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Cetaceans of the Moroccan coast: information from a reconstructed strandings database

HICHAM MASSKI[1,2] AND RENAUD DE STÉPHANIS[3,4]

[1]Institut National de Recherche Halieutique, Bd. Sidi Abderrahmane, 20 000 Casablanca, Morocco, [2]OKEANOS, Nature Preservation and Research, 43 Bd. d'Alsace, Casablanca, Morocco, [3]GEMA, Grupo de Ecología Marina Aplicada, Estación Biológica de Doñana, CSIC. C/Americo Vespucio, s/n, 41092, Isla de la Cartuja, Sevilla, Spain, [4]CIRCE, Conservation, Information and Research on Cetaceans, Cabeza de Manzaneda 3, Pelayo, Algeciras, Spain

Cetaceans of Morocco have been poorly studied to date, and only sporadic information comes from scientific cruises for this group. In an attempt to learn more on the occurrence, distribution and relative abundances of cetaceans in Morocco, a stranding database was reconstructed from various sources (stranding reports from state agencies and newspaper clippings). This inventory documented 205 cases of stranding between 1980 and 2009. Most of the strandings and most confirmed cases of interactions with human activity (fishing, for dolphins; collisions, for whales) were reported in the Strait of Gibraltar and adjacent areas from the Atlantic and the Mediterranean. Sixteen species were identified from the stranding database, of which seven species were the most abundant. These were striped dolphins, common dolphins, bottlenose dolphins, fin whales, sei whales, sperm whales and long-finned pilot whales. The fin and sei whales were present throughout the year and stranding of common and striped dolphins were minimal between September and December. The fin, sei and sperm whales seem to be present in Moroccan waters at birth and at different stages of their life cycle. Establishing an observation network of sufficient and sustainable density in Morocco is the most likely way to collect robust data for the calculation of credible population indicators for cetaceans. Monitoring will certainly improve through better collaboration among Moroccan institutions and a greater awareness in Moroccan civil society of environmental issues.

Keywords: Cetacean, inventory, distribution, stranding, Morocco, Canary Current

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INTRODUCTION

The trend towards an ecosystem approach to fisheries management requires a thorough understanding of marine ecosystems, their composition and their organization (Fulton, 2010; Jennings & Rice, 2011). Information on species composition and spatial distribution are essential for the development of such an approach. Cetaceans, by their size, abundance and status as predators that forage at different levels of marine trophic webs, are a fundamental component of flows of energy and materials in marine ecosystems (Hooker & Gerber, 2004; Pershing *et al.*, 2010). Development of robust ecosystem models for marine ecosystems also poses an acute need for information about species diversity, levels of abundance and spatial distribution (Smith *et al.*, 2015).

Morocco has an extensive Atlantic coastline from 36°N to 21°N that lies alongside the northernmost part of the Canary Current Large Marine Ecosystem. This ecoregion is one of the major eastern boundary systems and is classified as a Class I, highly productive (>300 gC m^{-2} $year^{-1}$) ecosystem (Carr, 2001; Carr & Kearns, 2003), in contrast to the oligotrophic Mediterranean ecosystem to the east (Lochet & Leveau, 1990; Psarra *et al.*, 2000; Christaki *et al.*, 2001; Holmer *et al.*, 2007; Crombet *et al.*, 2011). These ecosystems are in a major transition zone between tropical waters in the south, temperate waters in the north and the Mediterranean to the east. The fishing industry is an economically important part of the Moroccan food industry. All the marine ecosystems around Morocco have been heavily exploited by fishing since the late 1950s, and have been subject to management based on single-species approaches since the mid-1970s (Kifani *et al.*, 2008). Marine resources have been subject to annual scientific surveys carried by the *Institut National de Recherche Halieutique* (INRH) since 1983. These surveys provide information on the species exploited, the associated fauna and their environment. However, cetaceans are among the groups that are surveyed only sporadically, and thus suffer from a lack of information.

Moroccan cetaceans have been described in several species inventories (see Table 1 for review), and the extent of their geographic distribution is based on observations at sea and stranding reports. The best known area is the Strait of Gibraltar, where seven species of cetaceans have been described. Striped dolphins (*Stenella coeruleoalba* (Meyen, 1833)), common dolphins (*Delphinus delphis* Linnaeus, 1758) (Cañadas *et al.*, 2005; de Stephanis *et al.*, 2008a), bottlenose dolphins (*Tursiops truncatus* (Montagu, 1821)) (Louis *et al.*, 2014; Pérez *et al.*, 2011), long-finned pilot whales (*Globicephala melas* (Traill, 1809)) (de Stephanis *et al.*,

Corresponding author:
H. Masski
Email: hmasski@gmail.com

2008b, c; Verborgh *et al.*, 2009; Giménez *et al.*, 2011; Senigaglia *et al.*, 2012; Wierucka *et al.*, 2014), killer whales (*Orcinus phoc* (Linnaeus, 1758)) (Guinet *et al.*, 2007; Foote *et al.*, 2011; Esteban *et al.*, 2013; de Stephanis *et al.*, 2014), sperm whales (*Physeter macrocephalus* Linnaeus, 1758) (Engelhaupt *et al.*, 2009; de Stephanis *et al.*, 2013; Carpinelli *et al.*, 2014) and fin whales (*Balaenoptera physalus* (Linnaeus, 1758)) (Bentaleb *et al.*, 2011) are regularly seen in the Strait of Gibraltar. Opportunistic observations of other species in the area of the Strait include Risso's dolphin (*Grampus griseus* (G. Cuvier, 1812)), minke whales (*B. acutorostrata* Lacepede, 1804), and blue whale (*B. musculus* (Linnaeus, 1758)) (de Stephanis personal observation). A second well-known area is the Alboran Sea because of research programmes in northern Alboran Spanish waters. In addition to the species that occur in the Strait of Gibraltar, Cuvier's beaked whales (*Ziphius cavirostris* G. Cuvier, 1823) are common in the Alboran Sea (Cañadas *et al.*, 2002; Cañadas & Vázquez, 2014). Apart from these research programmes which do not focus on Moroccan waters, a number of inventories or collections of information have been done in the last 50 years, but unfortunately suffer from significant gaps, both in terms of described species and in the extent of their spatial and temporal distribution (see Table 1 for review), due mainly to economic constraints.

