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Spatiotemporal Variation of Stranded Marine Mammals in the Philippines from 2005 to 2022: Latest Stranding Hotspots and Species Stranding Status

Lemnuel V. Aragones,[1,2] Alessandra Nicole L. Morado,[1,2]
Marie Christine M. Obusan,[2,3] Honey Leen M. Laggui,[1,2] Jonah L. Bondoc,[2,4]
Leo Jonathan A. Suarez,[2,5] and Ewen Kye Lawler[6]

[1]*Institute of Environmental Science & Meteorology (IESM), College of Science (CS),*
University of the Philippines (UP) Diliman, Quezon City, Philippines
E-mail: ldaragones@up.edu.ph
[2]*Philippine Marine Mammal Stranding Network Inc., IESM, CS, UP Diliman, Quezon City, Philippines*
[3]*Institute of Biology, CS, UP Diliman, Quezon City, Philippines*
[4]*Natural Sciences Research Institute, CS, UP Diliman, Quezon City, Philippines*
[5]*Ocean Adventure, Ilanin Forest West, Subic Bay Freeport, Bataan, Philippines*
[6]*Centre for Conservation Ecology and Genomics, Institute for Applied Ecology, University of Canberra, Australia*

Abstract

This follow-up study to the first assessment of Philippine marine mammal strandings (1998 to 2009) assesses the spatiotemporal variation of strandings and the top five most frequently stranded species from a 2005-2022 dataset. It identifies stranding hotspot areas, estimates species stranding rates/status, and examines species composition and other stranding information. The 18-year database contained 1,368 stranding events with an annual average of 76 events. The total annual stranding frequency increased over the initial study period but fluctuated in the last seven years. Of the 30 species of marine mammals known in the Philippines, 27 species (26 cetaceans and one sirenian) were recorded in stranding records, and the top five most frequently stranded were (1) spinner dolphins (*Stenella longirostris*), (2) dugongs (*Dugong dugon*), (3) Risso's dolphins (*Grampus griseus*), (4) Fraser's dolphins (*Lagenodelphis hosei*), and (5) melon-headed whales (*Peponocephala electra*). Strandings consisted mostly of single animals (95%), and 55% of animals stranded alive. For each of the top five species, the frequency of stranding events increased annually. There was a peak in stranding frequency during the pre-southwest inter-monsoon season (March-April-May) for spinner and Risso's dolphins as well as melon-headed whales, with no seasonal trend for the Fraser's dolphins and dugongs. We identified stranding hotspots within 15 × 15 km grids along the coastline of the major island groups: Luzon, Visayas, and Mindanao. Thirty-five percent (497 of 1,422 grids) of the Philippine coastline had stranding records, with the majority in Luzon (*n* = 238), followed by Mindanao (*n* = 130) and Visayas (*n* = 128). Thirty-five stranding hotspots were identified: 24 in Luzon, 10 in Mindanao, and one in Visayas. Species stranding status categories were generated from log transformed stranding rates per species into standardized classification by quartiles. The stranding status of the top five most frequently stranded species was "very frequent" for spinner dolphins, and "frequent" for Fraser's and Risso's dolphins, dugongs, and melon-headed whales. The spatiotemporal variation of stranded marine mammals reflects the dynamic nature of the Philippine archipelago driven by monsoons and inter-monsoons and is exacerbated by fishing pressure and illegal activities. This study showed the importance of robust long-term marine mammal stranding databases for monitoring strandings and generating relevant information essential for their conservation.

Key Words: stranded marine mammals, Philippine Marine Mammal Stranding Network, stranding hotspots, stranding database, stranding status

Introduction

Stranding events provide vital information for monitoring health status, population trends, and biodiversity and distribution of marine mammals, as well as aspects of ocean health (Norman et al., 2004; Bossart, 2010; Ponnampalam, 2012; Truchon et al., 2013; Byrd et al., 2014). Established stranding networks and databases have been critical in generating important information such as spatiotemporal trends, probable causes, and species composition of stranding events (López et al., 2002; Aragones et al., 2010; Chan et al., 2017; Ijsseldijk et al., 2020). Important information generated from a stranding database can include the identification of stranding hotspots which represent areas of concern where the frequency of strandings is relatively high (Bradshaw et al., 2006; Aragones et al., 2010). Stranding databases can also be utilized to assess species stranding status (i.e., species rate of stranding) as a measure of potential threat to particular species or populations, especially in areas where abundance estimates are lacking and/or for rare species.

Recent studies have recommended the development of comprehensive and standardized databases for long-term monitoring (Foord et al., 2019; Dudhat et al., 2022). Fortunately, the Philippine Marine Mammal Stranding Network (PMMSN), established in 2005 (https://pmmsn.org), has maintained a national marine mammal stranding database since its inception. The PMMSN is a registered nonprofit organization that consists of volunteers from mandated agencies, academia, industry, and coastal local government units (LGUs). Through a Memoranda of Agreement (MOA) with all coastal regional offices of the Philippines' Bureau of Fisheries and Aquatic Resources (BFAR), the PMMSN has nationwide coverage, and has been authorized to respond to strandings and collect primary data. The database is kept and sustained by its research arm—Institute of Environmental Science and Meteorology, University of the Philippines (UP) Diliman in Quezon City. The PMMSN's effort in conducting training workshops and seminars facilitated the increase in stranding reports across the Philippines (Aragones et al., 2010). Furthermore, the PMMSN has been publishing biennial reports on marine mammal strandings (Aragones et al., 2017, 2022; Aragones & Laggui, 2019; Aragones & Morado, 2023). In a previous study of marine mammal strandings in the Philippines, Aragones et al. (2010) showed the importance of standardized databases and nationwide coverage by trained members organized according to regional stranding network chapters. They provided initial information on strandings and validated the local species composition of marine mammals (28 cetaceans and the dugong). The dugong and the Irrawaddy dolphin in the Philippines are both classified as "Critically Endangered" based on local status and are frequently involved in strandings (Aragones et al., 2010, 2017; Aragones & Laggui, 2019). They also attributed the proliferation of strandings to dynamite fishing, marine mammal–fisheries interactions, and toxins.

This study is an update of Aragones et al. (2010), which examined the 1998 to 2009 dataset. This study uses data from 2005 to 2022, starting from when the PMMSN was established in 2005 and systematic collection of the data began. Through the years, as the PMMSN conducted first response training workshops nationwide, the number of trained responders has increased and have added to the timeline of stranding data and also have added new data that had been missed in the original stranding database. As both stranding data and biological samples accumulated, opportunities became available to answer questions not just regarding strandings but also on the ecology, biology, and impacts of humans on these animals (Obusan et al., 2016; Bondoc et al., 2017). Despite this recent increase in collection of stranding data, there is still limited information regarding these animals in the Philippines in terms of abundance, distribution, and conservation status.

This study assessed the spatiotemporal variation of stranding events and the top five most frequently stranded species; generated fine-scale stranding hotspot areas and stranding status; and examined species composition and other vital information such as age class, sex, and animal condition (alive or dead) provided by these stranding datasets. Our results underpin the importance of an extensive national stranding network and a robust database.

Methods

Data Collection

The current study uses data collected by PMMSN from 2005 to 2022. It includes the 2005 to 2009 stranding data from Aragones et al. (2010) since there were 38 additional strandings for those years that were missed in the initial database. Prior to the establishment of the PMMSN in 2005, stranding data were either incomplete or unreported. Thus, stranding records beginning in 2005 onwards were considered in this study.

The PMMSN is authorized to respond and collect data by virtue of MOAs with the mandated agency BFAR. Stranding data throughout the Philippines were collected and collated by the PMMSN in collaboration with national government agencies such as the BFAR of the Department of Agriculture (DA), LGUs, academics, and NGOs following Aragones et al. (2010), which laid down a consistent framework for data collection. The locals from the LGU often report the stranding incident to the PMMSN or BFAR, and then trained personnel are mobilized to provide instructions and/or proceed to the site for proper response, including data gathering. The PMMSN uses standardized stranding report forms to collect data, including information on species, date and location of the stranding, sex, age class, type of stranding, and animal condition (i.e., whether animals are stranded dead or alive). Additional information was collected, including morphometrics, necropsy results, the types of samples that were collected (if any), possible cause of stranding, carcass state (i.e., freshly dead to mummified), and mode of disposal. Whenever possible, photographs and videos were also taken and recorded. Relevant archived stranding data from news and social media were also considered.

Data Analysis

General Stranding Information—*Stranding events* were classified as single, mass, out-of-habitat, or unusual mortality events. A *single stranding* refers to an individual animal or a mother–calf pair; a *mass stranding* indicates a simultaneous stranding of two or more cetaceans other than just a mother–calf pair (which are considered a single stranding); *out of habitat* refers to a near-stranding event (i.e., when pelagic marine mammals are found nearshore); and *unusual mortality events* (UMEs) are strandings involving several individuals across a wide geographic area under unusual circumstances or significant die-offs, which demand an immediate response (Gulland, 2006). *Stranding frequency* was analyzed by species composition, stranding type, sex, age class, and condition of the animals. The top five most frequently stranded species (MFSS) were identified from the overall stranding frequency data.

Spatial Variation of Total Stranding Frequency Using Fishnet Grids—Spatial analysis of total stranding frequency over the 18-y dataset was conducted using fishnet grids in *ArcGIS*, Version 10.7 software (Environmental Systems Research Institute [ESRI], 2018) positioned adjacent to the Philippine main island groups: Luzon, Visayas, and Mindanao (Figure 1). The 15 × 15 km grids were created along the Philippine coastline using the 'Create Fishnet' tool (https://desktop.arcgis.com/en/arcmap/latest/tools/data-management-toolbox/create-fishnet.htm). The 15 × 15 km grid size was based on the general average shoreline length of all Philippine coastal municipalities or cities and considering the complex coastal configuration of the islands. This grid size is also designed to identify LGU-level hotspots and inform the appropriate political decisionmakers' units regarding the implications of these areas to marine mammal conservation and management (see "Discussion"). All stranding events point location data were plotted, including every individual recorded under UMEs, to capture the spatial distribution of stranding events. The grids were classified according to those with or without strandings across the Philippine island groups. Similarly, the spatial variation of stranding frequency of the top five MFSS was also analyzed using the 'Fishnet' tool.

