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OPINION OPEN ACCESS

Marine Mammal Stranding Networks in the 21st Century: Whence and Whither?

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1 | A Rich History of Stranding Network Development

Marine mammals stranded ashore have captured human attention for centuries—Aristotle observed over 2000 years ago that dolphins sometimes came ashore for unknown reasons. Indigenous coastal communities from New Zealand to the Arctic have oral histories documenting stranding events (Marsh et al. 2022) and dramatic scenes of dead whales swarmed over by a curious public were recorded by 16th-century Dutch painters (Figure 1). The efforts of visionaries who saw the scientific potential in marine mammals stranded ashore have changed these events from spectacles to sites of scientific endeavor, providing the foundation for ocean biomonitoring programs worldwide. Stranded marine mammals have become recognized as sentinels for the health of conspecifics, their environment, and humans who depend on healthy ocean resources (Reddy et al. 2001). Continued investment in stranding network capacity could further enhance responses to both live and dead stranded animals, improving their welfare, expanding the science of these species, and better informing the "One Health" (an integrated, unifying approach that aims to optimize the health of people, animals, and ecosystem recognizing they are closely linked and inter-dependent) community and management actions for conservation.

Formal stranding network responses in the United States date back to 1883 (True 1883) when Frederick W. True (Marine Mammal Curator) and Spencer Fullerton Baird (Director) from the US National Museum of Natural History requested the Light Keepers of Cape Hatteras, NC, record data on marine mammal carcasses. In the United Kingdom, a 1913 agreement between the British Museum and Board of Trade recorded data on cetacean strandings by the "Receivers of Wreck" using a specific form transmitted to the museum by telegram (Fraser 1934). In 1968, New Zealand stranding data held in museums and private records were compiled by Gaskin (1968) to investigate potential causes of mass strandings (see Table 1 for a timeline of stranding network development). In the United States, Dr. James Mead and Mr. Charles Potter began their tenures at the Smithsonian Institution National Museum of Natural History in 1972, when they established the Stranding Event Alert Network "SEAN," and distributed brochures to ocean users requesting notification of cetacean carcasses discovered along the eastern seaboard from South Carolina to Massachusetts. These activities coincided with the passing of the Marine Mammal Protection Act of 1972 (MMPA) and were the impetus for the first US Marine Mammal Commission workshop on strandings in 1977. The workshop recommended development of regional stranding networks (Geraci and St. Aubin 1979). Over the following 20 years, regional stranding networks were also established in Europe, Asia, New Zealand, Canada, and Central and South America. The morbillivirus epizootics of 1987–1988 that caused strandings of thousands of seals in the United Kingdom and Europe and bottlenose dolphins (*Tursiops* spp.) along the east coast of the US-motivated governments to respond to strandings in these countries. A few years thereafter federal government-coordinated stranding networks were established in England and Wales in 1990, Scotland in 1992 and the United States in 1994.

FIGURE 1 | Restoration of Hendrick van Anthonissen's "View of Scheveningen Sands" by the Fitzwilliam Museum in 2014 revealed a beached whale (Figure 1a). Painted in 1641, the whale was obscured by 1873 when the painting was donated to the Fitzwilliam Museum in Cambridge, UK (Figure 1b). This painting's history reflects changing societal views to stranded whales (photos in the public domain).

Over the half century since the passing of the MMPA in 1972 and the international moratorium on commercial whaling in 1982, the responses to stranded marine mammals have advanced. The desire to improve the welfare of live animals ashore, as well as to maximize the science obtained from these animals, led to the publication in 1993 of the first globally recognized manual on how to respond to a stranded animal (Geraci and Lounsbury 1993, revised in 2005). To enhance coordination among responders, regional, national, and international networks have further developed (reviewed by Wilkinson and Worthy 1999; Simeone and Moore 2018). These networks are typically volunteer-led, with varying amounts of government, academic, and private support. A live dolphin ashore is no longer assumed to die, and sea otters, manatees, and pinnipeds have reproduced in the wild after release from rehabilitation (Newman et al. 2003; Yu et al. 2009; Wells et al. 2013; Adimey et al. 2016; Sharp et al. 2016; Neves et al. 2020). Stranding responders have been the drivers of improving marine mammal welfare globally.

