Mediterranean Marine Science

Vol 19, No 3 (2018)

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doi: [10.12681/mms.15835](https://doi.org/10.12681/mms.15835)

Research Article

Mediterranean Marine Science
Indexed in WoS (Web of Science, ISI Thomson) and SCOPUS
The journal is available on line at http://www.medit-mar-sc.net
DOI: http://dx.doi.org/10.12681/mms.15835

Sea turtles in the eastern margin of the North Atlantic: the northern Ibero-Moroccan Gulf as an important neritic area for sea turtles

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Handling Editor: Argyro Zenetos

Received: 23 January 2018 ; Accepted: 25 June 2018 ; Published on line: 31 December 2018

Abstract

This study summarises nearly 20 years (1997-2015) of tracking strandings of sea turtles along the Andalusian coast. During this period 2495 specimens were recorded, most of them Loggerhead turtles *Caretta caretta* (92.6%) and some Leatherback turtles *Demochelys coriacea* (7.1%). Two other species were almost insignificant, the Green turtle *Chelonia mydas* (0.2%) and Kemp's ridley turtle *Lepidochelys kempi* (0.1%). A significant number of turtles were recorded from the Atlantic coast, although in this area the incidence of living specimens was low. Spring and summer were the seasons with more specimens stranded, probably related to warmer and more productive waters. The size of the Loggerhead turtles observed highlights a significant presence of immature specimens in Andalusian waters, although mature individuals were not rare. In the case of Leatherback turtles, the adult stage was the only recorded. These results, combined with the fact that the Atlantic coast has a large continental shelf and an area of high primary productivity near the coast, suggest that the gulf of Cádiz may represent a neritic habitat used by the sea turtles. If this is the case, new and more effective conservation measures are needed in order to protect sea turtles in this area.

Keywords: Gulf of Cádiz; leatherback turtles; loggerhead turtles; Sea turtles; south Iberian Peninsula; Strait of Gibraltar; strandings.

Introduction

Migratory marine species use a large area to complete their ecological cycles, which include foraging and breeding areas in both marine and terrestrial environments. Hence, understanding the importance of ocean areas for these species is a relevant issue in order to facilitate management tasks (Wang *et al.,* 2016). In this context, the Strait of Gibraltar and its contiguous waters has been considered an important passage area or bridge connecting the western Mediterranean Sea with the Atlantic Ocean (Camiñas & De la Serna, 1995; Bellido *et al.,* 2010a) especially for Loggerhead sea turtles (*Caretta caretta* Linnaeus, 1758). In fact, five of the seven marine reptiles occurring worldwide have been cited in this area: Loggerheads, Leatherbacks *Dermochelys coriacea* (Vandelli, 1761), Green turtles *Chelonia mydas* (Linnaeus, 1758), Kemp's ridley *Lepidochelys kempii* (Garman, 1880) and Hawksbill turtles *Eretmochelys imbricata* (Linnaeus, 1766) (Brongersma, 1972; Nicolau *et al.,* 2016a); all of them are listed in the IUCN red list of threatened species (IUCN, 2017).

In the case of loggerheads, although there are important nesting areas within the Mediterranean Sea (Margaritoulis *et al.,* 2003), the Strait of Gibraltar plays a key role connecting specimens from nesting areas located in the Atlantic Ocean with foraging areas around South Balearic Islands (Camiñas & De la Serna, 1995). Thus, many juveniles born in the Atlantic (mainly the American coast) and eastern Mediterranean Sea remain in the western Mediterranean Sea around foraging areas (Clusa *et al.,* 2014; Báez *et al.,* 2017). Furthermore, according to Revelles *et al.* (2007), juvenile Loggerheads from Atlantic areas remain in the Mediterranean until they reach the minimum size (straight carapace length, SCL, of 36.0 cm) to overcome the superficial flow of Atlantic waters entering in the Mediterranean through the Strait of Gibraltar. Recent evidence stress the importance of the Strait of Gibraltar for the ecology of the Loggerhead in particular and maybe for migrating turtles to the Mediterranean Sea in general (Báez *et al.,* 2011). In addition, Ocaña *et al.* (2005) and Benhardouze *et al.* (2008; 2012) suggested that the Loggerhead could use the southern part of the Alboran Sea as a specific foraging area due to the abundance of *Polybius henslowii* Leach, 1820 (Decapoda, Brachyura), a potential prey. This has been corroborated in a study on the relative abundance of invertebrates and significant numbers of stranded Loggerhead from south Portugal by Nicolau *et al.* (2016b). Accordingly, studies developed by Bellido *et al.* (2010a, 2010b) on strandings of Loggerheads in the Andalusian coast highlight the possibility that sea turtles spend more time in these waters than would be expected if they were only migrating through the Strait of Gibraltar. Báez *et al.* (2011) suggested that there could be Loggerhead seasonal abundance peaks around the Strait of Gibraltar. On the other hand, recent proliferation of new nests on the east coast of Spain (revised in Báez *et al.,* 2017), and the evidence of hybridization between both populations (eastern Mediterranean Sea and Atlantic Ocean populations) in the context of climate change (Carreras *et al.,* 2015) forces towards a more comprehensive understanding of the importance of the waters surrounding the Strait of Gibraltar for the ecology of sea turtles.