Temporal Variation of Stranding Frequencies—To explore temporal trends in the frequency of stranding events recorded, generalized linear mixed models (GLMMs) were fitted, specifying a Poisson error distribution with a log link function (appropriate for count data). Year was modelled as a fixed effect because of an observed increase in stranding frequency across the study period. Year, species, and season were also included as random effects. Two GLMMs were run: the first using the entire dataset for all species (all species model) and the second using only data for the top five species (top five species model). For the top five species model, the seasonal effects were allowed to vary between species (i.e., random intercepts and slopes) since there were sufficient data per species to facilitate this type of analysis. Seasons were subdivided and classified as (1) December-January-February (DJF) as the northeast (NE) monsoon, (2) March-April-May (MAM) as the pre-southwest (SW) inter-monsoon, (3) June-July-August (JJA) as the SW monsoon, and (4) September-October-November (SON) as the pre-NE inter-monsoon (e.g., Villafuerte et al., 2017; Oliveros et al., 2019). The GLMMs were implemented in the *R* environment (R Core Team, 2023) using the 'glmer' function from the 'lme4' package (Bates et al., 2015), with overdispersion corrected for by the inclusion of an observation-level random effect term in each model.

Spatiotemporal Variation: Identification of Stranding Hotspots, Spatiotemporal Trend for All Species, and Top Five MFSS—A combination of spatial and temporal (spatiotemporal) analysis was employed in this study to identify trends in strandings. To produce spatiotemporally explicit maps for all species (combined) and top five MFSS, the mean annual stranding rates per 15 × 15 km grid were first calculated. Eighteen vector maps representing each study year were created showing grids with corresponding stranding frequency values. Each vector map was converted to raster maps to allow calculation of mean annual stranding rates per grid. The rates were generated by the 'Calculate Statistics' tool in *ArcGIS*, Version 10.7 (https://desktop.arcgis.com/en/arcmap/latest/tools/data-management-toolbox/calculate-statistics.htm). This tool created a single map by combining the 18 maps and displaying mean annual stranding rates for the grids. Finally, the stranding rates within the grids were classified into four categories—(1) low, (2) medium, (3) high, and (4) very high—using the Natural Jenks method. The Natural Jenks method produces logical groupings inherent in the data (de Smith et al., 2018). Grids with high and very high stranding rates were considered to be stranding hotspots. Subsequently, each stranding hotspot grid was identified at the municipal/city or LGU level, noting that, in some cases, a grid had multiple LGUs. To allow visualization of the development of the different hotspots within the 18-y period, stacked bar charts were employed showing the frequency of stranding events occurring in each

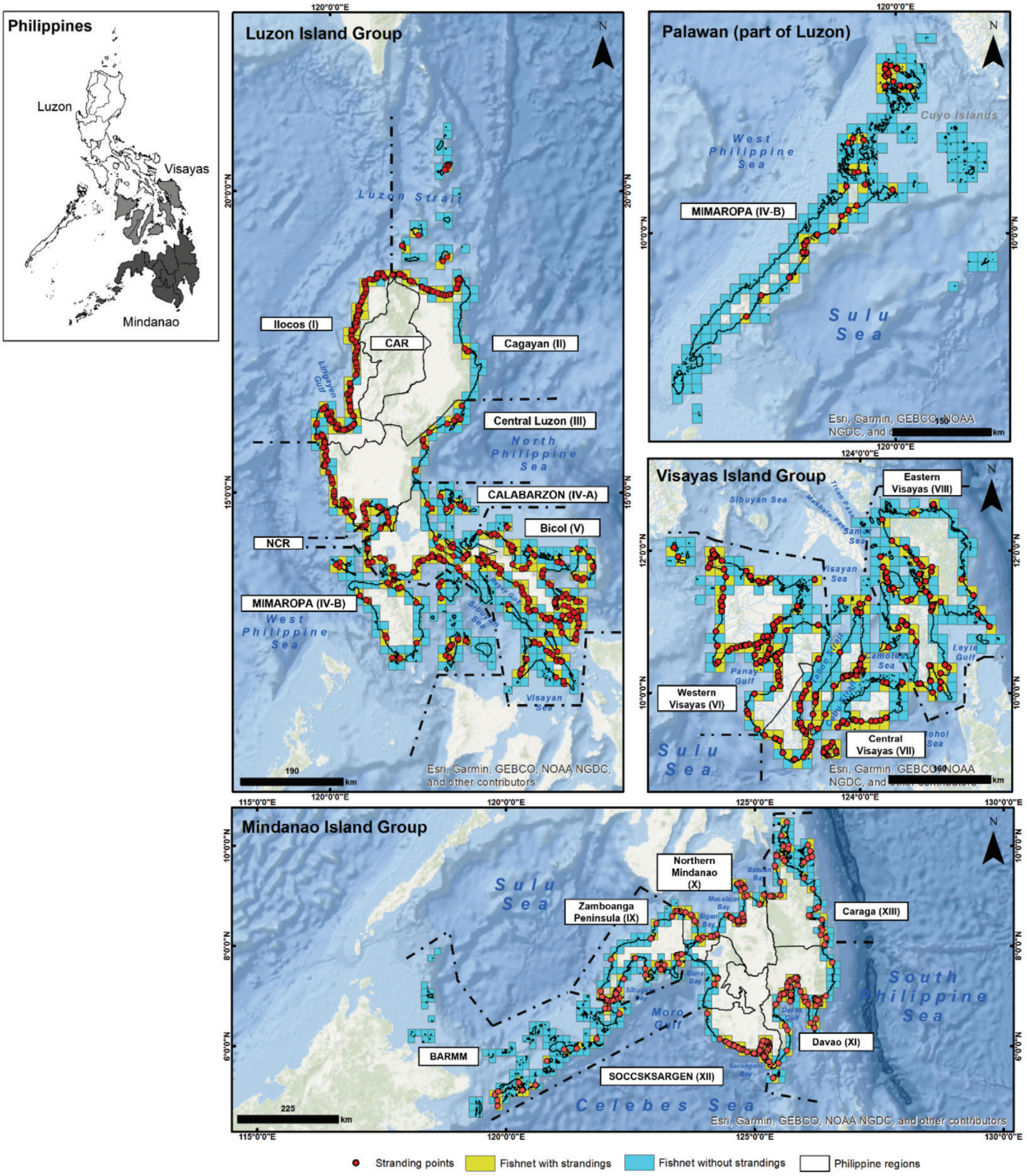

Figure 1. Marine mammal strandings from 2005 to 2022 across the Philippine coastline represented as 15 × 15 km cell grids subdivided into Luzon, Visayas, and Mindanao island groups. (Maps have varying scales.)

identified hotspot for all species over every 3-y interval. For the top five MFSS, maps were augmented by bar charts showing the development of the hotspots over the years.

Species Stranding Status—The application of species stranding status based on the mean annual stranding rate for each stranded marine mammal species in the Philippines was used in the study. This was generated by calculating the annual stranding rates of each species over the 18-y dataset. The rates were log transformed to normalize data and standardize classification by quartiles. The stranding status of each marine mammal species was classified either as an extremely rare species to strand (< -1.00), very rare (-0.50 to -0.99), rare (-0.49 to -0.01), moderate (0.00 to 0.49), frequent (0.50 to 0.99), and very frequent (> 1.00).

Results

Overall Trends

A total of 1,368 stranding events were recorded from 2005 to 2022 with an average of 76 events per year. In a moving average of 3-y intervals, the annual stranding frequencies generally increased from 29 (2005-2007) to 45 (2008-2010), 67 (2011-2013), 91 (2014-2016), 117 (2017-2019), and 106 (2020-2022). The single stranding event was the most common type (n = 1,294), consisting of 1,316 individuals (95%), including 21 mother–calf pairs. The rest of the 2,674 individuals consisted of 1,110 out of habitat, 202 mass strandings, and 46 associated with UMEs (Table 1).

Table 1. Frequency of strandings events per stranding type and total number of individuals per species from 2005 to 2022. **Note:** When the frequency of strandings is the same as the number of individuals, there is no need for showing those same numbers in brackets.