TABLE 1 | Dates of significant events during the history of marine mammal stranding network developments.

Year	Event
1883	Frederick W. True and Spencer Fullerton Baird from the US National Museum of Natural History request that the Light Keepers of Cape Hatteras NC recover stranded marine mammals from the surrounding beaches and wire descriptions of the species of stranded cetacean.
1913	In the United Kingdom an arrangement is made between the British Museum (Natural History) and the Board of Trade, whereby cetacean strandings on British coasts were reported by the "Receivers of Wreck" to the museum using a specific form transmitted by telegram (Fraser 1934).
1968	California Department of Fish and Wildlife in the United States begins systematically documenting southern sea otter strandings.
1972	US Congress passes the Marine Mammal Protection Act (MMPA).
1972–1974	Smithsonian Institution recovers cetacean carcasses along the US eastern seaboard and initiates informal network development.
1975	Goodall presents the extent of resources naturally available from strandings in Patagonia to the IWC.
1977	First US Marine Mammal Commission workshop on strandings (Geraci and St. Aubin 1979).
1981	Governments of the Netherlands and Seychelles host a workshop to develop plans for scientific research in the Indian Ocean Whale Sanctuary, use of data from strandings proposed.
1984	Robson (1984) publishes "Strandings," giving advice for live animal response and a call for "using strandings to save life and give seminal opportunities to discover more about cetacean behavior and intelligence."
1987	Second US Marine Mammal Stranding Workshop.
1988	The New Zealand Whale Stranding Data Base (NZWSDB) is established, compiling historical records from museums, agencies and private citizens.
1988	British Divers Marine Life Rescue is created in the United Kingdom in response to the phocine distemper epizootic.
1989	The Caribbean Stranding Network (Red Caribena de Variamentos) is established. https://manatipr.org/nosotros/rcv/.
1990	UK Government establishes the Cetacean Strandings Investigation Program (England and Wales).
1992	University of Las Palmas Gran Canaria Veterinary School conducts first necropsy on a stranded dolphin in the Canary Islands, Spain.
1992	UK Government establishes the Scottish Marine Animal Strandings Scheme.
1992	US MMPA amendments establish the Marine Mammal Health & Stranding Response Program.
1993	"Marine Mammals Ashore" is published by Geraci and Lounsbury.
2000	First regional stranding network in Brazil is established (ICMBio 2011).
2000	Canary Islands Stranding Network Investigation Program is established.
2003	IWC hosts workshop on "Euthanasia Protocols to Optimize Welfare Concerns for Stranded Cetaceans." https://iwc.int/document_3449.
2008	Philippines Marine Mammal Stranding Network database is established (Aragones et al. 2010).
2011	The national Brazilian stranding network (REMAB) is created, unifying regional ones.
2016	IWC workshop to develop "Practical guidance for the handling of cetacean stranding events" to guide IWC Welfare Action Plan (IWC/66/WKM&WI Rep02).
2017	IWC develops Expert Panel on Strandings.
2019	Society for Marine Mammalogy (SMM) Barcelona Declaration Goal 2 states SMM conference delegates will "enhance and strengthen international collaboration to ensure consistent, high-quality response to stranded marine mammals globally."
2020	Canary Islands Wildlife Health Network (Red VIGIA) is established.

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TABLE 1 | (Continued)

Year	Event
2020	Global Stranding Network website is established to share existing protocols and guides (www.globalstrandingnetwork.org).

Abbreviation: IWC, International Whaling Commission.

