



## ARTICLE OPEN ACCESS

# Unveiling Patterns in Cetacean Strandings Along Southern Atlantic Iberia: Temporal and Spatial Trends, Seasonality, and Causes of Death

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## ABSTRACT

We compiled 46 years of cetacean strandings in the Algarve, Portugal, describing temporal–spatial patterns, size–sex structure, and causes of death (COD). We analyzed national records and years with a dedicated regional stranding network (SN) to assess annual/seasonal trends, spatial hotspots, and compare biometrics and COD. In total, 1231 strandings were recorded; 73.2% were identified to 19 species. Five species comprised almost 68% of events: common dolphins 39.0%, striped dolphins 8.9%, minke whales 8.0%, bottlenose dolphins 8.0%, and harbor porpoises 4.3%. GAMs confirmed that recorded strandings rose over time and were higher during SN years (mean 63 yr.<sup>-1</sup>). Stranding hotspots occurred near Cape Santa Maria (Faro–Olhão), Lagos–Portimão, and Sagres; minke whales and harbor porpoises concentrated east of Cape Santa Maria. Seasonality was significant only for minke whales (spring peak). Size–sex patterns were largely similar, with exceptions for larger stranded striped dolphin females and minke strandings dominated by juveniles. COD assignment improved with monitoring and was assessed for 75.6% of the observed carcasses. Bycatch was the leading COD for common dolphins, bottlenose dolphins, and minke whales. This study highlights the importance of a regional stranding network and a need for more ecological studies of cetaceans in the region.

## 1 | Introduction

Strandings, or stranding events, refer to events in which single or multiple marine animals wash ashore that is, either dead or alive, unable to return to their natural habitat without assistance (Geraci and Lounsbury 2005). Cetacean strandings can result from both natural and/or anthropogenic causes. Underlying natural causes include diseases such as the well-documented morbillivirus (Van Bresseem et al. 2014), traumatic injuries from intraspecific or interspecific interactions (e.g.,

with other cetaceans or sharks; Crespo-Picazo et al. 2021; Díaz-Delgado et al. 2018; López et al. 2018; Puig-Lozano et al. 2020), and parasitic infections (Alwis et al. 2024; Arbelo et al. 2013; Cuvertoret-Sanz et al. 2020). Anthropogenic causes encompass a variety of threats, such as acoustic and chemical pollution, and ship strikes, the latter disproportionately affecting larger species (Nabi et al. 2018; Panigada et al. 2006; Peltier et al. 2019; Van Waerebeek et al. 2007). However, globally, the most widespread and impactful cause of mortality remains fisheries interactions (Alexandre et al. 2022; Anderson et al. 2020; Read et al. 2006),

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including bycatch (Peltier et al. 2016; Sonne et al. 2024), entanglements (How et al. 2021), and cases of lethal larynx strangulation (Gomerčić et al. 2009).

Systematic recording of stranding events plays a crucial role in improving our understanding of cetacean ecology and species diversity (Pyenson 2011). It also allows for the identification of spatial and temporal occurrence patterns, revealing possible stranding hotspots. Moreover, stranding records provide essential data to inform conservation and management strategies (McGovern et al. 2016; Olson et al. 2020; Saavedra et al. 2017). Stranded animals offer a cost-effective opportunity to collect biological samples, which contribute valuable insights into cetacean biology, demographic patterns (Peltier et al. 2012), and, in cases involving deceased individuals, causes of mortality. Such samples enable more in-depth research on life history (Arrigoni et al. 2011; Grandi et al. 2022), feeding ecology (Giménez et al. 2017, 2018; Marçalo et al. 2018, 2021), ecotoxicology (Monteiro et al. 2016; Pierce et al. 2008, 2013), and population dynamics and genetics (Bilgmann et al. 2011). Furthermore, recent studies have increasingly explored the drift and origin of stranded carcasses and how oceanographic conditions influence the likelihood, timing, and location of strandings (Deslias et al. 2024; Peltier et al. 2012; Saavedra et al. 2017). These approaches are particularly valuable for identifying areas heavily affected by bycatch pressure (Peltier et al. 2016).

Worldwide, cetacean stranding response efforts have been established, responding to and documenting both live and dead strandings, resulting in extensive datasets across diverse marine regions (e.g., the North Sea: IJsseldijk et al. 2020; South China Sea: Liu and Li 2019; Gulf of Mexico: Russell et al. 2022; UK: Williamson et al. 2021; Albrecht et al. 2024; Galiza/Spain: López et al. 2002; Saavedra et al. 2017; Mainland Portugal: Marçalo et al. 2021; Torres-Pereira, Araújo, et al. 2023). However, stranding data for mainland Portugal remain scarce, despite the region being a key habitat for cetaceans in Western Europe, with at least 28 species recorded (Vingada and Eira 2018). So far, studies on stranding patterns along the Portuguese mainland coast have focused on individual species, such as an outdated study on common dolphins, *Delphinus delphis* (Silva and Sequeira 2003), and most recently one on striped dolphins, *Stenella coeruleoalba* (Marçalo et al. 2021) and harbor porpoises, *Phocoena phocoena* (Torres-Pereira, Araújo, et al. 2023). Therefore, a comprehensive and up-to-date analysis covering multiple species and general stranding trends across any part of the mainland Portugal is still lacking.

Situated in the southwestern corner of the Iberian Peninsula and the southern Portuguese mainland, the Algarve region and its coastal waters are characterized by high productivity, biomass, and biodiversity, offering favorable conditions for high-trophic-level predators, such as cetaceans (Marçalo et al. 2024, 2025). At least 14 different cetacean species have been recorded in the region (Grilo et al. 2022). It functions as an important nursery and breeding area for common dolphins and common bottlenose dolphins, *Tursiops truncatus* (Castro et al. 2020; Grave 2022) and as a migratory corridor for North Atlantic fin whale, *Balaenoptera physalus* (Purcari 2023).

The present study aims to address existing knowledge gaps regarding cetacean strandings in the Algarve by focusing on the

five most frequently stranded species: the common dolphin, the striped dolphin, the common bottlenose dolphin, the northern minke whale (*Balaenoptera acutorostrata*), and the harbor porpoise. Using 46 years of stranding data (1978–2023) we aimed to (i) describe temporal patterns in strandings, (ii) identify potential stranding hotspots, (iii) provide insight into size-sex relationships, and finally (iv) understand the main causes of death, with the goal of informing conservation and management strategies for the region.

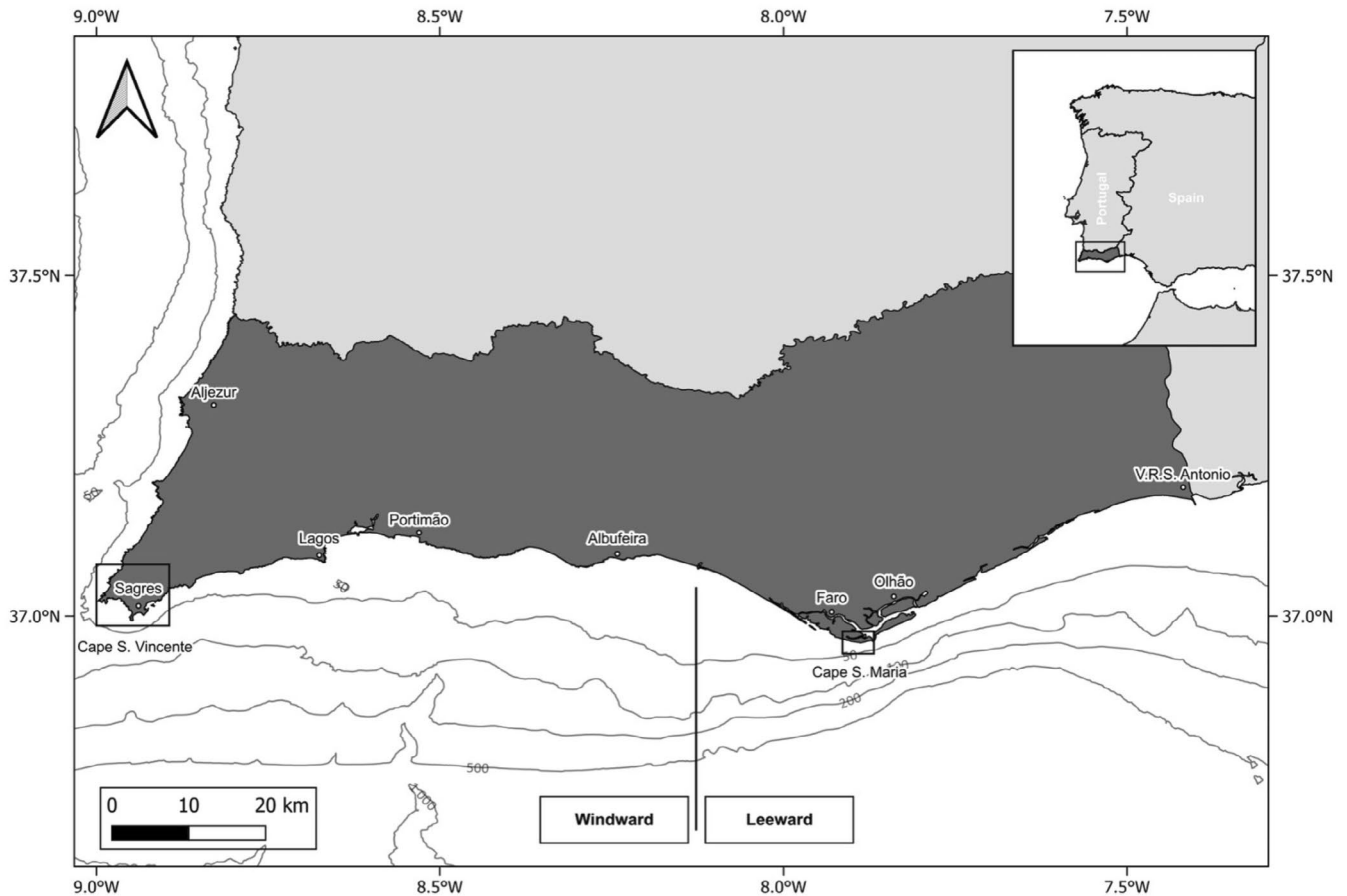
## 2 | Materials and Methods

### 2.1 | Study Area

The study was conducted along the coast of the Algarve, the southernmost region of mainland Portugal (Figure 1). This area includes a short stretch of the western coast (~50 km), characterized by rocky shores and Mesozoic limestone cliffs, ranging from Odeceixe (37°26' N–8°47' W) to Cape São Vicente, Sagres (37°00' N–8°56' W). The southern coast (~170 km) extending from Cape São Vicente to Vila Real de Santo António (37°11' N–7°25' W) is more heterogeneous and can be geographically divided into two subregions: windward and leeward. The windward region extends from Odeceixe (northern limit of the region) to Quarteira and features caves, cliffs, and sandy beaches. The leeward ranges from Quarteira to Vila Real de Santo António (eastern limit of the region) and includes the Ria Formosa lagoon system with its barrier islands and extensive sandy shores. The Algarve is bordered by a narrow continental shelf, 5 to 20 km wide, narrowing considerably near Cape Santa Maria off Faro. This highly dynamic region is ecologically important for cetaceans, influenced by both coastal upwelling and the inflow of warm Mediterranean waters (Marçalo et al. 2025).

### 2.2 | Data Collection

Cetacean stranding data were obtained from 1978 until 2023 from the Portuguese National Stranding Network, coordinated by the Institute of Conservation of Nature and Forests (ICNF). From 2010 to 2017 and from late 2020 to 2023, a regional stranding network operated in the study area with more constant dedicated effort. Stranding data from the regional network were annually integrated into the ICNF national database. The regional network involved formal coordination with all authorities (e.g., maritime police and ICNF), active monitoring through targeted beach surveys in remote areas, passive surveillance based on reports from the general public, and targeted outreach and education initiatives. Outreach efforts included public presentations, increased social media engagement, and the launch of a dedicated website in 2020. This improved awareness and reporting rates and ensured systematic recording of strandings of dead cetaceans and associated biological data collection and sampling. During periods when the regional stranding team was inactive, strandings were mainly reported by maritime authorities or ICNF rangers, and COD assessments were limited to external observations (e.g., presence of nets, cables, hooks, and sharp cuts to the body). Animals that were found adrift (mainly whales), but brought to shore and analyzed, were also counted as strandings at



**FIGURE 1** | Study area showing the boundaries of the Algarve, southern Portugal. Rectangles present the two relevant capes. Bathymetry lines display the narrow continental shelf around Cape S. Maria.

the nearest harbor. Furthermore, the regional network ensured animals were necropsied whenever possible, following a standardized dissection protocol (Kuiken and García Hartmann 1991). Relevant information (e.g., species, size, sex, stranding location/decimal degree coordinates and decomposition state—ranging from 1 (alive) to 5 (mummified remains)) was recorded on standardized datasheets, with each entry corresponding to a single stranded individual. Determination of the cause of death was based on gross external and internal examinations (Marçalo et al. 2021; Nicolau et al. 2016). Causes of death (COD) were categorized into classes and subclasses (in parenthesis) as follows: anthropogenic (bycatch, probable bycatch, trauma, collision), natural (illness, interspecies interactions, intraspecies interactions/shark attack), and undetermined. Probable bycatch, part of the subclass anthropogenic, was inferred when animals showed indicators such as good nutritional status, absence of clear net marks, recent prey in the stomachs, bruising, and localized hemorrhaging (Marçalo et al. 2021; Moore et al. 2013). Traumatic death was defined as evidence of acute fatal injury not attributable to fisheries interactions, vessel collision, or predation, based on gross necropsy findings.

### 2.3 | Data Analysis

We analyzed the annual, spatial, and seasonal distribution of strandings, as well as the causes of death for the whole

study period. Particular attention was given to the five most frequently stranded species: common dolphin, striped dolphin, minke whale, bottlenose dolphin, and harbor porpoise. For temporal analysis, strandings were aggregated into one initial 6-year period (1978–1983) followed by 5-year periods from 1984 to 2023 and analyzed on a yearly basis. Seasons were defined as follows: winter–January to March; spring–April to June; summer–July to September; and fall–October to December. Comparisons were made between periods with (SN) and without (no SN) an active stranding network. The relative stranding averages between densities and morphometric data (annual and seasonal) were analyzed using non-parametric tests (Mann–Whitney  $U$  test), as assumptions of normality (Shapiro–Wilk test) and homoscedasticity (Equal Variance Test) were not fulfilled. To assess the effect of a dedicated stranding network on stranding frequency, Generalized Additive Models (GAMs) were applied using the *mgcv* package in R (Wood 2017). Models were compared via Akaike information Criteria (AIC). The negative binomial distribution was selected due to overdispersion in the Poisson model, evidenced by residual diagnostics and Q–Q plots. Seasonality was further analyzed using Aligned Rank Transform ANOVAs to evaluate interaction between season and network presence. Additionally, for SN and no SN periods, Kruskal–Wallis tests followed by Dunn's post hoc tests (with Benjamini–Hochberg correction) were used. Spatial patterns were assessed through linear kernel density estimation, using 0.1 km intervals and interpolation up to 10 km. Maps of relative stranding densities

were produced in QGIS 3.36.0 for all strandings and for each of the five focal species.