There are few studies about the biology or migration patterns of Leatherbacks in the Andalusian coast due to its scarce presence in this area. According to Camiñas (1998, 2002) and Camiñas & González de Vega (1997), numerous specimens of large size (alive and dead) have been reported from a long time ago in the southern Atlantic coast of Spain. In addition, Camiñas & Valeiras (2001) highlighted the Strait of Gibraltar region, an important fishing and large vessel traffic area, as a critical area for both Loggerheads and Leatherbacks.

Every year, many injured turtles or their carcasses arrive to the coasts of Andalusian (Camiñas, 2002; Bellido *et al.,* 2010a). The study of these beached turtle parts provides valuable information about body size, diet, threats, abundance, geographical distribution or reproductive status (Chaloupka *et al.,* 2008). Although stranding data may be biased due to monitoring effort, temporal and spatial variation in recording, or inter-annual variation in surveying (Tomás *et al.,* 2008), it has becoming increasingly evident that stranding records, properly analysed, represent an important source of information on mortality factors, and spatial and temporal distribution of sea turtles (Casale *et al.,* 2010; Báez *et al.,* 2011; Nicolau *et al.,* 2016a).

In this paper we analysed the spatial and temporal distribution of strandings in the Andalusian coast (situated in both Atlantic Ocean and Mediterranean Sea) to infer patterns of distribution for sea turtles in waters around the Strait of Gibraltar. The ultimate goal of this study was to understand the role of the Strait of Gibraltar and its contiguous waters, the human activities in the area as well as the climatic variability influences in the ecological cycle of sea turtles populations.

Material and Methods

Study area

Andalusia is an autonomous region within Spain. The Andalusian coast involves five administrative political provinces (Huelva, Cadiz, Malaga, Granada, and Almeria), totalling, according to measures estimated using software QGIS 2.18, 925.2 km of coastline that extends from 37º 10´N, 7º 23´W to 37º 22´N, 1º 37´W (Fig. 1).

The Strait of Gibraltar connects the two Andalusian coast watersheds, the Atlantic and the Mediterranean. In order to develop comparative analyses, the Andalusian coast has been subdivided in four areas according to different criteria: geographical orientation, Atlantic Ocean influence, and extension of the continental shelf. The four areas (Fig. 1) are the Atlantic Coast (AC) from Ayamonte (in the border with Portugal) to Tarifa (349.9 km) bathed by Atlantic Ocean with a wide continental shelf; the west Alboran coast (WA) from Algeciras to Rincón de la Victoria (193.6 km) characterised for a strong influence of surface Atlantic waters and a narrow continental shelf; the east Alboran coast (EA) from Rincón de la Victoria to Almería (253.6 km) also with a narrow continental shelf and influence of Mediterranean/Atlantic waters, alternately, and the west Mediterranean coast (WM) from

Fig. 1: Study area showing the 4 areas established for this study. Key: AC: Atlantic coast; WA: West Alborán; East Alborán; and WM: West Mediterranean. Map provided by SEATURTLE. ORG Maptool.2017.

Níjar to Cuevas del Almazora (128.1 km) with the permanent and strong Almeria-Oran front (Tintoré *et al.,* 1988) and its waters considered as truly Mediterranean. This division has been previously supported by studies by Bellido *et al.,* 2012 on stranded Stripped dolphins (*Stenella coeruleoalba* Meyen, 1833).

Data collection

Loggerhead stranding data were collected along the four areas for 19 years (1997 to 2015) by the Regional Government (Consejería de Medio Ambiente y Ordenación del Territorio de la Junta de Andalucía) with the help of a volunteer stranding network and institutions that collaborated in the detection and attention to the stranded turtles. The high coastal occupation, development, and population density makes it unlikely that a stranding event would go unnoticed. Records include dead or injured turtles stranded on beaches and turtles found floating dead or in a weakened condition. All the measurements have been standardised using the functions provided by Báez *et al*. (2010), and stored in a database including the observer identification, name of the species, date, geographic coordinates, sex (if known), age, condition (alive, dead), curve carapace length (CCL) and, when it was possible, cause of stranding.

Data analysis

Stranding density (strandings per kilometre and year) was determined for these four areas. The different areas have different coast lengths; therefore, in order to allow for equal comparisons, we estimated the relative densities of strandings as the number of stranded turtles per 10 km per year.

We tested the frequency of Loggerhead stranding per area using a Chi-squared test (χ^2).