1.1 | Value of Stranding Response

Stranded animals have provided the basis for numerous scientific advances (see Table 2 for illustrative examples). The body of science that has grown from beach-cast animals is remarkable given the limited funds spent obtaining the information. Response to stranded animals has not only allowed studies of their anatomy, biology, and physiology, but also detected impacts of human activities on their health and survival. For example, fisheries bycatch and entanglement of marine mammals are regularly identified through examination of stranded marine mammals (Friedlaender et al. 2001; de Quirós et al. 2018; Torres-Pereira et al. 2023; Peltier et al. 2024). Gas bubble disease, resulting from exposure to underwater sonar, was identified through investigation of mass strandings of beaked whales (Fernández et al. 2005). That finding provided the information that enabled the Spanish government to prohibit further naval exercises around the Canary Islands in beaked whale habitat (Fernández et al. 2012). The efficacy of the US ship speed reduction rule was associated with a reduction in the number of stranded North Atlantic right whales detected with traumatic lesions typical of vessel strike (van der Hoop et al. 2015), though vessel strikes and entanglement mortalities of North Atlantic right whales continue, Sharp et al. (2019), and require continued monitoring. The impact of the *Deep Water Horizon* oil spill on dolphin populations in the Gulf of Mexico was assessed through examination of stranded animals, and the results used to guide the fines assessed to the responsible party (Venn-Watson et al. 2015). A suite of toxins, chemicals, and pathogens has been detected in stranded marine mammals, often for the first time in the marine environment (reviews in Gulland et al. 2018). The recent global spread of highly pathogenic avian influenza (HPAI) was detected in marine mammals by sampling stranded animals (Uhart et al. 2024). Mass strandings of baleen whales in Chile and Argentina have highlighted the increases in the extent and duration of harmful algal blooms that poison seafood consumed by both humans and marine mammals (Häussermann et al. 2017), emphasizing the role that understanding marine mammal health plays in the "One Health" concept.

1.2 | Limitations and Challenges Faced by Stranding Networks

Although stranded animals provide opportunities for scientific discovery, disease monitoring, toxin biomonitoring, and assessment of management actions, stranding networks are not achieving their full potential due to a number of limitations. There is still no globally recognized coordination of stranding responses. For example, HPAI recently killed tens of thousands of pinnipeds in South America and has been detected in sporadic cases of stranded seals and dolphins in the United States and Europe (Puryear et al. 2022; Runstadler and Puryear 2024; Uhart et al. 2024). Although this virus is of global concern (having potential to cause a pandemic in humans and kill critically endangered wildlife such as California condors) the lack of a formal global stranding network prevents the efficient, international dissemination of information on virus spread, case detections, and response protocols to stranding responders who could be faced with cases. Instead, communication among stranding responders around the world is dependent upon a few dedicated people working and communicating through a variety of independent organizations.

Internationally, the stranding community uses organizations such as the World Organization for Animal Health (WOAH), the Wildlife Disease Association, the Society for Marine Mammalogy, and the International Whaling Commission, among others, for communicating marine mammal disease information, with some stranding responders represented in multiple organizations, and others having no representation. Some countries such as the United States, the United Kingdom, and New Zealand have strong government directives, staff, and/or financial support for stranding responses, but such support can be unpredictable and change depending on their sitting administration's priorities. Other countries, on the other hand, depend upon volunteer private organizations to provide stranding response, care for animals, and collect and synthesize data.

The extent of medical care for individual marine mammals, data collection, and public outreach varies among responders due to differing resources, expertise, training, logistical support, and institutional missions. This results in variability in animal welfare, science, and communication of information to managers and the public. This variability limits the ability to broadly apply stranding data to understand threats to marine mammals, such as identifying impacts of human activities (fisheries interactions, vessel strikes, sound impacts, marine debris), documenting the emergence and spread of infectious disease, harmful algal blooms, and environmental contaminants, and detecting effects of climate change on marine mammal distribution and health. Individual responders collect a plethora of data, and some networks have shared databases (reviewed in Chan et al. 2017), yet there is no global meta-database of marine mammal stranding or health information, nor a simple, secure, accessible method to share basic stranding data. This limits the use of stranding data to inform One Health programs and their use in guiding conservation actions.