Various studies have demonstrated the viability of using cetacean strandings for studies on the biology, pathology and ecology of cetaceans as indicators of population density at sea (Fernández *et al.*, 2008; Castège *et al.*, 2013; van Elk *et al.*, 2014; Peltier *et al.*, 2014). In Morocco, in addition to the efforts made to build a stranding response network, research programmes are developing in the field of ecosystem modelling with a real need for local knowledge on ecosystem components. The use of historical strandings information is therefore a necessity for areas with low research coverage. In this study, we reconstructed a database of cetaceans stranded along the Moroccan coast during the period 1980–2009 and used it to describe the species present in the area, their relative importance and potential distribution, and their possible interactions with human activities.

MATERIALS AND METHODS

A review of cases of stranding was based on reports from state agencies available at INRH. The minimum criteria for acceptability of a stranding report were: (i) the source of the document was identifiable; (ii) taxonomic resolution was at least to Family; (iii) date and place of stranding were available. The main source of information came from internal stranding reports of INRH which has six research centres along the coast of Morocco (Figure 1) and which traditionally has provided scientific support in managing strandings at the request of local authorities and law enforcement agencies.

Various state agencies active in the field of fisheries (Department of Fisheries, National Fisheries Board) have regional structures and are involved in the management of strandings alongside local authorities and law enforcement agencies (National Police Force, Royal Navy). When established, reports of stranding are sent to INRH, sometimes accompanied by photos. These documents were also used and supplemented with press clippings relating mostly to strandings of large species frequently accompanied by usable images.

The results of the review were included in a database with standardized indicators. Species identification was improved on the basis of descriptions in the reports, biometric parameters and images when available. A confidence index from 1 to 3 was assigned to each individual identified to the species: level 1 was a confident identification; level 2 corresponded to a reasonable identification that could not be verified with the information available; level 3 corresponded to an identification made by an amateur without the possibility of a quality check of the identification. A latitude and longitude was assigned to each stranding using information in the reports, and gender, biological and biometric parameters were included in the database when available. The DCC (Decomposition Condition Code) (Jauniaux *et al.*, 2002) was estimated on the basis of the description of the carcass and an indicator of the state of the animal was recorded: live; intact; injured (as an indicator of possible interaction with boats and collision); and fin(s) removed (as an indicator of possible interaction with fisheries).

In order to distinguish geographic areas of stranding, a criterion of geographic continuity was defined on the basis of the average distance between 90% of the strandings (that was 40 km). Strandings of less than 40 km separation (large circle distance in Figure 1) were considered to belong to the same area. Only the sections containing more than 2% of the strandings (four cases) were considered, and isolated strandings were not retained for defining stranding areas. This simple design criterion distinguished 10 sections of variable length of the Moroccan coast in which stranding densities have been estimated. This approach was used in order to discard areas where stranding probability is low, such as areas with strong drift currents and areas with steep cliffs permanently in contact with waves that are hundreds of km in the Saharan zone. The unpopulated areas where little or no stranding was reported are also discarded.

RESULTS

Strandings of marine mammals have been recorded all along the Moroccan coast, from the border with Algeria in the Mediterranean to the east, to the north of Cape Blanc in the Atlantic Saharan region at 21°50′N. The review documented 205 cases of stranding between 1980 and 2009 along the Moroccan coast that are identified to Family, 180 cases identified to the level of genus and 169 identified to species. In total, 16 species belonging to six families were identified. The Delphinidae predominated (composed of Delphininae 44% and Globicephalinae 12%), followed by Balenopteridae (29%), Physeteridae (10%), Phocaenidae and Kogiidae (3% each) and Ziphiidae (1 case) (Figure 2). In the stranding identified to species, the degree of confidence in the identification was high for 42% of strandings, medium in 47% of cases and low in 12% of cases. The estimated misidentification rate in 48 strandings for which images were gathered was 5%.

Seven species appear as the most abundant in strandings along the Moroccan coast. These were the fin whales, sei whales (*B. borealis* Lesson, 1828), sperm whales (*Physeter macrocephalus* Linnaeus, 1758), striped dolphins, common dolphins, bottlenose dolphins and the long-finned pilot whale. Seven individuals of *Phocoena phocoena* (Linnaeus, 1758) stranded on the Atlantic coast between Dakhla and

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Table 1. Cetacean species inventory from Morocco and Canary Islands. [1] This work, [2] Aloncle (1964, 1967), [3] Bayed & Beaubrun (1987, 1996), [4] de Stephanis *et al.* (2008a), [5] Herráez *et al.* (2013), [6] Gutiérrez & Qninba (2010), [7] Fernández *et al.* (2008).

Family			Species	Morocco			Canary Islands			
				[1]	[2]	[3]	[4]	[5]	[6]	[7]
Mysticeti	*Balaenidae*		*Eubalaena glacialis*			•				
	Balaenopteridae		*Balaenoptera acutorostrata*	•		•	•		•	
			Balaenoptera borealis	•	•	•				
			Balaenoptera edeni			•				
			Balaenoptera musculus		•	•	•			
			Balaenoptera physalus	•	•	•	•			
			Megaptera novaengliae	•	•	•				
Odontoceti	*Delphinidae*	*Delphininae*	*Delphinus delphis*	•	•	•	•			•
			Lagenodelphis hosei							•
			Sousa teuszii			•				
			Stenella coeruleoalba	•		•	•	•	•	•
			Stenella frontalis					•	•	•
			Stenella longirostris					•		
			Steno bredanensis	•						•
			Tursiops truncatus	•	•	•	•	•	•	•
		Globicephalinae	*Globicephala macrorhynchus*		•	•		•		•
			Globicephala melas	•	•	•	•			
			Grampus griseus	•		•		•		•
			Orcinus orca	•	•	•				
			Pseudorca crassidens	•		•	•	•		
	Phocoenidae		*Phocoena phocoena*	•	•	•				
	Kogiidae		*Kogia breviceps*	•			•	•		•
	Physeteridae		*Physeter macrocephalus*	•		•			•	•
	Ziphiidae		*Hyperoodon ampullatus*		•	•				
			Mesoplodon densirostris					•	•	
			Mesoplodon europaeus							•
			Ziphius cavirostris	•		•			•	•

Casablanca (Figure 4). Finally, a single stranding of a 5.2 m *Ziphius cavirostris* was recorded at 32°60′N.