Differences between biometric data, that is, mean straight body length and maturity (mSBL) was evaluated using nonparametric tests (Mann-Whitney  $U$  test). Maturity (immature and mature) was inferred from total body length by sex and species using published thresholds:

*Common dolphin*: 195 cm (males), 188 cm (females) (Murphy et al. 2005, 2009).

*Striped dolphin*: 191 cm (males), 189 cm (females) (Roca-Monge et al. 2022).

*Bottlenose dolphin*: 238 cm (males), 232 cm (females) (Wells et al. 2025).

*Minke whale*: 6.85 m (males), 7.25 m (females) (Horwood 1990).

*Harbor porpoise*: 151 cm (males), 170 cm (females) (Torres-Pereira, Araújo, et al. 2023).

For the five important cetacean species, associations between sex and maturity were assessed using contingency table analysis. Chi-square tests of independence were used when expected cell counts were sufficient, while Fisher's exact tests were applied when expected counts were low. These analyses evaluated whether maturity composition differed between sexes within stranding records. For COD, we checked whether an active stranding network impacts the proportion of determined causes of death, using a Chi-square test. To test whether an active stranding network influenced the proportion of identified CODs, a Chi-square test was also applied. For increased reliability, COD analysis was limited to carcasses in decomposition state 3 or lower (Geraci and Lounsbury 2005). Pairwise comparisons of COD categories were conducted using Chi-square proportion tests with Bonferroni correction for multiple comparisons. All statistical analyses were conducted in RStudio v4.2.2.

### 3 | Results

During no SN ( $N = 34$ ), a total of 473 strandings were recorded, averaging 13.9 strandings per year. In contrast, during the 12 years with SN, 758 strandings were documented, averaging 63.2 strandings per year. Therefore, a total of 1231 cetacean strandings were recorded along the Algarve between 1978 and 2023 (Table 1). Of these, 901 individuals (73.2%) were identified to the species level. Among those that could not be identified to the species level, 320 (26%) were either identified to the suborder or the family, while the rest (0.8%,  $n = 10$ ) were labeled as “*Cetacea* ni”. The majority of strandings belonged to the suborder Odontoceti (toothed cetaceans, 77.7%), while Mysticeti (baleen whales) accounted for 12.7% of the total. Nineteen different species were documented as stranded during this 46 year study period. The five most frequently stranded species were the common dolphin (39.0%,  $n = 482$ ), followed by the striped dolphin (8.8%,  $n = 111$ ), the minke whale (8.0%,  $n = 99$ ), the bottlenose dolphin (8.0%,  $n = 98$ ), and the harbor porpoise (4.3%,  $n = 53$ ).

Together, these five species accounted for 68.2% of all recorded strandings and 93.1% of those identified to the species level.

#### 3.1 | Temporal and Seasonal Trends

Cetacean strandings were recorded in 42 of the 46 years of the study period. Overall, the data show a progressive increase in stranding records between 1978 and 2023. The years with the lowest number of strandings were 1980 and 1984 (each with  $N = 1$ ), while no strandings were reported in 1981, 1982, and 1990. The highest number of strandings was recorded in 2013 ( $N = 105$ ).

Prior to 2010, the number of strandings was generally low and variable, with a gradual increase and occasional peaks between 1990 and 2010. A notable increase in strandings occurred during periods when the regional stranding network (SN) was active. The average number of strandings per year during SN periods was 63, representing a nearly sixfold increase compared to periods without active monitoring. This difference was statistically significant (Mann-Whitney  $U$  test,  $p < 0.001$ ), suggesting that improved monitoring and reporting efforts—combined with potential ecological drivers—likely contributed to the increased number of recorded strandings (Figure 2; all species). Temporal trends for the five most frequently stranded species followed similar patterns, with clear increases corresponding to SN activity. For the common dolphin, strandings were significantly lower and more sporadic, with almost no peaks shown before 2010. With the implementation of the SN, a sharp increase was observed, with peak strandings occurring in 2013 (Figure 2; *D. delphis*). Striped dolphin strandings followed a similar trend, though with a lower magnitude overall (Figure 2; *S. coeruleoalba*). For the bottlenose dolphin, strandings were moderate and variable throughout the time series, with a noticeable increase in frequency during the SN periods, with the highest number of strandings (12) occurring during 2022 (Figure 2; *T. truncatus*). Recorded minke whale strandings were rare before 2000. After that, they increased moderately, and following SN implementation, strandings became more frequent, though year-to-year variability remained high (Figure 2; *B. acutorostrata*). Similarly, harbor porpoise strandings were present before the SN, but became more frequent after 2010. However, some SN years still recorded zero strandings, indicating interannual variability in occurrence (Figure 2; *P. phocoena*).

Generalized additive model (GAM) results highlighted a significant effect of the presence of the regional stranding network on cetacean stranding counts. The presence of a SN had a highly significant positive effect ( $p < 0.001$ ) on the amount of recorded strandings, with the model estimating a coefficient of 0.78, predicting more than twice as many strandings during periods with active monitoring. The yearly smooth term was also highly significant ( $p < 0.0001$ ), indicating that stranding counts fluctuate non-linearly over time. The estimated degrees of freedom ( $edf = 3.73$ ) support a nonlinear relationship, capturing interannual variability in the number of annual strandings (Figure 3).

Analyzing the data by seasons, once more the presence of a dedicated SN significantly increased the number of recorded strandings ( $p < 0.001$ ) overall and for four of the five most frequently

**TABLE 1** | Number of stranding of each species within a 6-year period (1978–1983) and 5-year periods (rest) along the study area.

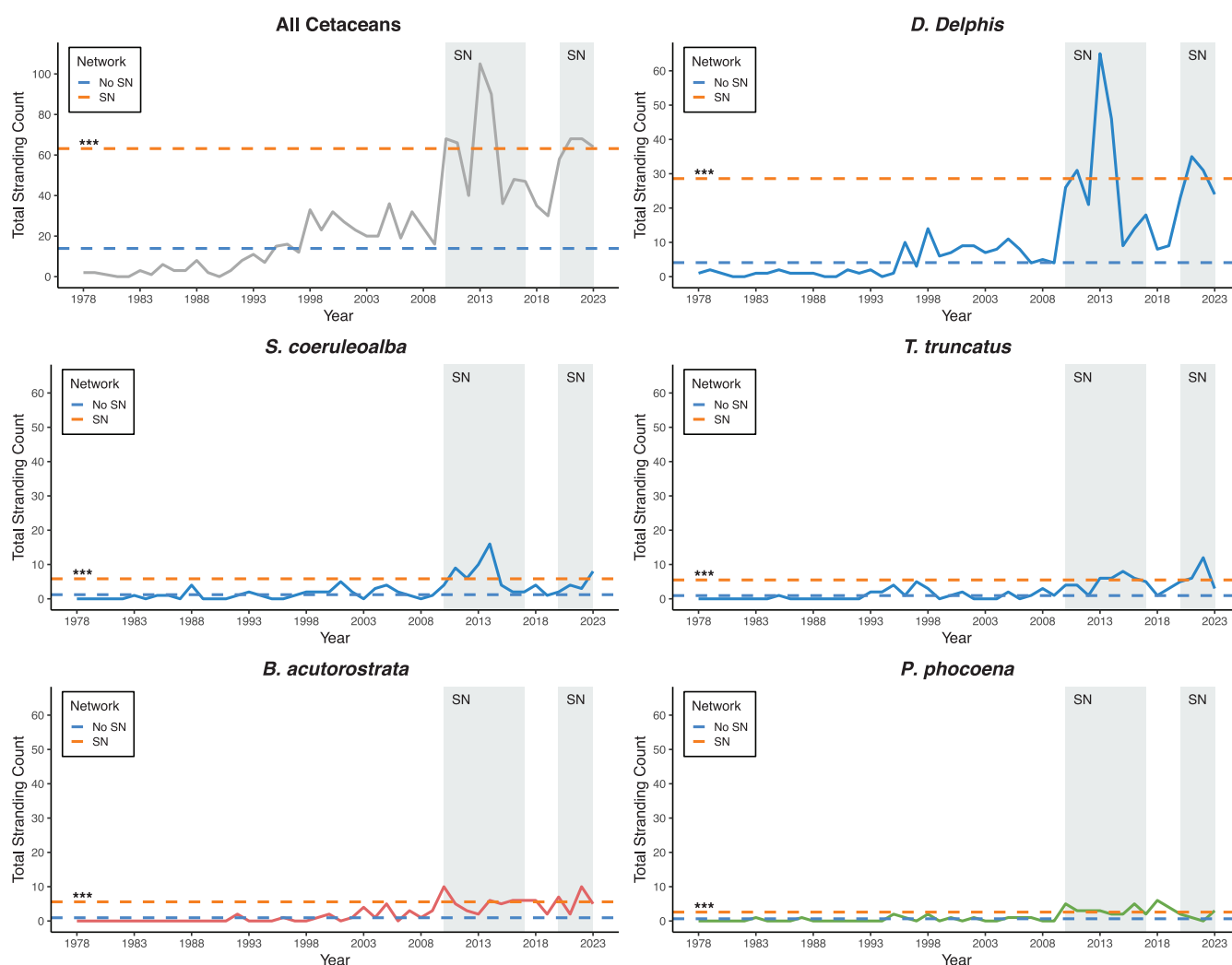
Species	1978– 1983	1984– 1988	1989– 1993	1994– 1998	1999– 2003	2004– 2008	2009– 2013	2014– 2018	2019– 2023	N total	% total
Balaenopteridae											
<i>Balaenoptera acutorostrata</i>	0	0	2	1	8	10	23	29	26	99	8.04%
<i>Balaenoptera ni</i>	0	0	0	0	0	1	8	8	12	29	2.36%
<i>Balaenoptera physalus</i>	0	1	0	1	3	1	2	4	2	14	1.14%
<i>Balaenoptera borealis</i>	1	0	0	0	0	0	0	0	2	3	0.24%
<i>Megaptera novaeangliae</i>	0	0	0	0	0	0	0	1	2	3	0.24%
Delphinidae											
<i>Delphinus delphis</i>	5	6	5	28	38	36	147	95	122	482	38.99%
<i>Delphinidae ni</i>	0	6	8	21	48	54	41	34	57	269	22.18%
<i>Stenella coeruleoalba</i>	1	6	3	4	11	10	30	28	18	111	8.85%
<i>Tursiops truncatus</i>	0	1	2	15	3	6	16	26	29	98	7.96%
<i>Grampus griseus</i>	0	0	2	1	2	1	6	5	0	17	1.38%
<i>Globicephala melas</i>	0	0	1	1	1	1	0	0	0	4	0.32%
<i>Pseudorca crassidens</i>	0	0	0	1	0	0	0	0	0	1	0.08%
<i>Orcinus orca</i>	0	0	0	0	0	0	0	0	1	1	0.08%
<i>Globicephala ni</i>	0	0	0	0	0	0	0	1	0	1	0.08%
<i>Globicephala macrorhynchus</i>	0	0	0	0	0	0	0	0	1	1	0.08%
Phocoenidae											
<i>Phocoena phocoena</i>	1	1	0	5	2	3	14	17	10	53	4.31%
Physeteridae											
<i>Physeter macrocephalus</i>	0	0	0	1	1	0	0	1	1	4	0.32%
Kogiidae											
<i>Kogia breviceps</i>	0	0	0	1	0	1	0	1	1	4	0.32%
<i>Kogia simus</i>	0	0	0	0	1	0	0	1	0	2	0.16%
Ziphiidae											
<i>Mesoplodon mirus</i>	0	0	0	0	0	0	4	1	0	5	0.41%
<i>Mesoplodon ni</i>	0	0	1	1	1	1	0	0	0	4	0.32%

(Continues)

**TABLE 1** | (Continued)

Species	1978–1983	1984–1988	1989–1993	1994–1998	1999–2003	2004–2008	2009–2013	2014–2018	2019–2023	N total	% total
<i>Ziphius cavirostris</i>	0	0	0	0	1	1	0	0	0	2	0.16%
<i>Mesoplodon bidens</i>	0	0	0	0	0	0	0	1	0	1	0.08%
Unidentified species											
Cetacea ni	0	0	0	1	1	1	3	2	2	10	0.81%
Mysticeti ni	0	0	0	0	1	2	1	2	2	8	0.65%
Odontocete ni	0	0	0	1	3	1	0	0	0	5	0.41%
<b>Total</b>	<b>8</b>	<b>21</b>	<b>24</b>	<b>83</b>	<b>125</b>	<b>130</b>	<b>295</b>	<b>257</b>	<b>288</b>	<b>1231</b>	

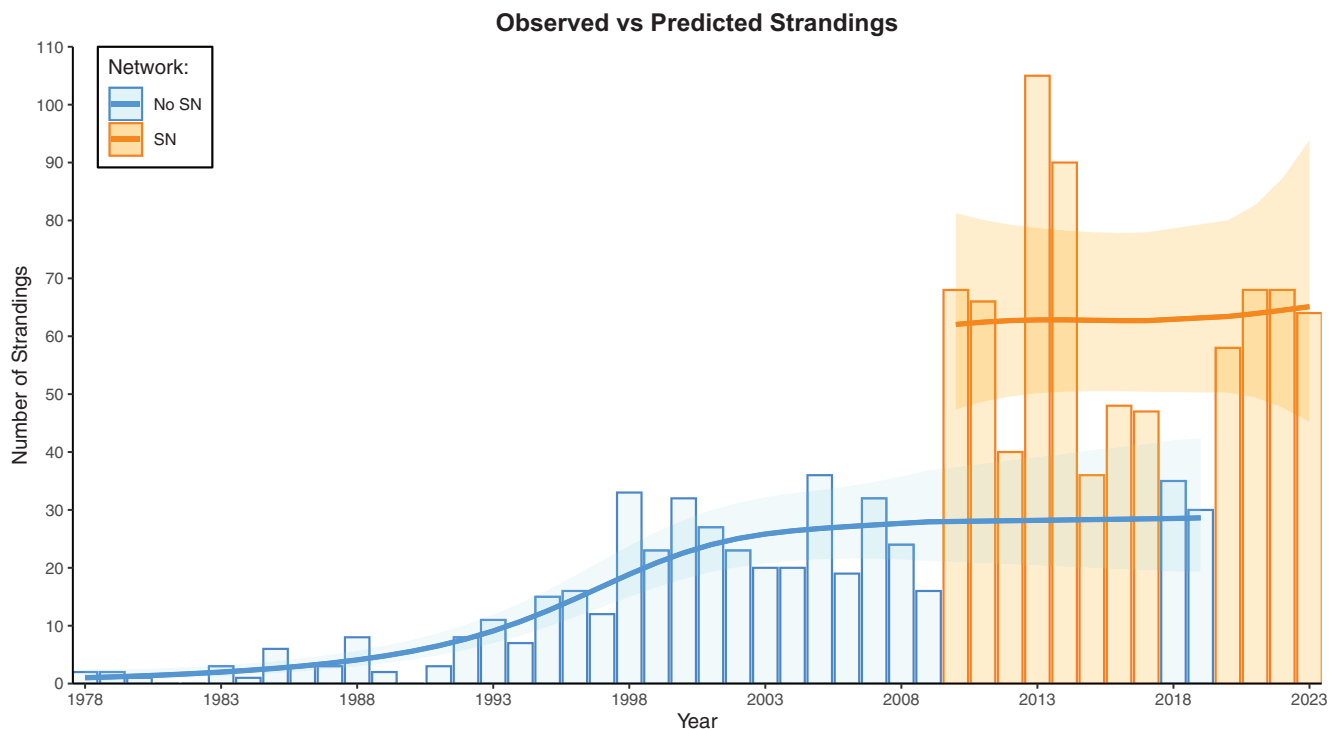
Note: It includes the percentage and sex ratio (animals with no confirmed sex were excluded). The five most stranded species are highlighted in gray.



