frontiers | Frontiers in Marine Science

TYPE Original Research
PUBLISHED 10 January 2025
DOI 10.3389/fmars.2024.1483805

OPEN ACCESS

EDITED BY
Lonneke Liza Ijsseldijk,
Utrecht University, Netherlands

REVIEWED BY
Mingli Lin,
Chinese Academy of Sciences (CAS), China
Mariel Tineke Irene Ten Doeschate,
University of Glasgow, United Kingdom

*CORRESPONDENCE
Zhaolong Cheng
chengzl@ysfri.ac.cn

RECEIVED 20 August 2024
ACCEPTED 16 December 2024
PUBLISHED 10 January 2025

CITATION
Yuan J, Gao Y, Wang N, Jiang T and Cheng Z (2025) Cetacean stranding records along the Shanghai–Zhejiang coastline in China: implications for distribution and conservation. *Front. Mar. Sci.* 11:1483805.
doi: 10.3389/fmars.2024.1483805

Cetacean stranding records along the Shanghai–Zhejiang coastline in China: implications for distribution and conservation

Jing Yuan[1], Yili Gao[1], Nan Wang[1], Tianhua Jiang[1] and Zhaolong Cheng[2]*

[1]Ningbo Key Laboratory of Agricultural Germplasm Resources Mining and Environmental Regulation, College of Science and Technology, Ningbo University, Cixi, China, [2]Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Qingdao, China

Cetacean ecology has been poorly studied in the Shanghai-Zhejiang waters of East China Sea, seriously hindering appropriate local conservation practices. Here stranding records from 1953 to 2023 around the Shanghai-Zhejiang waters were collated from literature, media, and social websites to clarify species composition and spatio-temporal variations of cetacean strandings. A total of 138 stranding records involving 197 individuals across 23 species were identified, comprising four Mysticeti and Odontoceti species. Cetacean stranding records occurred extensively along the Shanghai-Zhejiang coastline throughout the year and have grown swiftly since the 2000s. Narrow-ridged finless porpoise *Neophocaena asiaeorientalis* and common minke whale *Balaenoptera acutorostrata* were the most frequently stranded species. Over 84% of the stranding events involved only a single individual. Melon-headed whale *Peponocephala electra* predominated in mass stranding incidents. Spatially, the stranding reports showed a significant cluttering distribution pattern. Clustering of cetacean records occurred in the Yangtze River estuary, downstream region of Qiantang River, southeastern of Ningbo, and Oujiang River estuary. Seasonal analysis showed increased cetacean stranding events in spring, yet without a significant difference. Post-mortem examinations of stranded individuals showed that coastal fisheries and port activities were probably the dominant causes of local cetacean strandings. Standardizing cetacean stranding records, strengthening fisheries regulations, and rescue training programs are recommended to establish a dedicated cetacean stranding monitoring network, which is vital for cetacean conservation in this region.

KEYWORDS

cetacean, stranding, species biodiversity, the East China Sea, conservation

1 Introduction

Cetacean species are prioritized in ecological conservation research due to their critical importance in marine ecosystems (Roman et al., 2014). As top predators, cetaceans are essential to maintain ecosystem integrity (Pace et al., 2015). Moreover, cetaceans are considered indicator species because they are particularly sensitive to variations in oceanographic traits (Savery et al., 2013). Additionally, as "charismatic species", they draw significant public attention (Morais et al., 2021). However, given the wide-ranging, highly migratory, elusive nature of cetaceans, which spend most of their lifetime underwater, effective monitoring is inherently challenging and costly (Mann and Würsig, 2014). Consequently, understanding baseline ecological information about cetaceans is often financially hampered in most geographic regions. In this context, the collection of cetacean stranding records emerges as a cost-effective monitoring method to provide valuable cues on their ecology (IJsseldijk et al., 2020; Silva et al., 2021).

This method boasts several advantages compared to traditional methods, such as aerial surveys and passive acoustic techniques. First, long-term stranding datasets with detailed coordinates and time information have shown considerable potential in providing insights into species diversity, spatial distribution, population dynamics, group structure, and relative abundances (IJsseldijk et al., 2020; Tepsich et al., 2020; Tonay et al., 2020; Warlick et al., 2022). Furthermore, post-mortem examinations of stranded individuals could improve public comprehension of morphology, diseases, diets, and genetics of wild cetacean (Fernández et al., 2014; Cuvertoret-Sanz et al., 2020; Silva et al., 2021). Recent studies leveraging cetacean stranding events have significantly broadened people's understanding of cetacean ecology globally (IJsseldijk et al., 2020; Tepsich et al., 2020; Warlick et al., 2022)—for example, stranding records have suggested the spatial distribution and population decline of fin whales *Balaenoptera physalus* in the Mediterranean Sea (Tepsich et al., 2020). Pyenson (2011) has proven that stranding records could reliably estimate the relative abundance of cetacean populations through comparison with live surveys. Despite this, the relationship between the number of stranding events and the cetacean population remains uncertain (Warlick et al., 2022), necessitating caution in the analysis of these incidents.

Observed cetacean strandings may not necessarily and directly reflect the natural mortality rates of a specific species or population because they are usually complicated outcomes resulting from the cumulative effects of multiple factors (Li et al., 2021). Several studies have identified possible causes of cetacean strandings, encompassing natural factors such as disease, oceanographic and climatic patterns, and anthropogenic impacts, including fisheries interactions, maritime traffic, and marine pollution (Vishnyakova and Gol'din, 2015; Alvarado-Rybak et al., 2020; Cuvertoret-Sanz et al., 2020; Page-Karjian et al., 2020; Pennino et al., 2022; Torres-Pereira et al., 2023). Oceanographic and climatic features, e.g., atmospheric pressure, sea surface temperature, upwelling, regional wind, solar storms, and sea ice, could be generally associated with stranding events at a particular beach (Pulkkinen et al., 2020; Van Weelden et al., 2021; Brusius et al., 2022; Joyce et al., 2023). Extreme weather conditions, particularly typhoon, can lead to more cetacean strandings by inducing physiological injuries, temperature stress, and exhaustion (Coombs et al., 2019; Brusius et al., 2022). The most concerning causes of strandings are anthropogenic impacts, given the incessant emergence of plentiful reports on cetacean entanglements in fisheries gears (Puig-Lozano et al., 2020; Carlucci et al., 2021)—for example, one study attributed the high number of stranded harbor porpoises *Phocoena phocoena* along the Portuguese and Galician coasts to the interaction of fisheries (Torres-Pereira et al., 2023). Marine pollution, both chemical (plastic, heavy metal, oil spill) and acoustic pollution (shipping noise, seismic exploration noise, sonars, offshore construction noise), exerts significant impacts on cetaceans by disturbing their behaviors, elevating stress levels and precipitating diseases (López et al., 2020; Page-Karjian et al., 2020; Czapanskiy et al., 2021; Pires et al., 2021).

Cetacean stranding monitoring networks have been globally established and supported by several international organizations, conventions, and agreements (Gulland and Stockin, 2019; UNEP et al., 2022). The United Kingdom (Coombs et al., 2019), the United States of America (Onens et al., 2023), Brazil (Mayorga et al., 2020), Chile (Alvarado-Rybak et al., 2020), India (Dudhat et al., 2022), and the Philippines (Aragones et al., 2010) have all established long-term cetacean stranding networks. The 2019 World Marine Mammal Conference was organized to form the "Global Stranding Networks" and enhance international cooperation (Gulland and Stockin, 2019). In China, the science community has also made substantive contributions to cetacean stranding monitoring (Lin et al., 2019; Liu et al., 2022; Zuo et al., 2023)—for example, Liu et al. (2022) have compiled a national cetacean stranding dataset and evaluated the overall stranding pattern of cetaceans along the whole national coastline. Furthermore, due to the vast coastline length, species composition, spatial–temporal pattern, and stranding causes may vary among different regions and provinces. It is equally important to identify the specific stranding pattern within a region or province and point out priority conservation areas and issues to inform practical conservation decisions. Consequently, several regional stranding networks have been constructed, such as in Hong Kong (Parsons, 1998), Hainan Island (Liu et al., 2019), Taiwan (Chou et al., 2024), and Shandong Peninsula (Zuo et al., 2023), mainly distributed in the South China Sea Bo Sea and the Yellow Sea. However, stranding patterns in other regions remain inadequately analyzed and documented.

The Shanghai–Zhejiang area is located on the southern part of the Yangtze River Delta, to the north of the East China Sea and the west coast of the Pacific Ocean. It is characterized by a complex marine geomorphology with numerous bays, different kinds of islands and reefs, and mainstream or estuaries of several seagoing rivers, including two important large rivers in China, namely, Yangtze River and Qiantang River. Special geographical conditions facilitate the occurrence of coastal upwelling (Zhang et al., 2020), enhancing marine productivity and establishing vital habitats for fish and cetaceans (Barlow et al., 2021). Additionally, the region boasts a flourishing and rapidly expanding coastal economy, attributed to its abundant natural resources and strategic geographic position (Cao et al., 2018; Lin, 2020), which supports extensive marine aquaculture (Cui et al., 2024) and key maritime ports (Ruan et al., 2018). The rapid coastal developments can pose threats, as they may lead to more human disturbance and destruction of cetaceans' habitats—for example, unusual mass cetacean stranding events frequently reported in this region in 2021 and 2022 have raised significant concerns regarding the survival pressures faced by cetacean communities. These events underscore the urgent need for intensified conservation research to enhance understanding of the current status of cetaceans in the area.