		Stranding/out-of-habitat frequency (# of individuals)				Total stranding/ out-of-habitat frequency (# of individuals)
	Species	Single	Mass	Out-of-habitat	UME	
1	*Stenella longirostris*	213 (219)*	4 (8)	1		218 (228)
2	*Dugong dugon*	104 (105)*				104 (105)
3	*Grampus griseus*	95	4 (8)	1		100 (104)
4	*Lagenodelphis hosei*	88	4 (31)		1 (31)	93 (150)
5	*Peponocephala electra*	74 (76)*	6 (29)	9 (863)		89 (968)
6	*Kogia breviceps*	85 (87)*				85 (87)
7	*Stenella attenuata*	78 (82)*	1 (15)	1 (100)		80 (197)
8	*Globicephala macrorhynchus*	64	2 (5)	2 (7)	2 (10)	70 (86)
9	*Kogia sima*	69 (72)*	1 (2)			70 (74)
10	*Physeter macrocephalus*	64	1 (2)	1		66 (67)
10	*Tursiops aduncus*	44	5 (24)			49 (68)
11	*Steno bredanensis*	41	3 (14)			44 (55)
12	*Tursiops truncatus*	35	3 (8)	3 (22)		41 (65)
13	*Stenella coeruleoalba*	35 (36)*	4 (13)			39 (49)
14	*Feresa attenuata*	18	7 (37)		1 (5)	26 (60)
15	*Pseudorca crassidens*	22				22 (22)
16	*Ziphius cavirostris*	19	2 (4)			21 (23)
17	*Balaenoptera edeni*	21				21 (21)
18	*Mesoplodon densirostris*	17		1		18 (18)
19	*Balaenoptera* spp.	12				12 (12)
20	*Orcaella brevirostris*	9				9 (9)
21	*Balaenoptera omurai*	8				8 (8)
22	*Megaptera novaeangliae*	8				8 (8)
23	*Mesoplodon* spp.	4				4 (4)
24	*Balaenoptera physalus*	3				3 (3)
25	*Tursiops* spp.	2				2 (2)
26	*Indopacetus pacificus*	1	1 (2)			2 (3)
27	*Mesoplodon hotaula*	2 (3)*				2 (3)
28	*Delphinus delphis*	1				1 (1)
39	*Mesoplodon gingkodens*	1				1 (1)
30	Unidentified	57 (59)*		3 (114)		60 (173)
	Total	1,294 (1,316)	48 (202)	22 (1,110)	4 (46)	1,368 (2,674)

*With mother and calf (considered as single strandings but counted as two individuals)

**Individual records of each UME were integrated in spatial analysis to indicate expanse of the event.

General Stranding Information: Species Composition, Type of Stranding, Sex, Age Class, and Animal Condition

Twenty-seven marine mammal species representing two Orders (Cetacea and Sirenia) have stranded along the Philippine coastline over the 18-y study period (Table 1). Among these, the top five MFSS were the spinner dolphin (*Stenella longirostris*; *n* = 218), dugong (*Dugong dugon*; *n* = 104), Risso's dolphin (*Grampus griseus*; *n* = 100), Fraser's dolphin (*Lagenodelphis hosei*; *n* = 93), and melon-headed whale (*Peponocephala electra*; *n* = 89). The pygmy sperm whale (*Kogia breviceps*; *n* = 85), pantropical spotted dolphin (*Stenella attenuata*; *n* = 80), short-finned pilot whale (*Globicephala macrorhynchus*; *n* = 70), dwarf sperm whale (*Kogia sima*; *n* = 70), and sperm whale (*Physeter macrocephalus*; *n* = 66) were listed as sixth to tenth most frequent. The rest of the 17 species were members of various cetacean Families, including members of Delphinidae (Indo-Pacific [*Tursiops aduncus*] and common [*Tursiops truncatus*] bottlenose dolphins; rough-toothed [*Steno bredanensis*], striped [*Stenella coeruleoalba*], Irrawaddy [*Orcaella brevirostris*], and long-beak common [*Delphinus delphis*] dolphins; and pygmy [*Feresa attenuata*] and false [*Pseudorca crassidens*] killer whales), Ziphiidae (Cuvier's [*Ziphius cavirostris*], Blainville's [*Mesoplodon densirostris*], Longman's [*Indopacetus pacificus*], ginkgo-toothed [*Mesoplodon ginkgodens*], and Deraniyagala's [*Mesoplodon hotaula*] beaked whales), and Balaenopteridae (Bryde's, [*Balaenoptera brydei*], Omura's [*Balaenoptera omurai*], humpback [*Megaptera novaeangliae*], and fin [*Balaenoptera physalus*] whales).

All species that stranded have at least one single stranding type event record, while there were 12 species that have records of mass strandings. The species that most frequently mass stranded were the pygmy killer whale (*n* = 7 events with two to 12 individuals) followed by the melon-headed whale (*n* = 6 events involving two to nine individuals). The rare Longman's beaked whale had one mass stranding record. There were nine occasions when pods of hundreds of melon-headed whales were observed to be out of habitat. There were four recorded UMEs: once each for Fraser's dolphins (involving 31 individuals) and pygmy killer whales (four involving five individuals), and two for short-finned pilot whales (eight and three individuals, respectively). Note that in the 18-y database, only the short-finned pilot whale had records for all stranding types (single, mass, out-of-habitat, and UME).

The sex ratio between females (*n* = 337) and males (*n* = 327) was almost equal. There were 30 stranding events with mixed sex composition, which includes mother–calf pairs, mass stranding, and out-of-habitat incidents. However, the sex of animals in half of the total stranding events (*n* = 703) was undetermined as the responders were unable to record it. Most stranding events involved adults (72.5%), followed by subadults (15.2%), and the rest included calves, neonates, mother–calf pairs, and unknown. About 55% (*n* = 775) of the stranding events involved animals that were initially alive, while 44% (*n* = 571) were already dead, and only 1% (*n* = 6) was mixed (alive and dead). Among the live strandings, 23% were identified as females (*n* = 188) and 20% as males (*n* = 155). Conversely, a slightly higher proportion of dead strandings involved males (*n* = 173) as compared to females (*n* = 149).

Spatial Trends by Island Groups

In terms of frequency of stranding events per island group, Luzon had the highest number (*n* = 778), followed by Mindanao (*n* = 342) and then Visayas (*n* = 278). However, these were not uniformly distributed along the coastline. A total of 1,422 15 × 15 km grids were generated along the entire Philippine coastline (Figure 1). The Luzon island group has the longest coastline and, therefore, has the highest number of grids (*n* = 685), followed by the Mindanao (*n* = 400) and the Visayas (*n* = 337) island groups. Out of the 1,422 15 × 15 km grids, 496 grids had strandings. Luzon had the highest number of grids with strandings (*n* = 238), followed by the Mindanao (*n* = 130) and Visayas (*n* = 128) island groups. However, among these island groups, strandings were slightly more dispersed in the Visayas as indicated by a marginally higher proportion of total grids with strandings (37.98%) followed by Luzon (34.74%) and then Mindanao (32.50%).

Spatial Trends of Top Five Most Frequently Stranded Species

Spinner dolphins appeared to have the highest number of stranding grids (*n* = 145), followed by Risso's dolphins (*n* = 83), Fraser's dolphins (*n* = 79), melon-headed whales (*n* = 87), and dugongs (*n* = 57). Stranded spinner dolphins were recorded in 36% of Visayas' total grids with strandings, followed by 31% for Luzon and 20% for Mindanao. Dugong strandings were mostly located in Mindanao's grids (*n* = 23), with strandings appearing in 17 grids for both Luzon and Visayas. Fraser's dolphins stranded within about 15 to 16% of each island group's total grids. Risso's dolphin strandings occupied 21% of Luzon's total grids with strandings, 14% for Visayas, and 11% for Mindanao. Meanwhile, melon-headed whale strandings were reported in 17, 16, and 12% of Luzon, Visayas, and Mindanao total island grids, respectively.

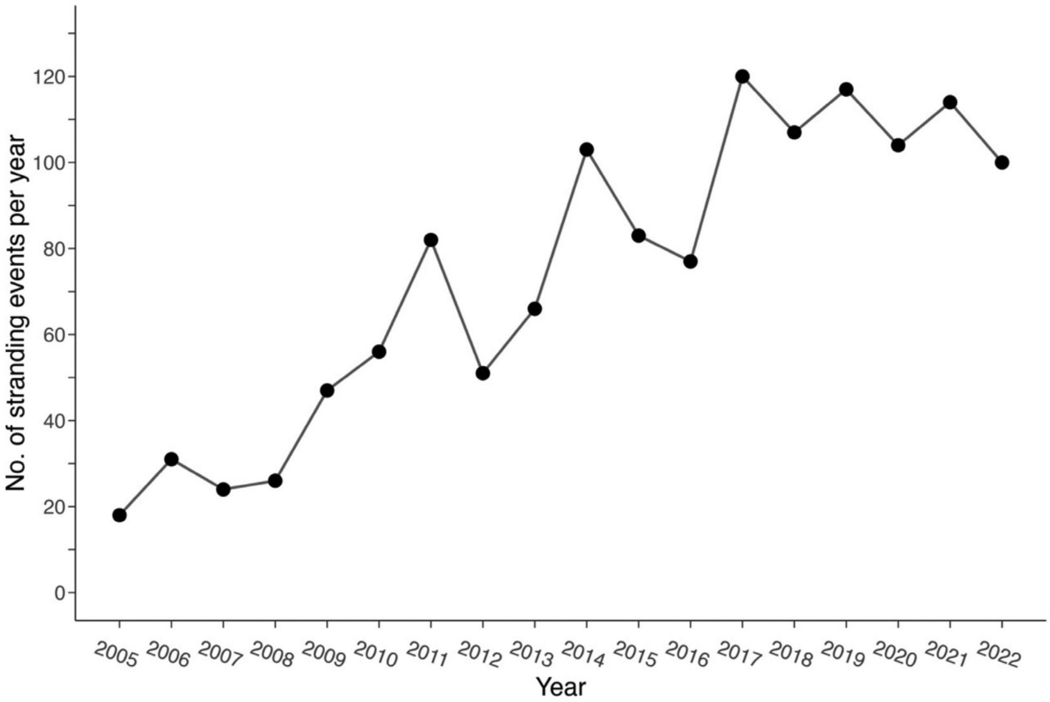

Figure 2. Annual total frequency of marine mammal strandings in the Philippines from 2005 to 2022

Temporal Trends

The frequency of recorded stranding events significantly increased between 2005 and 2022 in the all combined species model (z = 8.561, $p < 0.001$; Figure 2) and the top five species model (z = 6.204, $p < 0.001$; Figure 3a). The highest number of strandings occurred in 2017 with 122 recorded across the top five species, followed by 2019 (*n* = 120), 2021 (*n* = 116), 2018 (*n* = 109), 2014 (*n* = 105), and 2020 (*n* = 104). The lowest numbers of strandings were recorded in the early years of the network: 2005 (*n* = 23), 2007 (*n* = 28), and 2008 (*n* = 30).