**FIGURE 2** | Annual reported stranding count for six different taxonomic groups. Shaded regions are the periods with an active stranding network (SN). Dashed lines present the average number of strandings with (Orange) and without a stranding network (Blue). Significant difference was found between averages (\*\* $p < 0.001$ ). The y-axis scale for the *all cetaceans* plot is larger than the scales used in the species-specific plots.

stranded species, while no effect was detected for harbor porpoise (Figure 4). For the minke whale, significant seasonal effects were detected in both the No SN group ( $\chi^2 = 10.48$ ,  $p = 0.015$ ) and the SN

group ( $\chi^2 = 13.14$ ,  $p = 0.004$ ), with patterns persisting after adjusting for multiple comparison. In both groups, minke whale strandings were significantly higher during Spring than in Fall (No SN:



**FIGURE 3** | Observed and predicted annual cetacean strandings in Algarve (1978–2023), modeled using a Negative Binomial Generalized Additive Model (GAM). Bars represent observed strandings, while solid lines show model predictions, with shaded ribbons indicating 95% confidence intervals. The model includes a smooth term for year and a categorical predictor for the presence of a stranding network (SN vs. No SN). The SN was operational from 2010 onward, shown in orange; prior years without a formal network are shown in blue.

$p=0.010$ ; SN:  $p=0.012$ ). In the SN group for the minke whale, Spring strandings were also significantly higher than Winter ( $p=0.020$ ), while additional marginal contrasts were observed between Fall–Summer and Summer–Winter ( $p=0.06–0.07$ ) (Figure 4; *B. acutorostrata*). For the common dolphin, significant seasonal effects were detected in both the No SN group ( $\chi^2=8.01$ ,  $p=0.046$ ) and the SN group ( $\chi^2=8.77$ ,  $p=0.033$ ). However, post hoc Dunn’s pairwise comparisons with correction revealed no significant differences (all adjusted  $p>0.06$ ). Marginal trends in common dolphin strandings were observed, particularly between winter, spring, and summer in the SN group.

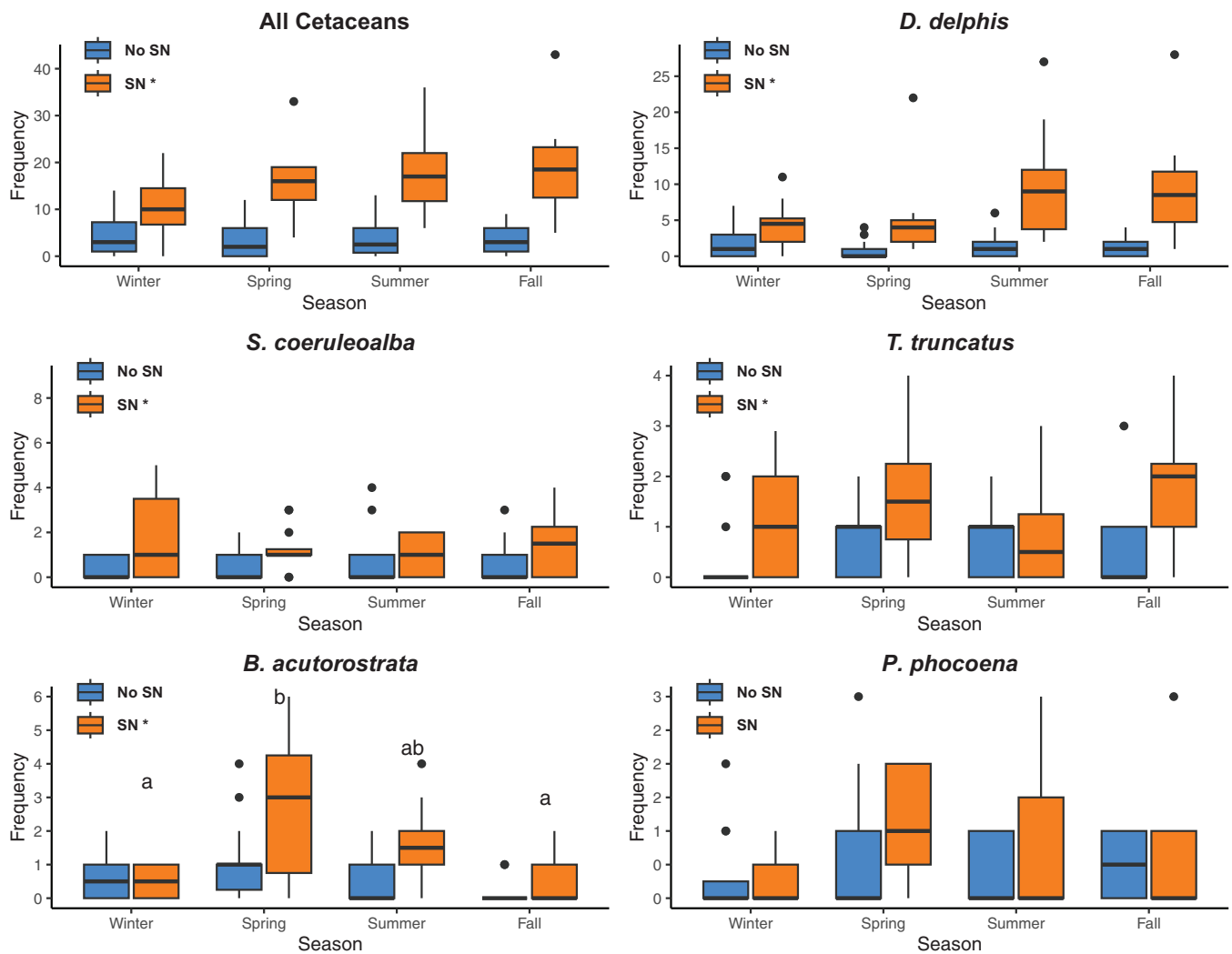
### 3.2 | Spatial Patterns

Cetacean strandings were recorded along the entire Algarve coastline, with distinct hotspots emerging in specific areas. The most prominent stranding locations were the Cape Santa Maria (off Faro–Olhão), the stretch between Lagos and Portimão, and Cape São Vicente in Sagres (Figure 5; All Cetaceans). The common dolphin, the most frequently stranded species, exhibited a similar spatial pattern, with hotspots at Cape Santa Maria, between Lagos and Portimão, and around Sagres. Very few strandings were recorded east of Cape Santa Maria (Figure 5; *D. delphis*). Striped dolphin strandings were mainly concentrated around the barrier islands off Olhão, the area west of Portimão, and between Sagres and Lagos, with very few events along the western coast (Figure 5; *S. coeruleoalba*). Bottlenose dolphin strandings occurred mainly around Cape Santa Maria and Sagres, with little to no records between these two areas (Figure 5; *T. truncatus*). In contrast, minke whales and harbor porpoises were more frequent

in the leeward region, east of Cape Santa Maria. Minke whale strandings were predominantly concentrated between Olhão and Vila Real de Santo António, with additional records west of Faro (Figure 5; *B. acutorostrata*). Finally, the harbor porpoise exhibited a primary hotspot just west of Vila Real de Santo António, with additional strandings recorded in front of the Faro–Olhão barrier islands and in the Portimão area (Figure 5; *P. phocoena*).

### 3.3 | Size and Sexual Maturity

Table 2 summarizes and compares mean straight body length (mSBL) and sex composition for the five most frequently stranded cetacean species. Out of the 482 common dolphins recorded, straight body length (SBL) and sex were recorded for 280 individuals. Slightly more males were recorded ( $N=146$ ), with a mSBL of  $181.65 \pm 33.28$  cm. When compared to females mSBL ( $178.48 \pm 26.72$  cm), they were not significantly larger ( $p>0.05$ ). Although immature were more frequent across both sexes, no significant association was found between sex and maturity ( $\chi^2$  test,  $p>0.05$ ). Among striped dolphins, both SBL and sex were available for 74 out of 111 stranded individuals. Striped dolphin females were more commonly recorded ( $N=44$ ) and had a significantly larger mSBL ( $190.03 \pm 31$  cm) than males ( $176.15 \pm 32.47$  cm) ( $p=0.033$ ). However, no relationship between sex and maturity was found ( $\chi^2$  test,  $p>0.05$ ). For bottlenose dolphins, only 50 out of 98 individuals had both SBL and sex recorded. The mean SBL for males was  $252.60 \pm 66.37$  cm, slightly smaller compared to females ( $269.75 \pm 42.79$  cm), with the size difference not indicating any significant pattern. No significant relationship between maturity and sex was found (Fisher’s exact



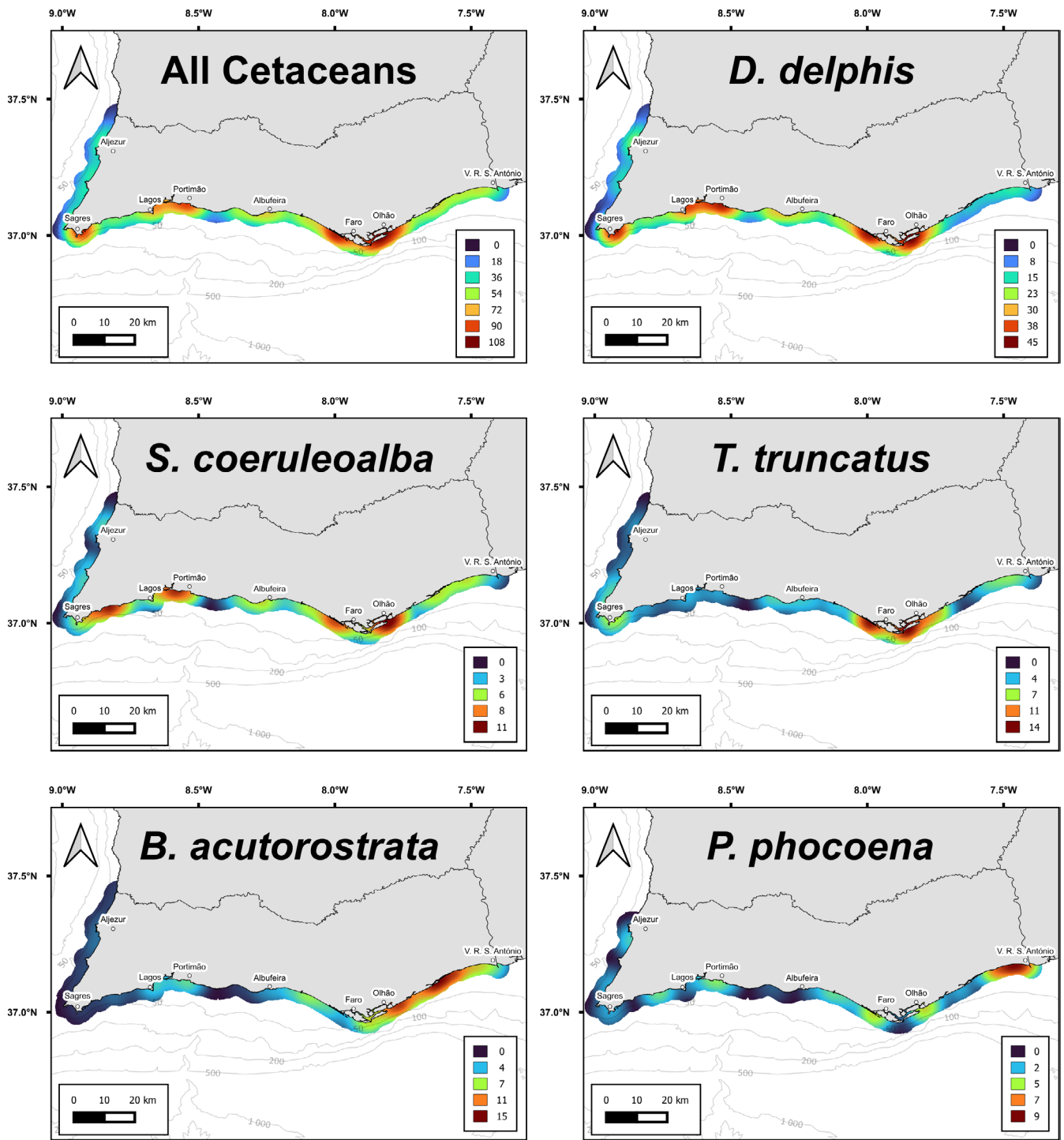
**FIGURE 4** | Seasonal stranding frequency of all and the most common stranded cetaceans in the Algarve, Portugal. Blue boxplots correspond to strandings occurring without the existence of a dedicated stranding network, while orange with the existence of a stranding network, asterisks correspond to significant differences. (\* =  $p < 0.001$ ; Different letters above bars indicate statistically significant differences among seasons ( $p < 0.05$ ); bars sharing a letter are not significantly different).

test,  $p > 0.05$ ). A total of 54 out of the 99 individual minke whales stranded had both sex and SBL recorded. No significant size difference in SBL was found between males ( $426.50 \pm 86.86$  cm) and females ( $444.86 \pm 56.36$  cm). However, a significantly higher number of immature individuals stranded overall ( $\chi^2$  test,  $p < 0.001$ ), with only two adult males recorded. Sex associated with maturity did not reveal any relevant trends (Fisher's exact test,  $p > 0.05$ ). Finally, for harbor porpoises, only 26 of the 53 recorded individuals had sex and SBL logged. Females had a larger mSBL ( $150.70 \pm 33.72$  cm) than males ( $136.50 \pm 30.22$  cm), but the comparison did not indicate that strandings were size related. Likewise, no clear association was detected between maturity and sex of the stranded individuals (Fisher's exact test,  $p > 0.05$ ).

