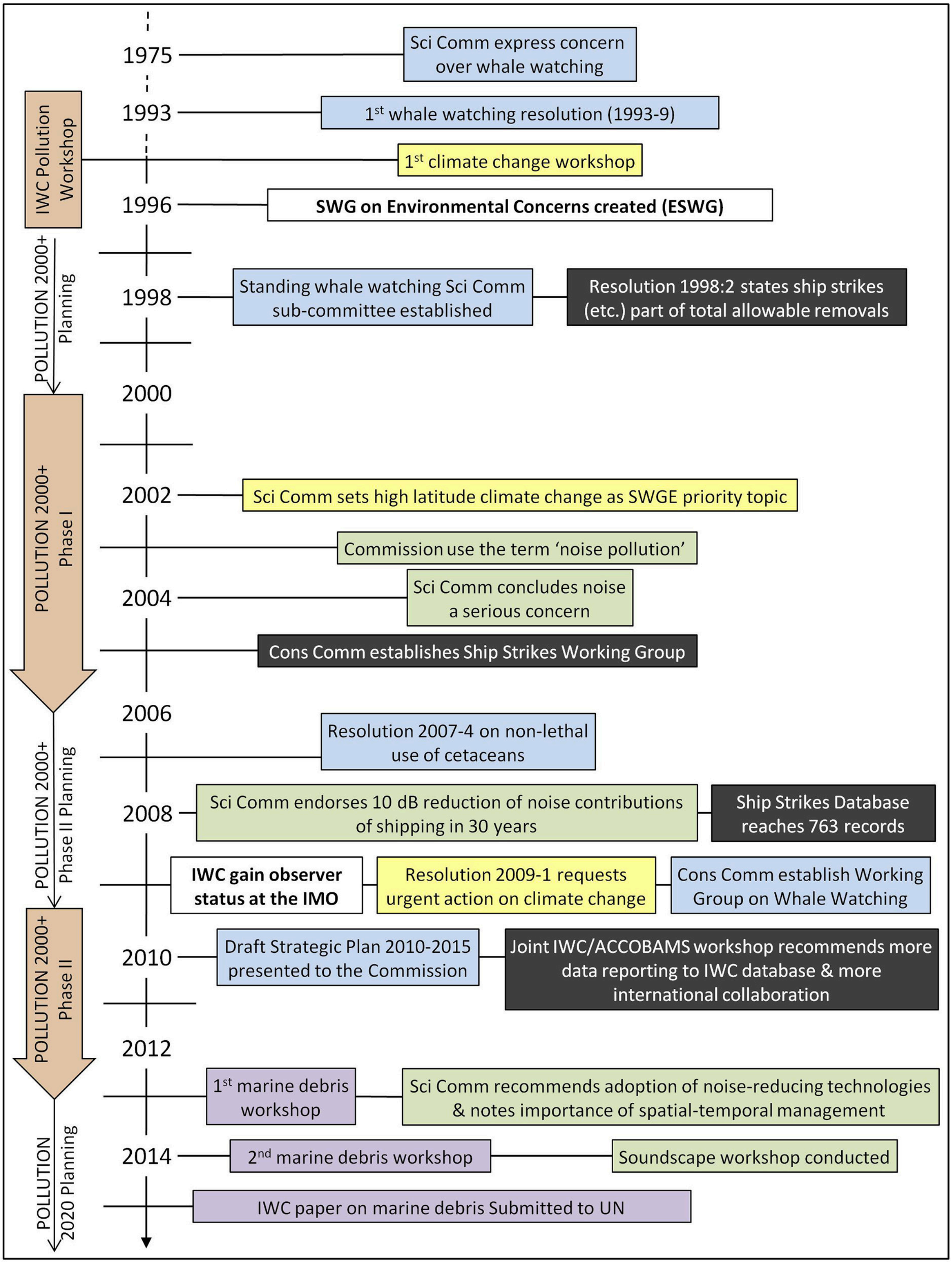


**FIGURE 1 | Notable events in the expansion of subjects under consideration at the IWC.**

management decision must consider broader human impacts as whaling does not occur in a vacuum. This review is limited to the progress made to date on certain issues (see **Figure 1**), but the IWC also has ongoing work streams on emergent diseases, whale disentanglement, marine renewable energy devices, and various other environmental and conservation concerns.