The spatial distribution of strandings was not homogeneous (Figure 1); areas with high stranding densities alternated with areas with few or no strandings, both in the Atlantic and the Mediterranean. Six areas can be identified as major areas of stranding with more than 95% of the stranding records: the area of Casablanca (area III in Figure 1, length 283 km) accounting for 27% of strandings with a density of 0.2 strandings km^{-1}; the area of the Strait of Gibraltar (area I, 180 km length) represents 22% of the strandings with a density of 0.26 strandings km^{-1}; the Bay of Agadir (area IV, 60 km length) totalling 9% of strandings with a density of 0.32 strandings km^{-1}; the areas of Kenitra (area II, 35 km length), Laayoune (area V, 90 km length) and Dakhla (area VI, 83 km length) each had around 5% of strandings with densities of 0.31, 0.12 and 0.14 strandings km^{-1}, respectively. Approximately 2% of strandings occurred in each of the following three areas: the Mediterranean of Nador (area VII, 70 km long), El Hoceima (area VIII, 40 km long) and El Jebha (area IX, 63 km long) with densities of 0.7, 0.1 and 0.1 strandings km^{-1}, respectively. Finally the area of Cape Juby (area X, 15 km long) accounted for 4% of strandings with a density of 0.53 strandings km^{-1}.

Of the 169 cases of strandings with reliable information regarding the status of the animals, 8% reached the shore alive. A total of 43% were found in very early stages of decomposition (DCC 1 and 2), 17% were at the start of decomposition (DCC 3) and 32% were in an advanced state of decomposition (DCC 4 and 5).

Injuries and mutilations were evident in 114 cases. A total of 47% of stranded animals did not show any injury, 40% had various injuries, some of which could be clearly identified, especially for whales, as the result of successive collisions at sea. However, the number of injuries by collision was only four individuals of the 33 documented, including one that arrived at the port of Casablanca on the bow of a ship. The majority of injuries could not be identified as antecedent to the stranding, except in cases of sectioned fins (11%), a common practice among fishermen to release the animal from the net. Fin removal was found primarily in dolphins and a few pilot whales. One case of a minke whale with pectoral fins removed was observed north of Rabat. The geographic distribution of intact individuals and that of injured individuals fit the general pattern of stranding. However, the Strait of Gibraltar showed a higher percentage of dolphins with fins removed (25%) when compared with the Casablanca region (14%), the whole Mediterranean (11%) and Agadir (0%) (Figure 3).

DISCUSSION

The review of strandings along the Moroccan coast identified 16 species of cetaceans. Only one has not been described in previous studies in Morocco; *Steno bredanensis* (G. Cuvier in Lesson, 1828) was identified once in an area (Tarfaya) close to the Canary Islands where this species has been found previously. Five species cited in the Canary Islands (Table 1) were not observed in the strandings database:

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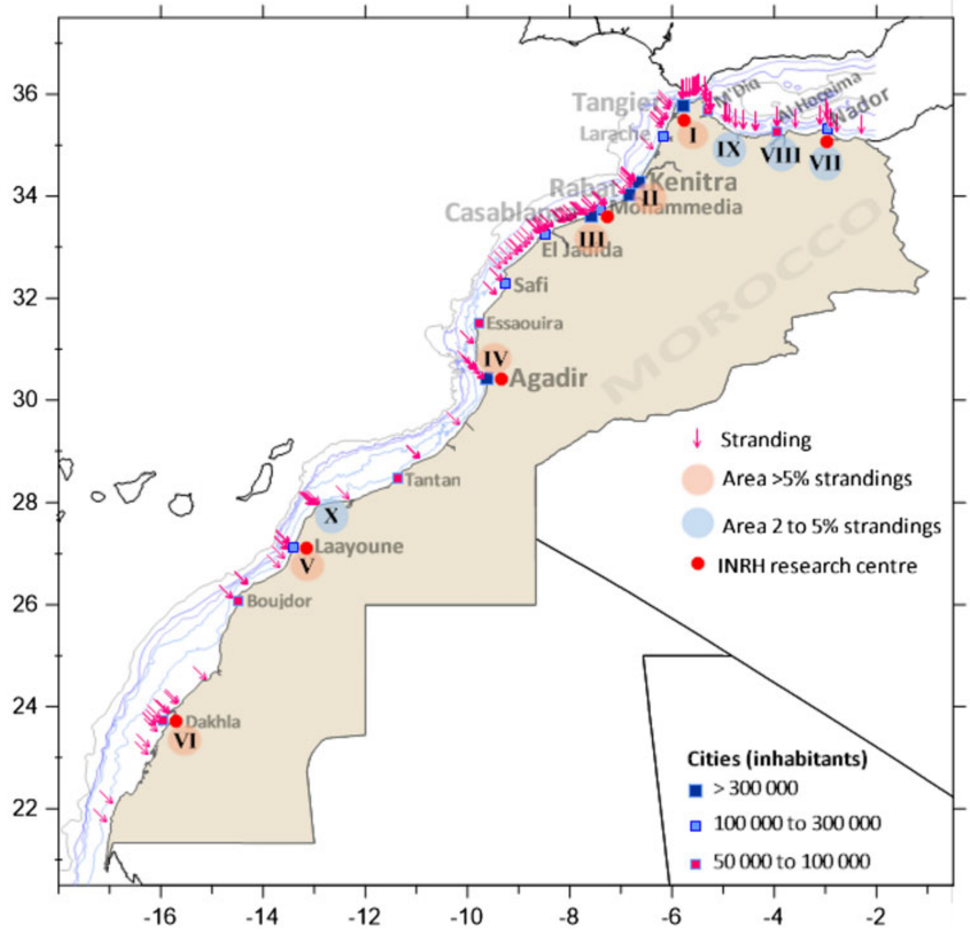

Fig. 1. Stranding records along the Moroccan coast during the period 1980–2009. Areas were defined by grouping stranding events of less than 40 km apart.