### 3.4 | Cause of Death

The proportion of strandings with an identified cause of death (COD) significantly increased when a dedicated network was active ( $\chi^2$  test,  $p < 0.001$ ). In this case, 43.9% of the cases had an attributed cause of death (Figure 6). When considering only

animals with decomposition state below moderate ( $\leq 3$ ), a total of 329 animals were analyzed, of which 75.6% had a COD successfully determined. The distribution of CODs varied significantly ( $\chi^2$  test,  $p < 0.001$ ). Bycatch alone accounted for 40.9% of all determined cases. When including animals classified as probable bycatch (7.3%), bycatch-related mortality represented nearly half (48.2%) of all identified COD. A pairwise comparison of proportions confirmed that bycatch alone significantly affected more animals compared to any other COD category ( $p < 0.001$ ). Traumatic deaths accounted for 15.7% and were significantly more frequent than all other causes except bycatch ( $p < 0.01$ ) (Figure 7; All cetaceans). As for the species-specific analysis, for the common dolphin, COD was determined for 164 out of 199 individuals. Significant differences were found in the proportion of COD occurrence ( $\chi^2$  test,  $p < 0.001$ ). Bycatch was the leading cause (45.73%), with probable bycatch accounting for an additional 9.04%, bringing bycatch-related mortality to 55.18%. Traumatic causes accounted for 20.10%, significantly higher than illness (4.02%), collision (2.51%), and interspecies interaction (1.00%) ( $p < 0.001$ ), but not significantly different from bycatch (Figure 7; *D. delphis*). Of the 50 stranded striped dolphins,



**FIGURE 5** | Spatial stranding patterns of all and the most common stranded cetaceans in the Algarve, Portugal. Note that colors might present a different number of animals due to the difference in the respective frequency of strandings.

COD was determined in 27 individuals, yielding a high proportion of undetermined cases (46%). The Chi-square test indicated no significant differences in COD ( $\chi^2$  test,  $p > 0.05$ ). Applying a pairwise proportion test only identified a significant difference between bycatch (20%) and probable bycatch (4%). No significant differences were detected among illness (10%), trauma (8%), collision (6%), and interspecies interaction (6%) (Figure 7; *S. coeruleoalba*). For the bottlenose dolphin, COD was determined for 31 out of the 36 individuals analyzed. For this species, Chi-square test indicated significant differences in COD occurrence ( $\chi^2$  test,

$p < 0.001$ ). Bycatch was the leading cause (52.78%), significantly more frequent than all others except trauma ( $p < 0.05$ ), again indicating the dominance of bycatch-related mortality (Figure 7; *T. truncatus*). For the minke whale, COD was determined for 25 out of the 32 individuals, and a significant difference between COD was found ( $\chi^2$  test,  $p < 0.001$ ). Bycatch once again was the most dominant COD (48.39%) and was significantly higher compared to trauma (6.45%) and illness (3.22%) ( $p < 0.05$ ). Following pairwise comparisons, bycatch was significantly more frequent than all other causes of death ( $p < 0.01$ ), while no significant

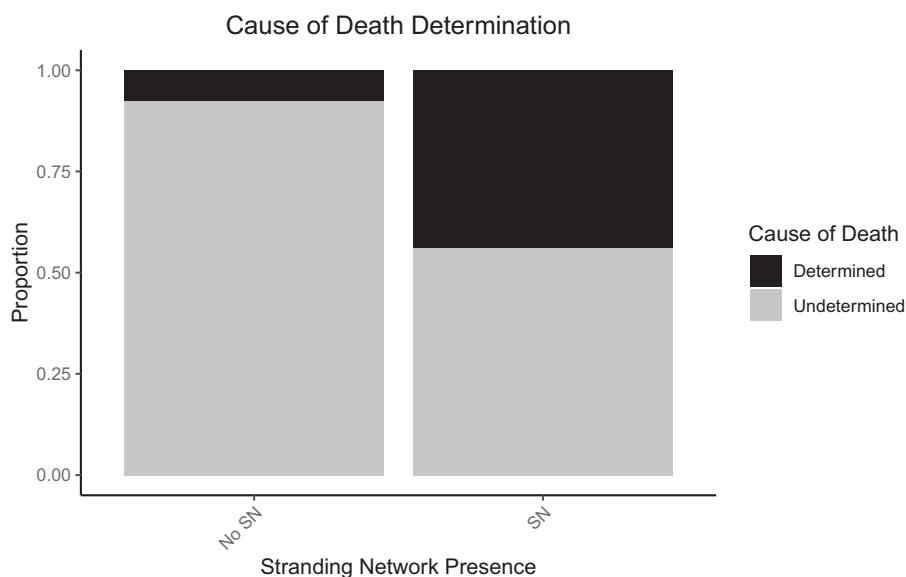
**TABLE 2** | Biometric data for five cetacean species, detailing sex ratios, mean standard body length (mSBL), standard deviation (SD), and observed minimum and maximum lengths.

Species	Sex	N	F:M ratio	mSBL (cm)	SD (cm)	Min	Max	Immature	Mature
<i>D. delphis</i>	Female	134	0.92	178.43	26.72	98.5	230	79	55
	Male	146		181.65	33.28	75	243	96	50
<i>S. coeruleoalba</i>	Female	44	1.47	<b>190.03*</b>	31	106	232	20	24
	Male	30		176.15	32.47	89.5	230	18	12
<i>T. truncatus</i>	Female	14	0.39	269.75	42.79	195	330	2	12
	Male	36		252.60	66.37	130	390	13	23
<i>B. acutorostrata</i>	Female	22	0.69	443.86	56.36	352	560	<b>22**</b>	0
	Male	32		426.50	86.86	300	693	<b>31**</b>	1
<i>P. phocoena</i>	Female	15	1.36	150.70	32.71	81	189	11	4
	Male	11		136.50	30.22	92	183	6	5

Note: It also categorizes individuals as immature or mature, providing insights into population structure and growth patterns. Female-to-male ratios indicate sex-based stranding distributions, while body length metrics highlight variations within and across species.

\* $p < 0.05$ .

\*\* $p < 0.001$ .

**FIGURE 6** | Comparison of the proportion of determined causes of death when the stranding network is inactive (No SN) or active (SN).

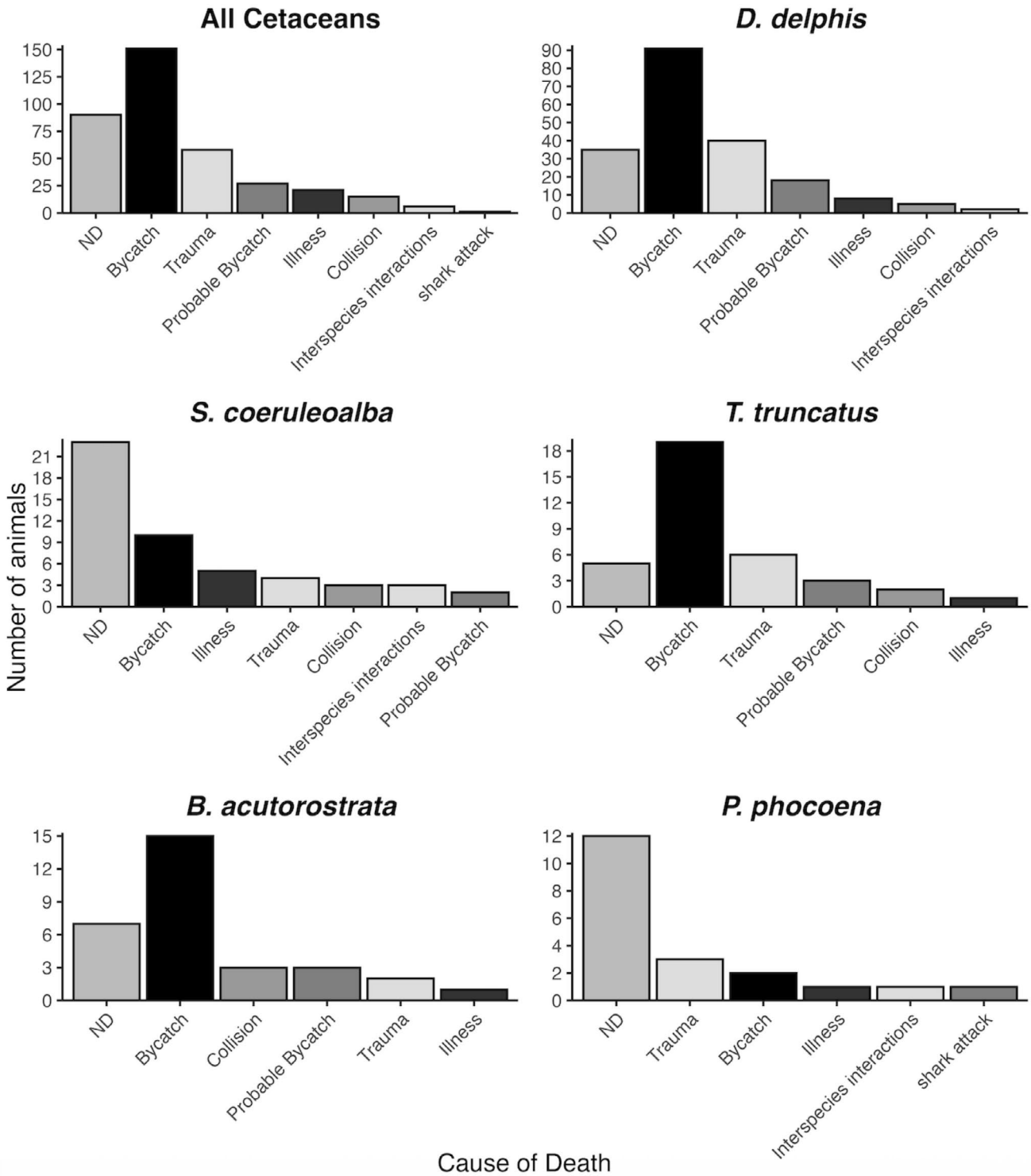
differences were detected among the remaining categories (Figure 7; *B. acutorostrata*). Lastly, for the harbor porpoise, 8 out of 20 individuals had an identified COD. Like the striped dolphin, harbor porpoise had a high percentage of non-determined COD (60%). The Chi-square test revealed no significant difference among COD ( $\chi^2$  test,  $p < 0.05$ ) (Figure 7; *P. phocoena*).

## 4 | Discussion

### 4.1 | Temporal and Seasonal Variations

Between 1978 and 2023, 19 cetacean species were recorded as stranded along the southwestern coast of the Iberian Peninsula. Stranding records increased over time, with a notable rise following the establishment of a dedicated stranding

network. Recorded strandings increased slowly and gradually up to the beginning of the 21st century, possibly related to a paradigm shift from legal capture for consumption (legal until 1981) to study and conservation subject in the area (Silva 1999; Silva and Sequeira 2003). Up to 2009, around 25 strandings were recorded annually, sharply increasing in 2010 with the regional network's implementation. This not only resulted in a greater number of strandings recorded annually, but also in more consistent reporting. Similar patterns in stranding records are observed worldwide, with the number of strandings increasing drastically with dedicated teams' attention and effort (Danil et al. 2010; Liu and Li 2019; Russell et al. 2022). The generalized additive model also confirmed that a dedicated stranding network positively affects the number of recorded strandings, effectively doubling the number of records. The five most stranded cetacean species in southern Portugal



**FIGURE 7** | Causes of death across all cetaceans and by species. Bycatch was the most frequent cause of death overall and in most species, particularly *D. delphis* and *T. truncatus*. Trauma, probable bycatch, illness, collision, interspecies interactions, and shark attack occurred less frequently. Undetermined cases (ND) were notably high in *S. coeruleoalba* and *P. phocoena*.

were: the common dolphin, striped dolphin, minke whale, bottlenose dolphin, and harbor porpoise. This pattern aligns with the results of previous studies conducted in the area, including a 2022 aerial (Gilles et al. 2023) and shipboard survey (Vingada and Eira 2018) off Portuguese waters. They reported the highest abundance of the same five species, suggesting that stranding frequency might reflect local species' occurrence.

Based on vessel and aerial surveys, the common dolphin is the most abundant species in the Algarve (Castro et al. 2020; Hammond et al. 2013; Moura et al. 2012). Generally, the most abundant species is also the one that strands the most (McGovern et al. 2016; Russell et al. 2022), and for southern Portugal this was no different, with common dolphins stranding several times more compared to other species. Recorded common dolphin strandings were significantly

higher when there was an active stranding network, with an average of 29 individuals per year. Similar patterns were found for the other species, where an active stranding network detected significantly more strandings. Striped dolphin abundance is estimated to be half that of common dolphins (Vingada and Eira 2018), with recorded strandings in the region being more than four times less. Given that only a small proportion of small delphinids ultimately strand (Peltier et al. 2012), the predominantly offshore distribution of striped dolphins (Gilles et al. 2023; Marçalo et al. 2021) likely reduces the probability that carcasses reach the coast, resulting in lower stranding rates. Lower abundance but similar strandings of bottlenose dolphins relative to striped dolphins are consistent with a more coastal distribution of the species that increases their stranding probability, reinforcing that distance to coast impacts stranding probability (distance hypothesis: Faerber and Baird 2010). Of the baleen whales, the minke whale is the most abundant in the Northeast Atlantic (Hammond et al. 2017; Gilles et al. 2023). Studies on the distribution of the minke whale in proximity to our study area mainly focused on the higher latitudes of the Northeastern Atlantic (Van Waerebeek et al. 1999; Vikingsson and Heide-Jørgensen 2015), the Macaronesia (Valente et al. 2019) and the west coast of Portugal (Brito et al. 2009; Van Waerebeek et al. 1999), being scarce for the southern coast of the Iberian Peninsula. Generally, information on summer feeding grounds has been previously described, while little information is available on winter breeding areas (Risch, Norris, et al. 2019; Risch, Wilson, et al. 2019). Seasonal movements may occur, but residency cannot be ruled out, and overall movement patterns remain poorly understood (Kavanagh et al. 2018; Vikingsson and Heide-Jørgensen 2015). However, based on Monteiro et al. 2025, minke whale stranding records for the northwestern and southwestern Iberian Peninsula occur mostly between April and July. Seasonal stranding patterns revealed that minke whales were the only ones to display significant differences between seasons. Significantly more strandings occurred during spring, which were patterns previously described in the western coast of the Iberian Peninsula, coinciding with the time when migrating minke whales pass the Mediterranean with their calves (Monteiro et al. 2025; Risch et al. 2014). Year-round strandings support the possibility of resident minke whales in our area (Carvalho 2018; Ferreira et al. 2016).