In the digital era, the Internet serves as a particularly useful tool to provide cetacean stranding records over a long term and on a large scale. One way to obtain systematic stranding records is searching for relevant data through the published or gray literature, which could be done most conveniently with the aid of online web tools nowadays (Chan et al., 2017). Researchers could combine sporadic stranding information in individual studies to cumulatively analyze the cetacean stranding pattern in a particular research area (Alvarado-Rybak et al., 2020; IJsseldijk et al., 2020). In addition, with the popularity of smart phones and computers, social media has been employed as an emerging tool to monitor "charismatic species" (Saltzman et al., 2022). Cetaceans, recognized as classic charismatic species, often incite public interest when they strand, leading to widespread social media coverage (Morais et al., 2021). The inclusion of social media reports could add documented evidence to traditional systematic reviews of literature, as they usually provide geocoded information and raw image data (Chen et al., 2023). Moreover, media reports could also reveal public sentiment toward the study species and their survival status, which has significant implications for conservation efforts (Wu et al., 2018). However, an important task is to evaluate the credibility of evidence from media reports as the information source of stranding events (Keshavarz, 2021). Despite their increasingly common inclusion in data collection for scientific studies, it is acknowledged that practices remain dependent on particular research fields and objectives (Song et al., 2016).

In this study, cetacean stranding records from all available sources over 70 years along the Shanghai–Zhejiang coastline were collated and analyzed to attain the following goals: (a) to clarify the general species composition of stranded cetaceans and the spatial–temporal pattern of cetacean stranding events, (b) to identify hotspot areas of cetacean strandings and potential threats affecting local cetacean populations in the region, and (c) to direct key conservation and management efforts toward key areas and issues of high priority. The overall results will facilitate a systemic cetacean stranding network to improve cetacean stranding responses in this region.

2 Materials and methods

2.1 Study area

This study was conducted along an approximately 8,067-km-long coastline (including continental and island areas) of Shanghai–Zhejiang waters in southeastern China, the western Pacific Ocean. The study area contained the coastal regions in eight administrative districts, including Shanghai (SH), Jiaxing (JX), Zhoushan (ZS), Hangzhou (HZ), Shaoxing (SX), Ningbo (NB), Taizhou (TZ), and Wenzhou (WZ), stretching from north to south (Figure 1). This region has several famous fishing grounds, such as the Yangtze River Estuary Fishing Ground, Zhoushan Fishing Ground (the largest fishing ground in China), Yushan Fishing Ground, and Wen (Zhou)-Tai (Zhou) Fishing Ground. It is also known for important international ports, including Shanghai Port, Ningbo-Zhoushan Port, Taizhou Port, and Wenzhou Port. We divided 1 year into four periods to discern seasonal variations of cetacean strandings: spring (March to May), summer (June to August), fall (September to November), and winter (December to February).

2.2 Data collection

This study defined stranding as live or dead animals on or near shore and carcasses in open water (Geraci and Lounsbury, 2005). Cetacean stranding records were collated from a systematic search of the Chinese peer-reviewed literature, books, dissertations, conference papers, governmental or nongovernmental media reports, and social websites for the time period January 1953 to September 2023.

We carried out an exhaustive bibliographic search for all literature data using three large Chinese electronic databases: China National Knowledge Infrastructure (CNKI), WANFANG DATA, and VIP. For the search, we used Chinese word groups including "搁浅" (strand) OR "死亡" (death) OR "记录" (record) AND "鲸" (cetacean or whale) OR "海豚" (dolphin) OR "江豚" (porpoise) OR "水生动物" (marine animals) OR "海兽" (marine mammals) AND "中国" (China) OR "浙江" (Zhejiang) OR "市名" (district name). All literature containing these keywords anywhere in the fulltext was thoroughly examined, and relevant records in the target regions were compiled together into a Microsoft Excel file. Relevant cited references were also checked for additional records. Any relevant literature resource, if not available in the three databases, was requested or purchased through a Chinese search engine (Baidu, released in 2000). Finally, we obtained stranding reports from 1953 to 2019 through the search.

Data from media reports were accessed online by exploring Internet digitized resources, including newspapers, videos, magazines, and broadcasting. Firstly, we used the Chinese search engine Baidu, official website of China's Agriculture and Rural Affairs Bureau, and social websites including WeChat, TikTok, MicroBlog, and Zhihu to search for stranding information (accessed on May 2024). Keywords included the names of the study province or all of the eight districts, e.g., "Shanghai" and "cetacean", "dolphin", "porpoise", "marine mammal", or "marine animal" in Chinese. Only media reports identified by experts or which had direct evidence including clear photographs, videos, or detailed descriptions were included in this study. Notably, after an exhaustive search, media reports of cetacean strandings after February 1998 were available.

All records were manually checked to remove ambiguous reports and to confirm no duplication for any stranding event.

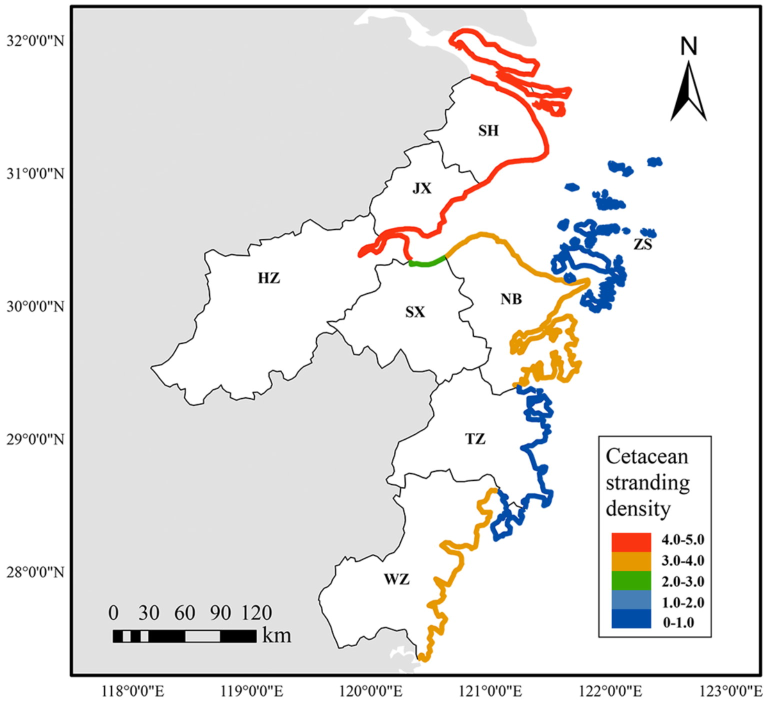

FIGURE 1
Geographic map of the study area and stranding density of cetacean (i.e., number of stranded individuals per 100 km of coastline) in eight districts along the Shanghai–Zhejiang coastline.

Except for stranding events involving the same species, number of individuals, location, and date, all events were considered as distinct events. Therefore, there is a risk of repeated calculations due to a lack of effective post-release monitoring in the study region, as the released live animals may strand back in neighboring beaches. However, this error remain acceptable, as a manual inspection of all available records suggested relatively few (two) possible cases. The above-mentioned activities were independently performed by one participant of this work.

For each cetacean stranding record, the following information was extracted: species, number, date (year/month/day), and location (district and exact coordinate) of discovery, biological feature (age stage, sex, body length, and weight), survival condition (alive or dead), injury or decomposition description, evidence of stranding cause (e.g., fishery vessel entanglement or collision, bycatch, extreme weather, tidal currents, starvation, or illnesses), and specific information source. Furthermore, if available, information on stranding response was also recorded, including the actors involved and the outcome of the stranded animals (e.g., releasing into the wild, burying *in situ*, keeping the carcasses of dead animals as specimens in academic institutions, being illegally sold in the local market, or destroying). Based on the number of stranded animals, the stranding events were further categorized into single (n = 1), pair (n = 2), and mass events ($n \geq 3$). For standard processing, all stranded individuals were identified at the species level. If it was impossible to accurately confirm all of the above-mentioned details, the record was labeled as "unknown" for ambiguous information. The completeness of information was represented by the proportion of available information categories.

2.3 Data analysis

The locations of all stranding events from 1953 to 2023 were visualized on maps to reveal the spatial distribution of each species (the specific stranding latitude and longitude are available in the appendix). For each district, the encounter density of strandings was calculated as the number of stranded individuals per unit distance (100 km) of the coastline (Barbieri et al., 2013). The length of the coastline was obtained from the National Geographic Information Public Service platform (https://www.tianditu.gov.cn/).

In this study, Kolmogorov–Smirnov (KS) test was used to assess whether all variables were normally distributed. For normally distributed data with the same variance, one-way ANOVA test followed by Dunnett's or Bonferroni's test was carried out to see geographic variations in stranding events among the eight districts. Otherwise, Kruskal–Wallis test followed by Dunn–Bonferroni *post-hoc* test was applied, and Wilcoxon–Mann–Whitney test was also performed for pairwise comparisons between groups. The cetacean stranding density of each district (stranded individuals per 100 km) were mapped to present spatial differences. Moran's I index was applied to measure the spatial autocorrelation and to evaluate whether stranding locations were spatially dispersed or clustered in the study region. Furthermore, grid cell counts and Getis-Ord Gi* hotspot analysis were applied to determine coastal cetacean stranding hotspots according to the spatial pattern.

The number of stranding events that occurred per year or month was calculated to explore the temporal pattern. The augmented Dickey–Fuller (ADF) unit root test was carried out to examine the stationarity of the time series. Furthermore, Mann–Kendall (MK) trend test was implemented to identify the annual variation of stranding events. Subsequently, one-way ANOVA or Kruskal–Wallis test, followed by relevant *post-hoc* tests, was used to determine seasonal differences according to the normality.

All analyses were performed using ArcMap 10.8, SPSS Statistics 24.0, and MATLAB (R2021a). Statistical significance was set at p <0.05.

3 Results

From 1953 to 2023, a total of 138 independent stranding records involving 197 individuals in the study area were compiled. These data were predominantly sourced from media platforms and literature (see Table 1). Four records lacking exact coordinates or specific location details were omitted from spatial analysis, while three records without detailed year information were excluded from temporal analysis.