Expected values in the Chi-squared tests were calculated according to the length of coast for each area, and total Loggerhead strandings sea turtle observed. Thus, we tested the observed turtle stranding distribution per area versus weighted random distribution per area.

Chi-squared test (χ^2), allows us to know if there are significant differences between areas or not. Therefore, in order to determine the differences in the distribution of Loggerhead strandings along the coast, a Bonferroni normal statistics test was developed testing by municipality (Byers *et al.,* 1984; Cameron & Spencer, 2008). This test allows us to know the municipality in which strandings were significantly higher or lower than expected according to availability and was made by obtaining confidence intervals for the prevalence in each area using the formula:

$$\hat{p} - Z_{\alpha/2k}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \leq \hat{p} \leq \hat{p} + Z_{\alpha/2k}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$$

where $\hat{p}$ is the proportion of strandings by area, $\alpha = 0.05$, k is the number of areas tested, $Z_{\alpha/2k}$ is the upper standard normal table value corresponding to a probability tail area of $\alpha/2k$, and n is the total number of strandings. The availability of each municipality was calculated according to its coast length. The observed prevalence was the proportion of strandings computed for each municipality. If the confidence interval of the observed prevalence in a municipality overlapped the expected prevalence according to availability, then there was no significant difference between prevalence and availability. If the confidence interval was more than the availability of a municipality, strandings in that municipality were more than expected, whereas if the confidence interval was below availability, strandings in that municipality were less than expected (Byers *et al.,* 1984; Cameron & Spencer, 2008; Bellido *et al.,* 2010a).

The time series was analysed for each sea turtle species. To identify periodicity, we searched for common interannual trends and cyclicity in the time series using spectral analysis. Spectral analysis was performed with the software PAST (available from https://folk.uio.no/ohammer/past/) (Hammer *et al.,* 2001; Hammer & Harper, 2006).

The Curve Carapace Length (CCL) data recorded were tested for normality using the Kolmogorov-Smirnov test. When data were not normal, significant differences between sizes of stranded Loggerheads were analysed using the Kruskal–Wallis test (Sokal & Rohlf, 1981).

In order to determine the causes of the strandings, specimens found alive were moved to the recovery centre for veterinary examination and rehabilitation. In those cases, the cause of injury was determined by external inspection, radiography and, if the animal died, by necropsy. Turtle injuries were classified into five causal categories: Debilitated Turtle Syndrome (DTS), disease (i.e., cold-stunned, emaciation, buoyancy), trauma, interaction with fisheries (i.e., presence of remnants of nets, hooks, and/or fishing lines), and other causes not determined (Bellido *et al.,* 2010b; Nicolau *et al.,* 2016a). In the area of study, a longline fishery operates mainly in oceanic waters but net fisheries are more frequent in neritic waters.

In a previous study Báez *et al.* (2011) observed a relationship between the frequency of Loggerhead stranding versus the North Atlantic Oscillation (NAO). The NAO is the largest source of climate variability in the northern hemisphere. The NAO index is based on the difference between the high-pressure centre located over the Azores archipelago and the low-pressure centre in the Atlantic Ocean near Iceland. The NAO acts as the main source of climate variability in the North Atlantic by modifying the intensity of the westerlies (Hurrell, 1995).

In a similar way to Báez *et al*. (2011), we compared sea turtles stranded per area versus NAO for adults and immature individuals using Spearman's rank correlations. However, due to infrequent sampling measurements available, the analysis was limited to immature Loggerheads. Thus, the number of immature Loggerheads (< 66 cm) per year and area, weighted with the total number of sea turtle measurements for that year in all areas pooled together, was correlated with NAO. The monthly values for the NAO for the period were provided by the National Oceanic and Atmospheric Administration (NOAA) (available at: http://www.noaa.gov). The NAO index do not only undergo interannual variability but also intraannual variability, which mainly occurs during winter (Hurrell, 1995). Thus, NAO shows the most variability during the winter and we therefore used the average of months between November (previous year) to March (current year).

Results

Number of stranding records and temporal variation

Between 1997 and 2015, 2495 sea turtles were reported stranded along the Andalusian coastline. The recorded strandings included Loggerheads, *Caretta caretta* (N = 2311; 92.6%) and Leatherbacks, *Dermochelys coriacea* (N = 175; 7.1%). Other species were registered but they were excluded from this study because their numbers were not statistically relevant: Green turtle, *Chelonia mydas* (N = 6; 0.2%) and Kemp's ridley turtle, *Lepidochelys kempi* (N = 3; 0.1%).

In the case of Loggerheads, we observed a strong interannual variability. Thus, the periods 1997-2000 and 2006-2009 could be considered as a low strandings term. However, the periods 2001-2005 and 2010-2013 show an elevated number of stranding higher than the mean (Fig. 2). We did not observe any interannual temporal trends. Leatherback strandings show little variability during of studied period (Fig. 3).