Finally, for the harbor porpoise, there was a significant increase in annual average strandings with an active stranding network. Abundance of this species has been declining and the population is critically endangered in Iberia (Torres-Pereira, Ferreira, et al. 2023). Strandings in southern Portugal are considerably lower when compared to that of northern Portugal (Torres-Pereira, Araújo, et al. 2023), where they are also more abundant, possibly due to higher habitat suitability (Torres-Pereira et al. 2022). We found that strandings with an active stranding network did not increase gradually in recent years, as compared to the north of Portugal (Torres-Pereira, Araújo, et al. 2023).

It is important to recognize that cetacean strandings exhibit significant interannual variability and are influenced by a complex interplay of biotic and abiotic factors (Evans et al. 2005; Warlick et al. 2022). Strandings are not solely a reflection of population abundance, but are also shaped by oceanographic and meteorological conditions, such as sea

surface temperature, wind patterns, and storm frequency (Peltier et al. 2012, 2016; Saavedra et al. 2017). Moreover, the likelihood of a carcass reaching the coastline is affected by the distance to shore at the time of death, as offshore mortalities are less likely to result in strandings due to decomposition, sinking, or advection away from land (Marçalo et al. 2021). As such, annual fluctuations in stranding rates are expected and should be interpreted with caution, particularly when used as proxies for population trends or health.

## 4.2 | Spatial Distribution

Cetacean strandings occurred along the entire Algarve coast, clearly presenting areas where strandings are more likely to happen, that is hotspots. The main stranding areas are Cape Santa Maria, the most southern part of the study area (between Faro and Olhão), Portimão, Lagos and finally Sagres. These areas are important fishing grounds, holding some of the most important fishing harbors in the region (Alexandre et al. 2022).

The common dolphin is the most abundant species and occurs throughout the entire study area (Brouder et al. 2025; Castro et al. 2020; Gilles et al. 2023). Our results indicate, however, that most of the common dolphin strandings were recorded west of Olhão. Due to its abundance and opportunistic behavior, it is the species that is mostly sighted and seen interacting with local coastal fisheries (Alexandre et al. 2022; Marçalo et al. 2024, 2025), especially the purse seine fishery (Dias et al. 2022; Marçalo et al. 2015, 2025). High degrees of overlap between the species and purse seine fishing effort occur around and west of Cape Santa Maria, mainly around important fishing ports such as Portimão and Quarteira (Brouder 2022). This stems from a strong ecological convergence as both the purse seine fishery and the common dolphin target sardines, *Sardina pilchardus*—a key prey species and dietary preference for common dolphins (Marçalo et al. 2018). A strong relationship between local fishery interaction and stranding location is therefore extremely likely. Furthermore, the narrower continental shelf around Sagres and Cape Santa Maria also presents the ideal area for common dolphin strandings, as they come closer to the shore. Upwelled rich water and associated productivity create ideal conditions for cetacean abundance (Brito et al. 2009; Castro et al. 2020; Moura et al. 2012), which may also impact stranding location and occurrence. Striped dolphins revealed similar stranding patterns, mainly around important fishing ports. However, strandings around the Sagres area were less concentrated and more spread out towards Lagos. Although they seem to prefer deeper waters off the continental shelf (Azzolin et al. 2020; Gilles et al. 2023), stomach content analysis suggests they may be using more neritic waters and interacting with coastal fisheries, resulting in similar stranding patterns as those of common dolphins (Marçalo et al. 2021).

Compared to the smaller delphinids, bottlenose dolphin strandings seem to be higher around the two capes and around the eastern coast. Bottlenose dolphins display differentiation between coastal and pelagic ecotypes in the Atlantic (Di Tullio et al. 2016; Louis et al. 2014; Oudejans et al. 2015) and Pacific

Oceans (Félix et al. 2017; Perrin et al. 2011). Their strong ecological plasticity allows this species to inhabit both marine and estuarine ecosystems (Di Tullio et al. 2016; Fernández et al. 2011). In mainland Portugal, more specifically in the south, bottlenose dolphin occurrence has both been recorded close to the shore and offshore, mainly in very productive areas of the continental shelf (Ferreira et al. 2023; Gilles et al. 2023; Grave 2022). The narrow continental shelf around Cape Santa Maria (Faro) and Cabo de São Vicente (Sagres) might increase the probability of overlap between the two ecotypes in the area, increasing the probability of occurrence and therefore increasing stranding probability. Higher stranding numbers in the leeward area might also be related to prey preference and therefore habitat suitability, as preferred prey species overlap with fisheries (Alexandre et al. 2022; Marçalo et al. 2024).

In the Northeastern Atlantic, minke whales are the most abundant Mysticeti species, inhabiting both pelagic and coastal areas (Risch, Norris, et al. 2019). In the Northern Iberian Peninsula, minke distribution revealed to be dependent on various oceanographic factors and prey availability (Thibault et al. 2025). Adult individuals seem to prefer deeper waters, while juveniles prefer shallower waters (Robinson et al. 2023). This pattern is also evident in our region, as revealed by Monteiro et al. 2025, which found that the diet of stranded individuals—most of which were immature—consisted of neritic prey species, indicating coastal habitat use in the area. The narrow continental shelf towards the west of Cape Santa Maria might provide ideal conditions for immature individuals to feed. We speculate that local oceanographic conditions and prey availability may draw minke whales closer to the coast, where overlap with fisheries could increase mortality risk and the probability of subsequent stranding, especially for juveniles.

As mentioned before, harbor porpoise distribution and abundance in the western Iberian Peninsula are higher around northern areas (Galicia and northern-central Portugal). For the Algarve, higher suitability was found towards the windward area (Torres-Pereira et al. 2022). In contrast, most strandings in the Algarve occurred towards the leeward area and around estuaries or lagoon systems, being highly concentrated west of Vila Real de Santo António, the eastern border of southern Portugal. This border is defined by the separation of Spain and Portugal by one of the major rivers of the Iberian Peninsula—Gadiana River. Furthermore, harbor porpoise strandings seem to also occur around Portimão, where we find the Arade estuary and Ria de Alvor, and around Faro and Olhão, around the Ria Formosa inlets. Studies have shown that harbor porpoises have been shown to prefer shallow coastal water with strong or dynamic hydrological activity (Lambert et al. 2017) and are known to be associated with riverine environments and estuaries (Gil et al. 2019; Stern et al. 2017; Taupp 2021; Wenger and Koschinski 2012). Therefore, a relationship between these systems and harbor porpoise activity is possible. However, information about the distribution and activity of the harbor porpoise in the Algarve is extremely scarce and warrants further investigation.

### 4.3 | Size and Sexual Maturity

Strandings of common dolphins showed a relatively equal number of males and females, with no significant difference in

length, contrary to another study where more females and significantly smaller individuals stranded (Marçalo et al. 2018). Comparatively, female maximum size was lower, while for males it was similar to those recorded in northwestern Spain (Murphy et al. 2021; Read 2016). Compared to the Mediterranean, recorded maximum length was similar for females and higher for males (Vella et al. 2021). More immature individuals stranded for both sexes, a trend that seems to persist from past studies (Silva and Sequeira 2003) and has been recorded in other European regions (Mannocci et al. 2012). However, contrasting results have been found in the southwestern Atlantic, where fewer immature common dolphins stranded (Grandi et al. 2022), meaning that maturity-related strandings vary regionally.

For the striped dolphin, more females stranded compared to males, presented by a high F:M ratio. Stranded female average length was significantly higher compared to males, in line with Marçalo et al. (2021). This, however, is not a result of sexual dimorphism but rather due to a behavioral or ecological driver. Although striped dolphins generally present a more offshore distribution (Certain et al. 2008; Gilles et al. 2023), groups in the Mediterranean—and females in western Iberia (Mainland Portugal)—have been observed to prefer neritic prey, leading to habitat use closer to the coast (Azzolin et al. 2020; Marçalo et al. 2021). This results in not only closer contact with possible anthropogenic coastal threats, such as fisheries and boat collisions in the area, but also increases the probability of carcass detection and actual stranding. The recorded maximum size was almost identical for both sexes, even though males have been found to be slightly larger than females (Jefferson et al. 2008).

For the bottlenose dolphin, strandings are heavily skewed towards males, with more than double the amount of strandings recorded for males than for females. Similar patterns were found in Ireland (McGovern et al. 2016). No significant differences were found in mean body length, largely due to the high variability in their recorded lengths. As mentioned before, different ecotypes may exist within one region. These may vary morphologically, with coastal individuals being generally smaller with larger fins (Perrin et al. 2011; Wells and Scott 2018). Thus, finding an accurate proxy size for length at maturity for the species is challenging. In this study, we found that mature individuals stranded more frequently, consistent with findings in other studies (Grattarola et al. 2023; Russell et al. 2022).

Like bottlenose dolphins, minke whale strandings were skewed towards males. However, contrary to previous studies, the sex ratio did not show a significant excess of males over females (Risch et al. 2014). We found a significant difference in the maturity of stranded individuals, with immature minke whales dominating the strandings. This finding aligns with previous studies reporting a higher proportion of immature compared to mature minke whales (Miyakawa et al. 2016; Monteiro et al. 2025). Although juvenile females had an average body length approximately 20cm greater than males, our results showed no significant difference in total length across sexes, supporting the view that strandings are not strongly biased by length or sex (Miyakawa et al. 2016). The observed seasonal stranding patterns, combined with significantly higher juvenile strandings, suggest that younger individuals may use coastal

habitats more frequently during potential migration to forage (Monteiro et al. 2025; Robinson et al. 2023).

Consistent with previous studies on harbor porpoises, no significant difference in total body length was found between males and females (Galatius 2005; Torres-Pereira, Araújo, et al. 2023). More immature harbor porpoises stranded, a pattern also found in the northwest of the Iberian Peninsula and in other regions of Europe (Mahfouz et al. 2014; Siebert et al. 2006; Torres-Pereira, Araújo, et al. 2023). In small cetaceans, elevated bycatch and other stressors can depress survival enough that frequently used areas effectively function as sinks; bycatch assessment is therefore important to understand source–sink dynamics (Reeves et al. 2013). For harbor porpoises, regional analyses of North Sea strandings indicate that certain regions may operate as a sink, with disproportionately high juvenile male mortality relative to other regions (IJseldijk et al. 2020). In Iberian waters, recent stranding and genetic evidence show increasing mortality signals and a rapid population decline, consistent with the risk that parts of the range could act as sinks (Ben Chehida et al. 2023; Torres-Pereira, Araújo, et al. 2023).

#### 4.4 | Cause of Death

The existence of stranding networks aids in identifying possible causes of death (Obusan et al. 2016). In fact, our work shows that an active stranding network significantly increases the number of determined causes of death. This highlights the importance of a stranding network in understanding what the main antagonists in cetacean welfare are in any region. When the stranding network is inactive or there is no stranding network, animals that strand are analyzed in a less extensive way, that is only biometric information and external marks are recorded. This leads to insufficient data being collected to confirm cause of death. Nevertheless, even with an active stranding network determination might prove to be a challenge. A significantly higher number of undeterminable cases were found in species like the striped dolphin and harbor porpoise. Firstly, carcass decomposition state is one of, if not the most important, factor when considering identifying cause of death. For animals that use offshore habitats, such as the striped dolphin, preservation of the carcass is less likely (Marçalo et al. 2021). Its freshness is affected by the time it spends adrift and oceanographic conditions which could explain the lower number of determined causes of death for this species (Peltier et al. 2012; Saavedra et al. 2017). For the harbor porpoise, advanced decomposition has hindered the determination of possible bycaught animals (Siebert et al. 2020). Body decomposition, frequently found in stranded harbor porpoises in the Netherlands (Kuijpers et al. 2022), has been found to occur rapidly in small delphinid species (Peltier et al. 2012). Secondly, cetaceans are threatened by surveys (geotechnical surveys and sonars), exploitation (wind power production and pipeline installation), pollution (macro-pollutants including plastics, biotoxins, heavy metals, pesticides, pharmaceuticals), and disease; all of which are not readily detectable with necropsies.

Significant cetacean mortality in the Algarve is caused by anthropogenic factors, of which, most were primarily due to direct interactions with fishing activity. The common dolphin is one of the species highly impacted by fisheries activity, mainly due

to bycatch (Fernández-Contreras et al. 2010; Goetz et al. 2014; Peltier et al. 2016). As mentioned before, common dolphins and coastal Portuguese fisheries such as the purse seine fishery, target the same species, leading to overlap and frequent interactions, mostly during the periods of higher purse seine fishing effort for sardine during summer and early fall seasons (Alexandre et al. 2022; Dias et al. 2022; Marçalo et al. 2018). Along the Portuguese coast, common dolphins have been found to associate with purse seiners, feeding on sardines and chub mackerel (Alexandre et al. 2022; Brouder 2022; Dias et al. 2022). Furthermore, animals also accidentally get entangled in bottom set nets, posing additional threats to the species (Marçalo et al. 2024; Vingada and Eira 2018). Traumatic anthropogenic incidents such as boat collisions, are more likely to occur in areas with a large fishing presence and in large recreational boat marinas, which is typical in the Algarve, as it is also a year-round tourist region. The high frequency of interaction between cetaceans and human activities in these areas increases the risk of trauma-related deaths (Olaya-Ponzone et al. 2020).

The bottlenose dolphin also presented high mortality because of bycatch. This species stands out as a generalist predator, whose depredatory behavior has been extensively studied worldwide (Chávez-Martínez et al. 2022; Giménez et al. 2017; Santos et al. 2001, 2007). In the southern Iberian Peninsula Atlantic waters, bottlenose dolphins feed mostly on pelagic and demersal fish and cephalopods (Ana Marçalo pers. Comm.; Giménez et al. 2017), overlapping with target species of local and coastal artisanal fisheries (Alexandre et al. 2022; Marçalo et al. 2024). Interactions affect most fishery types, with bottom-set net fishing gear being the main target of cetacean depredation, especially of bottlenose dolphins (Alexandre et al. 2022; Marçalo et al. 2024, 2025). This interaction may prove fatal, mainly due to incidental capture (e.g., in the form of entanglement) and/or ingestion of fishing gear (Alexandre et al. 2022; Marçalo et al. 2024; Wells et al. 2008).

Minke whales' abundance and coastal distribution make them particularly vulnerable to entanglement in fishing gear, potentially resulting in high mortality (Northridge et al. 2010; Ryan et al. 2016). Previous studies have shown that minke whales are especially susceptible to fixed fishing gear, such as gillnets and traps (Mathias et al. 2023; Vingada and Eira 2018). Given that this species may use coastal areas east of Cape Santa Maria—like bottlenose dolphins (Alexandre et al. 2022)—the spatial overlap with fisheries likely increases the risk of harmful interactions. Our results support this, suggesting that the area is indeed hazardous for minke whales. Juveniles appear to frequent coastal areas possibly to feed, which elevates their chances of interacting with fishing gear and suffering, for example, entanglement-related mortality.