3.1 Species composition

All 138 records contained 32 baleen whale stranding events (32 individuals) and 106 toothed whale stranding events (165 individuals). In total, four Mysticeti species (four Balaenopteridae) and 19 Odontoceti species (11 Delphinidae, four Ziphiidae, one Physeteridae, one Kogiidae, one Lipotidae, and one Phocoenidae) were identified. Among them, seven were listed as threatened by the IUCN Red List (critically endangered, CR: one species; endangered, EN: one species; vulnerable, VU: three species; near threatened, NT: two species). All species were listed as national first-class or second-class protected animals in China (see Table 2).

The four most abundant species, including the narrow-ridged finless porpoise *Neophocaena asiaeorientalis*, common minke whale *Balaenoptera acutorostrata*, fin whale *Balaenoptera physalus*, and Bryde's whale *Balaenoptera edeni*, occupied the majority of stranding events (67% of all the records) (Table 2).

Most stranding events were single-stranding events (84%, 116 out of 138), involving all baleen whales and most toothed whale records (79%, 84 out of 106). For the toothed whale, only 13 (12%, 13 out of 106) were confirmed as pair-stranding events, while nine (8%) were confirmed as mass stranding events. Narrow-ridged finless porpoises occupied most pair-stranding events (46%, six out of 13). In addition, narrow-ridged finless porpoises (33%, three out of nine) and melon-headed whales (33%, three out of nine) were frequently observed in mass stranding events.

TABLE 1 Information sources of cetacean stranding events along the Shanghai–Zhejiang coastline, 1953–2023.

Information source	Number of stranding events	Number of stranded animals
Official government report	5	6
Media reports	72	122
Published literature	54	61
Social websites	7	8
Total	138	197

3.2 Spatial distribution

As shown in Figure 2, cetacean stranding events occurred in all districts along the Shanghai–Zhejiang coastline. The number of events, species, individuals, and stranding densities were calculated for each district. Ningbo had the highest number of stranding events (29%, 39 out of 134), followed by Wenzhou (20%, 27 out of 134) and Shanghai (16%, 22 out of 134). At the same time, the number of stranded species varied among different districts. Ningbo exhibited the highest number of stranded species (n = 12), followed by Wenzhou (n = 11), Shanghai (n = 10), Taizhou (n = 9), and Zhoushan (n = 9). The highest stranding densities were detected in Shanghai (4.4 individuals per 100 km), Jiaxing (4.1 individuals per 100 km), and Hangzhou (4.1 individuals per 100 km) (Table 3; Figure 1). However, no significant variation in cetacean stranding events was observed among the eight coastal districts (Kruskal–Wallis test, X^2 = 3.306, df = 7, p = 0.855).

The overall spatial autocorrelation analysis revealed significant clustering in the distribution of cetacean stranding events within the study area (Moran's I index, Z-score = 6.49, p < 0.05). High-density stranding grids were observed around the Yangtze River estuary, downstream of the Qiantang River, Xiangshan Port, and Oujiang River estuary (Figure 3). The Getis-Ord Gi* analysis also identified these areas as cetacean stranding hotspots with a statistical significance interval at 90%–99% (Figure 4).

3.3 Temporal pattern

An increasing trend of cetacean stranding events was observed across the past 71 years, and these peaked in 2021 (Figure 5). The ADF unit root test statistic confirmed the stationarity of the time series analyzed in this study (T-statistic value = -20.45, p < 0.05). Most stranding records occurred in the last 23 years, between 2001 and 2023 (104 out of 135), while the remaining records between 1953 and 2000 were fragmentally distributed (Figure 5). The MK trend test, conducted at 99% significance level, indicated a significant upward annual trend in the time series data under study (Z-score = 4.86, p < 0.05).

Cetacean stranding events were observed throughout the year. The month and season with the highest number of stranding events were April and spring, respectively (Figure 6). However, significant seasonal variation was not found in cetacean stranding records (Kruskal–Wallis test, X^2 = 3.055, df = 3, p = 0.383). Additionally, given the considerable proportion of the narrow-ridged finless porpoise records, seasonal analysis within this species was employed. No statistically significant seasonal variation was identified either (Kruskal–Wallis test, X^2 = 2.436, df = 3, p = 0.487).

TABLE 2 Cetacean stranding species, events, and individuals along the Shanghai–Zhejiang coastline, 1953–2023.

Suborder	Species	Latin name	No. of stranding events	No. of stranded individuals	Vulnerability
Mysticeti	Bryde's whale	*Balaenoptera edeni*	8	8	LC, I
	Fin whale	*Balaenoptera physalus*	9	9	VU, I
	Common minke whale	*Balaenoptera acutorostrata*	12	12	LC, I
	Omura's whale	*Balaenoptera omurai*	2	2	DD, I
	Unidentified Mysticeti		1	1	
Odontoceti	Cuvier's beaked whale	*Ziphius cavirostris*	1	1	DD, II
	Baird's beaked whale	*Berardius bairdii*	1	1	NT, II
	Longman's beaked whale	*Indopacetus pacificus*	1	1	LC, II
	Blainville's beaked whale	*Mesoplodon densirostris*	5	5	LC, II
	Killer whale	*Orcinus orca*	3	5	DD, II
	Long-beaked common dolphin	*Delphinus capensis*	1	1	LC, II
	Common dolphin	*Delphinus delphis*	1	1	LC, II
	Indo-Pacific bottlenose dolphin	*Tursiops truncatus*	4	7	LC, II
	Striped dolphin	*Stenella coeruleoalba*	1	1	LC, II
	False killer whale	*Pseudorca crassidens*	1	3	NT, II
	Rough-toothed dolphin	*Steno bredanensis*	4	5	LC, II
	Melon-headed whale	*Peponocephala electra*	4	30	LC, II
	Short-finned pilot whale	*Globicephala macrorhynchus*	1	7	LC, II
	Indo-Pacific humpback dolphin	*Sousa chinesis*	2	2	VU, I
	Risso's dolphin	*Grampus griseus*	3	3	LC, II
	Sperm whale	*Physeter macrocephalus*	2	2	VU, I
	Pygmy sperm whale	*Kogia breviceps*	2	2	LC, II
	Baiji	*Lipotes vexillifer*	5	6	CR,I
	Finless porpoise	*Neophocaena asiaeorientalis*	63	80	EN, I/II
	Unidentified Odontoceti		1	2	
Total			138	197	

The conservation status in China: Grade I or II National Key Protected Animal Species.

3.4 Survival conditions and responses

Only 60 stranding records described injury and decomposition patterns. As shown in Figure 7A, most stranded individuals only had scratches and epidermal injuries. Some individuals had bruise injuries or cut injuries on the body from fishing net entanglement, ship collisions, or propeller errors. Additionally, a minority of the recently deceased animals or carcasses were found without any injuries. There were 43 reports that mentioned the possible causes of stranding events based on the observed evidence. Up to 28 reports documented fishery-related stranding events (e.g., fishing net entanglement and marine fisheries bycatch). A total of 10 reports mentioned that "cetacean could not return to deep waters due to a rapid ebb tide." Furthermore, three reports considered severe weather conditions, such as typhoons and rainstorms, as the main causes of cetacean stranding events.

Information on survival conditions was provided for 158 individuals. Of these, 56 animals were found dead (10 baleen whales and 46 toothed whales), while 102 animals were found alive (six baleen whales and 96 toothed whales) (Figure 7B). Of the 102 live animals, 69 were successfully reintroduced to their natural habitat, yet no effective post-release monitoring was conducted. Medical treatments and rehabilitation attempts have initially been conducted in recent years, but few succeeded. Among all deceased individuals, almost 37% were kept as specimens in museums and universities, 6% were buried *in situ*, 4% were found by police officers or the public being illegally sold in local markets, and 3% were removed by currents. Information regarding the disposal of the remaining 50% is unavailable.

Five types of actors were identified at this area from these stranding reports: local governmental agencies, academic actors, civil society organizations, media, and the general public. Similarly, four categories of functions were recognized, including (i)

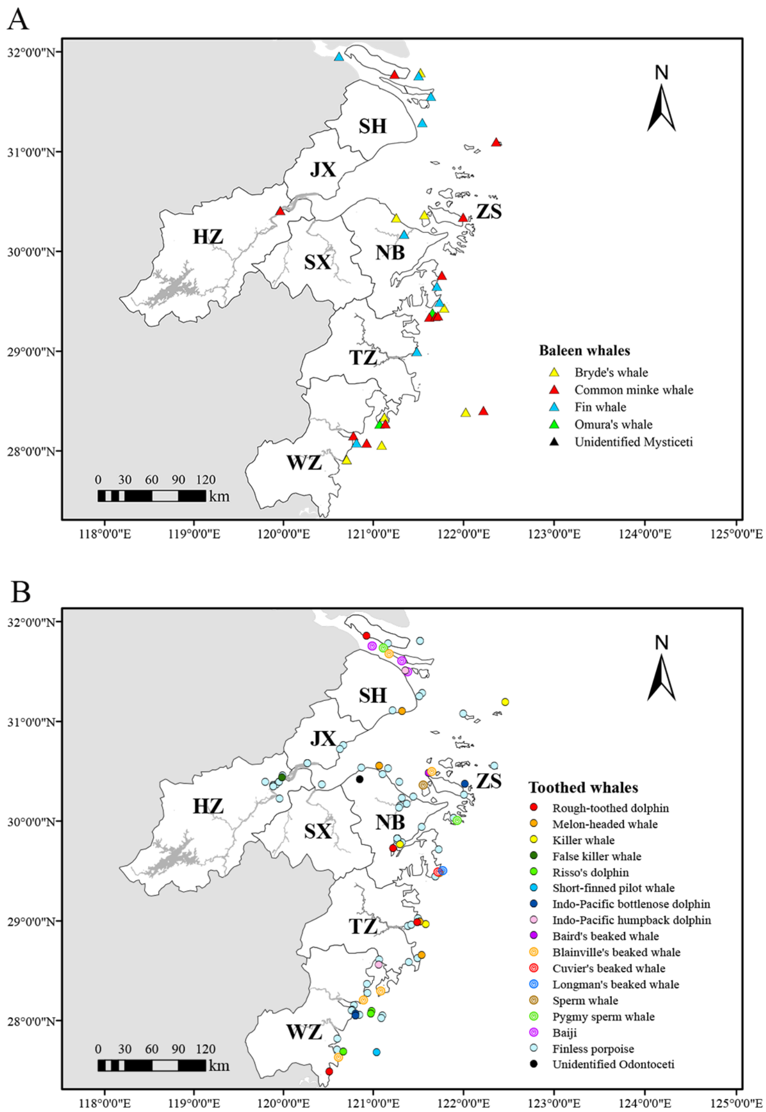

FIGURE 2
Spatial distribution pattern of cetacean stranding events along the Shanghai–Zhejiang coastline, 1953–2023. **(A)** Stranding events of baleen whales. **(B)** Stranding events of toothed whales.