All top five species were recorded in the stranding database every year since the national stranding network started in 2005, except for the dugong in 2005 and 2007, and melon-headed whale in 2012 (Figure 3a). Spinner dolphin stranding events were considerably more common than other species (Figures 3a & 3b). The sudden peak in spinner dolphin strandings was most notable among the annual trends of the five species (Figure 3a). The spinner dolphin had a peak of 30 stranding events in 2014, and relatively high strandings of spinner dolphins were also observed in 2017 (*n* = 21) and 2019 (*n* = 23). Peak number of strandings among the other four MFSS were dugong in 2017 (*n* = 15), melon-headed whale in 2010 (*n* = 9) and 2020 (*n* = 13), Fraser's dolphin in 2020 (*n* = 12), and Risso's dolphin in 2017 (*n* = 12).

The top five species model supported a consistent seasonal pattern in stranding frequency for Risso's dolphins, spinner dolphins, and melon-headed whales, where strandings were most common during MAM (Figure 3b). While the wide 95% confidence intervals surrounding the model estimates indicate considerable uncertainty, it is reasonable to presume that this pattern is non-random given the consistency in the trend across the three species in the model estimates and the raw data means. In contrast, the GLMM showed no consistent seasonal trend in Fraser's dolphins or dugongs.

Spatiotemporal Trends

Figure 4 shows the map of the mean annual stranding rates for each island group. Out of the 496 grids with strandings, there were 329 low stranding rate grids (0.06 to 0.17), 132 medium grids (0.18 to 0.39), 30 high grids (0.40 to 0.78), and five very high grids (0.79 to 1.22). Grids with high and very high annual stranding rates were considered hotspot areas. Out of the low stranding rate grids, the majority were found in Luzon Island (44%), while Visayas and Mindanao Islands accounted for 28% each. About 52% of the total medium stranding rate

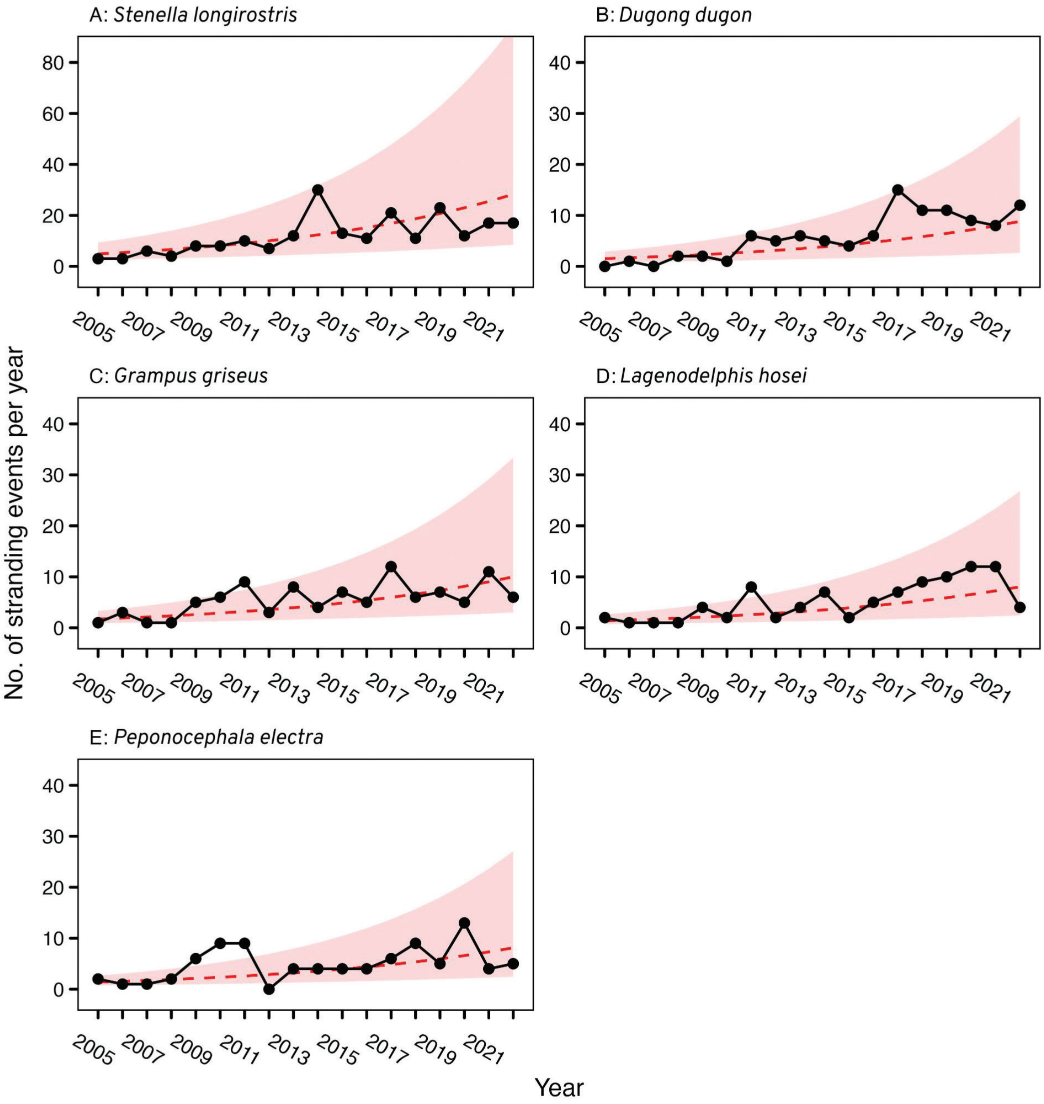

Figure 3a. Annual rates of marine mammal strandings in the Philippines and top five most frequent stranded species (MFSS) from 2005 to 2022 (A = spinner dolphin [*Stenella longirostris*], B = dugong [*Dugong dugon*], C = Risso's dolphin [*Grampus griseus*], D = Fraser's dolphin [*Lagenodelphis hosei*], and E = melon-headed whale [*Peponocephala electra*]). Black dots represent the number of recorded stranding events each year. Red lines represent predictions from the top five species model (red shaded areas represent ±95% CI).

grids were found in Luzon, with the rest in Visayas (27%) and Mindanao (22%). Similarly, most of the stranding hotspots (Table 2), which were comprised of high and very high stranding rate grids, were in Luzon. Around 63 and 100% of the high and very high stranding rate grids, respectively, were found in this island group. Mindanao had 33% of the high stranding rate grids, while only one high stranding grid was identified in Visayas.

The stranding hotspots identified to the municipal- or city-level (LGUs) are summarized in Table 2. There were 35 municipal/city-level stranding hotspots. As indicated above, most of these stranding hotspots were in Luzon Island, and 16 out of 24 hotspots in Luzon were found in Region I (Ilocos Region). The top stranding municipal/city hotspot located in Region I is Badoc & Currimao (H1) in the province of Ilocos Norte,

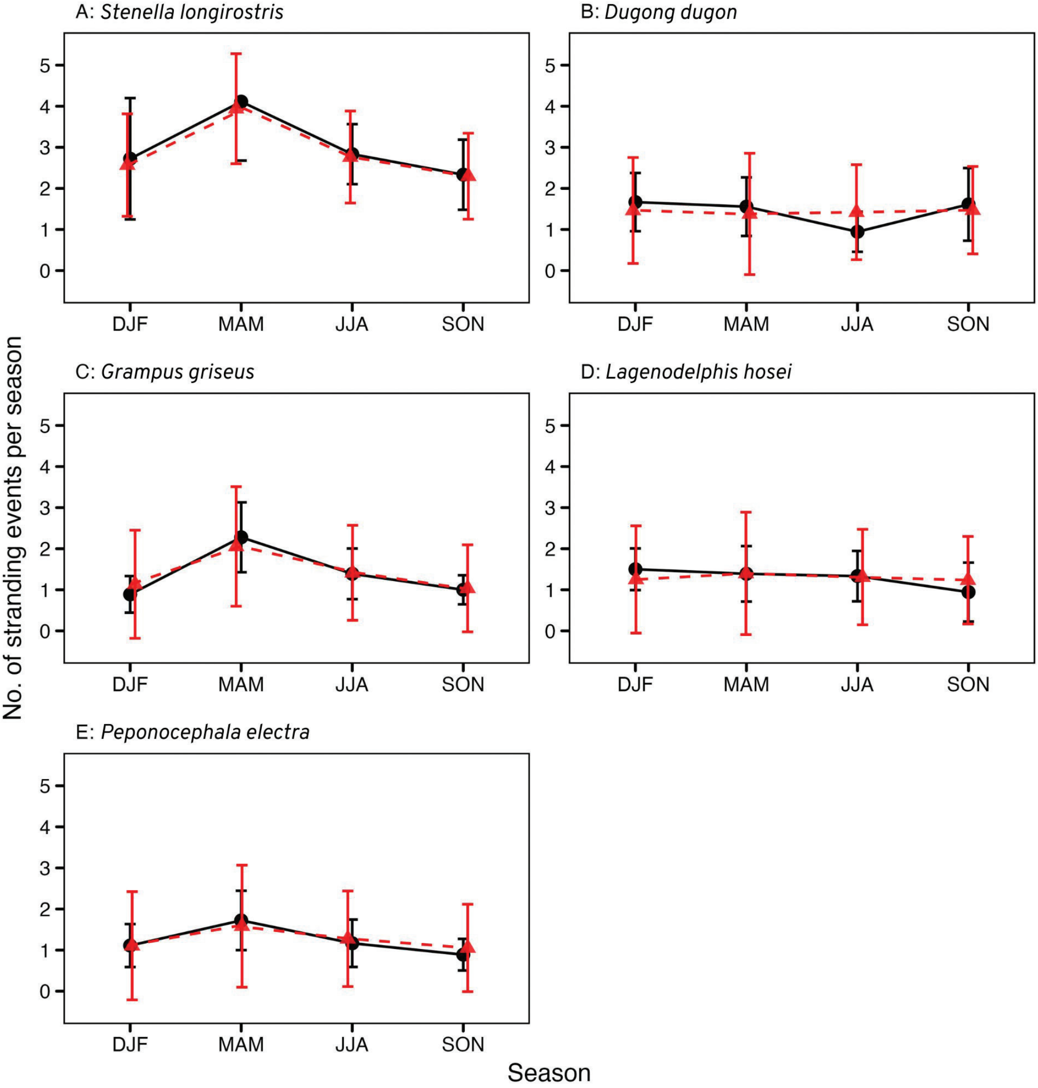

Figure 3b. Seasonal rates of marine mammal strandings in the Philippines and top five MFSS from 2005 to 2022 (A = spinner dolphin, B = dugong, C = Risso's dolphin, D = Fraser's dolphin, and E = melon-headed whale). Black dots represent the mean (±95% CI) number of strandings recorded in the DJF, MAM, JJA, and SON seasons. Red dotted lines represent predictions from the top five species model (red triangles indicate the means ±95% CI) for the number of strandings recorded each season while holding year constant.