#### 4.5 | Study Limitations

While this study offers a valuable, long-term overview of cetacean strandings in southern Portugal, some limitations should be considered when interpreting the results. Stranding data are inherently influenced by several factors, including carcass buoyancy, oceanographic conditions, accessibility of the coastline, and variability in reporting effort. These may affect species

detection rates and the spatial distribution of strandings. Notably, monitoring intensity varied across the study period, with significantly more records during years when a dedicated stranding network was in place. While this variation was accounted for in our analyses, differences in effort likely influenced the number and quality of records in earlier periods.

Despite these constraints, the high number of analyzed strandings—particularly during active network periods—allowed for meaningful temporal, seasonal, and spatial comparisons. Furthermore, cause of death was determined in a substantial proportion of fresh specimens, providing rare and valuable insights into mortality drivers in the region.

Lastly, although the study focused on the most frequently stranded species, it captures key patterns relevant to conservation and management and sets a strong baseline for future monitoring. This work highlights the importance of sustained and coordinated stranding response efforts to improve data quality and support effective marine mammal conservation.

## 5 | Conclusion

From 1978 to 2023, reported cetacean strandings along the Algarve increased gradually over time, increasing steeply with the establishment of a dedicated stranding network. The GAM indicates monitoring effort roughly doubled recorded events, underscoring that reporting effort strongly shapes time-series patterns. The five most frequent stranded cetaceans (common dolphin, striped dolphin, minke whale, bottlenose dolphin, harbor porpoise) mirror local occurrence, with hotspots near Cape Santa Maria, Portimão, Lagos, and Sagres where a narrow shelf, upwelling productivity, and intense coastal fisheries overlap. Minke whales showed clear seasonality, peaking in spring (April–July), and strandings were dominated by immature animals, suggesting coastal use during movement or foraging. The critically endangered harbor porpoise (Torres-Pereira, Ferreira, et al. 2023) strands significantly less in the south than the north (Torres-Pereira, Araújo, et al. 2023), with events concentrated near estuarine systems. Causes of death were determined more often under active monitoring and were predominantly anthropogenic, especially involving fishery interactions, while offshore habits and decomposition hinder diagnosis in some species (e.g., striped dolphin). Overall, strandings provide valuable insight into cetacean biology and ecology, and should be further analyzed considering oceanographic factors for an even deeper understanding. This study provides evidence that sustained, standardized monitoring and targeted bycatch mitigation in the Algarve and especially around the stranding hotspots should be a priority. Furthermore, it reveals that focused research on cetaceans in the Algarve is essential, to better understand regional cetacean ecology and habitat use.

### Author Contributions

Conceptualization: J.H., S.C., A.M. Data curation: J.H., S.C., A.F., J.P., L.N., A.M. Formal analysis: J.H., S.C. Funding acquisition: A.M. Investigation: J.H., S.C., A.F., M.C., J.P., A.S., L.N., A.M. Methodology: J.H., S.C., A.M. Project administration: A.M. Supervision: A.M.

Validation: J.H., A.M. Visualization: J.H., S.C., A.M. Writing – original draft: J.H., S.C., A.M. Writing – review and editing: J.H., A.M.

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### Conflicts of Interest

The authors declare no conflicts of interest.

### Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

### References

- Albrecht, S., C. Minto, E. Rogan, et al. 2024. “Emaciated Enigma: Decline in Body Conditions of Common Dolphins in the Celtic Seas Ecoregion.” *Ecology and Evolution* 14, no. 10: e70325. <https://doi.org/10.1002/ece3.70325>.
- Alexandre, S., A. Marçalo, T. A. Marques, et al. 2022. “Interactions Between Air-Breathing Marine Megafauna and Artisanal Fisheries in Southern Iberian Atlantic Waters: Results From an Interview Survey to Fishers.” *Fisheries Research* 254: 106430. <https://doi.org/10.1016/j.fishres.2022.106430>.
- Alwis, H. A. S. S., S. Albrecht, S. Murphy, et al. 2024. *Stomach Parasite Burden and Health Status of Stranded Common Dolphins, Delphinus delphis*. Springer Science and Business Media LLC. <https://doi.org/10.21203/rs.3.rs-4906242/v1>.
- Anderson, R., M. Herrera, A. Ilangakoon, et al. 2020. “Cetacean Bycatch in Indian Ocean Tuna Gillnet Fisheries.” *Endangered Species Research* 41: 39–53. <https://doi.org/10.3354/esr01008>.
- Arbelo, M., A. Espinosa De Los Monteros, P. Herráez, et al. 2013. “Pathology and Causes of Death of Stranded Cetaceans in the Canary Islands (1999–2005).” *Diseases of Aquatic Organisms* 103, no. 2: 87–99. <https://doi.org/10.3354/dao02558>.
- Arrigoni, M., P. Manfredi, S. Panigada, L. Bramanti, and G. Santangelo. 2011. “Life-History Tables of the Mediterranean Fin Whale From Stranding Data.” *Marine Ecology* 32, no. s1: 1–9. <https://doi.org/10.1111/j.1439-0485.2011.00437.x>.
- Azzolin, M., A. Arcangeli, G. Cipriano, et al. 2020. “Spatial Distribution Modelling of Striped Dolphin (*Stenella coeruleoalba*) at Different Geographical Scales Within the EU Adriatic and Ionian Sea Region,

- Central-Eastern Mediterranean Sea." *Aquatic Conservation: Marine and Freshwater Ecosystems* 30, no. 6: 1194–1207. <https://doi.org/10.1002/aqc.3314>.
- Ben Chehida, Y., T. Stelwagen, J. P. A. Hoekendijk, et al. 2023. "Harbor Porpoise Losing Its Edge: Genetic Time Series Suggests a Rapid Population Decline in Iberian Waters Over the Last 30 Years." *Ecology and Evolution* 13, no. 12: e10819. <https://doi.org/10.1002/ece3.10819>.
- Bilgmann, K., L. M. Möller, R. G. Harcourt, C. M. Kemper, and L. B. Beheregaray. 2011. "The Use of Carcasses for the Analysis of Cetacean Population Genetic Structure: A Comparative Study in Two Dolphin Species." *PLoS One* 6, no. 5: e20103. <https://doi.org/10.1371/journal.pone.0020103>.
- Brito, C., N. Vieira, E. Sá, and I. Carvalho. 2009. "Cetaceans' Occurrence Off the West Central Portugal Coast: A Compilation of Data From Whaling, Observations of Opportunity and Boat-Based Surveys." *Journal of Marine Animals and Their Ecology* 2, no. 1: 10–13.
- Brouder, S. 2022. "The Spatial Distribution of the Common Dolphin (*Delphinus delphis*) Along the Portuguese Mainland Coast and Their Interaction With the Purse Seine Fishery." Master's thesis, University of Bologna. Sapientia – Repositório da Universidade do Algarve.
- Brouder, S., T. A. Marques, N. Oliveira, P. Monteiro, J. M. S. Gonçalves, and A. Marçalo. 2025. "When Sardines Disappear: Tracking Common Dolphin, *Delphinus delphis*, Distribution Responses Along the Western Iberian Coast." *Animals* 15, no. 11: 1552. <https://doi.org/10.3390/ani15111552>.
- Carvalho, F. L. 2018. "Arrojamentos de cetáceos ao longo da costa do Algarve: Causas de morte e ensaios piloto de mitigação com alarmes acústicos em pescarias costeiras algarvias." Universidade do Algarve, p. 69. Master dissertation.
- Castro, J., A. Couto, F. O. Borges, et al. 2020. "Oceanographic Determinants of the Abundance of Common Dolphins (*Delphinus delphis*) in the South of Portugal." *Oceans* 1, no. 3: 165–173. <https://doi.org/10.3390/oceans1030012>.
- Certain, G., V. Ridoux, O. Van Canneyt, and V. Bretagnolle. 2008. "Delphinid Spatial Distribution and Abundance Estimates Over the Shelf of the Bay of Biscay." *ICES Journal of Marine Science* 65, no. 4: 656–666. <https://doi.org/10.1093/icesjms/fsn046>.
- Chávez-Martínez, K., E. Morteo, I. Hernández-Candelario, S. Z. Herzka, and C. A. Delfín-Alfonso. 2022. "Opportunistic Gillnet Depredation by Common Bottlenose Dolphins in the Southwestern Gulf of Mexico: Testing the Relationship With Ecological, Trophic, and Nutritional Characteristics of Their Prey." *Frontiers in Marine Science* 9: 870012. <https://doi.org/10.3389/fmars.2022.870012>.
- Crespo-Picazo, J. L., C. Rubio-Guerri, M. A. Jiménez, et al. 2021. "Bottlenose Dolphins (*Tursiops truncatus*) Aggressive Behavior Towards Other Cetacean Species in the Western Mediterranean." *Scientific Reports* 11, no. 1: 21582. <https://doi.org/10.1038/s41598-021-00867-6>.
- Cuvertoret-Sanz, M., C. López-Figueroa, A. O'Byrne, et al. 2020. "Causes of Cetacean Stranding and Death on the Catalanian Coast (Western Mediterranean Sea), 2012–2019." *Diseases of Aquatic Organisms* 142: 239–253. <https://doi.org/10.3354/dao03550>.
- Danil, K., S. J. Chivers, M. D. Henshaw, J. L. Thieleking, R. Daniels, and J. A. St. Leger. 2010. "Cetacean Strandings in San Diego County, California, USA: 1851–2008." *Journal of Cetacean Research and Management* 11, no. 2: 163–184. <https://doi.org/10.47536/jcrm.v11i2.622>.
- Deslias, C., P. Daniel, A. López, J. Martínez-Cedeira, V. Ridoux, and H. Peltier. 2024. "Predicting the Drift of Small Cetaceans Stranded Along the Atlantic Coast of the Iberian Peninsula: Parametrization of the MOTHY Drift Model." *PLoS One* 19, no. 12: e0315593. <https://doi.org/10.1371/journal.pone.0315593>.
- Di Tullio, J. C., T. B. R. Gandra, A. N. Zerbin, and E. R. Secchi. 2016. "Diversity and Distribution Patterns of Cetaceans in the Subtropical Southwestern Atlantic Outer Continental Shelf and Slope." *PLoS One* 11, no. 5: e0155841. <https://doi.org/10.1371/journal.pone.0155841>.
- Dias, I. C., A. Marçalo, D. Feijó, I. Domingos, and A. A. Silva. 2022. "Interactions Between the Common Dolphin, *Delphinus delphis*, and the Portuguese Purse Seine Fishery Over a Period of 15 Years (2003–2018)." *Aquatic Conservation: Marine and Freshwater Ecosystems* 32, no. 8: 1351–1364. <https://doi.org/10.1002/aqc.3828>.
- Díaz-Delgado, J., A. Fernández, E. Sierra, et al. 2018. "Pathologic Findings and Causes of Death of Stranded Cetaceans in the Canary Islands (2006–2012)." *PLoS One* 13, no. 10: e0204444. <https://doi.org/10.1371/journal.pone.0204444>.
- Evans, K., R. Thresher, R. M. Warneke, et al. 2005. "Periodic Variability in Cetacean Strandings: Links to Large-Scale Climate Events." *Biology Letters* 1, no. 2: 147–150. <https://doi.org/10.1098/rsbl.2005.0313>.
- Faerber, M. M., and R. W. Baird. 2010. "Does a Lack of Observed Beaked Whale Strandings in Military Exercise Areas Mean no Impacts Have Occurred? A Comparison of Stranding and Detection Probabilities in the Canary and Main Hawaiian Islands." *Marine Mammal Science* 26, 602–613. <https://doi.org/10.1111/j.1748-7692.2010.00370.x>.
- Félix, F., A. Calderón, M. Vintimilla, and R. A. Bayas-Rea. 2017. "Decreasing Population Trend in Coastal Bottlenose Dolphin (*Tursiops truncatus*) From the Gulf of Guayaquil, Ecuador." *Aquatic Conservation: Marine and Freshwater Ecosystems* 27, no. 4: 856–866. <https://doi.org/10.1002/aqc.2763>.
- Fernández, R., M. B. Santos, G. J. Pierce, et al. 2011. "Fine-Scale Genetic Structure of Bottlenose Dolphins, *Tursiops truncatus*, in Atlantic Coastal Waters of the Iberian Peninsula." *Hydrobiologia* 670, no. 1: 111–125. <https://doi.org/10.1007/s10750-011-0669-5>.
- Fernández-Contreras, M. M., L. Cardona, C. H. Lockyer, and A. Aguilar. 2010. "Incidental Bycatch of Short-Beaked Common Dolphins (*Delphinus delphis*) by Pair Trawlers Off Northwestern Spain." *ICES Journal of Marine Science* 67, no. 8: 1732–1738. <https://doi.org/10.1093/icesjms/fsq077>.
- Ferreira, M., C. Eira, A. López, and M. Sequeira. 2023. "*Tursiops truncatus* Roaz." In *Livro Vermelho dos Mamíferos de Portugal Continental*, edited by M. L. Mathias, C. Fonseca, L. Rodrigues, C. Grilo, M. Lopes-Fernandes, J. M. Palmeirim, M. Santos-Reis, P. C. Alves, J. A. Cabral, M. Ferreira, A. Mira, C. Eira, N. Negrões, J. Paupério, R. Pita, A. Rainho, L. M. Rosalino, J. T. Tapisso, and J. Vingada. FCiências.ID, ICNF.
- Ferreira, M., A. Marçalo, L. Nicolau, et al. 2016. "Redes de arrojamentos e reabilitação: 2013–2016." Anexo do 4º Relatório de progresso do projeto LIFE MarPro NAT/PT/00038, p. 25.
- Galatius, A. 2005. "Sexually Dimorphic Proportions of the Harbour Porpoise (*Phocoena phocoena*) Skeleton." *Journal of Anatomy* 206, no. 2: 141–154. <https://doi.org/10.1111/j.1469-7580.2005.00381.x>.
- Geraci, J. R., and V. J. Lounsbury. 2005. *Marine Mammals Ashore: A Field Guide for Strandings*. 2nd ed. National Aquarium in Baltimore.
- Gil, Á., A. M. Correia, and I. Sousa-Pinto. 2019. "Records of Harbour Porpoise (*Phocoena phocoena*) in the Mouth of the Douro River (Northern Portugal) With Presence of an Anomalous White Individual." *Marine Biodiversity Records* 12, no. 1: 1. <https://doi.org/10.1186/s41200-018-0160-3>.
- Gilles, A., M. Authier, N. Ramirez-Martinez, et al. 2023. "Estimates of Cetacean Abundance in European Atlantic Waters in Summer 2022 From the SCANS-IV Aerial and Shipboard Surveys."
- Giménez, J., A. Marçalo, M. García-Polo, et al. 2018. "Feeding Ecology of Mediterranean Common Dolphins: The Importance of Mesopelagic Fish in the Diet of an Endangered Subpopulation." *Marine Mammal Science* 34, no. 1: 136–154. <https://doi.org/10.1111/mms.12442>.
- Giménez, J., A. Marçalo, F. Ramirez, et al. 2017. "Diet of Bottlenose Dolphins (*Tursiops truncatus*) From the Gulf of Cadiz: Insights From Stomach Content and Stable Isotope Analyses." *PLoS One* 12, no. 9: e0184673. <https://doi.org/10.1371/journal.pone.0184673>.