TABLE 3 Spatial distribution pattern of cetacean stranding events among eight coastal districts along the Shanghai–Zhejiang coastline, 1953–2023.

Districts	Coastline length (km)	No. of stranding events		No. of stranded individuals		No. of stranded species	Stranding density (individuals per 100 km)
		Baleen whale	Toothed whale	Baleen whale	Toothed whale		
Shanghai	587	6	16	6	20	10	4.4
Jiaxing	121	0	4	0	5	1	4.1
Hangzhou	339	1	11	1	14	3	4.1
Shaoxing	40	0	1	0	1	1	2.5
Ningbo	1,562	10	29	10	45	12	3.5
Zhoushan	2,444	3	10	3	13	10	0.7
Taizhou	1,681	6	10	6	27	9	1.0
Wenzhou	1,293	6	21	6	37	11	3.3

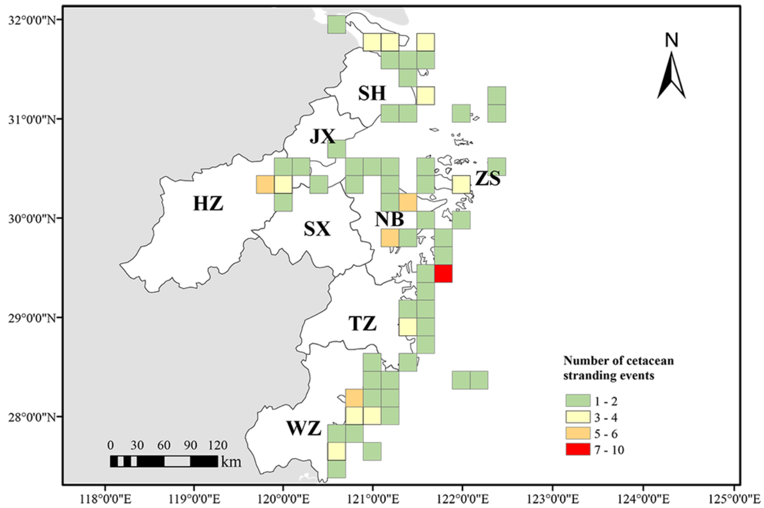

FIGURE 3
Grid cells of cetacean stranding events along the Shanghai–Zhejiang coastline, 1953–2023. Grid cell side length: 20 km * 20 km.

organizational, (ii) scientific, (iii) information spread, and (iv) assisted. Local government agencies, being primarily tasked with organizational duties, were responsible for the majority of response activities and enforcement of fishery regulations in stranding reports, with a total of 63 cases. Academic actors (universities, institutes, and museums) and civil society organizations (aquariums, non-governmental organizations) played a scientific role, primarily offering advice and technical guidance for rescue operations. The media's role was to disseminate information, often engaging in news release activities and environmental education. The function of the general public (fishermen, citizens, and tourists) is to assist by being the first to witness stranding events and provide support for response activities. The average completeness of information was 69.39% for all reports. Ningbo (74.21%) and Hangzhou (72.55%) had the highest completeness, with no significant differences observed among various districts (Kruskal–Wallis test, X^2 = 7.352, df = 7, p = 0.393).

4 Discussion

Cetacean stranding databases are cost-effective tools to gain an understanding of cetacean occurrence, population distribution, current status, potential threats, and environmental health risks within a region (IJsseldijk et al., 2020; Li et al., 2021; Silva et al., 2021; Warlick et al., 2022). As a result of growing concern about cetacean survival status and ocean health, diverse cetacean databases have been established worldwide to fill knowledge gaps in baseline data (Coombs et al., 2019; Gulland and Stockin, 2019; UNEP et al., 2022; Onens et al., 2023). In this study, all available cetacean stranding records from 1953 to 2023

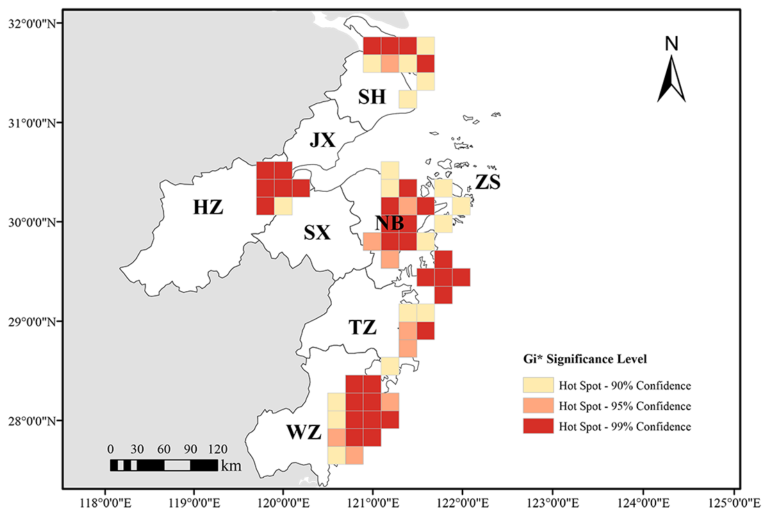

FIGURE 4
Geographic hotspots of cetacean stranding events along the Shanghai–Zhejiang coastline, 1953–2023.

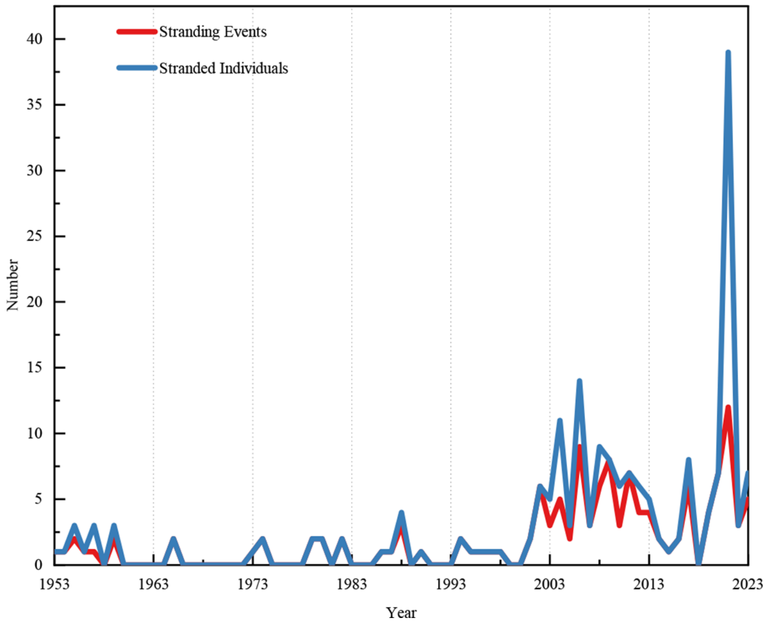

FIGURE 5
Annual trends of cetacean stranding events and stranded individuals during 71-year records along the Shanghai–Zhejiang coastline.

were collated through a comprehensive review of public reports along the coastline of the Shanghai–Zhejiang region in China despite the lack of a systematic cetacean strandings network there. Despite the lack of a systematic cetacean strandings network, this study offered important insights into cetacean species diversity, spatio-temporal stranding trends, and possible stranding causes in this region. The results demonstrated significant species richness and spatio-temporal variability in cetacean strandings, warranting further study. Furthermore, the research gathered the potential stranding causes and the current status of stranding response activities, highlighting an urgent requirement of a systematic stranding surveillance and response program to support the conservation and management of cetaceans in the Shanghai–Zhejiang area.

4.1 Species characteristics

This cetacean stranding database confirmed 23 different species, approximately 64% of the 36 species reported for the country, further underscoring a remarkable cetacean biodiversity in the nearby waters around the Shanghai–Zhejiang area. The stranded species encompassed a variety of cetacean species (four Mysticeti species and 19 Odontoceti species), ranging from near-shore to deep-sea species. It is worth noting that this diversity was comparable with that reported in some of China's regions or neighboring waters of southeast Asia where systematic stranding networks have been established, notably in the northern South China Sea (29 species, Lin et al., 2019), Hainan (15 species, Liu et al., 2019), Taiwan (27

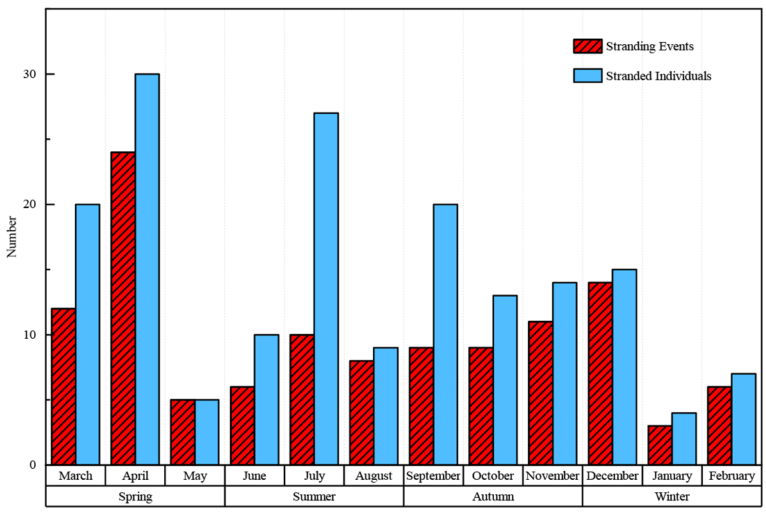

FIGURE 6
Seasonal and monthly trends of cetacean stranding events and stranded individuals along the Shanghai–Zhejiang coastline.