While not exhaustive, this review demonstrates that important contributions to the conservation of cetaceans and their habitats are increasingly being made between actors from many nations within the fora provided by the IWC. It is clear that this "modern" IWC will continue to facilitate key efforts to address the many threats now challenging the survival of viable, healthy cetacean populations around the world.

## AUTHOR CONTRIBUTIONS

All authors contributed original text to the manuscript. MPS initiated the concept. AJW compiled, edited, and (for the most part) referenced the material.

## ACKNOWLEDGMENTS

Part of this review was written by AJW under contract with Humane Society International.

## REFERENCES

Ashford-Hodges, N., and Simmonds, M. P. (2014). *Climate Change and Cetaceans: An Update*. Paper Submitted to the IWC Scientific Committee: SC/65b/E12.

Carlson, C. (2013). *A Review of Whale Watch Guidelines and Regulations around the World Version 2012*. Available online at: https://iwc.int/index.php?cID=3107&cType=document

Cisneros-Montemayor, A. M., Sumaila, U. R., Kaschner, K., and Pauly, D. (2010). The global potential for whale watching. *Mar. Policy* 34, 1273–1278. doi: 10.1016/j.marpol.2010.05.005

Hoyt, E., and Iñiguez, M. (2008). *The State of Whale Watching in Latin America*. Chippenham, UK: WDCS; Yarmouth Port, USA: IFAW; and London: Global Ocean.

IFAW (International Fund for Animal Welfare), WWF (World Wildlife Fund), and WDCS (Whale and Dolphin Conservation Society). (1997). *Report of the Workshop on the Educational Values of Whale Watching, Provincetown, Massachusetts, USA*. International Fund for Animal Welfare; World Wildlife Fund; Whale and Dolphin Conservation Society.

IMO (International Maritime Organization) (2012). *New and Amended Existing Traffic Separation Schemes.* IMO, London.

International Convention for the Regulation of Whaling, (1946). *International Convention for the Regulation of Whaling*. Washington, DC: International Convention for the Regulation of Whaling.

IWC (International Whaling Commission) (1975). *Report of the Scientific Committee*. Document IWC/27/4 available from IWC website.

IWC (International Whaling Commission) (1994). *Chairman's Report of the Forty-Fifth Annual Meeting, Appendix 9, IWC Resolution 1993-9*. International Whaling Commission.

IWC (International Whaling Commission) (1997a). *Resolution 1996-8 Resolution on Environmental Change and Cetaceans*. International Whaling Commission.

IWC (International Whaling Commission) (1997b). *Resolution 1996-2 Resolution on Whalewatching*. International Whaling Commission.

IWC (International Whaling Commission) (1998). *Annual Report of the International Whaling Commission 1997*. International Whaling Commission.

IWC (International Whaling Commission) (1999a). Report of the Scientific Committee. *J. Cetacean Res. Manage.* 1(Suppl.), 1–52.

IWC (International Whaling Commission) (1999b). "Chairman's report of the fiftieth annual meeting," in *Annual Report of the International Whaling Commission 1998*.

IWC (International Whaling Commission) (1999c). *Annual Report of the International Whaling Commission 1998*. International Whaling Commission.

IWC (International Whaling Commission) (2000a). Report of the Scientific Committee. *J. Cetacean Res. Manage.* 2(Suppl.), 1–65.

IWC (International Whaling Commission) (2000b). *Annual Report of the International Whaling Commission 1999*. International Whaling Commission.

IWC (International Whaling Commission) (2001a). *Annual Report of the International Whaling Commission 2000*. International Whaling Commission.

IWC (International Whaling Commission) (2001b). Report of the Scientific Committee. *J. Cetacean Res. Manage*. 3(Suppl.), 1–76.

IWC (International Whaling Commission) (2002). Report of the Scientific Committee. *J. Cetacean Res. Manage.* 4(Suppl.), 1–78.

IWC (International Whaling Commission) (2003a). Report of the Scientific Committee. *J. Cetacean Res. Manage.* 5(Suppl.), 1–92.

IWC (International Whaling Commission) (2003b). *Annual Report of the International Whaling Commission 2002*. International Whaling Commission.

IWC (International Whaling Commission) (2004a). *Chairman's Report of the Fifty-Fifth Annual Meeting, Annex C, IWC Resolution 2003-1: The Berlin Initiative on Strengthening the Conservation Agenda of the International Whaling Commission*. International Whaling Commission.