Spatial and seasonal occurrence

The Atlantic Coast (AC) comprises less than 40% of the total Andalusian coast in terms of length; however, it receives 60.3% of the total strandings of Loggerhead and 81.7% of Leatherbacks. Meanwhile, the Alboran areas (WA and EA), 48.4% of the coast length, accounts for 34.8% of Loggerheads and 17.2% of Leatherbacks. Finally, the Mediterranean Coast (WM) area (13.8% of the coast) only adds the remaining 4.9% of Loggerheads and 1.1% of Leatherbackss (Table 1).

In the Andalusian coast live Loggerheads accounted for 24.3% of all stranded specimens. In the WA and EA areas, live stranded Loggerheads comprised, approximately, 50% of the records. Meanwhile, in the adjacent areas, this proportion is lower (9.6% for AC and 23.0% for WM) (Fig. 4).

In the case of Leatherbacks, only 1% of strandings were of living specimens, all of them in the AC.

According to the χ^2 developed on the spatial distribution of Loggerhead strandings, there are significant differences in the incidence of specimens among areas (χ^2 = 561.62; df = 3; P = 2.1*10^{-121}).

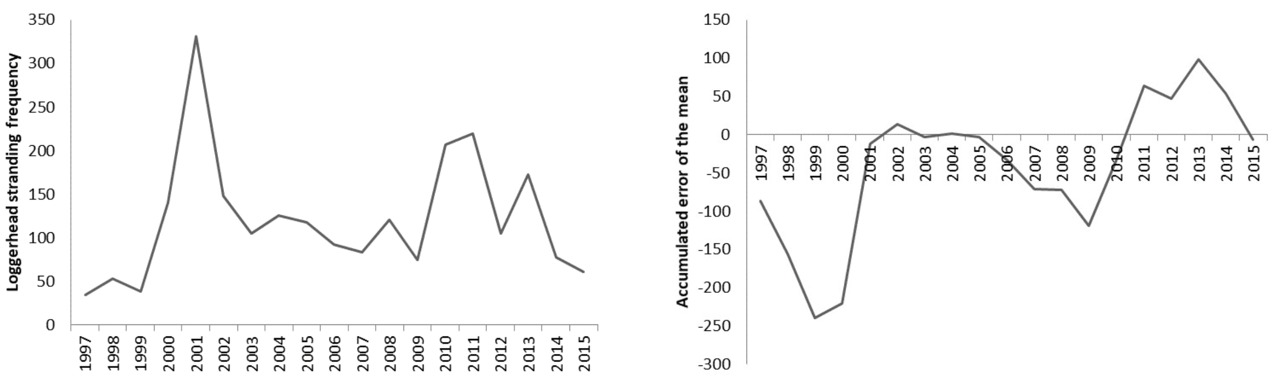

Fig. 2: Interannual variability of Loggerhead strandings in the study period 1997-2015. A) Loggerhead stranding frequency observed per year. B) Accumulated error of the mean Loggerhead strandings per year (mean = 122).

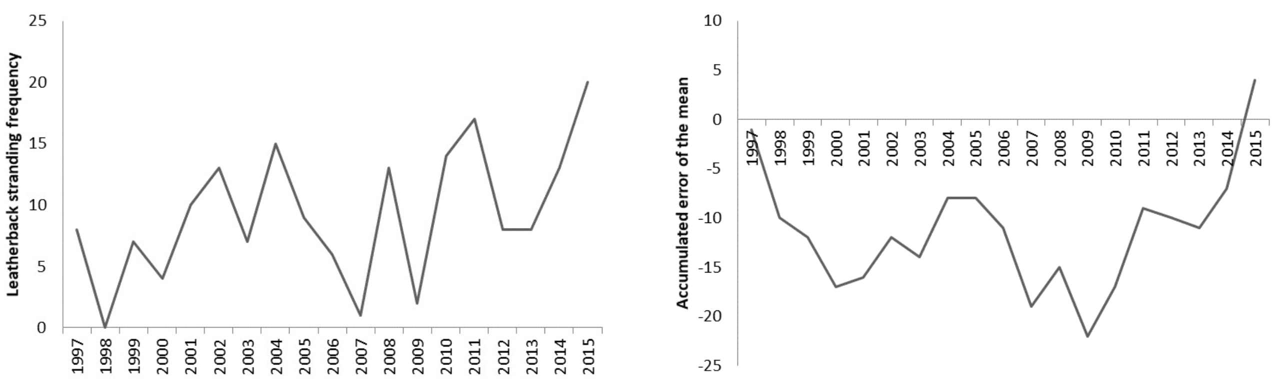

Fig. 3: Interannual variability of Leatherback strandings in the study period 1997-2015. A) Leatherback stranding frequency observed per year. B) Accumulated error of the mean Leatherback strandings per year (mean = 9).