and Dagupan City & Eastern Lingayen (H3) in Pangasinan with the mean annual stranding rate of 1.22 and 1.11, respectively. The second stranding hotspot was found in Santa Ana of Cagayan in Region II. Region V (Bicol) hosted four stranding hotspots with the highest mean annual stranding rate recorded in Del Gallego, Camarines Sur. In Mindanao Island, stranding hotspots were concentrated in Regions XI (n = 4) and XII (n = 4). Region XI (Davao Region) stranding hotspots included Mati City, Southern Davao City, Maco, Tagum City, Mabini, and Northern Davao City. All hotspots in Region XII (SOCCSKSARGEN [South Catobato, Catobato, Sultan Kudarat, Sarangani, and General Santos City]) were located along Sarangani Bay: Alabel & Malapatan, Glan, General Santos City, and Maasim.

Figure 5 shows the 35 hotspots and how each has developed over 3-y intervals ("periods") through the 18-y study period. Generally,

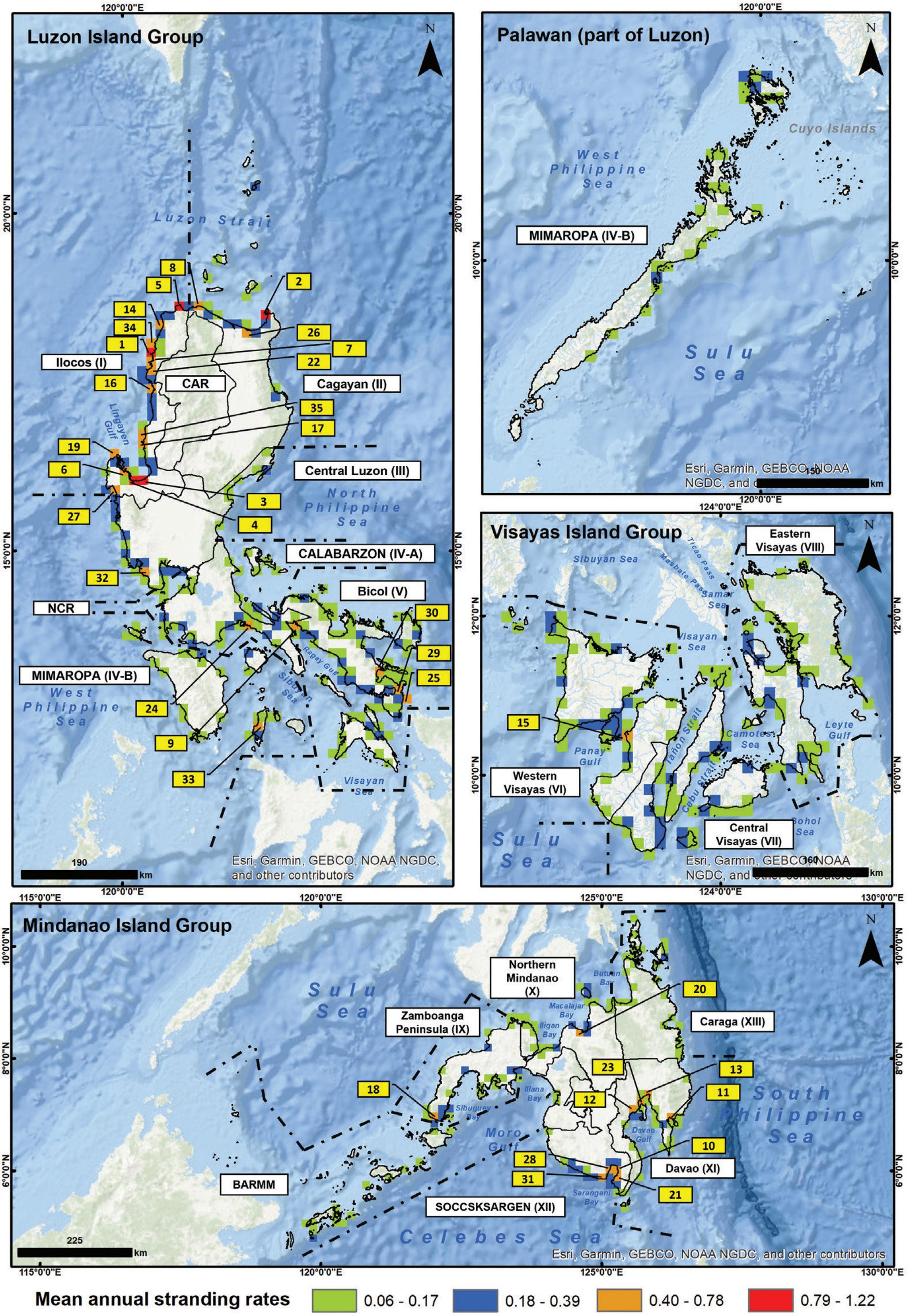

Figure 4. Marine mammal mean annual stranding rates from 2005 to 2022 across the Philippine coastline represented as 15 × 15 km fishnet grids subdivided into Luzon, Visayas, and Mindanao island groups (number labels represent stranding hotspots as listed in Table 2)

Table 2. Marine mammal stranding hotspots in the Philippines derived from 2005 to 2022 dataset

	Municipality/City	Province	Island group (Region)	Mean annual rate
Red hotspots (with mean annual rates of 0.7785 to 1.2222)				
1	Badoc & Currimao	Ilocos Norte	Luzon (Region I)	1.22
2	Santa Ana	Cagayan	Luzon (Region II)	1.17
3	Dagupan City & Eastern Lingayen	Pangasinan	Luzon (Region I)	1.11
4	Western Lingayen, Labrador & Sual	Pangasinan	Luzon (Region I)	0.94
5	Pagudpud	Ilocos Norte	Luzon (Region I)	0.89
Orange hotspots (with mean annual rates of 0.3896 to 0.7784)				
6	Alaminos City	Pangasinan	Luzon (Region I)	0.78
7	Cabugao, Sinait & San Juan	Ilocos Sur	Luzon (Region I)	0.78
8	Claveria & Sanchez-Mira	Cagayan	Luzon (Region I)	0.78
9	Del Gallego	Camarines Sur	Luzon (Region V)	0.78
10	Alabel & Malapatan	Sarangani	Mindanao (Region XII)	0.72
11	Mati City	Davao Oriental	Mindanao (Region XI)	0.72
12	Southern Davao City	Davao del Sur	Mindanao (Region XI)	0.72
13	Maco, Tagum City & Mabini	Compostela Valley & Davao del Norte	Mindanao (Region XI)	0.61
14	Pasuquin	Ilocos Norte	Luzon (Region I)	0.61
15	Pulupandan & Bago City	Negros Occidental	Visayas (Region VI)	0.61
16	Narvacan	Ilocos Sur	Luzon (Region I)	0.56
17	San Fernando City & Bauang	La Union	Luzon (Region I)	0.56
18	Zamboanga City	Zamboanga del Sur	Mindanao (Region IX)	0.56
19	Bolinao	Pangasinan	Luzon (Region I)	0.50
20	Cagayan de Oro City	Misamis Oriental	Mindanao (Region X)	0.50
21	Glan	Sarangani	Mindanao (Region IX)	0.50
22	Magsingal & Santo Domingo	Ilocos Sur	Luzon (Region I)	0.50
23	Northern Davao City	Davao del Sur	Mindanao (Region XI)	0.50
24	Padre Burgos & Agdangan	Quezon	Luzon (Region IV-A)	0.50
25	Barcelona	Sorsogon	Luzon (Region V)	0.44
26	Buguey	Cagayan	Luzon (Region I)	0.44
27	Dasol	Pangasinan	Luzon (Region I)	0.44
28	General Santos City	Sarangani	Mindanao (Region XII)	0.44
29	Gubat	Sorsogon	Luzon (Region V)	0.44
30	Legazpi City	Albay	Luzon (Region V)	0.44
31	Maasim	Sarangani	Mindanao (Region XII)	0.44
32	Morong	Bataan	Luzon (Region III)	0.44
33	Odiongan	Romblon	Luzon (Region IV-B)	0.44
34	Paoay & Currimao	Ilocos Norte	Luzon (Region I)	0.44
35	San Juan	La Union	Luzon (Region I)	0.44