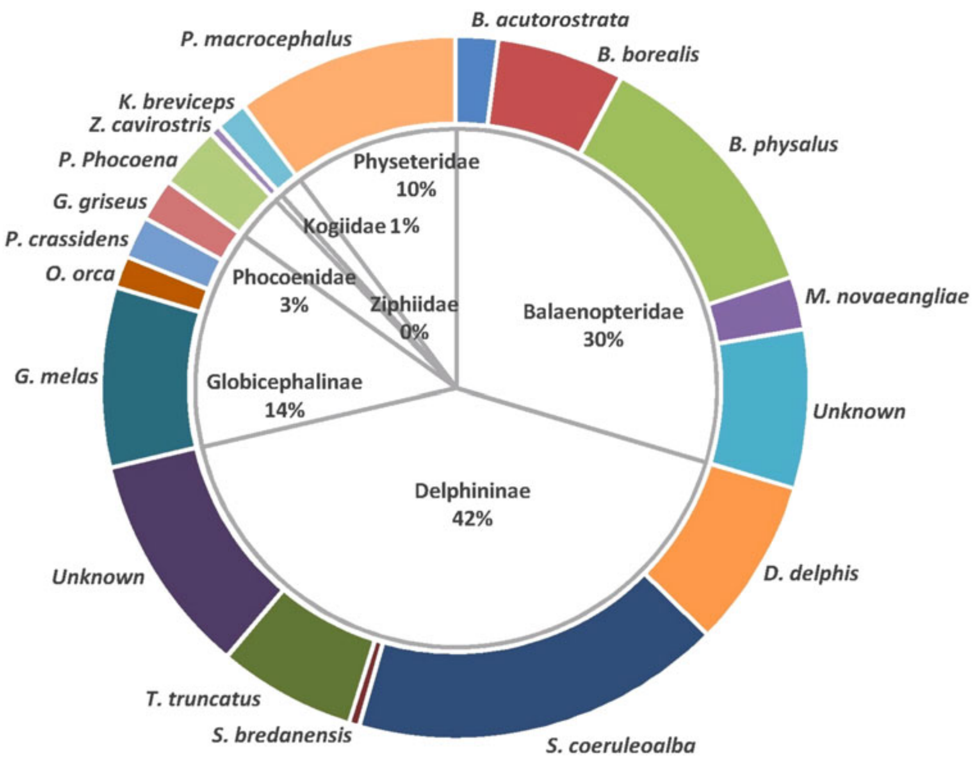

Fig. 2. Relative importance of stranded cetacean species off Morocco in the reconstructed stranding database for the period 1980–2009.

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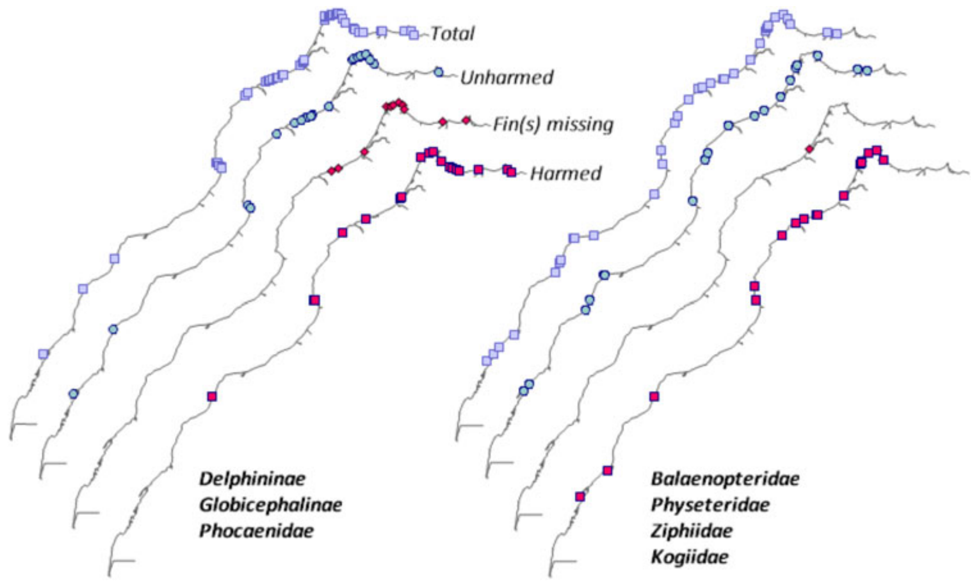

Fig. 3. Geographic distribution of cetacean stranding along the Moroccan coast categorized according to carcass condition and focusing on injuries (1980–2009).

Mesoplodon densirostris (Blainville, 1817), *M. europaeus* (Gervais, 1855), *Stenella frontalis* (G. Cuvier, 1829), *S. longirostris* (Gray, 1828) and *Lagenodelphis hosei* Fraser, 1956. Furthermore, six species have been described in other works carried out in Morocco: *Sousa teuszii* (Kükenthal, 1892), *Balaenoptera musculus, B. edeni* Anderson, 1878, *Eubalaena glacialis* (Müller, 1776), *Hyperoodon ampullatus* (Forster, 1770) and *Globicephala macrorhynchus* Gray, 1846. The Canarian strait that separates the Canary islands from the Moroccan coast is 60 NM wide; therefore the species found in the Canary Islands have a high probability of also being present on the Moroccan coast. Therefore, the expected number of cetacean species for the Moroccan coast is 26 species.