Table 1. Number of strandings distributed per area in the Andalusian coast, for Loggerhead (*Caretta caretta*) and Leatherback (*Dermochelys coriacea*) turtles. Percentages for coast extensions and numbers of strandings are indicated.

Andalusian Coast		***Caretta caretta***		***Dermochelys coriacea***	
Area	**% coast**	**N**	**%**	**N**	**%**
Atlantic Coast (AC)	37.8	1393	60.3	143	81.7
West Alboran coast (WA)	20.9	421	18.2	19	10.9
East Alboran coast (EA)	27.5	384	16.6	11	6.3
West Mediterranean Coast (WM)	13.8	113	04.9	2	1.1

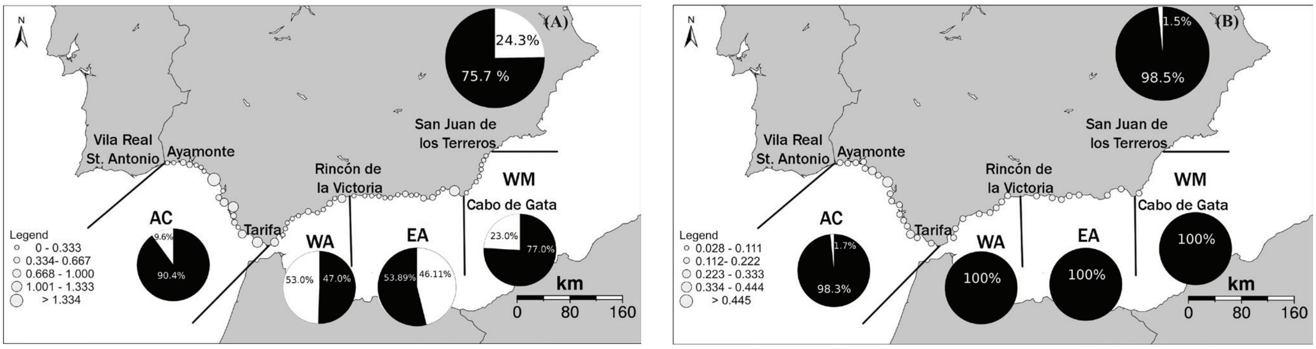

Fig. 4: Relative stranding densities of marine turtles (number of strandings per 10 km) on the Andalusian coast between 1997 and 2015: A Loggerheads (N = 2311) and B Leatherbacks (N = 175). Key: large pies refer to the proportion of total dead and alive stranded turtles, and small white circles refer to the proportion of dead and alive stranded turtles at the AC, WA, EA, and WM sectors: black dead turtles; white living turtles.

The Bonferroni test highlights that while the Atlantic coast can be considered a zone with more strandings than expected for Loggerheads, the rest of the Andalusian coast (Mediterranean) receives fewer strandings than expected according to its coast length (Table 2). Only four municipalities in the Andalusian coast received more strandings than expected according to spatial availability, all of them in the Gulf of Cadiz in the Atlantic Area (Fig. 5). On the other hand, in the Mediterranean Sea (WA, EA, and WM), municipalities with fewer strandings than expected are more frequent.

χ^2 for Leatherback turtles yielded similar results, with significant differences among areas ($\chi^2 = 191.74$; df = 3; P = $2.56*10^{-41}$).

Seasonal occurrence

Significant differences were found in the incidence of Loggerhead strandings among seasons (χ^2= 99.42; df = 3; P =$2.071*10^{-21}$). Loggerhead strandings were more frequent during spring and summer in the Andalusian coast. Significant differences among seasons were found for Leatherbacks. The maximum incidence of strandings was recorded during the summer months in the Atlantic coast ($\chi^2 = 16.01$; df = 3; P = 0.0011).

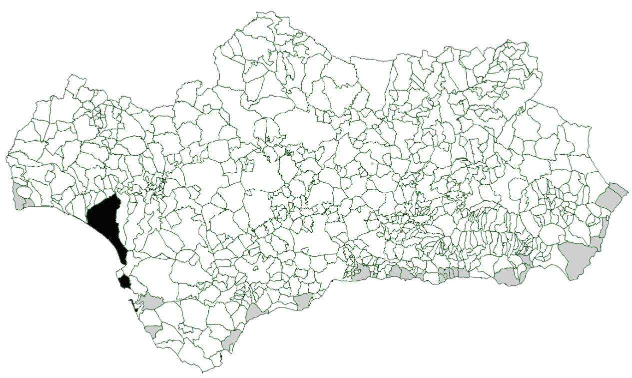

Fig. 5: Map of municipalities with strandings of Loggerhead (*Caretta caretta*) in the Andalusian coast (N = 2329, total coastline length considered = 925.2 km) according to Bonferroni normal statistics. Bonferroni intervals provide confidence intervals Z = 0.0004. Municipalities with more strandings than expected are shown in black; municipalities with less strandings than expected are shown in grey. Key: AC: Atlantic coast; WA: West Alborán; EA: East Alborán; WM: West Mediterranean Coast.