IWC (International Whaling Commission) (2004b). Report of the Scientific Committee. *J. Cetacean Res. Manage.* 6(Suppl.), 1–60.

IWC (International Whaling Commission) (2004c). *Annual Report of the International Whaling Commission 2003*. International Whaling Commission.

IWC (International Whaling Commission) (2005a). Report of the Scientific Committee. *J. Cetacean Res. Manage*. 7(Suppl.), 1–62.

IWC (International Whaling Commission) (2005b). *Annual Report of the International Whaling Commission 2004*. International Whaling Commission.

IWC (International Whaling Commission) (2006). *Annual Report of the International Whaling Commission 2005*. International Whaling Commission.

IWC (International Whaling Commission) (2007a). Resolution 2007-3, Report of the Scientific Committee. *J. Cetacean Res. Manage*. 9(Suppl.), 1–73.

IWC (International Whaling Commission) (2007b). *Annual Report of the International Whaling Commission 2006*. International Whaling Commission.

IWC (International Whaling Commission) (2008a). *Chairman's Report of the Fifty-Nine Annual Meeting. Annex E. Resolutions Adopted at the 59th Annual Meeting*. Annual Report of the International Whaling Commission 2007.

IWC (International Whaling Commission) (2008b). *Annual Report of the International Whaling Commission 2007*. International Whaling Commission.

IWC (International Whaling Commission) (2009a). Report of the Scientific Committee. *J. Cetacean Res. Manage.* 11(Suppl.), 1–74.

IWC (International Whaling Commission) (2009b). *Annual Report of the International Whaling Commission 2008*. International Whaling Commission.

IWC (International Whaling Commission) (2010a). *Annual Report of the International Whaling Commission 2009*. International Whaling Commission.

IWC (International Whaling Commission) (2010b). Report of the workshop on cetaceans and climate change, 21–25 February 2009, Certosa di Pontignano dal Rettore dell Universitadegli Studi de Siena, Italy. SC/61/Rep4. *J. Cetacean Res. Manage*. (Suppl.) 11, 451–480.

IWC (International Whaling Commission) (2011a). *Five Year Strategic Plan for Whale watching 2011–2016*. Available online at: http://iwc.int/index.php?cID=3102&cType=document&download=1

IWC (International Whaling Commission) (2011b). Report of the Scientific Committee. *J. Cetacean Res. Manage.* 12(Suppl.), 1–75.

IWC (International Whaling Commission) (2011c). Report of the IWC POLLUTION 2000+ Phase II Workshop. SC/62/Rep4. *J. Cetacean Res. Manage.* 12, 423–436.

IWC (International Whaling Commission) (2011d). *Report of the Joint IWC-ACCOBAMS Workshop on Reducing Risk of Collisions between Vessels and Cetaceans. IWC/63/CC8*. Available online at: https://iwc.int/index.php?cID=370&cType=document&download=1

IWC (International Whaling Commission) (2012a). Report of the Scientific Committee. *J. Cetacean Res. Manage.* 13(Suppl.), 1–73.

IWC (International Whaling Commission) (2012b). Report of the Workshop on Small Cetaceans and Climate Change. SC/63/Rep1. *J. Cetacean Res. Manage.* 13, 319–336.

IWC (International Whaling Commission) (2012c). *Annual Report of the International Whaling Commission 2011*. International Whaling Commission.

IWC (International Whaling Commission) (2013a). *Report of the IWC 2013 Whale Watch Operators Workshop*. Available online at: https://iwc.int/document_3392

IWC (International Whaling Commission) (2013b). Report of the Scientific Committee. *J. Cetacean Res. Manage.* 14(Suppl.), 1–86.

IWC (International Whaling Commission) (2013c). *Annual Report of the International Whaling Commission 2012*. International Whaling Commission.

IWC (International Whaling Commission) (2014a). Report of the Scientific Committee. *J. Cetacean Res. Manage.* 15(Suppl.), 1–75.

IWC (International Whaling Commission) (2014b). Report of the IWC Scientific Committee Workshop on Marine Debris, 13–17 May 2013, Woods Hole, USA. *J. Cetacean Res. Manage.* 15(Suppl.), 519–541.

IWC (International Whaling Commission) (2014c). *Annual Report of the International Whaling Commission 2013*. International Whaling Commission.