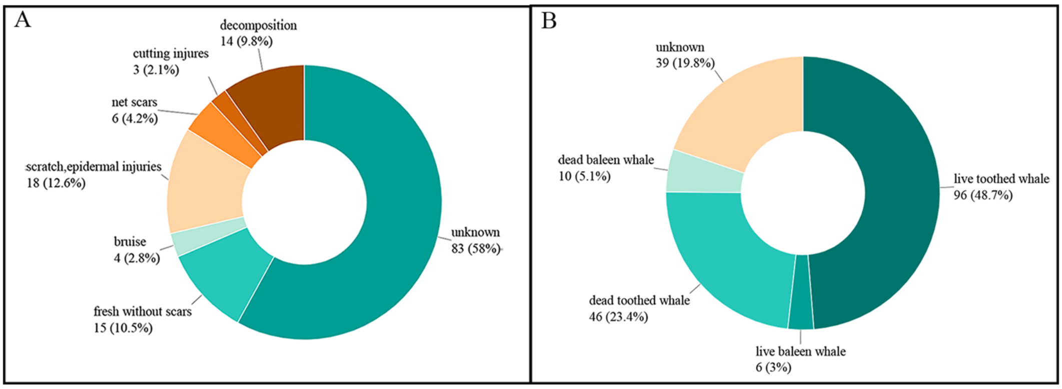

FIGURE 7
(A) Cetacean stranding causes and **(B)** dead-to-alive ratio of stranded individuals along the Shanghai–Zhejiang coastline, 1953–2023.

species, Chou et al., 2024), Indonesia (26 species, Mustika et al., 2022), and the Philippines (23 species, Aragones et al., 2010). These findings demonstrated the Shanghai–Zhejiang area as a critically valuable area for China's or the global marine biodiversity protection, which also necessitated a cetacean stranding network to enforce monitoring efforts. The Shanghai–Zhejiang area's high cetacean diversity might emanate from its oceanographic physical complexity and specific locations at the confluence of several large rivers and oceans, which may also increase orientation and navigation difficulty in cetaceans, and ultimately lead to stranding events (Warlick et al., 2022). Furthermore, the substantial cetacean diversity could also reflect the local complex marine ecosystem, which is especially valuable for scientific studies in assessing the health status of diverse marine ecosystems (Friess et al., 2020). In addition, with the high-quality development of the regional marine economy over the past decades (Cao et al., 2018; Lin, 2020), numerous offshore and coastal constructions in the Zhejiang–Shanghai area might trigger anthropogenic threats on the high cetacean diversity, warranting future research on interactions between cetaceans and environmental disturbance there.

Stranding reports might underestimate the abundance of stranded animals. Not all marine animals that died at sea strand on the beach, and not all animals that strand on the beach are found and the information recorded, especially in the absence of a systematic stranding surveillance program. Due to the possible missed information, the collated records represent a minimum of the amount of stranded animals on the beach. Furthermore, an unavoidable deviation exists in the analysis of stranding records owing to media's interest, data integrity and availability, regional differences in the accessibility of coasts, and urbanization degree (Huggins et al., 2015; Coombs et al., 2019). Nevertheless, many studies have confirmed that stranding reports could greatly mirror the species abundance of cetaceans found in boat-based surveys (Mayorga et al., 2020; Mustika et al., 2022). To our knowledge, the present study remains the most reliable knowledge about the characteristics of cetacean species in the Shanghai–Zhejiang area and reflects the relative abundance of specific species to some extent. However, caution is needed when interpreting the results of the analysis of cetacean stranding data.

Commonly, the species with the most stranding records are usually abundant, near-shore species, or both (Liu et al., 2019, 2022; Mustika et al., 2022). The narrow-ridge finless porpoises, common minke whales, Fin whales, and Bryde's whales were the most common stranders in the Shanghai–Zhejiang area. The narrow-ridge finless porpoise was the dominant species, accounting for 46% of all stranding records. However, the mean of the annual stranding reports for this species in this study area (approximately three cases per year) was lower compared to that reported in coastal waters around the Shandong Peninsula (approximately 30 cases per year) over the past 20 years (Zuo et al., 2023). Notably, the lower number of reported stranding events for finless porpoises might indicate underreporting rather than a smaller population in this research due to the lack of an effective regional stranding monitoring network. Despite this, our results still suggested that the Shanghai–Zhejiang area could be a critical habitat for this endangered species, necessitating further research efforts to evaluate its ecology status. Common minke whale, one of the most widely distributed baleen whale worldwide (Risch et al., 2019), has been frequently stranded sometimes in the earlier years but has not been reported since 2014. Stranding reports of fin whale and Bryde's whale occasionally occurred since 2001, although they were seasonally present in this area. The findings reflect shifts in the distribution patterns of these species over time, potentially attributable to changes in oceanography or climate (Zhao et al., 2017; Van Weelden et al., 2021).

For cryptic cetacean species, sporadic stranding records might be the best available evidence for their whereabouts (Wang et al., 2015). The current study presented valuable evidence on the occurrence of Cuvier's beaked whale *Ziphius cavirostris*, a data-deficient species classified by IUCN. Furthermore, stranding records might overlook the abundance of offshore and deep-sea species, just as they were extensively underrepresented in databases globally (Coombs et al., 2019; Lin et al., 2019; Alvarado-Rybak et al., 2020; Mayorga et al., 2020). Common dolphin *Delphinus delphis*, long-beaked common dolphin *Delphinus capensis*, and Indo-Pacific bottlenose dolphin *Tursiops truncatus* were rarely reported to be stranded in this study area, presumably as they inhabited areas far away from the coast and could hardly be washed ashore (Prado et al., 2016; Moore et al., 2020). In addition, melon-headed whales were prevalently found to be involved in mass stranding events, consistent with their preference of residing in a large group size (Hamilton, 2018).

4.2 Spatial hotspots and temporal trends

Globally, it is widely acknowledged that a spatial pattern of long-term stranding reports could partially mirror the distribution pattern of cetacean, as stranded animals or carcasses usually get washed or drifted from nearby waters (Moore et al., 2020; Liu et al., 2022). The present results observed a primary spatial pattern of cetacean stranding reports along the Shanghai–Zhejiang coastline, which would be highly valuable in identifying priority areas for regional conservation and management. Spatially, Ningbo, Wenzhou, and Shanghai had the highest number of stranding events and stranded species richness than other districts (Table 3), indicating that coastal waters around these districts might possibly host abundant and various cetaceans. Furthermore, the spatial pattern of cetacean stranding records could also be influenced by multiple factors, especially the distribution of stranding triggers (including natural and anthropogenic induces) (Vishnyakova and Gol'din, 2015; Cuvertoret-Sanz et al., 2020). The results found that several cetacean stranding hotspots were located nearby the ports and estuaries areas (Figure 4), regions marked by significant topographic complexity and human activity. This finding highlights an elevated risk of accidental stranding or mortality, emphasizing the need for a dedicated stranding monitor and response program in these areas. Notably, stranding events in the Zhoushan Archipelago, the largest Chinese archipelago with thousands of small islands and approximately 2,400 km of coastline, could be largely underreported due to the plentiful remote and inaccessible coasts.

The results herein showed that cetacean stranding records increased continuously over 71 years of study and more rapidly since 2001 (Figure 5). The significant upward annual trend was most probably attributed to advances in the awareness of the public on wildlife protection and the developments of media, as media reports were not available before 1998. It highlighted the important function of citizen science and mass media in stranding networks and raised the strong demand for improved reporting and storage systems of cetacean stranding data. On the other hand, the increasing trend of stranding reports might also partly mirror an increase in cetacean mortality events (IJsseldijk et al., 2020), which further indicated that cetacean population might be decreasing over time due to rapid economic developments as reported globally (Jaramillo-Legorreta et al., 2019; Alvarado-Rybak et al., 2020). The seasonality of cetacean strandings differed with species and locations, which might be attributed to the integrative effect of multiple factors (Fernández et al., 2014; Vishnyakova and Gol'din, 2015). In this study, the overall and finless porpoise species-specific seasonality analyses both showed that cetaceans were stranded throughout the year, and the peak was observed in spring. These findings might be collectively driven by the seasonality of prey distribution (IJsseldijk et al., 2020; Thorne et al., 2022), environmental factors (Warlick et al., 2022), and coastal human activities (Saavedra et al., 2017)—for example, it was well established that small cetaceans typically distributed near the food sources, mainly including fishes and invertebrates (Goetz et al., 2015; Paradell et al., 2021). Despite limited data on cetacean prey distribution in the study area, some fish species including *Coilia mystus*, *Engraulis japonicus*, and *Larimichthys crocea* were found to be assembling near the shore in spring, which might serve as a food source for cetacean species (Zhang et al., 2019; Chen et al., 2022).

4.3 Causes of cetacean stranding

Relevant information from original reports was also documented to assess potential cetacean stranding causes (Figure 7A). The analysis revealed that interactions with fisheries and marine aquaculture were the most frequently cited explanations for strandings, indicating a significant threat to cetacean populations despite media reports that were more likely to cover cases with clear indications of stranding causes.