Life stages

CCL average for Loggerhead was 48.6 cm (sd = 15.6; range = 15-97 cm; N = 1254). Most of the strandings corresponded to inmature Loggerheads, according to the minimum size established for nesting females in the

Table 2. Municipalities where strandings of Loggerhead (*Caretta caretta*) occurred; total strandings on the Andalusian coast (N = 2329). Total and relative coastline length per municipality are included (total coastline length considered = 925.2 km). *Key:* E = expected proportion of usage. p = proportion of strandings observed in each zone (observed). Bonferroni intervals provide confidence intervals for Z = 0.0004. a: Municipalities with fewer strandings than expected according to availability; b: Municipalities with more strandings than expected according to availability.

Municipalities	n	Length/zone (Km)	Relative length	E	*p*	Bonferroni interval		
Ayamonte	8	7.5	0.008	0.008	0.003	0.007	≤ *p* ≤	-0.001[a]
Isla Cristina	14	12.3	0.013	0.013	0.006	0.011	≤ *p* ≤	0.001[a]
Lepe	25	15.9	0.017	0.017	0.011	0.018	≤ *p* ≤	0.004
Cartaya	9	6.2	0.007	0.007	0.004	0.008	≤ *p* ≤	0.000
Punta Umbría	43	13.8	0.015	0.015	0.018	0.028	≤ *p* ≤	0.009
Huelva	38	7.1	0.008	0.008	0.016	0.025	≤ *p* ≤	0.008
Palos de la Frontera	20	9.5	0.010	0.010	0.009	0.015	≤ *p* ≤	0.002
Moguer	24	6.3	0.007	0.007	0.010	0.017	≤ *p* ≤	0.003
Almonte	500	49.7	0.054	0.054	0.215	0.243	≤ *p* ≤	0.186[b]
San Lúcar de Barrameda	17	7.3	0.008	0.008	0.007	0.013	≤ *p* ≤	0.001
Chipiona	59	12.6	0.014	0.014	0.025	0.036	≤ *p* ≤	0.014[b]
Rota	101	21.2	0.023	0.023	0.043	0.057	≤ *p* ≤	0.029[b]
Puerto de Santa María	50	20.4	0.022	0.022	0.021	0.032	≤ *p* ≤	0.011
Puerto Real	2	14.8	0.016	0.016	0.001	0.003	≤ *p* ≤	-0.001[a]
Cádiz	116	29.8	0.032	0.032	0.050	0.065	≤ *p* ≤	0.035[b]
San Fernando	40	15.1	0.016	0.016	0.017	0.026	≤ *p* ≤	0.008
Chiclana de la Frontera	41	12.2	0.013	0.013	0.018	0.027	≤ *p* ≤	0.008
Conil	16	13.1	0.014	0.014	0.007	0.013	≤ *p* ≤	0.001[a]
Vejer de la Frontera	24	7.4	0.008	0.008	0.010	0.017	≤ *p* ≤	0.003
Barbate	91	24.8	0.027	0.027	0.039	0.053	≤ *p* ≤	0.026
Tarifa	142	42.9	0.046	0.046	0.061	0.078	≤ *p* ≤	0.044
Algeciras	96	31.6	0.034	0.034	0.041	0.055	≤ *p* ≤	0.027
Los Barrios	2	2.5	0.003	0.003	0.001	0.003	≤ *p* ≤	-0.001
La Línea	35	16.4	0.018	0.018	0.015	0.023	≤ *p* ≤	0.007
San Roque	17	18.6	0.020	0.020	0.007	0.013	≤ *p* ≤	0.001[a]
Manilva	17	9.2	0.010	0.010	0.007	0.013	≤ *p* ≤	0.001
Casares	3	3.1	0.003	0.003	0.001	0.004	≤ *p* ≤	-0.001
Estepona	36	22.7	0.025	0.025	0.015	0.024	≤ *p* ≤	0.007[a]
Marbella	57	29.1	0.031	0.031	0.024	0.035	≤ *p* ≤	0.014
Mijas	11	12	0.013	0.013	0.005	0.009	≤ *p* ≤	0.000[a]
Fuengirola	27	8.2	0.009	0.009	0.012	0.019	≤ *p* ≤	0.004
Benalmádena	44	9.5	0.010	0.010	0.019	0.028	≤ *p* ≤	0.009
Torremolinos	17	6.5	0.007	0.007	0.007	0.013	≤ *p* ≤	0.001
Málaga	78	24.2	0.026	0.026	0.033	0.046	≤ *p* ≤	0.021
Rincón de la Victoria	13	8.5	0.009	0.009	0.006	0.011	≤ *p* ≤	0.000
Vélez-Málaga	34	25.4	0.027	0.027	0.015	0.023	≤ *p* ≤	0.006[a]
Algarrobo	3	2.2	0.002	0.002	0.001	0.004	≤ *p* ≤	-0.001
Torrox	14	9.1	0.010	0.010	0.006	0.011	≤ *p* ≤	0.001
Nerja	17	13.5	0.015	0.015	0.007	0.013	≤ *p* ≤	0.001[a]
Almuñecar	26	21.1	0.023	0.023	0.011	0.018	≤ *p* ≤	0.004[a]
Salobreña	1	8.4	0.009	0.009	0.000	0.002	≤ *p* ≤	-0.001[a]