The numbers of reports of stranded marine mammals have increased in most parts of the world in recent years, partially due to increased awareness and communications about stranding events (Simeone et al. 2015). The widespread use of social media has resulted in heightened public awareness, speculations, expectations, and scrutiny of stranding responses. The recovery

TABLE 2 | Examples of scientific advances dependent upon the response to marine mammal strandings that illustrate the range of studies that utilize sampling of stranded animals.

Scientific field		Examples	References
Anatomy		Vaquita morphology	Brownell (1983)
		Dental morphology	Loch et al. (2013)
		Vasal passage anatomy of Delphinidae	Mead (1975)
		Beaked whale anatomy	Rommel et al. (2006)
		Aquatic adaptations	Reidenberg (2007)
		Manatee diaphragm	Rommel and Reynolds (2000)
		Comparative sinus morphology	Racicot and Berta (2013)
Life history	Diet	Methods review	Barros and Clark (2009); Bowen and Iversen (2013)
		Beluga diet	Quakenbush et al. (2015)
		Pilot whale stomach contents	Beatson et al. (2007)
		Niche feeding in bottlenose dolphins	Gibbs et al. (2011)
	Age, growth, reproduction	Longevity, growth curves, physical maturity	Evans and Hindell (2004); Guarino et al. (2021)
		Aging methods review	Read et al. (2018)
		Vaquita life history	Hohn et al. (1996)
		Age of sexual maturity, calving interval, lactation period, and ovulation and pregnancy rates	Calzada et al. (1996); Roca et al. (2022)
Genetics	Novel species identification	Rice's whale, Beaked whale species, Fraser's dolphin	Perrin et al. (1973); Rosel et al. (2021), Carroll et al. (2021), Yamada et al. (2019)
	Stock structure	Bottlenose dolphin stock structure	McLellan et al. (2002)
	Evolution	Risso's dolphin diversity, elephant seal fitness associations	Chen et al. (2018); Hoffman et al. (2024)
Physiology	Respiratory	Dolphin pulmonary function	Fahlman et al. (2024)
	Metabolism	Sea otter energy budgets	Cortez et al. 2016
	Endocrinology	Blubber and baleen hormones to evaluate reproduction and stress	Hunt et al. (2016); Lysiak et al. (2018); Agusti et al. (2022)
	Hearing	Audiograms	Pacini et al. (2011); Mooney et al. (2020)
Range and distribution		Beaked whales in UK waters	MacLeod et al. (2004)
		Longman's beaked whale distribution	Dalebout et al. (2003); Kobayashi et al. (2021)

(Continues)

TABLE 2 | (Continued)

Scientific field		Examples	References
Health and disease	Emerging pathogen and zoonosis detection	Morbillivirus epizootics	Kennedy et al. (1988); Krafft et al. (1995)
		Brucella detection	Foster et al. (2002); Hernández-Mora et al. (2008)
		Toxoplasmosis in sea otters, Hawaiian monk seals, Maui's dolphins	Li et al. (2022)
		Influenza in pinnipeds, cetaceans	Webster et al. (1981); Uhart et al. (2024).
		Fungal pathogens	Burek-Huntington et al. 2014; Huggins et al. (2020); Teman et al. (2021)
		Novel pathogens	Nielsen et al. (2017); Stokholm et al. 2022
	Chemical pollution	Association of pollutants with cancer in belugas, California sea lions	Martineau et al. (2002); Gulland et al. (2020).
		Reviews of pollutant levels and effects	Fossi and Panti (2018)
		Pollutant levels in tissues of strandings	Ross et al. (2004, 2013); Dorneles et al. (2010).
	Effects of harmful algal blooms	Domoic acid toxicosis in sea lions	Scholin et al. (2000).
		Saxitoxin poisoning of large whales	Geraci et al. (1989)
		Brevetoxicosis in manatees, dolphins	Fire et al. (2015)
	Climate change effects	Pathogen spread in the Arctic	Goertz et al. (2013)
Effects of human activities	Ocean noise, sonar	Mass strandings caused by naval sonar	Balcomb and Claridge (2001); Fernández et al. (2005)
	Fisheries interactions	Bycatch distribution, lesions	Byrd et al. (2008); Peltier et al. (2016); Torres-Pereira et al. (2023); Zuo et al. (2023).
	Vessel strikes	Incidence, locations, effects of management actions	Laist et al. (2001); Douglas et al. (2008); van der Hoop et al. (2013); Berman-Kowalewski et al. (2010); Peltier et al. (2019); Sharp et al. 2019; Winkler et al. (2020).
	Oil spills	Effects on sea otters of *Exon Valdez* spill, effects on dolphins of *Deep Water Horizon* oil spill	Monson et al. (2000); Venn-Watson et al. (2015)
	Plastic pollution	Review	Zantis et al. (2021).