The work of Pyenson (2010) and Peltier *et al.* (2014) provides insights on the possibilities offered by the use of stranding data as proxy population indicators. They claim that strandings provide similar rank-order relative abundance as surveys (Pyenson, 2010) if data are sufficiently robust. Statistical credibility can be achieved if there are structured cetacean observation networks that have proactive monitoring. The database built for this study was constructed on the basis of archived and accessible documents. The number of strandings which satisfied the criteria for acceptable levels of information was 205 over the period 1980–2009, however the data were sporadic before 1993. For the period 1993–2009, when information was continuous, the average number of annual strandings was 12, low compared with the 700 annual strandings (average for 2000–2010) along the French Atlantic coast with a length equivalent to the Moroccan Atlantic coast (Van Canneyt, 2014). This suggests a low level of documentation of stranding events, combined with the bias associated with the concentration of stranding's observations in populated areas due to unequal detection probabilities and reporting rates, which is a common issue in opportunistic sampling designs (Authier *et al.*, 2014; De Barba *et al.*, 2010). Thus, the identified stranding areas and associated frequencies do not fulfil the conditions to be used as stranding indicators but can be considered as indicative information for further investigations. Nonetheless, two identified areas draw attention with their high stranding occurrences despite unfavourable geographic characteristics to stranding detection: the strait of Gibraltar and the area of Tarfaya. The first one is dominated by steep cliffs with few low-access creeks and beaches and the second one is a sparsely populated desert area. In addition, cetacean identification is difficult for people with little or no training and additionally difficult when carcasses are partly degraded. However, the level of estimated species misidentification was 5%.

Despite the low relative frequency of strandings, the rarity of records of some species (*B. musculus* was mentioned twice) (Bayed & Beaubrun, 1987, 1996; de Stephanis, personal observation), the unclear location of sightings (sightings of *B. edeni* and *E. glacialis* could not be traced), and other possible problems associated with the nature of the data, this study enhances the knowledge on cetaceans of the Moroccan coast which is a poorly documented area. Stranding distributions help to identify species distributions. For example, the spatial distributions of strandings of *D. delphis* and *S. coeruleoalba* are telling (Figure 4); while strandings of *S. coeruleoalba* are concentrated in the Strait of Gibraltar and the Bay of Agadir (67% of total), those of *D. delphis* are concentrated in the western Mediterranean and on the Atlantic coast at 33–34°N (79%). This comparison is valid only if both species have similar sensitivity to the causes of stranding. The occurrence of stranding at different periods of the year indicates whether species visit Moroccan waters continuously or seasonally (Figure 4). When considering only fresh animals (DCC 1 and 2), fin and sei whales were present throughout the year, but strandings of common and striped dolphins were minimal between September and December. Length distributions in the stranding database provide information on the stage of life at stranding: the fin, sei and sperm whales appear to be present in Moroccan waters at birth and at different stages of their life cycle. This suggest the presence of resident populations of fin and sei whales in the Northern Canary Current region. The spatial distribution of strandings highlights areas of frequent interactions with humans. Confirmed cases of collisions with vessels were exclusively with baleen whales in areas with high traffic or near major