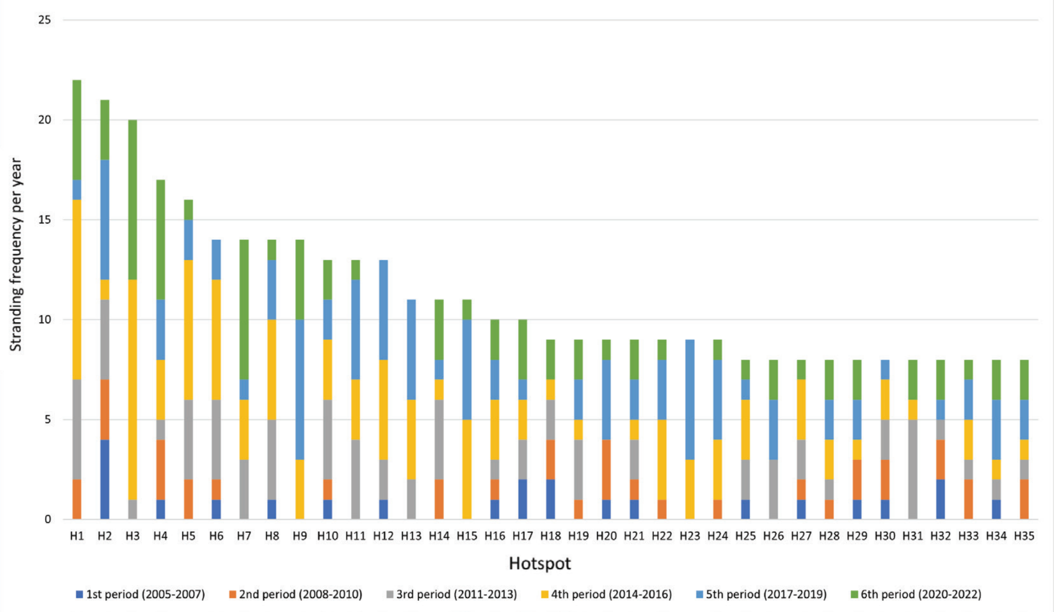

Figure 5. Development of the 35 stranding hotspots of all stranding events across the 18-y period (each stacked bar represents a 3-y period)

the periods during the latter half of the study had the most strandings across all hotspots, and these hotspots started to develop as early as the 1st period (2005 to 2007). Most of the hotspots (*n* = 26) started to accumulate strandings since the 2nd and 3rd periods (2008 to 2010 and 2011 to 2013), and the remaining hotspots began to develop from the 4th period (2014 to 2016). The 26 hotspots consistently had strandings in the later 5th and 6th (2017 to 2022) periods except for Cagayan de Oro City (H20) and Magsingal & Santo Domingo (H22), which only had strandings in the initial four periods. Out of the six hotspots that started to develop in the 3rd period, Dagupan City & Eastern Lingayen (H3), Cabugao, Sinait & San Juan (H7), and Maasim (H31) were notable. Although H3 was among the top five hotspots, it only had strandings in three periods, which peaked in the 4th (*n* = 11) and 6th (*n* = 8) periods. H7 had a steady increase in strandings until the 6th period during which it had seven events. On the other hand, H31 started with a high number of strandings (*n* = 5) and levelled off in the 4th and 6th periods. Del Gallego (H9), Pulupandan & Bago City (H15), and Northern Davao City (H23) were the most recent hotspots to develop (started in the 4th period). H23 was notable since it had only two periods with strandings: the 4th and 5th periods.

The hotspots of the top five MFSS and their temporal patterns are shown in Figure 6. Only those very high stranding rate grids of the top five MFSS were further analyzed temporally. Among the top five MFSS, only Risso's dolphin had no very high stranding hotspots and had 68 low and 15 high stranding rate grids. The spinner dolphin had 103 low, 35 high, and seven very high stranding rate grids. These seven hotspots include the municipalities or cities of Badoc & Currimao, Mobo, Lapu-Lapu City, Del Gallego, Donsol, Odiongan, and Legazpi City (in descending order of rates) and had strandings for 2 to 4 y over the course of the 18-y period. One to two stranding events on average occurred in every year a hotspot had strandings, except in Donsol, which had three strandings in 2017. For Fraser's dolphin, there were 59 low, 11 medium, eight high, and one very high stranding rate grid. The only stranding hotspot for this species was in Dagupan City & Eastern Lingayen with 10 strandings in 2015, and one each in 2020 and 2021. There were 39 low, nine medium, and six high stranding rate grids for the dugong. The three hotspots identified for the dugong were Mati City, Glan, and Busuanga. There were 2 to 4 y with one to two stranding events that occurred every year, except for Mati City and Busuanga with four in 2011 and 2017, respectively. The melon-headed whale had two stranding hotspots located in Pilar and Maasim municipalities that had 2 to 3 y with one to two events that occurred each year. The other grids had 60 low and nine high stranding rates.

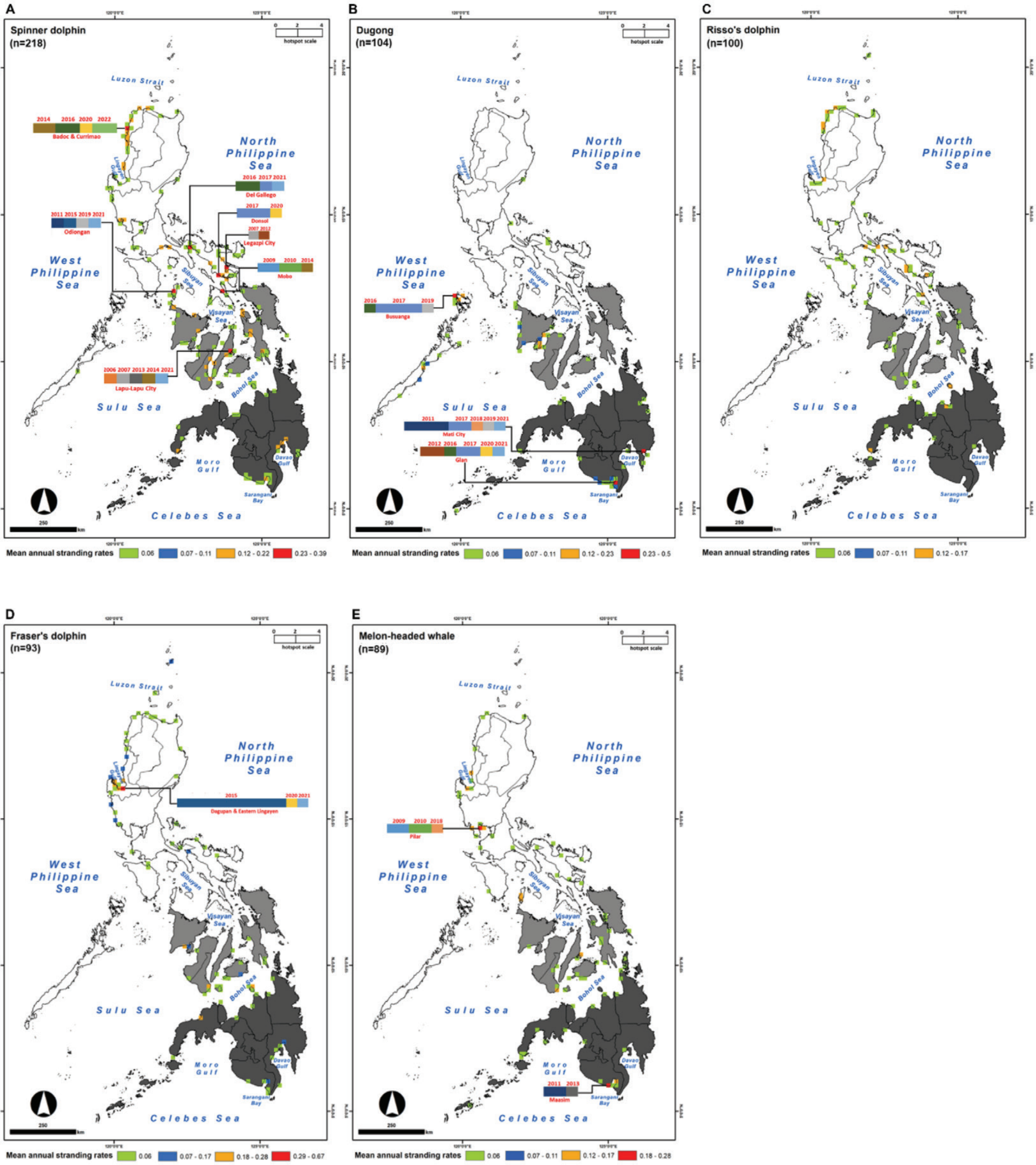

Figure 6. Mean annual stranding rates of the top five MFSS from 2005 to 2022 across the Philippine coastline represented as 15 × 15 km fishnet grids subdivided into Luzon, Visayas, and Mindanao island groups. Each panel represents one of the top five MFSS (A = spinner dolphin, B = dugong, C = Risso's dolphin, D = Fraser's dolphin, and E = melon-headed whale). The development of each red grid across the 18-y period is displayed with the (black and grey) frequency scale as reference for the total recorded strandings every year.