of populations such as humpback whales (*Megaptera novaeangliae*) and some pinniped species or stocks, as well as shifts in distribution associated with climate change, has led to a rise in stranding reports due to increased presence of these animals along human-populated coastlines. Increases in vessel traffic, ocean noise, harmful algal blooms, and coastal run-off of pathogens and pollutants also cause more marine mammals to strand (Plön et al. 2024). Caring for and sampling rising numbers of stranded marine mammals increases demands on stranding networks and emphasizes the need for communication and collaboration among responders.

1.3 | Opportunity and Future Directions

The increased reports of stranded animals, advances in live animal care, and continuously growing amount and types of information that are learned from marine mammal strandings are opportunities for enhancing the stranding networks around the world. A single formal international organization with regional chapters dedicated to stranding response could enable rapid communication among members about species, locations, timings, and causes of strandings, and consequently improve communication about threats to both marine mammals and coastal communities. This information could inform managers to enable timely enactment of steps to mitigate risks and protect marine mammals. Table 2 presented here could become a web-based resource updated regularly to maximize use of information from stranding responses. Oliveira et al. (2024) recently outlined how a stranding network could be improved in Brazil to enhance the utility of the data generated for management. Such a vision could be applied elsewhere.

For example, for HPAI cases in marine mammals, shared resources could enhance diagnostics and promote timely sharing of response protocols to enhance human and animal protection from the disease. Similarly, information on timing, location, and sources of injury to marine mammals from vessels, fisheries, and other human activities can currently be slow to reach people at local, national, or international levels who could use the information to mitigate activities harming marine mammals. For example, the popular press reported that humpback whale carcasses found along the east coast of the United States in 2023 were suspected to have died as a consequence of offshore wind energy development. This is despite necropsies by stranding network responders identifying lesions typical of vessel strikes in these dead whales, and construction for wind energy platforms had not yet started (Hussain 2024; Thorne and Wiley 2024). A formal pathway for communicating stranding responders' findings efficiently to managers and the public could prevent such misunderstandings.

For stranding networks to achieve their full potential, they need the support that comparable organizations dedicated to human (e.g., the World Health Organization, Centers for Disease Control) and livestock health (e.g., WOAH) are given.

The formation of a unifying community-led stranding network organization could overcome some of the limitations resulting from varied capabilities of organizations of different sizes and resources and the patchiness in response capabilities. This could influence positive change for marine mammal health and welfare, supporting the alignment of response and animal care practices, standardized data collection, management, and reporting, and the establishment of agreed research priorities in the face of environmental change. Cultural and legal frameworks influencing responses to marine mammal strandings vary around the world, and a unified stranding network community could enhance the standardization of response guidelines to improve animal welfare. The Society for Marine Mammalogy called for increased international capacity in stranding response in the Barcelona Declaration in 2019 (https://www.wmmconference.org/barcelona-declaration). Let us act upon this now and build upon the last half-century of expertise in stranding response to further improve animal welfare and use the science generated from stranding responses to provide for conservation actions. It is time to establish a formal Global Marine Mammal Stranding Network with regional chapters and strong private and public support.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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