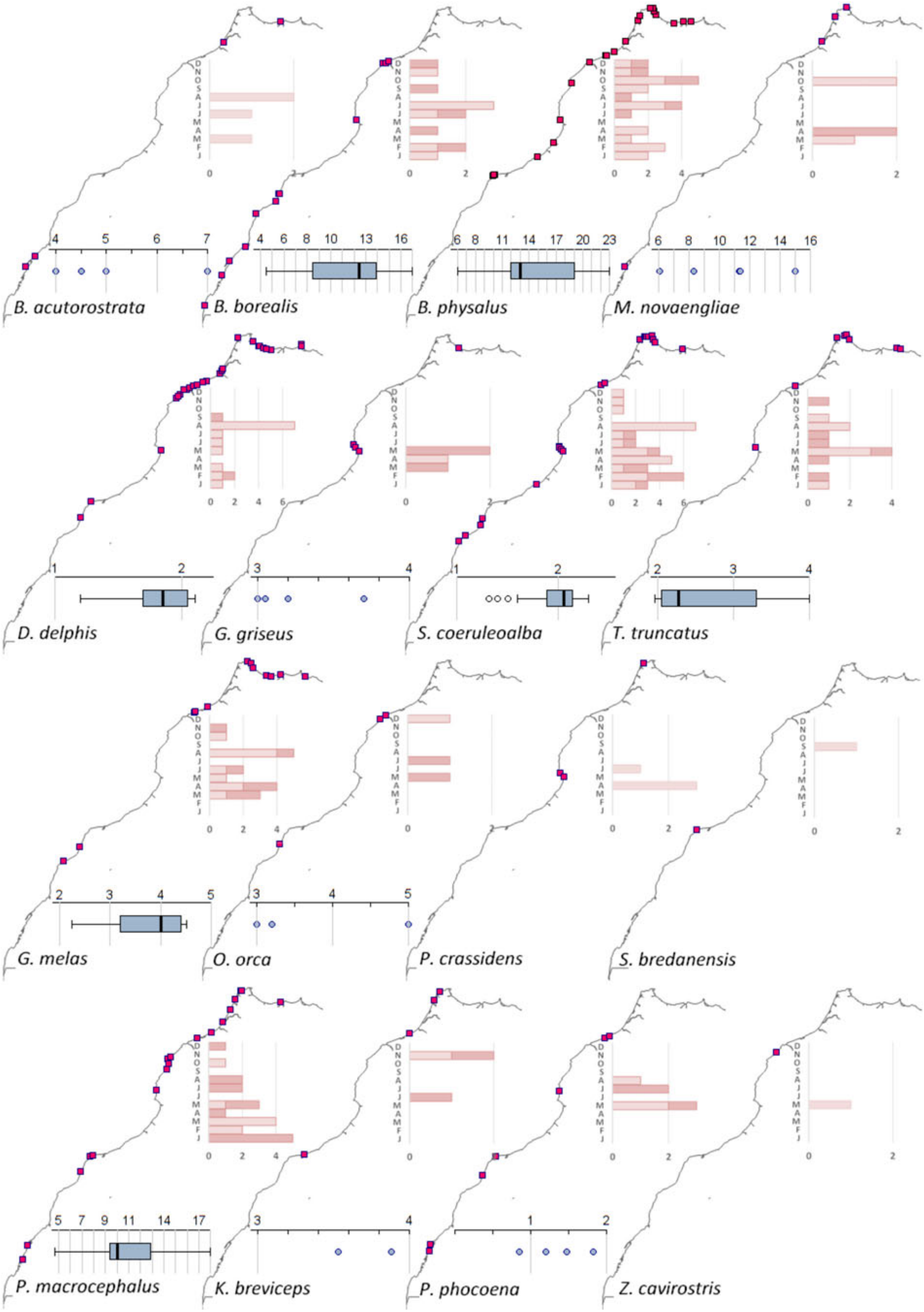

Fig. 4. Distribution of cetacean species strandings along the Moroccan coast during the period 1980–2009. Boxplots or point graphics indicate the length distributions (m) of each species, and histograms show intra-annual frequencies of strandings categorized by the state of the carcass (DCC 1–3 in light and 4–5 in dark colour).

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commercial ports, in the Strait of Gibraltar, Casablanca and Agadir. Nevertheless, the proportion of cases of collisions accounts for less than 10% of all of the baleen whale strandings. Similarly, the western Mediterranean and the Strait of Gibraltar appear to be areas where interactions with dolphins and pilot whales seem more frequent than on the Atlantic coast. The areas of Casablanca (27% of total strandings) showed few sectioned fins (2%) compared with the Strait of Gibraltar (22% of total strandings, with 16% of sectioned fins). The frequent use of drift nets in the latter area, currently under eradication, may be directly responsible.

Information from strandings is increasingly used in ecological studies on cetaceans for estimation of population indicators (Maldini *et al*., 2005; Pyenson, 2010; Peltier *et al*., 2014), as well as in traditional areas where strandings are an essential source of information (e.g. pathology, toxicology). In the context of a developing country such as Morocco, where the cost of acquiring information is a major obstacle to scientific research, using strandings as an information source is a necessity in the study of cetaceans in particular, and for ecological studies in general. The data gathered in this study cannot be used as proxy of population densities, but can direct the choices when building ecosystem models (end to end models) and for prioritizing future research programmes on cetaceans. Two Moroccan research organizations have structures that collect information on strandings: INRH through its research centres network and the Cetacean and Pinnipeds Study Group Morocco (GECPM). INRH has regularly produced stranding reports with restricted distribution since 2010, and GECPM communicates through publication of summaries of comments received (Bayed & Beaubrun, 1996). Establishing an observation network and structured monitoring of sufficient and sustainable density in Morocco are the most likely ways to collect robust data for the calculation of credible population indicators for cetaceans. Monitoring of cetaceans in Morocco will certainly improve through better collaboration among Moroccan institutions (including research) and a greater awareness in Moroccan civil society of environmental issues.

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Supplementary materials and methods

The supplementary material for this article can be found at http://www.journals.cambridge.org/mbi

REFERENCES

Aloncle H. (1964) Premières observations sur les petits cétacés des côtes marocaines. *Bulletin de l'Institut des Pêches Maritimes du Maroc* 12, 21–42.

Aloncle H. (1967) Deuxième note sur les petits cétacés de la baie Ibéro-Marocaine. *Bulletin de l'Institut des Pêches Maritimes du Maroc* 15, 33–44.

Authier M., Peltier H., Dorémus G., Dabin W., Van Canneyt O. and Ridoux V. (2014) How much are stranding records affected by variation in reporting rates? A case study of small delphinids in the Bay of Biscay. *Biodiversity and Conservation* 23, 2591–2612.

Bayed A. and Beaubrun P.-C. (1987) Les mammifères marins du Maroc: Inventaire préliminaire. *Mammalia* 51, 437–446.

Bayed A. and Beaubrun P.-C. (1996) Distribution actualisée des Cétacés le long des côtes marocaines. In *Actes de la 5ème Conférence Internationale RIMMO pour la protection des Mammifères marins en Méditerranée occidentale: « Le bassin Corso-Liguro-Provençal, une Mer à protéger »*, Antibes, 15–17 novembre 1996.

Bentaleb I., Martin C., Vrac M., Mate B., Mayzaud P., Siret D., de Stephanis R. and Guinet C. (2011) Foraging ecology of Mediterranean fin whales in a changing environment elucidated by satellite-tracking and baleen plate stable isotopes. *Marine Ecology Progress Series* 438, 285–302.

Cañadas A., Sagarminaga R., De Stephanis R., Urquiola E. and Hammond P.S. (2005) Habitat preference modelling as a conservation tool: proposals for marine protected areas for cetaceans in southern Spanish waters. *Aquatic Conservation: Marine and Freshwater Ecosystems* 15, 495–521.

Cañadas A., Sagarminaga R. and García-Tiscar S. (2002) Cetacean distribution related with depth and slope in the Mediterranean waters off southern Spain. *Deep Sea Research Part I: Oceanographic Research Papers* 49, 2053–2073.

Cañadas A. and Vázquez J.A. (2014) Conserving Cuvier's beaked whales in the Alboran Sea (SW Mediterranean): identification of high density areas to be avoided by intense man-made sound. *Biological Conservation* 178, 155–162.