Table 3. The annual stranding rates, and conservation and stranding status of marine mammal species that stranded in the Philippines from 2005 to 2022 (after Aragones, 2008; Aragones et al., 2010, 2017, 2022; Aragones & Laggui, 2019)

Species	CITES[1]	IUCN *Red List*[2]	Annual stranding rate (log transformed)	Stranding status[6]
Order Cetacea				
Suborder Odontoceti (Toothed whales, dolphins, and porpoises)				
Family Delphinidae[3]				
Stenella longirostris (Spinner dolphin)	II	LC	12.06(1.08)	Very frequent
Lagenodelphis hosei (Fraser's dolphin)	II	LC	6.78(0.83)	Frequent
Grampus griseus (Risso's dolphin)	II	LC	5.56(0.75)	Frequent
Peponocephala electra (Melon-headed whale)	II	LC	4.83(0.68)	Frequent
Globicephala macrorhynchus (Short-finned pilot whale)	II	LC	4.33(0.64)	Frequent
Stenella attenuata (Striped dolphin)	II	LC	4.33(0.64)	Frequent
Tursiops aduncus (Indo-Pacific bottlenose dolphin)	II	NT	2.61(0.42)	Moderate
Steno bredanensis (Rough-toothed dolphin)	II	LC	2.44(0.39)	Moderate
Tursiops truncatus (Common bottlenose dolphin)	II	LC	2.33(0.37)	Moderate
Stenella coeruleoalba (Pantropical spotted dolphin)	II	LC	2.11(0.32)	Moderate
Feresa attenuata (Pygmy killer whale)	II	LC	1.61(0.21)	Moderate
Pseudorca crassidens (False killer whale)	II	NT	1.22(0.09)	Moderate
Orcaella brevirostris (Irrawaddy dolphin)	I	EN	0.50(-0.30)	Rare
Delphinus delphis (Longbeak common dolphin)	II	LC	0.06(-1.22)	Very rare
Family Kogiidae[3] (Pygmy and dwarf sperm whales)				
Kogia breviceps (Pygmy sperm whale)	II	LC	1.61(0.21)	Moderate
Kogia sima (Dwarf sperm whale)	II	LC	3.89(0.59)	Frequent
Family Physeteridae[3]				
Physeter macrocephalus (Sperm whale)	I	VU	3.61(0.56)	Frequent
Family Ziphiidae[3] (Beaked whales)				
Ziphius cavirostris (Cuvier's beaked whale)	II	LC	1.17(0.07)	Moderate
Mesoplodon densirostris (Blainville's beaked whale)	II	LC	1.00(0.00)	Moderate
Indopacetus pacificus (Longman's beaked whale)	II	LC	0.17(-0.77)	Rare
Mesoplodon hotaula (Deranayigala's beaked whale)	Unclassified	DD	0.11(-0.96)	Rare
Mesoplodon gingkodens (Ginkgo-toothed beaked whale)	II	DD	0.06(-1.22)	Very rare
Suborder Mysticeti (Baleen whales)				
Family Balaenopteridae[3] (Rorquals)				
Balaenoptera edeni (Bryde's whale)	I	LC	1.17(0.07)	Moderate
Balaenoptera omurai (Omura's whale)	I	DD	0.44(-0.36)	Rare
Megaptera novaeangliae (Humpback whale)	I	LC	0.44(-0.36)	Rare
Balaenoptera physalus (Fin whale)	I	VU	0.17(-0.77)	Rare
Order Sirenia				
Family Dugongidae				
Dugong dugon[4, 5] (Dugong)	I	VU	5.61(0.77)	Frequent

[1] CITES Appendix I – These are most endangered species among CITES species; they are threatened with extinction and prohibited for international trade except for uncommercial purposes (e.g., scientific research) (valid from 22/6/2022).
CITES Appendix II – These are species not threatened with extinction unless trade is uncontrolled (valid from 22/6/2022).

[2] Based on IUCN *Red List* categories: Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), and Data Deficient (DD) (Version 2022-2).

[3] Protected under Bureau of Fisheries and Aquatic Resources (BFAR) Fisheries Administrative Order Nos. 185 series of 1992 and 185-1 series of 1997.

[4] Protected under Department of Environment and Natural Resources (DENR) Administrative Order No. 55 series of 1991.

[5] Classified as "Critically Endangered" under the DENR AO 2019-09.

[6] Stranding categories were based on values of annual stranding rates: very rare (< -1.00), rare (-0.01 to -1.00), moderate (0.00 to 0.50), frequent (0.51 to 1.00), and very frequent (> 1.00).

The annual stranding rates, calculated stranding status (SS), and latest conservation status (based on the International Union for Conservation of Nature [IUCN] *Red List* and CITES) of the 27 marine mammals that stranded in the Philippines from 2005 to 2022 are summarized in Table 3. When calculating species SS, only one species was classified as very frequent (spinner dolphin), three were frequent (Fraser's and Risso's dolphins, and dugong), nine moderate (melon-headed, short-finned pilot, dwarf sperm, and sperm whales; and striped, Indo-Pacific and common bottlenose, rough toothed, and pantropical spotted dolphins), six rare (pygmy killer, false killer, pygmy sperm, Cuvier's beaked, Blainville's beaked, and Bryde's whales), and eight very rare (Irrawaddy and long beaked common dolphins; and Longman's beaked, Deranayigala's beaked, ginkgo-toothed beaked, Omura's, humpback, and fin whales). The two most critically endangered marine mammal species in the Philippines—the dugong and the Irrawaddy dolphin—had SS of frequent and rare, respectively. Sperm and fin whales are currently classified as "Vulnerable" under the IUCN *Red List*, and they had SS of moderate and very rare, respectively.

Discussion

The establishment and continuation of a national stranding database has improved the current knowledge on marine mammals confirmed in the Philippines. To date, there are 30 marine mammals recorded in the Philippines, including 29 cetaceans and the dugong (Aragones, 2008; Aragones & Laule, 2008; Aragones et al., 2010, 2017, 2022; Aragones & Laggui, 2019). This study recorded 27 stranded species out of the 30 confirmed species. The two species that did not strand from 2005 to 2022 are killer whales (*Orcinus orca*; only stranding recorded in Sarangani Bay in 2004) and minke whales (*Balaenoptera acutorostrata*; only recorded in Bacoor, Cavite; Herre, 1925), while the third species, the blue whale (*Balaenoptera musculus*), has, fortunately, yet to strand. In this study, four species of cetaceans have been added to the list as the first records within the Philippine waters: Deranayigala's beaked whale, ginkgo-toothed beaked whale, fin whale, and long-beak common dolphin. As late as 2001, there were only 17 species confirmed in the Philippines (Leatherwood et al., 1992; Perrin et al., 2005). Since then, some species have been removed from the list of confirmed marine mammal species in the country because of the absence of sightings or strandings, while many others have been added through stranding records (Aragones et al., 2010). Without a comprehensive stranding database, the list of marine mammals in the Philippines would have remained inaccurate given the lack of large-scale surveys.

The presence of a diverse assemblage of marine mammals in the Philippines highlights the importance of the dynamic and complex marine ecosystem inherent in this archipelagic country. The Philippine archipelago is bordered by vast oceanic basins (North, South, and West Philippine Seas and Celebes Sea); dynamic internal seas (e.g., Sulu and Bohol Seas); and gulfs (e.g., Davao and Lingayen Gulfs), bays (e.g., Sarangani and Macajalar Bays), straits (e.g., Tañon and Cebu Straits), and passes (e.g., Ticao and Masbate Passes), all of which are influenced seasonally by monsoons (Cabrera et al., 2011; Gordon et al., 2011; Villanoy et al., 2011), upwellings (Udarbe-Walker & Villanoy, 2001), fronts, and runoffs (Cabrera et al., 2011; Custado & David, 2021). The oceanographic and climatic factors likely contribute to the high productivity within its waters. Similar observations of a diverse array of marine mammals were reported both in the archipelagoes of the Canary and Hawaiian Islands (Faerber & Baird, 2010; Baird et al., 2013a, 2013b).

A concerning rise in marine mammal stranding events has been observed over the past 18-y period in the Philippines. Globally, a similar increasing trend in strandings has been observed in association with a rise in a variety of contributory factors, including fisheries effort and interactions, ship strike, disease, climate variability, and reduced prey availability (Norman et al., 2004; Gulland & Hall, 2007; Leeney et al., 2008; Truchon et al., 2013; Prado et al., 2016; Peltier et al., 2019; Olson et al., 2020). Aragones et al. (2010) suggested that the increase in strandings observed in their initial assessment (1998 to 2009) was an artifact of the growing awareness of strandings in the Philippines as the PMMSN's coverage expanded and the number of trained responders increased. To date, the PMMSN has certified 4,800 first responders from BFAR regional offices, LGUs, and other concerned institutions (e.g., Philippine Coast Guard, Philippine Navy, higher education institutions, and NGOs). From 2010 to 2022, training sessions were continuously conducted every year, producing an annual average of 262 additional trained responders. In addition, the availability and affordability of electronic communication (e.g., mobile phones, Internet accessibility) might have contributed to the rise of reported strandings nationwide. However, we suggest the increasing trend in strandings reported in this study is most likely beyond the artifact effects alone but that they are influenced by the growing human activities in our marine environment, often resulting in the amplification of marine mammal–human/fisheries interactions (discussed further below).

The top five MFSS showed interesting annual patterns across the Philippines. Patterns in number of strandings per species per year were attributed to the peaks observed in spinner dolphin in 2014, and melon-headed whale in 2010 and 2020. Spinner dolphins have consistently been the top MFSS among marine mammals in the Philippines annually, except in 2010 and 2020 when there were unusually high numbers of strandings for other species. The peak in 2010 was driven by the mass stranding that occurred in Region III, while the peak in 2020 was caused by an unexplained rise in strandings overall. The 2014 peak in the spinner dolphins ($n = 30$) has been harder to explain. There were no major mass strandings nor UME involved, and most of the spinners that stranded involved single events.

The pygmy killer whale and melon-headed whale were the main species that mass stranded and were reported stranded out of habitat in the Philippines, similar to other reports in the literature. The pygmy killer whale's major mass stranding hotspot was identified as Taiwan by Brownell et al. (2009). Similarly, the melon-headed whales have several mass stranding (Southall et al., 2006) and out-of-habitat records in Hawaii (Baird, 2016) and Japan (Amano et al., 2014). This species is known to be very social and is often found in groups numbering in the hundreds (Jefferson et al., 2015).