(continued)

Table 2 (Continued)

Municipalities	n	Length/zone (Km)	Relative length	E	*p*	Bonferroni interval		
Motril	41	17.8	0.019	0.019	0.018	0.027	≤ *p* ≤	0.008
Gualchos	7	11.2	0.012	0.012	0.003	0.007	≤ *p* ≤	-0.001 [a]
Lújar	0	1.9	0.002	0.002	0.000	0.000	≤ *p* ≤	0.000 [a]
Rubite	**0**	3.3	0.004	0.004	0.000	0.000	≤ *p* ≤	0.000 [a]
Polopos	0	3.2	0.003	0.003	0.000	0.000	≤ *p* ≤	0.000 [a]
Sorvilán	0	3.8	0.004	0.004	0.000	0.000	≤ *p* ≤	0.000 [a]
Albuñol	2	10.7	0.012	0.012	0.001	0.003	≤ *p* ≤	-0.001 [a]
Adra	42	20.5	0.022	0.022	0.018	0.027	≤ *p* ≤	0.009
Berja	8	3.2	0.003	0.003	0.003	0.007	≤ *p* ≤	-0.001
El Ejido	37	28.9	0.031	0.031	0.016	0.025	≤ *p* ≤	0.007 [a]
Roquetas de Mar	29	19.2	0.021	0.021	0.012	0.020	≤ *p* ≤	0.005 [a]
Enix	0	3.2	0.003	0.003	0.000	0.000	≤ *p* ≤	0.000 [a]
Almería	122	38.5	0.042	0.042	0.052	0.068	≤ *p* ≤	0.037
Níjar	32	58.2	0.063	0.063	0.014	0.022	≤ *p* ≤	0.006 [a]
Carboneras	23	18.1	0.020	0.020	0.010	0.017	≤ *p* ≤	0.003 [a]
Mojacar	17	15.8	0.017	0.017	0.007	0.013	≤ *p* ≤	0.001 [a]
Garrucha	9	2.1	0.002	0.002	0.004	0.008	≤ *p* ≤	0.000
Vera	18	6.3	0.007	0.007	0.008	0.014	≤ *p* ≤	0.002
Cuevas de la Almanzora	9	18.2	0.020	0.020	0.004	0.008	≤ *p* ≤	0.000 [a]
Pulpí	5	9.4	0.010	0.010	0.002	0.005	≤ *p* ≤	-0.001 [a]

western North Atlantic (87.2 cm; TEWG 2009) and for the Mediterranean (66.5-84.7 cm, Margaritoulis *et al.,* 2003). A proportion of the turtles stranded may correspond to potential adults, especially if these turtles have a Mediterranean origin (Fig. 6), since the CCL for nesting females in the Mediterranean Sea are shorter than the CCL value for those in the North Atlantic Ocean. CCL data for Loggerheads were not normal. Significant differences were found between sizes of stranded Loggerheads in the different areas (Kruskal–Wallis test: $H = 66.59$; $P = 2.29*10^{-14}$) (Table 3, Fig. 6).

The median Leatherback CCL was 129.11 cm (sd = 27.48, range = 55-210 cm; N = 54). Not significant differences were found between sizes of stranded Leatherbacks in the different areas (Kruskal–Wallis test: H = 2. 328 P= 0.312).

Causes of stranding

The cause of stranding was assessed in 586 Loggerheads and 15 Leatherbacks. Due to the advanced decomposition state of many specimens, the cause of stranding for 76% of Loggerhead strandings and 93% of Leatherbacks could not be determined (Fig. 7).

Taking into account only the strandings for which it was possible to determine the cause of death, up to 43% of the stranding of Loggerhead could be directly attributed to anthropogenic causes, trauma (6.1%) and interaction with fisheries (36.9%). On the other hand, natural causes account for the remaining 57% of the strandings, Debilitated Turtle Syndrome –DTS- (37.1%) and disease (19.9%). Regarding interaction with fisheries, strandings involving baits from several gears using hooks accounted for 47.1% of the total and nets accounted for the remaining 52.9% (Fig. 7). In the Atlantic coast bycatch by nets was more frequent than in the Mediterranean area (58.1% and 41.9% respectively). However, accidents with hooks and baits were more common in the Mediterranean coast (79.0%) than in the Atlantic coast (21.0%).