Carpinelli E., Gauffier P., Verborgh P., Airoldi S., David L., Di-Méglio N., Cañadas A., Frantzis A., Rendell L., Lewis T., Mussi B., Silvia Pace D. and De Stephanis R. (2014) Assessing sperm whale (*Physeter macrocephalus*) movements within the western Mediterranean Sea through photo-identification. *Aquatic Conservation: Marine and Freshwater Ecosystems* 24(S1), 23–30.

Carr M.-E. (2001) Estimation of potential productivity in Eastern Boundary Currents using remote sensing. *Deep-Sea Research Part II: Topical Studies in Oceanography* 49, 59–80.

Carr M.-E. and Kearns E.J. (2003) Production regimes in four Eastern Boundary Current systems. *Deep-Sea Research Part II: Topical Studies in Oceanography* 50, 3199–3221.

Castège I., Soulier L., Hémery G., Mouchès C., Lalanne Y., Dewez A., Pautrizel F., d' Elbée J. and D'Amico F. (2013) Exploring cetacean stranding pattern in light of variation in at-sea encounter rate and fishing activity: lessons from time surveys in the south Bay of Biscay (East-Atlantic; France). *Journal of Marine Systems* 109–110(Supplement), S284–S292.

Christaki U., Giannakourou A., Wambeke F.V. and Grégori G. (2001) Nanoflagellate predation on auto- and heterotrophic picoplankton in the oligotrophic Mediterranean Sea. *Journal of Plankton Research* 23, 1297–1310.

Crombet Y., Leblanc K., Quéguiner B., Moutin T., Rimmelin P., Ras J., Claustre H., Leblond N., Oriol L. and Pujo-Pay M. (2011) Deep silicon maxima in the stratified oligotrophic Mediterranean Sea. *Biogeosciences* 8, 459–475.

De Barba M., Waits L.P., Genovesi P., Randi E., Chirichella R. and Cetto E. (2010) Comparing opportunistic and systematic sampling methods for non-invasive genetic monitoring of a small translocated brown bear population. *Journal of Applied Ecology* 47, 172–181.

de Stephanis R., Cornulier T., Verborgh P., Salazar Sierra J., Pérez Gimeno N. and Guinet C. (2008a) Summer spatial distribution of cetaceans in the Strait of Gibraltar in relation to the oceanographic context. *Marine Ecology Progress Series* 353, 275–288.

de Stephanis R., García-Tíscar S., Verborgh P., Esteban-Pavo R., Pérez S., Minvielle-Sebastia L. and Guinet C. (2008b) Diet of the social groups of long-finned pilot whales (*Globicephala melas*) in the Strait of Gibraltar. *Marine Biology* 154, 603–612.

de Stephanis R., Verborgh P., Pérez S., Esteban R., Minvielle-Sebastia L. and Guinet C. (2008c) Long-term social structure of long-finned pilot whales (*Globicephala melas*) in the Strait of Gibraltar. *Acta Ethologica* 11, 81–94.

de Stephanis R., Giménez J., Carpinelli E., Gutierrez-Exposito C. and Cañadas A. (2013) As main meal for sperm whales: plastics debris. *Marine Pollution Bulletin* 69, 206–214.

de Stephanis R.D., Giménez J., Esteban R., Gauffier P., García-Tiscar S., Sinding M.-H.S. and Verborgh P. (2014) Mobbing-like behavior by pilot whales towards killer whales: a response to resource competition or perceived predation risk? *Acta Ethologica* 18, 69–78.

van Elk C.E., van de Bildt M.W.G., Jauniaux T., Hiemstra S., van Run P.R.W.A., Foster G., Meerbeek J., Osterhaus A.D.M.E. and Kuiken T. (2014) Is dolphin morbillivirus virulent for white-beaked dolphins (*Lagenorhynchus albirostris*)? *Veterinary Pathology* 51, 1174–1182.

Engelhaupt D., Rus Hoelzel A., Nicholson C., Frantzis A., Mesnick S., Gero S., Whitehead H., Rendell L., Miller P., De Stephanis R., Canãdas A., Airoldi S. and Mignucci-Giannoni A.A. (2009) Female philopatry in coastal basins and male dispersion across the North Atlantic in a highly mobile marine species, the sperm whale (*Physeter macrocephalus*). *Molecular Ecology* 18, 4193–4205.

Esteban R., Verborgh P., Gauffier P., Giménez J., Afán I., Cañadas A., García P., Murcia J.L., Magalhães S., Andreu E. and de Stephanis R. (2013) Identifying key habitat and seasonal patterns of a critically endangered population of killer whales. *Journal of the Marine Biological Association of the United Kingdom* 94, 1317–1325.

Fernández A., Esperón F., Herraéz P., de los Monteros A.E., Clavel C., Bernabé A., Sánchez-Vizcaino J.M., Verborgh P., DeStephanis R., Toledano F. and Bayón A. (2008) Morbillivirus and pilot whale deaths, Mediterranean Sea. *Emerging Infectious Disease Journal* 14, 792–794.

Foote A.D., Vilstrup J.T., De Stephanis R., Verborgh P., Abel Nielsen S.C., Deaville R., Kleivane L., Martín V., Miller P.J.O., Øien N., Pérez-Gil M., Rasmussen M., Reid R.J., Robertson K.M., Rogan E., Similä T., Tejedor M.L., Vester H., Víkingsson G.A., Willerslev E., Gilbert M.T. and Piertney S.B. (2011) Genetic differentiation among North Atlantic killer whale populations. *Molecular Ecology* 20, 629–641.

Fulton E.A. (2010) Approaches to end-to-end ecosystem models. *Journal of Marine Systems*, 81, 171–183.

Giménez J., Stephanis R.D., Gauffier P., Esteban R. and Verborgh P. (2011) Biopsy wound healing in long-finned pilot whales (*Globicephala melas*). *Veterinary Record* 168, 101–101.