- Goetz, S., F. L. Read, M. Ferreira, et al. 2014. "Cetacean Occurrence, Habitat Preferences and Potential for Cetacean–Fishery Interactions in Iberian Atlantic Waters: Results From Cooperative Research Involving Local Stakeholders." *Aquatic Conservation: Marine and Freshwater Ecosystems* 25, no. 1: 138–154. <https://doi.org/10.1002/aqc.2481>.
- Gomerčić, M. U., A. Galov, T. Gomerčić, et al. 2009. "Bottlenose Dolphin (*Tursiops truncatus*) Depredation Resulting in Larynx Strangulation With Gill-Net Parts." *Marine Mammal Science* 25, no. 2: 392–401. <https://doi.org/10.1111/j.1748-7692.2008.00259.x>.
- Grandi, M. F., F. M. Heredia, A. Sosa Drouville, N. A. Dellabianca, and E. A. Crespo. 2022. "Body Growth and Reproductive Parameters of Common Dolphins From the Southwestern Atlantic." *Marine Mammal Science* 38, no. 4: 1470–1488. <https://doi.org/10.1111/mms.12934>.
- Grattarola, C., L. Minoia, F. Giorda, et al. 2023. "Health Status of Stranded Common Bottlenose Dolphins (*Tursiops truncatus*) and Contamination by Immunotoxic Pollutants: A Threat to the Pelagos Sanctuary—Western Mediterranean Sea." *Diversity* 15, no. 4: 569. <https://doi.org/10.3390/d15040569>.
- Grave, S. A. 2022. "Mapping Bottlenose Dolphin (*Tursiops truncatus*) Behaviour in the Southern Coast of Portugal." Master's thesis, Universidade de Evora (Portugal).
- Grilo, C., B. C. Afonso, F. Afonso, et al. 2022. "Mammals in Portugal: A Data Set of Terrestrial, Volant, and Marine Mammal Occurrences in Portugal." *Ecology* 103, no. 6: e3654. <https://doi.org/10.1002/ecy.3654>.
- Hammond, P. S., C. Lacey, A. Gille, et al. 2017. "Estimates of Cetacean Abundance in European Atlantic Waters in Summer 2016 From the SCANSIII Aerial and Shipboard Surveys." *SCANS-III Project Report* 1: 40.
- Hammond, P. S., K. Macleod, P. Berggren, et al. 2013. "Cetacean Abundance and Distribution in European Atlantic Shelf Waters to Inform Conservation and Management." *Biological Conservation* 164: 107–122. <https://doi.org/10.1016/j.biocon.2013.04.010>.
- Horwood, J. 1990. *Biology and Exploitation of the Minke Whale (Balaenoptera acutorostrata)*. CRC Press, Inc.
- How, J. R., W. K. De La Mare, D. K. Coughran, M. C. Double, and S. De Lestang. 2021. "Gear Modifications Reduced Humpback Whale Entanglements in a Commercial Rock Lobster Fishery." *Marine Mammal Science* 37, no. 3: 782–806. <https://doi.org/10.1111/mms.12774>.
- IJsseldijk, L. L., M. T. I. ten Doeschate, A. Brownlow, et al. 2020. "Spatiotemporal Mortality and Demographic Trends in a Small Cetacean: Strandings to Inform Conservation Management." *Biological Conservation* 249: 108733. <https://doi.org/10.1016/j.biocon.2020.108733>.
- Jefferson, T. A., M. A. Webber, and R. L. Pitman. 2008. *Marine Mammals of the World: A Comprehensive Guide to Their Identification*. Elsevier.
- Kavanagh, A. S., G. Kett, N. Richardson, E. Rogan, and M. J. Jessopp. 2018. "High Latitude Winter Sightings of Common Minke Whale Calves (*Balaenoptera acutorostrata*) in the Northeast Atlantic." *Marine Biodiversity Records* 11, no. 1: 22. <https://doi.org/10.1186/s4120-018-0157-y>.
- Kuijpers, N. W., L. Van Schalkwijk, L. L. IJsseldijk, D. S. Willems, and S. Veraa. 2022. "Post-Mortem Computed Tomography Pulmonary Findings in Harbor Porpoises (*Phocoena phocoena*)." *Animals* 12, no. 11: 1454. <https://doi.org/10.3390/ani12111454>.
- Kuiken, T., and M. García Hartmann. 1991. "Cetacean Pathology: Dissection Techniques and Tissue Sampling." *ECS Newsletter: Special Issue* 17: 1–39.
- Lambert, C., E. Pettex, G. Dorémus, et al. 2017. "How Does Ocean Seasonality Drive Habitat Preferences of Highly Mobile Top Predators? Part II: The Eastern North-Atlantic." *Deep Sea Research. Part II, Topical Studies in Oceanography* 141: 133–154. <https://doi.org/10.1016/j.dsr2.2016.06.011>.
- Liu, M., and S. Li. 2019. "An Overview of Cetacean Stranding Around Hainan Island in the South China Sea, 1978–2016: Implications for Research, Conservation and Management." *Marine Policy* 101: 147–153. <https://doi.org/10.1016/j.marpol.2018.04.029>.
- López, A., M. B. Santos, G. J. Pierce, A. F. González, X. Valeiras, and A. Guerra. 2002. "Trends in Strandings and By-Catch of Marine Mammals in North-West Spain During the 1990s." *Journal of the Marine Biological Association of the United Kingdom* 82, no. 3: 513–521. <https://doi.org/10.1017/S0025315402005805>.
- López, B. D., A. López, S. Methion, and P. Coveló. 2018. "Infanticide Attacks and Associated Epimeletic Behaviour in Free-Ranging Common Bottlenose Dolphins (*Tursiops truncatus*)." *Journal of the Marine Biological Association of the United Kingdom* 98, no. 5: 1159–1167. <https://doi.org/10.1017/S0025315417001266>.
- Louis, M., A. Viricel, T. Lucas, et al. 2014. "Habitat-Driven Population Structure of Bottlenose Dolphins, *Tursiops truncatus*, in the North-East Atlantic." *Molecular Ecology* 23, no. 4: 857–874. <https://doi.org/10.1111/mec.12653>.
- Mahfouz, C., F. Henry, L. Courcot, et al. 2014. "Harbour Porpoises (*Phocoena phocoena*) Stranded Along the Southern North Sea: An Assessment Through Metallic Contamination." *Environmental Research* 133: 266–273. <https://doi.org/10.1016/j.envres.2014.06.006>.
- Mannocci, L., W. Dabin, E. Augeraud-Véron, J.-F. Dupuy, C. Barbraud, and V. Ridoux. 2012. "Assessing the Impact of Bycatch on Dolphin Populations: The Case of the Common Dolphin in the Eastern North Atlantic." *PLoS One* 7, no. 2: e32615. <https://doi.org/10.1371/journal.pone.0032615>.
- Marçalo, A., F. Carvalho, M. Frade, et al. 2025. "Reducing Cetacean Interactions With Bottom Set-Nets and Purse Seining Using Acoustic Deterrent Devices in Southern Iberia." *Aquatic Conservation: Marine and Freshwater Ecosystems* 35, no. 2: e70061. <https://doi.org/10.1002/aqc.70061>.
- Marçalo, A., J. Giménez, L. Nicolau, et al. 2021. "Stranding Patterns and Feeding Ecology of Striped Dolphins, *Stenella coeruleoalba*, in Western Iberia (1981–2014)." *Journal of Sea Research* 169: 101996. <https://doi.org/10.1016/j.seares.2021.101996>.
- Marçalo, A., I. Katara, D. Feijó, et al. 2015. "Quantification of Interactions Between the Portuguese Sardine Purse-Seine Fishery and Cetaceans." *ICES Journal of Marine Science* 72, no. 8: 2438–2449. <https://doi.org/10.1093/icesjms/fsv076>.
- Marçalo, A., L. Nicolau, J. Giménez, et al. 2018. "Feeding Ecology of the Common Dolphin (*Delphinus delphis*) in Western Iberian Waters: Has the Decline in Sardine (*Sardina pilchardus*) Affected Dolphin Diet?" *Marine Biology* 165, no. 3: 44. <https://doi.org/10.1007/s00227-018-3285-3>.
- Marçalo, A., V. Samel, F. Carvalho, M. Frade, K. Erzini, and J. M. Gonçalves. 2024. "Evaluating Dolphin Interactions With Bottom-Set Net Fisheries Off Southern Iberian Atlantic Waters." *Fisheries Research* 278: 107100. <https://doi.org/10.1016/j.fishres.2024.107100>.
- Mathias, M. L., C. Fonseca, L. Rodrigues, et al. 2023. "Livro vermelho dos mamíferos de Portugal continental." <http://hdl.handle.net/10174/35224.FCiências.ID; ICNF>
- McGovern, B., R. M. Culloch, M. O'Connell, and S. Berrow. 2016. "Temporal and Spatial Trends in Stranding Records of Cetaceans on the Irish Coast, 2002–2014." *Journal of the Marine Biological Association of the United Kingdom* 98, no. 5: 977–989. <https://doi.org/10.1017/S0025315416001594>.
- Miyakawa, N., T. Kishiro, Y. Fujise, G. Nakamura, and H. Kato. 2016. "Sexual Dimorphism in Pelvic Bone Shape of the North Pacific Common Minke Whales (*Balaenoptera acutorostrata*)." *Open Journal of Animal Sciences* 6, no. 2: 131–136. <https://doi.org/10.4236/ojas.2016.62016>.
- Monteiro, S. S., J. Torres, M. Ferreira, et al. 2016. "Ecological Variables Influencing Trace Element Concentrations in Bottlenose Dolphins

- (*Tursiops truncatus*, Montagu 1821) Stranded in Continental Portugal.” *Science of the Total Environment* 544: 837–844. <https://doi.org/10.1016/j.scitotenv.2015.12.037>.
- Monteiro, S. S., A. Torres-Pereira, M. Ferreira, et al. 2025. “What’s on the Menu? Diet of Common Minke Whales (*Balaenoptera acutorostrata*) Stranded on the Atlantic Iberian Coast.” *Marine Environmental Research* 205: 107024. <https://doi.org/10.1016/j.marenvres.2025.107024>.
- Moore, J. E., K. A. Curtis, R. L. Lewison, et al. 2013. “Evaluating Sustainability of Fisheries Bycatch Mortality for Marine Megafauna: A Review of Conservation Reference Points for Data-Limited Populations.” *Environmental Conservation* 40: 329–344. <https://doi.org/10.1017/S03789291300012X>.
- Moura, A. E., N. Sillero, and A. Rodrigues. 2012. “Common Dolphin (*Delphinus delphis*) Habitat Preferences Using Data From Two Platforms of Opportunity.” *Acta Oecologica* 38: 24–32. <https://doi.org/10.1016/j.actao.2011.08.006>.
- Murphy, S., A. Collet, and E. Rogan. 2005. “Mating Strategy in the Male Common Dolphin (*Delphinus delphis*): What Gonadal Analysis Tells Us.” *Journal of Mammalogy* 86, no. 6: 1247–1258. [https://doi.org/10.1644/1545-1542\(2005\)86\[1247:MSITMC\]2.0.CO;2](https://doi.org/10.1644/1545-1542(2005)86[1247:MSITMC]2.0.CO;2).
- Murphy, S., P. G. H. Evans, E. Pinn, and G. J. Pierce. 2021. “Conservation Management of Common Dolphins: Lessons Learned From the North-East Atlantic.” *Aquatic Conservation: Marine and Freshwater Ecosystems* 31, no. S1: 137–166. <https://doi.org/10.1002/aqc.3212>.
- Murphy, S., A. Winship, W. Dabin, et al. 2009. “Importance of Biological Parameters in Assessing the Status of *Delphinus delphis*.” *Marine Ecology Progress Series* 388: 273–291. <https://doi.org/10.3354/meps08129>.
- Nabi, G., R. W. McLaughlin, Y. Hao, et al. 2018. “The Possible Effects of Anthropogenic Acoustic Pollution on Marine Mammals’ Reproduction: An Emerging Threat to Animal Extinction.” *Environmental Science and Pollution Research* 25, no. 20: 19338–19345. <https://doi.org/10.1007/s11356-018-2208-7>.
- Nicolau, L., M. Ferreira, J. M. Santos, et al. 2016. “Sea Turtle Strandings Along the Portuguese Mainland Coast: Spatio Temporal Occurrence and Main Threats.” *Marine Biology* 163: 21. <https://doi.org/10.1007/s00227-015-2783-9>.
- Northridge, S., A. Cargill, A. Coram, L. Mandleberg, S. Calderan, and B. Reid. 2010. “Entanglement of Minke Whales in Scottish Waters; An Investigation Into Occurrence, Causes and Mitigation.” Contract Report. Final Report to Scottish Government CR/2007/49, 57.
- Obusan, M. C. M., W. L. Rivera, M. A. T. Siringan, and L. V. Aragonés. 2016. “Stranding Events in The Philippines Provide Evidence for Impacts of Human Interactions on Cetaceans.” *Ocean and Coastal Management* 134: 41–51. <https://doi.org/10.1016/j.ocecoaman.2016.09.021>.
- Olaya-Ponzone, L., R. Espada, E. Martín Moreno, I. Cárdenas Marcial, and J. C. García-Gómez. 2020. “Injuries, Healing and Management of Common Dolphins (*Delphinus delphis*) in Human-Impacted Waters in the South Iberian Peninsula.” *Journal of the Marine Biological Association of the United Kingdom* 100, no. 2: 315–325. <https://doi.org/10.1017/S0025315420000090>.
- Olson, J. K., J. Aschoff, A. Goble, S. Larson, and J. K. Gaydos. 2020. “Maximizing Surveillance Through Spatial Characterization of Marine Mammal Stranding Hot Spots.” *Marine Mammal Science* 36, no. 4: 1083–1096. <https://doi.org/10.1111/mms.12696>.
- Oudejans, M. G., F. Visser, A. Englund, E. Rogan, and S. N. Ingram. 2015. “Evidence for Distinct Coastal and Offshore Communities of Bottlenose Dolphins in the Northeast Atlantic.” *PLoS One* 10, no. 4: e0122668. <https://doi.org/10.1371/journal.pone.0122668>.
- Panigada, S., G. Pesante, M. Zanardelli, F. Capoulade, A. Gannier, and M. T. Weinrich. 2006. “Mediterranean Fin Whales at Risk From Fatal Ship Strikes.” *Marine Pollution Bulletin* 52, no. 10: 1287–1298. <https://doi.org/10.1016/j.marpolbul.2006.03.014>.
- Peltier, H., M. Authier, R. Deaville, et al. 2016. “Small Cetacean Bycatch as Estimated From Stranding Schemes: The Common Dolphin Case in the Northeast Atlantic.” *Environmental Science & Policy* 63: 7–18. <https://doi.org/10.1016/j.envsci.2016.05.004>.
- Peltier, H., A. Beaufile, C. Cesarini, et al. 2019. “Monitoring of Marine Mammal Strandings Along French Coasts Reveals the Importance of Ship Strikes on Large Cetaceans: A Challenge for the European Marine Strategy Framework Directive.” *Frontiers in Marine Science* 6: 486. <https://doi.org/10.3389/fmars.2019.00486>.
- Peltier, H., W. Dabin, P. Daniel, et al. 2012. “The Significance of Stranding Data as Indicators of Cetacean Populations at Sea: Modelling the Drift of Cetacean Carcasses.” *Ecological Indicators* 18: 278–290. <https://doi.org/10.1016/j.ecolind.2011.11.014>.
- Perrin, W. F., J. L. Thieleking, W. A. Walker, F. I. Archer, and K. M. Robertson. 2011. “Common Bottlenose Dolphins (*Tursiops truncatus*) in California Waters: Cranial Differentiation of Coastal and Offshore Ecotypes.” *Marine Mammal Science* 27, no. 4: 769–792. <https://doi.org/10.1111/j.1748-7692.2010.00442.x>.
- Pierce, G. J., F. Caurant, and R. J. Law. 2013. “Bioaccumulation of POPs and Toxic Elements in Small Cetaceans Along European Atlantic Coasts.” In *Proceedings of the ECS/ASCOBANS/ACCOBAMS Joint Workshop on Chemical Pollution and Marine Mammals* 55: 7284.
- Pierce, G. J., M. B. Santos, S. Murphy, et al. 2008. “Bioaccumulation of Persistent Organic Pollutants in Female Common Dolphins (*Delphinus delphis*) and Harbour Porpoises (*Phocoena phocoena*) From Western European Seas: Geographical Trends, Causal Factors and Effects on Reproduction and Mortality.” *Environmental Pollution* 153, no. 2: 401–415. <https://doi.org/10.1016/j.envpol.2007.08.019>.
- Puig-Lozano, R., A. Fernández, P. Saavedra, et al. 2020. “Retrospective Study of Traumatic Intra-Interspecific Interactions in Stranded Cetaceans, Canary Islands.” *Frontiers in Veterinary Science* 7: 107. <https://doi.org/10.3389/fvets.2020.00107>.
- Purcari, A. M. 2023. “Cetacean Distribution and Habitat Modelling in the NE Atlantic Ocean.”
- Pyenson, N. D. 2011. “The High Fidelity of the Cetacean Stranding Record: Insights Into Measuring Diversity by Integrating Taphonomy and Macroecology.” *Proceedings of the Royal Society B: Biological Sciences* 278, no. 1724: 3608–3616. <https://doi.org/10.1098/rspb.2011.0441>.
- Read, A. J., P. Drinker, and S. Northridge. 2006. “Bycatch of Marine Mammals in U.S. and Global Fisheries.” *Conservation Biology* 20, no. 1: 163–169. <https://doi.org/10.1111/j.1523-1739.2006.00338.x>.
- Read, F. 2016. “Understanding Cetacean and Fisheries Interactions in the North-West Iberian Peninsula.” Doctoral dissertation, Universidade de Vigo.
- Reeves, R., K. McClellan, and T. Werner. 2013. “Marine Mammal Bycatch in Gillnet and Other Entangling Net Fisheries, 1990 to 2011.” *Endangered Species Research* 20, no. 1: 71–97. <https://doi.org/10.3354/esr00481>.
- Risch, D., M. Castellote, C. W. Clark, et al. 2014. “Seasonal Migrations of North Atlantic Minke Whales: Novel Insights From Large-Scale Passive Acoustic Monitoring Networks.” *Movement Ecology* 2, no. 1: 24. <https://doi.org/10.1186/s40462-014-0024-3>.
- Risch, D., T. Norris, M. Curnock, and A. Friedlaender. 2019. “Common and Antarctic Minke Whales: Conservation Status and Future Research Directions.” *Frontiers in Marine Science* 6: 247. <https://doi.org/10.3389/fmars.2019.00247>.
- Risch, D., S. C. Wilson, M. Hoogerwerf, N. C. F. Van Geel, E. W. J. Edwards, and K. L. Brookes. 2019. “Seasonal and Diel Acoustic Presence of North Atlantic Minke Whales in the North Sea.” *Scientific Reports* 9, no. 1: 3571. <https://doi.org/10.1038/s41598-019-39752-8>.