Evidence has demonstrated that many cetacean species are under direct threats from aquaculture facilities (Heinrich et al., 2019; Methion and Díaz López, 2019; Piwetz et al., 2024) and fishing gears (Leeney et al., 2008; López, 2012; Vishnyakova and Gol'din, 2015; Jaramillo-Legorreta et al., 2019), including entanglement, habitat fragmentation, and behavior change—for example, with an opportunistic foraging strategy, many cetacean species prefer waters inside shellfish aquaculture areas as foraging grounds (Methion and Díaz López, 2019; Piwetz et al., 2024). Furthermore, the accidental capture of cetaceans in fishing gears has also been reported as a serious concern worldwide (Jaramillo-Legorreta et al., 2019; Puig-Lozano et al., 2020; Carlucci et al., 2021)—for example, it has been reported that entanglements in gillnets have heavily accelerated the extinction of a small population of *Vaquita Phocoena sinus* in Mexico (Jaramillo-Legorreta et al., 2019). According to the China Fisheries Statistics Yearbook of 2022, offshore aquaculture in the study area reached 834 km^2 and substantially overlapped with most cetacean stranding sites. Furthermore, the Shanghai–Zhejiang region operated a fleet of 25,537 fishing vessels, representing the busiest waters in China. Considering such intensive aquaculture and fishery industries here, monitoring and rescue efforts should be enforced on the target of reducing cetacean injuries and deaths in this area.

Strong tidal current was considered another key factor for cetacean stranding events. For some cetacean species, behavioral variations such as migration and feeding related to tidal rhythms have been reported (Tsujii et al., 2022). During ebb tides, cetaceans often approach shallow coastal waters for prey (Kimura et al., 2022). However, in shallow water regions characterized by limited depth and varied seabed topography, cetaceans' echolocation capabilities are constrained by reduced detection ranges, rendering them susceptible to stranding in the event of substantial tidal fluctuations. This finding suggests that more attention should be paid to strongly tidal estuaries so as to prevent cetacean stranding, consistent with the results in previous spatial analyses. Notably, information on stranding causes is not available in most reports. Future stranding reports should include all pertinent information to the fullest extent possible to elucidate the comprehensive causes of cetacean strandings.

4.4 Recommendations to improve stranding responses

Only 138 stranding events have been reported over the past 71 years along this extensive coastline. A previous database recorded 1,320 stranding events in Taiwanese waters over the past 25 years. Along the Shandong Peninsula, 203 finless porpoise stranding events were reported based on public reports between 2000 and 2018, yet these coastlines were relatively short. Reporting efforts in the Shanghai–Zhejiang region were once again found to be relatively inadequate. In most districts of the study area, stranding response activities were operated by local non-professional governmental agencies (generally fishery administration and police) with other governmental duties, also indicating the lack of a well-established stranding response network. Thus, some recommendations to improve the cetacean stranding response were hereby provided based on the findings.

First, local stranding response networks and rapid rescue teams should be established immediately. Systematically established stranding response networks, comprising government authorities, cetacean species experts, experienced veterinarians, media practitioners, and the public, could provide timely, high-quality assistance to live stranded animals, compile specific information on long-term stranding records, and thereby provide valuable input for conservation decision-making (Simeone and Moore, 2018). Considering the expansive Chinese coastline, all provinces and districts are suggested to construct provincial and local stranding response networks to prevent and rapidly resolve stranding events. In recent years, district-level aquatic wildlife rescue centers have been gradually established from 2007 to 2022 in this study area, marking the beginning of the leading professional rescue organizations of governments. These organizations are encouraged to coordinate logistics with other participants and establish local stranding response networks as their roles of authority. Policy efforts should be strengthened to increase the engagement of people in stranding responding activities as well as in monitoring and reporting efforts—for example, local coast guards, maritime security patrols, and communities should incorporate cetacean stranding detection into their routine patrols. In areas prone to strandings, it is imperative to reinforce fisheries regulations and establish rapid response teams to mitigate the risk of human-induced injuries and enhance the survival rates of stranded animals.

Second, more detailed and standard stranding information should be provided. Due to the lack of harmonized standards, stranding reports are subject to varying degrees of omission, regardless of information sources. Some information is roughly estimated and vague, which may invalidate assumptions in further research. Additionally, online reports are rather sporadic and cannot be preserved for a long period, leading to difficulties in stranding data collection. These troubles could be solved by establishing a smart, systematic, and well-preserved citizen-based website usually recommended in biological sciences (Kittelberger et al., 2021; Lehtiniemi et al., 2020). All required information categories of cetacean stranding events should be included in this network to assist with information collection in a standardized way. However, users should be enabled to upload reports at any time, providing only essential details—clear photographic or video documentation, precise time and location data from mobile devices, and the number of animals involved—to maintain engagement. Subsequently, authorities, experts, and volunteers should be responsible for the timely verification, completion, and compilation of additional information.

Finally, more research should be further conducted to understand the recovery process of surviving stranded cetaceans and the causes of stranding events. The ratio of live animals could somewhat reflect the regional detection and rescue capability of stranding events. In this study, live individuals occupied 64.56% of all stranded animals, which is comparable to that of other regions in China with available records (Lin et al., 2019; Liu et al., 2019, 2022; Chou et al., 2024)—for example, in Taiwan, only 38.9% of the stranded animals were alive (Chou et al., 2024), while in Hainan, this figure was 53.57% (Liu et al., 2019). Despite numerous live stranding incidents, limited rehabilitation knowledge has been acquired, as the majority of animals were released on-site—for example, a male melon-headed whale in a mass stranding event was rehabilitated for 22 days before dying, providing a critical understanding of the physiological and behavioral traits in this mysterious offshore species and informing the utilization of medical treatments for other cetacean species. Due to insufficient research interests and capabilities, these issues have rarely been systematically researched or reported. Fostering collaboration with local universities and research institutes is a potentially effective strategy to tackle this issue. Such initiatives are vital, as they are critical to improve the survival rates of stranded animals and to advance the public's comprehension of environmental risks to both marine ecosystems and human health.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

JY: Conceptualization, Writing – review & editing, Methodology, Writing – original draft. YG: Methodology, Writing – review & editing. NW: Data curation, Visualization, Writing – review & editing. TJ: Data curation, Visualization, Writing – review & editing. ZC: Conceptualization, Supervision, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

We sincerely thank all those who participated in and reported on these cetacean stranding programs for their contribution to this dataset, including government agencies, museum directors, academic institutions and individuals, medias, citizen organizations, and volunteers. We also would like to thank our colleagues for their constant support to this research.

Conflict of interest

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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2024.1483805/full#supplementary-material

References

Alvarado-Rybak, M., Toro, F., Escobar-Dodero, J., Kinsley, A. C., Sepúlveda, M. A., Capella, J., et al. (2020). 50 years of cetacean strandings reveal a concerning rise in Chilean Patagonia. *Sci. Rep.* 10, 9511. doi: 10.1038/s41598-020-66484-x

Aragones, L. V., Roque, M. A. A., Flores, M. B., Encomienda, R. P., Laule, G. E., Espinos, B. G., et al. (2010). The Philippine marine mammal strandings from 1998 to 2009: animals in the Philippines in peril? *Aquat. Conserv. Mar. Freshw. Ecosyst.* 36, 219. doi: 10.1578/am.36.3.2010.219

Barbieri, M. M., Raverty, S., Bradley Hanson, M., Venn-Watson, S., Ford, J. K. B., and Gaydos, J. K. (2013). Spatial and temporal analysis of killer whale (*Orcinus orca*) strandings in the North Pacific Ocean and the benefits of a coordinated stranding response protocol. *Mar. Mamm. Sci.* 29, E448–E462. doi: 10.1111/mms.12044

Barlow, D. R., Klinck, H., Ponirakis, D., Garvey, C., and Torres, L. G. (2021). Temporal and spatial lags between wind, coastal upwelling, and blue whale occurrence. *Sci. Rep.* 11, 6915. doi: 10.1038/s41598-021-86403-y

Brusius, B. K., de Souza, R. B., and Barbieri, E. (2022). "Stranding of marine animals: Effects of environmental variables," in *Life below water*. Eds. W.L. Filho, A. M. Azul, L. Brandli, A. Lange Salvia and T. Wall (Springer, Dordrecht), 1–10. doi: 10.1007/978-3-319-71064-8_102-1

Cao, L., Li, J., Ye, M., Pu, R., Liu, Y., Guo, Q., et al. (2018). Changes of ecosystem service value in a coastal zone of Zhejiang Province, China, during rapid urbanization. *Int. J. Environ. Res. Public Health* 15, 1301. doi: 10.3390/ijerph15071301

Carlucci, R., Capezzuto, F., Cipriano, G., D'Onghia, G., Fanizza, C., Libralato, S., et al. (2021). Assessment of cetacean-fishery interactions in the marine food web of the Gulf of Taranto (Northern Ionian Sea, Central Mediterranean Sea). *Rev. Fish Biol. Fisher.* 31, 135–156. doi: 10.1007/s11160-020-09623-x

Chan, D., Tsui, H., and Kot, B. (2017). Database documentation of marine mammal stranding and mortality: current status review and future prospects. *Dis. Aquat. Organ.* 126, 247–256. doi: 10.3354/dao03179

Chen, M., Yu, D., Wang, K., Zhang, K., and Wang, Z. (2022). Seasonal and diel activities of the Yangtze finless porpoise in natural and highly disturbed habitats: Implications for conservation planning of freshwater cetaceans. *Aquat. Conserv. Mar. Freshw. Ecosyst.* 32, 605–616. doi: 10.1002/aqc.3788

Chen, Y., Sherren, K., Smit, M., and Lee, K. Y. (2023). Using social media images as data in social science research. *New Media Soc* 25, 849–871. doi: 10.1177/14614448211038761

Chou, L. S., Yao, C. J., Wang, M. C., Chi, W. L., Ho, Y., and Yang, W. C. (2024). Cetacean stranding response program and spatial-temporal analysis in Taiwan 1994–2018. *Anim. (Basel)* 14, 1823. doi: 10.3390/ani14121823

Coombs, E. J., Deaville, R., Sabin, R. C., Allan, L., O'Connell, M., Berrow, S., et al. (2019). What can cetacean stranding records tell us? A study of UK and Irish cetacean diversity over the past 100 years. *Mar. Mamm. Sci.* 35, 1527–1555. doi: 10.1111/mms.12610