In this study, stranding frequencies did not vary that much among seasons, with notable exceptions such as peak strandings during MAM during the pre-SW inter-monsoon. The findings of the study were in contrast with others which observed heightened strandings during the monsoon seasons (Redfern et al., 2017; Dudhat et al., 2022). A variety of factors may influence the seasonal patterns of strandings observed in this study, including and perhaps primarily oceanographic factors. For instance, the high frequency of strandings during the NE monsoon season during DJF may be driven by the upwelling occurrence in northwestern Luzon (Udarbe-Walker & Villanoy, 2001). The high productivity in the upwelling zone may attract marine mammals in this area which, in turn, may influence strandings (Anderson et al., 2012). The remnant productivity of the NE monsoon (Liu et al., 2002) could also explain the observed peaks in strandings during the MAM season. Furthermore, a possible peak in fishing effort for small pelagic fish species during the MAM (inter-monsoon) season in the Philippines (Villanoy et al., 2011) may have put the animals at higher risk of fisheries interactions (Hines et al., 2020; Verutes et al., 2020). Seasonal stranding patterns were observed in spinner dolphin, Risso's dolphin, and melon-headed whale, but not in Fraser's dolphin nor dugong. The UME of Fraser's dolphin in 2015 occurred in the DJF season. All four UMEs for Fraser's dolphin occurred during the DJF and March months. All of these were likely caused by illegal fishing and dynamite blasting.

Apparent spatial patterns were observed in the strandings over the 18-y study period. The majority of the strandings and concentration of hotspots were in Luzon, particularly in the northern and northwestern sections. In the Visayas, strandings were more dispersed; hence, only one hotspot was generated. Strandings were also relatively dispersed in the Mindanao, with a concentration of its hotspots mostly found within bays. Furthermore, the presentation of stranding hotspot development showed that 63% of all stranding hotspots started to develop within the first 6 y of the 18-y period of the study and consistently had strandings in every 3-y period. Various factors may have led these animals to strand in the same area through the years. These may include seasonal factors such as monsoons (Ijsseldijk et al., 2018; Dudhat et al., 2022), oceanographic factors (Saavedra et al., 2017; Warlick et al., 2022), and fisheries interactions (Obusan et al., 2016). The concentration of strandings in the northwestern Luzon coincided with the upwelling zone in this region (Udarbe-Walker & Villanoy, 2001; see Figure 4). The continuous accumulation pattern suggests that strandings may likely continue to occur within these hotspots in the succeeding years. Therefore, assessing the causes of strandings in these areas is important. This trend in areas and accumulation patterns (mentioned above) where these animals often strand may also imply site fidelity (after Pyenson, 2010, 2011). Pyenson (2010) suggested that stranding records, especially of live marine mammals over long periods of coverage, may represent site fidelity and even suggested that stranding records can yield richer species assemblages than line transects. Note that 55% of all stranding events involved live animals and, among the top stranded species, the spinner dolphins represented 60% of live animals. It is also interesting to note that nine of the 35 hotspots in this study are categorized as cities. The future of the marine mammals within these areas poses a challenge as these cities further urbanize. The usual progression and expansion of urbanization often results in the proliferation of infrastructural developments particularly along the coasts (e.g., ports, hotels/resorts, residential areas). On the other hand, this finding may also result from more people around cities reporting strandings.

The top five MFSS and their hotspots showed interesting spatiotemporal patterns across the Philippines. Spinner dolphins, evidently, had the most widespread stranding events across the

Philippines. Moreover, six out of seven of its hotspots were located within the central waters of the Philippines. Such findings coincided with spinner sightings recorded in central regions in the Philippines, particularly in the eastern Sulu Sea and Tañon Strait (Dolar, 1999; Dolar et al., 2006a, 2006b). Integrating all this information generated for spinner dolphins, it is likely that they are the most widespread and most common marine mammal species in the Philippines, and it reinforces the notion that one of their primary habitats within the study area is the central Philippines. Strandings of Fraser's dolphins were also spread across the Philippines but were mostly concentrated in northwestern Luzon and the Lingayen Gulf. The UME of Fraser's dolphin specifically occurred in the top hotspot—Dagupan City & Eastern Lingayen—that was caused by dynamite blast (Aragones et al., 2017). There was also a lack of strandings of Fraser's dolphin in the shallow and internal waters which coincides with the species' preference for deep waters (Dolar et al., 2006a, 2006b; Weir et al., 2008; Witte et al., 2012). Although no hotspot was generated for Risso's dolphins, northwestern Luzon and the central Philippines seemed to be important stranding areas, similar to spinner dolphins. The same pattern as the other three cetacean species was also seen in stranding sites of melon-headed whales, and many strandings occurred in the central Philippines.

The dugong, being an herbivore, expectedly had different stranding locations and hotspots compared to the other four MFSS which are carnivores. Dugongs are seagrass specialists and have an affinity to coastal areas and are, therefore, more prone to impacts from human activities such as fishing (legal and illegal), vessel traffic, and coastal development than the offshore cetaceans. The fact that this species is uncommon, rarely seen, and observed by locals in the Philippines but has exceptional stranding records (2nd most common) implies that the remaining populations, although unquantified, are critically impacted by various previously described anthropogenic factors. Note that the dugong, together with the Irrawaddy dolphin, are the two most endangered marine mammal species in the Philippines. Whereas the Irrawaddy dolphin was categorized only as a rare species to strand, the dugong was classified as a frequent species to strand. The majority of the dugongs that stranded upon examination were already dead (83%; $n = 84$) but had good body condition. Thus, the dugong is more in peril than the Irrawaddy dolphins with regards to strandings as an additional threat, most likely due to the suspected increasing passive fishing gears (e.g., fish corrals) and illegal activities (e.g., dynamite fishing), particularly along the coasts (Aragones et al., 2010, 2017, 2022; Aragones & Laggui, 2019; Veloria et al., 2021; Aragones & Morado, 2023). We are currently working on using stranding points to further elucidate important areas for dugongs in the Philippines.

Fisheries production affects strandings because of prey competition between humans and marine mammals, resulting in direct interactions with fishing gears and fishers (Trites et al., 1997; DeMaster et al., 2001; Kaschner, 2004). Total fisheries production in the Philippines increased from 1980 to 2010 and gradually declined from 2010 to 2020 (Bureau of Fisheries and Aquatic Resources [BFAR] Reports, 2005-2020; Anticamara & Go, 2016). Aside from affecting prey sources, fisheries primarily impact strandings via fisheries interactions. In the Philippines, it was identified that 33% of marine mammal strandings from 1998 to 2013 had evidence of direct and indirect human interactions (Obusan et al., 2016). These interactions were determined as fishing gear entanglement and entrapment, fishing and navigation vessel collision, direct capture, and physical attack.

Improving the resolution of stranding hotspot areas is always a challenge. However, it is especially important for an archipelagic nation like the Philippines with a complex coastal configuration and 7,641 islands. In Aragones et al. (2010), stranding hotspots were identified on a larger scale (delineated according to administrative regions). In this study, 15 × 15 km grids were used to demarcate finer-scale patterns (i.e., municipality/city level) from 1,368 stranding events. Each coastal municipality/city has their respective municipal/city waters. Municipal waters include all inland waters plus those from the coastline mark up to 15 km (maximum) offshore (Republic Act 8550, The Philippine Fisheries Code of 1998). By generating these finer-scale hotspot grids, appropriate information is provided to, and supposedly actionable by, the concerned LGUs. By providing appropriate evidence-based results vital to the management and conservation of the Philippine fisheries and aquatic resources, including marine mammals, these concerned offices can be proactive rather than reactive. The following are our actionable recommendations to these stranding hotspot LGUs and concerned regional offices: (1) establish their own stranding response team and rehabilitation tank; (2) eradicate the illegal fishing activities by providing appropriate crew and patrol boats; (3) conduct regular information, education, and communication (IEC) campaigns regarding marine mammals and their threats/vulnerability; (4) review the registry of fishers and their fishing gears (special attention to those that impact the five MFSS as discussed) within their municipal waters and regulate them accordingly;

and (5) institutionalize these programs to sustain their implementation.

Data collection on strandings is crucial in generating information, especially for developing countries which have limited resources for extensive surveys on marine mammals (Aragones et al., 1997). Through time, the PMMSN has moved from collecting Level A (e.g., species, date, location) and Level B (e.g., morphometrics, blood collection, human–marine mammal interactions) data to collecting Level C data (e.g., necropsy, tissue collection for various studies) (Geraci & Lounsbury, 1993; Perrin & Geraci, 2002). Trained responders, veterinarians, and graduate students have helped in the collection of this higher level of information. In fact, since 2020, the PMMSN has integrated body scoring and bycatch protocols into the basic data collection. Experience and lessons learned throughout the years, along with the information gathered by the stranding network, support the suggestion that strandings present alternative ways to investigate bycatch and trace potential links to fisheries, even in live cetaceans that strand for reasons unrelated to fishing. Also, close monitoring of pathogenic diseases, human-induced impacts such as plastics in the gastrointestinal tract, and acoustic trauma (from dynamite blasts) are also in place. The systematic mechanism established provides new insights on marine mammals and subsequently enables the monitoring of these animals, including their stranding status.

Conclusions

The study showed that vital information regarding marine mammals, including LGU-level stranding hotspots, top five MFSS, species stranding status, and other relevant details on these charismatic animals, can be generated from a well-maintained and long-term stranding database. Given many unknown variables such as relative abundance and distinct populations that are key to conservation, establishing the species stranding status can provide a proxy to the potential impacts of strandings to these already vulnerable and threatened groups of animals. The additional threat of strandings to the locally critically endangered dugong is imminent. In general, the spatiotemporal variation in the strandings reflects the complex and dynamic nature of the Philippine archipelago that is primarily driven by monsoons and inter-monsoons, and exacerbated by human impacts such as increasing fishing pressure and illegal activities. The fisheries–marine mammal interactions must be seriously considered in the development of national programs like Fisheries Management Areas and possibly Action Plans for dugongs and Irrawaddy dolphins. The importance of continuing and advancing the monitoring of marine mammal strandings is imperative as effects of human impacts such as increasing population and fishing pressure, accelerated climate change, pollution, illegal fishing, and unsustainable development are inevitable.

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