- Robinson, K. P., D. A. I. MacDougall, C. C. G. Bamford, et al. 2023. "Ecological Habitat Partitioning and Feeding Specializations of Coastal Minke Whales (*Balaenoptera acutorostrata*) Using a Recently Designated MPA in Northeast Scotland." *PLoS One* 18, no. 7: e0246617. <https://doi.org/10.1371/journal.pone.0246617>.
- Roca-Monge, K., R. González-Barrientos, M. Suárez-Esquivel, et al. 2022. "Age and Sexual Maturity Estimation of Stranded Striped Dolphins, *Stenella coeruleoalba*, Infected With *Brucella ceti*." *Oceans* 3, no. 4: 494–508. <https://doi.org/10.3390/oceans3040033>.
- Russell, M., J. Bloodgood, and R. Carmichael. 2022. "Spatial, Temporal and Demographic Patterns of Cetacean Strandings in the Northcentral Gulf of Mexico." *Journal of Cetacean Research and Management* 23, no. 1: 171–182. <https://doi.org/10.47536/jcrm.v23i1.356>.
- Ryan, C., R. Leaper, P. G. Evans, et al. 2016. "Entanglement: An Emerging Threat to Humpback Whales in Scottish Waters."
- Saavedra, C., G. J. Pierce, J. Gago, et al. 2017. "Factors Driving Patterns and Trends in Strandings of Small Cetaceans." *Marine Biology* 164, no. 8: 165. <https://doi.org/10.1007/s00227-017-3200-3>.
- Santos, M. B., R. Fernández, A. López, J. A. Martínez, and G. J. Pierce. 2007. "Variability in the Diet of Bottlenose Dolphin, *Tursiops truncatus*, in Galician Waters, North-Western Spain, 1990–2005." *Journal of the Marine Biological Association of the United Kingdom* 87, no. 1: 231–241. <https://doi.org/10.1017/S0025315407055233>.
- Santos, M. B., G. J. Pierce, R. J. Reid, I. A. P. Patterson, H. M. Ross, and E. Mente. 2001. "Stomach Contents of Bottlenose Dolphins (*Tursiops truncatus*) in Scottish Waters." *Journal of the Marine Biological Association of the United Kingdom* 81, no. 5: 873–878. <https://doi.org/10.1017/S0025315401004714>.
- Siebert, U., A. Gilles, K. Lucke, et al. 2006. "A Decade of Harbour Porpoise Occurrence in German Waters—Analyses of Aerial Surveys, Incidental Sightings and Strandings." *Journal of Sea Research* 56, no. 1: 65–80. <https://doi.org/10.1016/j.seares.2006.01.003>.
- Siebert, U., I. Pawliczka, H. Benke, et al. 2020. "Health Assessment of Harbour Porpoises (*Phocoena phocoena*) From Baltic Area of Denmark, Germany, Poland and Latvia." *Environment International* 143: 105904. <https://doi.org/10.1016/j.envint.2020.105904>.
- Silva, M. A. 1999. "Diet of Common Dolphins, *Delphinus delphis*, Off the Portuguese Continental Coast." *Journal of the Marine Biological Association of the United Kingdom* 79, no. 3: 531–540. <https://doi.org/10.1017/S0025315498000654>.
- Silva, M. A., and M. Sequeira. 2003. "Patterns in the Mortality of Common Dolphins (*Delphinus delphis*) on the Portuguese Coast, Using Stranding Records, 1975–1998." *Aquatic Mammals* 29, no. 1: 88–98. <https://doi.org/10.1578/016754203101023924>.
- Sonne, C., S. S. Lam, S. Y. Foong, W. A. Wan Mahari, N. L. Ma, and M. S. Bank. 2024. "A Global Meta-Analysis of Gillnet Bycatch of Toothed Whales: Mitigation Measures and Research Gaps." *IScience* 27, no. 12: 111482. <https://doi.org/10.1016/j.isci.2024.111482>.
- Stern, S. J., W. Keener, I. D. Szczepaniak, and M. A. Webber. 2017. "Return of Harbor Porpoises (*Phocoena phocoena*) to San Francisco Bay." *Aquatic Mammals* 43, no. 6: 691–702. <https://doi.org/10.1578/AM.43.6.2017.691>.
- Taupp, T. 2021. "Against All Odds: Harbor Porpoises Intensively Use an Anthropogenically Modified Estuary." *Marine Mammal Science* 38, no. 1: 288–303. <https://doi.org/10.1111/mms.12858>.
- Thibault, R., S. Methion, and B. Díaz López. 2025. "Fine-Scale Habitat Selection of Minke Whales (*Balaenoptera acutorostrata*) in Northwest Iberian Peninsula Waters." *Marine Biology* 172, no. 2: 27. <https://doi.org/10.1007/s00227-024-04586-0>.
- Torres-Pereira, A., H. Araújo, F. L. Matos, et al. 2022. "Harbour Porpoise Abundance in Portugal Over a 5-Year Period and Estimates of Potential Distribution." *Animals* 12, no. 15: 1935. <https://doi.org/10.3390/ani12151935>.
- Torres-Pereira, A., H. Araújo, S. S. Monteiro, et al. 2023. "Assessment of Harbour Porpoise Bycatch Along the Portuguese and Galician Coast: Insights From Strandings Over Two Decades." *Animals* 13, no. 16: 2632. <https://doi.org/10.3390/ani13162632>.
- Torres-Pereira, A., M. Ferreira, C. Eira, A. López, and M. Sequeira. 2023. "*Phocoena phocoena* boto." In *Livro Vermelho dos Mamíferos de Portugal Continental*, edited by M. L. Mathias, C. Fonseca, L. Rodrigues, C. Grilo, M. Lopes-Fernandes, J. M. Palmeirim, M. Santos-Reis, P. C. Alves, J. A. Cabral, M. Ferreira, A. Mira, C. Eira, N. Negrões, J. Paupério, R. Pita, A. Rainho, L. M. Rosalino, J. T. Tapisso, and J. Vingada. FCIências.ID, ICNF.
- Valente, R., A. M. Correia, Á. Gil, L. González García, and I. Sousa-Pinto. 2019. "Baleen Whales in Macaronesia: Occurrence Patterns Revealed Through a Bibliographic Review." *Mammal Review* 49, no. 2: 129–151. <https://doi.org/10.1111/mam.12148>.
- Van Bresselem, M.-F., P. Duignan, A. Banyard, et al. 2014. "Cetacean Morbillivirus: Current Knowledge and Future Directions." *Viruses* 6, no. 12: 5145–5181. <https://doi.org/10.3390/v6125145>.
- Van Waerebeek, K., A. N. Baker, F. Félix, et al. 2007. "Vessel Collisions With Small Cetaceans Worldwide and With Large Whales in the Southern Hemisphere, an Initial Assessment." *Latin American Journal of Aquatic Mammals* 6, no. 1: 43–69. <https://doi.org/10.5597/lajam.00109>.
- Van Waerebeek, K., M. A. Vely, M. Sequeira, et al. 1999. "Spatial and Temporal Distribution of the Minke Whale, *Balaenoptera acutorostrata* (Lacépède, 1804), in the Southern Northeast Atlantic Ocean and the Mediterranean Sea, With Reference to Stock Identity." *Journal of Cetacean Research and Management* 1, no. 3: 223–238.
- Vella, A., S. Murphy, J. Giménez, et al. 2021. "The Conservation of the Endangered Mediterranean Common Dolphin (*Delphinus delphis*): Current Knowledge and Research Priorities." *Aquatic Conservation: Marine and Freshwater Ecosystems* 31, no. S1: 110–136. <https://doi.org/10.1002/aqc.3538>.
- Vikingsson, G. A., and M. P. Heide-Jørgensen. 2015. "First Indications of Autumn Migration Routes and Destination of Common Minke Whales Tracked by Satellite in the North Atlantic During 2001–2011." *Marine Mammal Science* 31, no. 1: 376–385. <https://doi.org/10.1111/mms.12144>.
- Vingada, J., and C. Eira. 2018. "Conservação de Cetáceos e Aves Marinhas em Portugal Continental." O projeto LIFE+ MarPro. Conservation of Cetaceans and Seabirds in Continental Portugal. Relatório final do projecto NAT/PT, 38.
- Warlick, A. J., J. L. Huggins, D. M. Lambourn, et al. 2022. "Cetacean Strandings in the US Pacific Northwest 2000–2019 Reveal Potential Linkages to Oceanographic Variability." *Frontiers in Marine Science* 9: 758812. <https://doi.org/10.3389/fmars.2022.758812>.
- Wells, R. S., J. B. Allen, S. Hofmann, et al. 2008. "Consequences of Injuries on Survival and Reproduction of Common Bottlenose Dolphins (*Tursiops truncatus*) Along the West Coast of Florida." *Marine Mammal Science* 24, no. 4: 774–794. <https://doi.org/10.1111/j.1748-7692.2008.00212.x>.
- Wells, R. S., A. A. Hohn, M. D. Scott, et al. 2025. "Life History, Reproductive, and Demographic Parameters for Bottlenose Dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida." *Frontiers in Marine Science* 12: 1531528. <https://doi.org/10.3389/fmars.2025.1531528>.
- Wells, R. S., and M. D. Scott. 2018. "Bottlenose Dolphin, *Tursiops truncatus*, Common Bottlenose Dolphin." In *Encyclopedia of Marine Mammals*, edited by B. Würsig, J. G. M. Thewissen, and K. M. Kovacs, 3rd ed., 118–125. Academic Press. <https://doi.org/10.1016/B978-0-12-804327-1.00072-8>.

Wenger, D., and S. Koschinski. 2012. "Harbour Porpoise (*Phocoena phocoena* Linnaeus, 1758) Entering the Weser River After Decades of Absence." *Marine Biology Research* 8: 737–745. <https://doi.org/10.1080/17451000.2012.676184>.

Williamson, M. J., M. T. ten Doeschate, R. Deaville, A. C. Brownlow, and N. L. Taylor. 2021. "Cetaceans as Sentinels for Informing Climate Change Policy in UK Waters." *Marine Policy* 131: 104634. <https://doi.org/10.1016/j.marpol.2021.104634>.

Wood, S. N. 2017. *Generalized Additive Models*. Chapman and Hall/CRC. <https://doi.org/10.1201/9781315370279>.