Cui, Y., Xu, H., An, D., and Yang, L. (2024). Evaluation of marine economic development demonstration zone policy on marine industrial structure optimization: a case study of Zhejiang, China. *Front. Mar. Sci.* 11. doi: 10.3389/fmars.2024.1403347

Cuvertoret-Sanz, M., López-Figueroa, C., O'Byrne, A. O., Canturri, A., Martí-Garcia, B., Pintado, E., et al. (2020). Causes of cetacean stranding and death on the Catalonian coast (western Mediterranean Sea), 2012–2019. *Dis. Aquat. Organ.* 142, 239–253. doi: 10.3354/dao03550

Czapanskiy, M. F., Savoca, M. S., Gough, W. T., Segre, P. S., Wisniewska, D. M., Cade, D. E., et al. (2021). Modelling short-term energetic costs of sonar disturbance to cetaceans using high-resolution foraging data. *J. Appl. Ecol.* 58, 1643–1657. doi: 10.1111/1365-2664.13903

Dudhat, S., Pande, A., Nair, A., Mondal, I., Srinivasan, M., and Sivakumar, K. (2022). Spatio–temporal analysis identifies marine mammal stranding hotspots along the Indian coastline. *Sci. Rep.* 12, 4128. doi: 10.1038/s41598-022-06156-0

Fernández, R., Pierce, G. J., MacLeod, C. D., Brownlow, A., Reid, R. J., Rogan, E., et al. (2014). Strandings of northern bottlenose whales, *Hyperoodon ampullatus*, in the north-east Atlantic: seasonality and diet. *J. Mar. Biol. Assoc. U.K.* 94, 1109–1116. doi: 10.1017/S002531541300180X

Friess, D. A., Yando, E. S., Wong, L. W., and Bhatia, N. (2020). Indicators of scientific value: An under-recognised ecosystem service of coastal and marine habitats. *Ecol. Indic.* 113, 106255. doi: 10.1016/j.ecolind.2020.106255

Geraci, J. R., and Lounsbury, V. J. (2005). *Marine mammals ashore: a field guide for strandings* (Galveston: Texas A&M sea grant publication).

Goetz, S., Read, F. L., Ferreira, M., Portela, J. M., Santos, M. B., Vingada, J., et al. (2015). Cetacean occurrence, habitat preferences and potential for cetacean-fishery interactions in Iberian Atlantic waters: results from cooperative research involving local stakeholders. *Aquat. Conserv. Mar. Freshw. Ecosyst.* 25, 138–154. doi: 10.1002/aqc.2481

Gulland, F., and Stockin, K. (2019). "Harmonizing global strandings response," in *Report from the Society for Marine Mammalogy/European cetacean society conference workshop* (European Cetacean Society, Barcelona).

Hamilton, L. J. (2018). Large mass strandings of selected odontocete species: statistics, locations, and relation to earth processes. *J. Cetacean Res. Manage* 19, 57–78. doi: 10.47536/jcrm.v19i1.415

Heinrich, S., Genov, T., Fuentes Riquelme, M., and Hammond, P. S. (2019). Fine-scale habitat partitioning of Chilean and Peale's dolphins and their overlap with aquaculture. *Aquat. Conserv. Mar. Freshw. Ecosyst.* 29, 212–226. doi: 10.1002/aqc.3153

Huggins, J. L., Oliver, J., Lambourn, D. M., Calambokidis, J., Diehl, B., and Jeffries, S. (2015). Dedicated beach surveys along the central Washington coast reveal a high proportion of unreported marine mammal strandings. *Mar. Mammal Sci.* 31, 782–789. doi: 10.1111/mms.12184

IJsseldijk, L. L., Ten Doeschate, M. T. I., Brownlow, A., Davison, N. J., Deaville, R., Galatius, A., et al. (2020). Spatiotemporal mortality and demographic trends in a small cetacean: Strandings to inform conservation management. *Biol. Conserv.* 249, 108733. doi: 10.1016/j.biocon.2020.108733

Jaramillo-Legorreta, A. M., Cardenas-Hinojosa, G., Nieto-Garcia, E., Rojas-Bracho, L., Thomas, L., Ver Hoef, J. M., et al. (2019). Decline towards extinction of Mexico's vaquita porpoise (*Phocoena sinus*). *R. Soc Open Sci.* 6, 190598. doi: 10.1098/rsos.190598

Joyce, T. W., Ferguson, M. C., Berchok, C. L., Wright, D. L., Crance, J. L., Braen, E. K., et al. (2023). The role of sea ice in the distribution, habitat use, and phenology of eastern North Pacific gray whales. *Mar. Ecol–Prog. Ser.* 709, 141–158. doi: 10.3354/meps14271

Keshavarz, H. (2021). Evaluating credibility of social media information: current challenges, research directions and practical criteria. *Inf. Discovery Deliv.* 49, 269–279. doi: 10.1108/idd-03-2020-0033

Kimura, S. S., Sagara, T., Yoda, K., and Ponnampalam, L. S. (2022). Habitat preference of two sympatric coastal cetaceans in Langkawi, Malaysia, as determined by passive acoustic monitoring. *Endanger. Species Res.* 48, 199–209. doi: 10.3354/esr01194

Kittelberger, K. D., Hendrix, S. V., and Şekercioğlu, Ç. H. (2021). The value of citizen science in increasing our knowledge of under-sampled biodiversity: an overview of public documentation of Auchenorrhyncha and the hoppers of North Carolina. *Front. Environ. Sci.* 9. doi: 10.3389/fenvs.2021.710396

Leeney, R. H., Amies, R., Broderick, A. C., Witt, M. J., Loveridge, J., Doyle, J., et al. (2008). Spatio-temporal analysis of cetacean strandings and bycatch in a UK fisheries hotspot. *Biodivers. Conserv.* 17, 2323–2338. doi: 10.1007/s10531-008-9377-5

Lehtiniemi, M., Outinen, O., and Puntila-Dodd, R. (2020). Citizen science provides added value in the monitoring for coastal non-indigenous species. *J. Environ. Manage.* 267, 110608. doi: 10.1016/j.jenvman.2020.110608

Li, W. T., Chou, L. S., Chiou, H. Y., Chen, I. H., and Yang, W. C. (2021). Analyzing 13 years of cetacean strandings: multiple stressors to cetaceans in Taiwanese waters and their implications for conservation and future research. *Front. Mar. Sci.* 8. doi: 10.3389/fmars.2021.606722

Lin, M., Xing, L., Fang, L., Huang, S., Yao, C., Turvey, S. T., et al. (2019). Can local ecological knowledge provide meaningful information on coastal cetacean diversity? A case study from the northern South China Sea. *Ocean Coast. Manage.* 172, 117–127. doi: 10.1016/j.ocecoaman.2019.02.004

Lin, Y. (2020). Coupling analysis of marine ecology and economy: case study of Shanghai, China. *Ocean Coast. Manage.* 195, 105278. doi: 10.1016/j.ocecoaman.2020.105278

Liu, M., Lin, M., and Li, S. (2022). Species diversity and spatiotemporal patterns based on cetacean stranding records in China 1950–2018. *Sci. Total Environ.* 822, 153651. doi: 10.1016/j.scitotenv.2022.153651

Liu, M., Lin, M., Zhang, P., Xue, T., and Li, S. (2019). An overview of cetacean stranding around Hainan Island in the South China Sea 1978–2016: implications for research, conservation and management. *Mar. Policy* 101, 147–153. doi: 10.1016/j.marpol.2018.04.029

López, B. D. (2012). Bottlenose dolphins and aquaculture: interaction and site fidelity on the northeastern coast of Sardinia (Italy). *Mar. Biol.* 159, 2161–2172. doi: 10.1007/s00227-012-2002-x

López, B. G., Bossi, R., Eulaers, I., Dietz, R., Peñalver, J., Schulz, R., et al. (2020). Stranded cetaceans warn of high perfluoroalkyl substance pollution in the western Mediterranean Sea. *Environ. pollut.* 267, 115367. doi: 10.1016/j.envpol.2020.115367

Mann, J., and Würsig, B. (2014). "Observing and quantifying cetacean behavior in the wild: current problems, limitations, and future directions," in *Primates and cetaceans: field research and conservation of complex mammalian societies*. Eds. J. Yamagiwa and L. Karczmarski (Springer, New York), 335–344.

Mayorga, L. F. S. P., Vanstreels, R. E. T., Bhering, R. C. C., Mamede, N., Costa, L. M. B., Pinheiro, F. C. F., et al. (2020). Strandings of cetaceans on the Espírito Santo coast, southeast Brazil 1975–2015. *ZooKeys* 948, 129–152. doi: 10.3897/zookeys.948.50468

Methion, S., and Díaz López, B. (2019). Natural and anthropogenic drivers of foraging behaviour in bottlenose dolphins: influence of shellfish aquaculture. *Aquat. Conserv. Mar. Freshw. Ecosyst.* 29, 927–937. doi: 10.1002/aqc.3116

Moore, M. J., Mitchell, G. H., Rowles, T. K., and Early, G. (2020). Dead cetacean? Beach, bloat, float, sink. *Front. Mar. Sci.* 7. doi: 10.3389/fmars.2020.00333

Morais, P., Afonso, L., and Dias, E. (2021). Harnessing the Power of Social Media to Obtain Biodiversity Data About Cetaceans in a Poorly Monitored Area. *Front. Mar. Sci.* 8. doi: 10.3389/fmars.2021.765228

Mustika, P. L. K., High, K. K., Putra, M. I. H., Sahri, A., Ratha, I. M. J., Prinanda, M. O., et al. (2022). When and where did they strand? The spatio-temporal hotspot patterns of cetacean stranding events in Indonesia. *Oceans* 3, 509–526. doi: 10.3390/oceans3040034

Onens, P., Wilkin, S., Fauquier, D., Spradlin, T., Manley, S., Greig, D., et al. (2023). Report of marine mammal strandings in the United States: national overview 2019.