IWC (International Whaling Commission) (2014d). *Report of the IWC Workshop on Mitigation and Management of the Threats Posed by Marine Debris to Cetaceans*. IWC/65/CCRep04. Available online at: https://archive.iwc.int/pages/view.php?ref=3497&k=&search=%21collection97&offset=0&order_by=relevance&sort=DESC&archive=0

IWC (International Whaling Commission) (2015a). Report of the Scientific Committee, 2014. *J. Cetacean Res. Manage.* 16(Suppl.), 1–87.

IWC (International Whaling Commission) (2015b). *Report of the IWC Climate Change Steering Group Meeting,* University of Glasgow, Available online at: https://iwc.int/climate-change

IWC (International Whaling Commission) (2016). Report of the Scientific Committee 2015. *J. Cetacean Res. Manage.* 17(Suppl.), 1–92.

NOAA (National Oceanographic and Atmospheric Administration) (2015). Marine debris website: http://marinedebris.noaa.gov/research-impacts/what-we-know-about-entanglement-and-ingestion

NOAA (National Oceanographic and Atmospheric Administration) Marine Debris Program. (2014). *Report on the Entanglement of Marine Species in Marine Debris with an Emphasis on Species in the United States*. Silver Spring, MD: National Oceanographic and Atmospheric Administration.

O'Connor S., Campbell R., Cortez H. and Knowles T. (2009). *Whale Watching Worldwide: Tourism Numbers, Expenditures and Expanding Economic Benefits, a Special Report from the International Fund for Animal Welfare*. Yarmouth: IFAW.

Pachauri, R. K., and Reisinger, A. (eds.). (2007). *Climate Change 2007: Synthesis Report, Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* IPCC.

Polyakova, O., Mazur, D., Ilyashenko, V., and Lebedev, A. (2012). *Contamination Problems of the Gray Whales*. Available online at: https://archive.iwc.int/pages/view.php?ref=3346&search=%21collection83&order_by=relevance&sort=DESC&offset=0&archive=0&k=&curpos=9

Reijnders, P. J. H., Donovan, G. P., Aguilar, A., and Björge, A. (eds.). (1999). Report of the Workshop on Chemical Pollution and Cetaceans. *J. Cetacean Res. Manage*. 1, 1–42.

Southall, B. L., Rowles, T., Gulland, F., Baird, R. W., and Jepson, P. D. (2013). *Final Report of the Independent Scientific Review Panel Investigating Potential Contributing Factors to a 2008 Mass Stranding of Melon-Headed Whales (Peponocephala electra) in Antsohihy, Madagascar*. Available online at: www.cascadiaresearch.org/Hawaii/Madagascar_ISRP_Final_report.pdf

Tejedor, A., Vera, J., Silber, G., Sagarminaga, R., Bettridge, S., and Palomares, M. (2013). *Report of a Workshop to Develop a Plan to Reduce the Risk of Whale-Ship Strikes, Santa Cruz de Tenerife (Canary Islands, Spain)*. Available online at: http://www.alnitak.info

Wright, A. J. (ed.). (2009). *Report of the Workshop on Assessing the Cumulative Impacts of Underwater Noise with Other Anthropogenic Stressors on Marine Mammals: From Ideas to Action. Monterey, California, U.S.A., 26th–29 August, 2009*. Okeanos—Foundation for the Sea, Darmstadt, Germany.

**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.

# Advantages of publishing in Frontiers

**OPEN ACCESS**
Articles are free to read, for greatest visibility

**COLLABORATIVE PEER-REVIEW**
Designed to be rigorous – yet also collaborative, fair and constructive

**FAST PUBLICATION**
Average 85 days from submission to publication (across all journals)

**COPYRIGHT TO AUTHORS**
No limit to article distribution and re-use

**TRANSPARENT**
Editors and reviewers acknowledged by name on published articles

**SUPPORT**
By our Swiss-based editorial team

**IMPACT METRICS**
Advanced metrics track your article's impact

**GLOBAL SPREAD**
5'100'000+ monthly article views and downloads

**LOOP RESEARCH NETWORK**
Our network increases readership for your article

**Frontiers**
EPFL Innovation Park, Building I • 1015 Lausanne • Switzerland
Tel +41 21 510 17 00 • Fax +41 21 510 17 01 • info@frontiersin.org
**www.frontiersin.org**

**Find us on**