Guinet C., Domenici P., De Stephanis R., Barrett-Lennard L., Ford J.K.B. and Verborgh P. (2007) Killer whale predation on bluefin tuna: exploring the hypothesis of the endurance-exhaustion. *Marine Ecology Progress Series* 347, 111–119.

Gutiérrez Exposito C. and Qninba A. (2010) Observations de Tortues, d'Oiseaux et de Mammifères marins au large des côtes atlantiques marocaines durant l'automne 2010. *Bulletin de l'Institut Scientifique, Rabat, section Sciences de la Vie* 32, 129–132.

Herráez P., de los Monteros A.E., Fernández A., Edwards J.F., Sacchini S. and Sierra E. (2013) Capture myopathy in live-stranded cetaceans. *Veterinary Journal* 196, 181–188.

Holmer M., Marba N., Diaz-Almela E., Duarte C.M., Tsapakis M. and Danovaro R. (2007) Sedimentation of organic matter from fish farms in oligotrophic Mediterranean assessed through bulk and stable isotope (δ^{13C} and δ^{15N}) analyses. *Aquaculture* 262, 268–280.

Hooker S.K. and Gerber L.R. (2004) Marine reserves as a tool for ecosystem-based management: the potential importance of megafauna. *BioScience* 54, 27.

Jennings S. and Rice J. (2011) Towards an ecosystem approach to fisheries in Europe: a perspective on existing progress and future directions: towards an ecosystem approach to fisheries in Europe. *Fish and Fisheries* 12, 125–137.

Jauniaux T., Garcia-Hartmann M., Haelters J., Tavernier J. and Coignoul F. (2002) Echouage de mammifères marins: guide d'intervention et procédures d'autopsie. *Annales de Médecine Vétérinaire, Université de Liège, Faculté de médecine vétérinaire* 146, 261–276.

Kifani S., Masski H. and Faraj A. (2008) The need of an ecosystem approach to fisheries: the Moroccan upwelling-related resources case. *Fisheries Research* 94, 36–42.

Lochet F. and Leveau M. (1990) Transfers between a eutrophic ecosystem, the river Rhône, and an oligotrophic ecosystem, the north-western Mediterranean Sea. *Hydrobiologia* 207, 95–103.

Louis M., Viricel A., Lucas T., Peltier H., Alfonsi E., Berrow S., Brownlow A., Covelo P., Dabin W., Deaville R., De Stephanis R., Gally F., Gauffier P., Penrose R., Silva M.A., Guinet C. and Simon-Bouhet B. (2014) Habitat-driven population structure of bottlenose dolphins, *Tursiops truncatus*, in the North-East Atlantic. *Molecular Ecology* 23, 857–874.

Maldini D., Mazzuca L. and Atkinson S. (2005) Odontocete stranding patterns in the main Hawaiian islands (1937–2002): how do they compare with live animal surveys? *Pacific Science* 59, 55–67.

Peltier H., Jepson P.D., Dabin W., Deaville R., Daniel P., Van Canneyt O. and Ridoux V. (2014) The contribution of stranding data to monitoring and conservation strategies for cetaceans: developing spatially explicit mortality indicators for common dolphins (*Delphinus delphis*) in the eastern North-Atlantic. *Ecological Indicators* 39, 203–214.

Pérez S., García-López Á., Stephanis R.D., Giménez J., García-Tiscar S., Verborgh P., Mancera J.M. and Martínez-Rodriguez G. (2011) Use of blubber levels of progesterone to determine pregnancy in free-ranging live cetaceans. *Marine Biology* 158, 1677–1680.

Pershing A.J., Christensen L.B., Record N.R., Sherwood G.D. and Stetson P.B. (2010) The impact of whaling on the ocean carbon cycle: why bigger was better. *PLoS ONE* 5, e12444.

Psarra S., Tselepides A. and Ignatiades L. (2000) Primary productivity in the oligotrophic Cretan Sea (NE Mediterranean): seasonal and inter-annual variability. *Progress in Oceanography* 46, 187–204.

Pyenson N.D. (2010) Carcasses on the coastline: measuring the ecological fidelity of the cetacean stranding record in the eastern North Pacific Ocean. *Paleobiology* 36, 453–480.

Senigaglia V., de Stephanis R., Verborgh P. and Lusseau D. (2012) The role of synchronized swimming as affiliative and anti-predatory behavior in long-finned pilot whales. *Behavioural Processes* 91, 8–14.

Smith M., Fulton E., Day R., Shannon L. and Shin Y.-J. (2015) Ecosystem modelling in the southern Benguela: comparisons of Atlantis, Ecopath with Ecosim, and OSMOSE under fishing scenarios. *African Journal of Marine Science* 37, 65–78.

Van Canneyt O., Kerric A., Authier M., Dabin W., Demaret F., Dorémus G. and Spitz J. (2014) Les échouages de mammifères marins sur le littoral français en 2013. *Rapport UMS – Observatoire PELAGIS pour le Ministère de l'Ecologie, du Développement Durable*

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et de l'Energie, Direction de l'eau et de la biodiversité, Programme Observatoire du Patrimoine Naturel, 54 pp.

Verborgh P., De Stephanis R., Pérez S., Jaget Y., Barbraud C. and Guinet C. (2009) Survival rate, abundance, and residency of long-finned pilot whales in the Strait of Gibraltar. *Marine Mammal Science* 25, 523–536.

and

Wierucka K., Verborgh P., Meade R., Colmant L., Gauffier P., Esteban R., de Stephanis R. and Caadas A. (2014) Effects of a morbillivirus epizootic on long-finned pilot whales *Globicephala melas* in Spanish Mediterranean waters. *Marine Ecology Progress Series* 502, 1–10.

Correspondence should be addressed to:
H. Masski
Institut National de Recherche Halieutique,
Bd. Sidi Abderrahmane, 20 000 Casablanca, Morocco
email: hmasski@gmail.com

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