Pace, D. S., Tizzi, R., and Mussi, B. (2015). Cetaceans Value and Conservation in the Mediterranean Sea. *J. Biodivers. Endanger. Species* S1, 4. doi: 10.4172/2332-2543.S1.004

Page-Karjian, A., Lo, C. F., Ritchie, B., Harms, C. A., Rotstein, D. S., Han, S., et al. (2020). Anthropogenic contaminants and histopathological findings in stranded cetaceans in the southeastern United States 2012–2018. *Front. Mar. Sci.* 7. doi: 10.3389/fmars.2020.00630

Paradell, O. G., Methion, S., Rogan, E., and López, B. D. (2021). Modelling ecosystem dynamics to assess the effect of coastal fisheries on cetacean species. *J. Environ. Manage.* 285, 112175. doi: 10.1016/j.jenvman.2021.112175

Parsons, E. C. M. (1998). Strandings of small cetaceans in Hong Kong territorial waters. *J. Mar. Biol. Assoc. U. K.* 78, 1039–1042. doi: 10.1017/S0025315400045021

Pennino, M. G., Rufener, M. C., Giménez, J., Berlinguer, F., Bollo, E., Appino, S., et al. (2022). Understanding the causes of mortality and contaminant loads of stranded cetacean species in Sardinian waters (Italy) using Bayesian Hierarchical Models. *J. Sea Res.* 181, 102170. doi: 10.1016/j.seares.2022.102170

Pires, A. L. M. S., de Sá Maciel, I., dos Santos Alves, M. A., and Tardin, R. H. (2021). The effects of anthropogenic noise on cetaceans in Brazil: the need to consider recent scientific advances in environmental licensing. *J. Coast. Conserv.* 25, 1–39. doi: 10.1007/s11852-021-00832-5

Piwetz, S., Pearson, H. C., Honkus, K. A., and Würsig, B. (2024). Dusky dolphin (*Lagenorhynchus obscurus*) habitat use in a mussel farming region and changes over time. *N. Z. J. Mar. Freshw. Res.* 1–23. doi: 10.1080/00288330.2024.2334287

Prado, J. H., Mattos, P. H., Silva, K. G., and Secchi, E. R. (2016). Long-term seasonal and interannual patterns of marine mammal strandings in subtropical western South Atlantic. *PloS One* 11, e0146339. doi: 10.1371/journal.pone.0146339

Puig-Lozano, R., Fernández, A., Sierra, E., Saavedra, P., Suárez-Santana, C. M., de la Fuente, J., et al. (2020). Retrospective study of fishery interactions in stranded cetaceans, Canary Islands. *Front. Vet. Sci.* 7. doi: 10.3389/fvets.2020.567258

Pulkkinen, A., Moore, K., Zellar, R., Uritskaya, O., Karaköylü, E., Uritsky, V., et al. (2020). Statistical analysis of the possible association between geomagnetic storms and cetacean mass strandings. *J. Geophys. Res-Biogeo.* 125, e2019JG005441. doi: 10.1029/2019JG005441

Pyenson, N. D. (2011). The high fidelity of the cetacean stranding record: insights into measuring diversity by integrating taphonomy and macroecology. *Proc. R. Soc* 278, 3608–3616. doi: 10.1098/rspb.2011.0441

Risch, D., Norris, T., Curnock, M., and Friedlaender, A. (2019). Common and Antarctic minke whales: Conservation status and future research directions. *Front. Mar. Sci.* 6, 247. doi: 10.1029/2019JG005441

Roman, J., Estes, J. A., Morissette, L., Smith, C., Costa, D., Mccarthy, J., et al. (2014). Whales as marine ecosystem engineers. *Front. Ecol. Environ.* 12, 377–385. doi: 10.1890/130220

Ruan, X., Feng, X., and Pang, K. (2018). Development of port service network in OBOR via capacity sharing: an idea from Zhejiang Province in China. *Marit. Policy Manage.* 45, 105–124. doi: 10.1080/03088839.2017.1391412

Saavedra, C., Pierce, G. J., Gago, J., Jusufovski, D., Cabrero, Á., Cerviño, S., et al. (2017). Factors driving patterns and trends in strandings of small cetaceans. *Mar. Biol.* 164, 1–17. doi: 10.1007/s00227-017-3200-3

Saltzman, J., Graham, J., Wester, J., White, E. R., and Macdonald, C. C. (2022). Sawfish: Social media to assess public perceptions, behaviors, and attitudes towards a critically endangered species. *Front. Conserv. Sci.* 3. doi: 10.3389/fcosc.2022.987909

Savery, L. C., Wise, S. S., Falank, C., Wise, J., Gianios, C., Thompson, W. D., et al. (2013). Global assessment of oceanic lead pollution using sperm whales (*Physeter macrocephalus*) as an indicator species. *J. Environ. Anal. Toxicol.* 79, 236–244. doi: 10.1016/j.marpolbul.2013.12.007

Silva, V. S., Skueresky, N., Lopes, F., Koch, T. K., Ott, P. H., Siciliano, S., et al. (2021). Integrating morphology and DNA barcoding to assess cetacean diversity in Brazil. *Mamm. Res.* 66, 349–369. doi: 10.1007/s13364-021-00555-w

Simeone, C. A., and Moore, K. M. (2018). "Stranding response," in *CRC handbook of marine mammal medicine*. Eds. F. M. Gulland, L. A. Dierauf and K. L. Whitman (CRC Press, Boca Raton, Florida), 3–18.

Song, H., Omori, K., Kim, J., Tenzek, K. E., and Jung, J. Y. (2016). Trusting Social Media as a Source of Health Information: Online Surveys Comparing the United States, Korea, and Hong Kong. *J. Med. Internet Res.* 18, e25. doi: 10.2196/jmir.4193

Tepsich, P., Schettino, I., Atzori, F., Azzolin, M., Campana, I., Carosso, L., et al. (2020). Trends in summer presence of fin whales in the western Mediterranean Sea Region: new insights from a long-term monitoring program. *PeerJ* 8, e10544. doi: 10.7717/peerj.10544

Thorne, L. H., Heywood, E. I., and Hirtle, N. O. (2022). Rapid restructuring of the odontocete community in an ocean warming hotspot. *Glob. Change Biol.* 28, 6524–6540. doi: 10.1111/gcb.16382

Tonay, A. M., Uzun, B., Dede, A., Amaha Öztürk, A., Danyer, E., Aytemiz Danyer, I., et al. (2020). Population genetic structure of the short-beaked common dolphin from the Black Sea and the Turkish Straits System. *Mitochondr. DNA A* 31, 257–264. doi: 10.1080/24701394.2020.1788008

Torres-Pereira, A., Araújo, H., Monteiro, S. S., Ferreira, M., Bastos-Santos, J., Sá, S., et al. (2023). Assessment of harbour porpoise bycatch along the Portuguese and Galician coast: insights from Strandings over two decades. *Anim. (Basel)* 13, 2632. doi: 10.3390/ani13162632

Tsujii, K., Akamatsu, T., Okamoto, R., Mori, K., and Mitani, Y. (2022). Tidal effects on periodical variations in the occurrence of singing humpback whales in coastal waters of Chichijima Island, Ogasawara. *Japan. Sci. Rep.* 12, 19702. doi: 10.1038/s41598-022-24162-0

UNEP, C. M. S and ASCOBANS (2022). Progress Report of the Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS).

Van Weelden, C., Towers, J. R., and Bosker, T. (2021). Impacts of climate change on cetacean distribution, habitat and migration. *Clim. Change Ecol.* 1, 100009. doi: 10.1016/j.ecochg.2021.100009

Vishnyakova, K., and Gol'din, P. (2015). Seasonality of strandings and bycatch of harbour porpoises in the Sea of Azov: the effects of fisheries, weather conditions, and life history. *I.C.E.S. J. Mar. Sci.* 72, 981–991. doi: 10.1093/icesjms/fsu192

Wang, Y., Li, W., and Van Waerebeek, K. (2015). Strandings, bycatches and injuries of aquatic mammals in China 2000-2006, as reviewed from official documents: a compelling argument for a nationwide strandings programme. *Mar. Policy* 51, 242–250. doi: 10.1016/j.marpol.2014.07.016

Warlick, A. J., Huggins, J. L., Lambourn, D. M., Duffield, D. A., D'Alessandro, D. N., Rice, J. M., et al. (2022). Cetacean strandings in the US Pacific northwest 2000-2019 reveal potential linkages to oceanographic variability. *Front. Mar. Sci.* 9. doi: 10.3389/fmars.2022.758812

Wu, Y., Xie, L., Huang, S. L., Yuan, Z., and Liu, W. (2018). Using social media to strengthen public awareness of wildlife conservation. *Ocean Coast. Manage.* 153, 76–83. doi: 10.1016/j.ocecoaman.2017.12.010

Zhang, H., Yoshizawa, S., Iwasaki, W., and Wang, X. (2019). Seasonal fish assemblage structure using environmental DNA in the Yangtze Estuary and its adjacent waters. *Front. Mar. Sci.* 6. doi: 10.3389/fmars.2019.00515

Zhang, X., Liu, J., Saito, Y., Xu, G., Chen, B., and Chen, L. (2020). Sedimentary signals of the upwelling along the Zhejiang coast, China. *Estuar. Coast. Shelf Sci.* 232, 106396. doi: 10.1016/j.ecss.2019.106396

Zhao, L., Zhu, Q., Miao, X., Xu, M., Wu, F., Dai, Y., et al. (2017). An overview of cetacean strandings, bycatches and rescues along the western coast of the Taiwan Strait, China: 2010–2015. *Acta Oceanol. Sin.* 36, 31–36. doi: 10.1007/s13131-017-1100-5

Zuo, T., Li, Y., Cheng, Z., Wang, J., Sun, J., Yuan, W., et al. (2023). Finless porpoise bycatch and stranding along the Shandong peninsula, China, based on public reports from 2000 to 2018. *Anim. (Basel)* 13, 3868. doi: 10.3390/ani13243868