In Leatherbacks, the causes of stranding has been very difficult to assess (Fig. 7). In most cases, specimens

Table 3. Mean of Loggerhead Curve Carapace Length (CCL) by areas.

Area	Mean (cm)	N	Standard deviation	Range
Atlantic Coast (AC)	51.23	728	14.416	15-90
West Alboran coast (WA)	44.81	242	17.333	18-97
East Alboran coast (EA)	43.94	235	15.321	15-80
West Mediterranean Coast (WM)	50.55	49	16.772	16-94

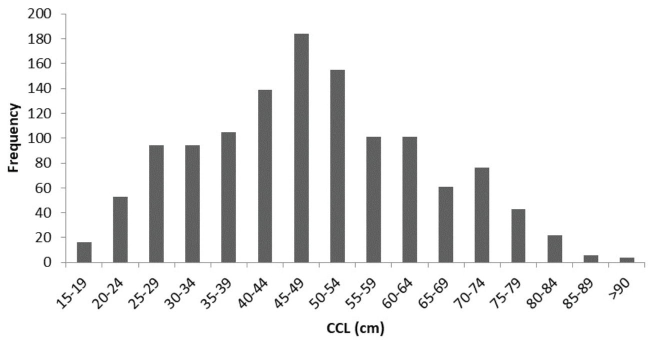

Fig. 6: Frequency of the Curved Carapace Length (CCL) of measured Loggerheads (N = 1254). Measurements in centimetres (cm).

stranded were found dead in an advanced state of decomposition. In many of the cases, interaction with fisheries has been established by observation of nets marks in the flippers. We observed a significant non-parametric correlation between NAO winter and the immature sea turtle stranding per area AC (Rho = -0.579; P = 0.024), and EA (Rho = 0.604; P = 0.017).

Discussion

Andalusian waters have not been considered a permanent habitat for sea turtles until now; therefore, all the stranded turtles were presumed to be specimens migrating between the Atlantic Ocean and Mediterranean Sea feeding and breeding grounds (e.g., Camiñas & De la Serna, 1995; Camiñas & Gonzalez de Vega, 1997; Camiñas, 2002; Tomás *et al.,* 2008). Nevertheless, the high frequency of strandings and its steady rate through the years suggest both important mortality/injury causes to turtles in the area and a significant presence of sea turtles in the marine waters situated on the Andalusian coast, especially of two species, Loggerhead and Leatherback. Taking into account that the Atlantic area only accounts for approximately 40% of the total Andalusian coast, it is a significant fact that it has received nearly 61% of all Loggerheads and 84% of Leatherbacks turtles stranded in Andalusia in the study period. In the beaches located to the south of Portugal, following the coastal line from Spain, a similar rate of strandings has been reported by Nicolau *et al.* (2016a). In addition, the analyses carried out by the authors indicate that the Atlantic coast of Andalusia present more strandings of sea turtles that was expected according to its availability. Hence, the Gulf of Cadiz, a region with a large continental shelf is, presumably, an area with a high density of sea turtles. According to Casale *et al.* (2008), Atlantic Loggerhead sea turtles frequent shallow waters in areas of the Mediterranean where the continental shelf is also large.

During the first period of study, 1997-2000, the rate of strandings was the lowest of all the periods. This was probably due to the initial stage of the organisation and implementation of the stranding network. After its consolidation, the rate of strandings increased, covering nearly the totality of the cases produced.

The abundance of strandings in the Andalusian coast is higher in spring and summer for both Loggerheads and Leatherbacks. It is remarkable that the same pattern of seasonal stranding in the Atlantic area has been reported in the south of Portugal (Nicolau *et al.,* 2016a), with a peak in spring for Loggerheads and a peak in summer for Leatherbacks. Therefore, it could be possible to consider the Iberian sector of the Ibero-Moroccan Gulf (south of Portugal and Gulf of Cadiz) as a singular temporal habitat for sea turtles.

The mean CCL of Loggerheads found stranded dead in the Andalusian coast was 48.6 cm and 129.1 cm for Leatherbacks. In the case of Loggerheads, this size indicates the predominance of immature specimens (Margaritoulis *et al.,* 2003; TEWG, 2009) in these waters. This is consistent with previous studies that point out the migratory character of the species moving through the Strait of Gibraltar (Camiñas and de la Serna, 1995; Bellido *et al.,* 2010a, b). The structure of the Leatherback population in the Mediterranean basin is not clear, with no evidence of nesting beaches (Márquez, 1990). Thus, they may be adults searching for feeding grounds (Márquez, 1990).

Loggerheads stranded in the AC presented a mean of 51.2 cm of CCL, very close to the mean obtained by Nicolau *et al.* (2016a) for Loggerheadss stranded in the south of Portugal (50.0 cm); therefore, they could form part of the same population. Casale *et al.* (2010) reported similar sizes of turtles stranded dead and captured by bottom trawlers in the north Adriatic coast (49.1 and 48.0 cm

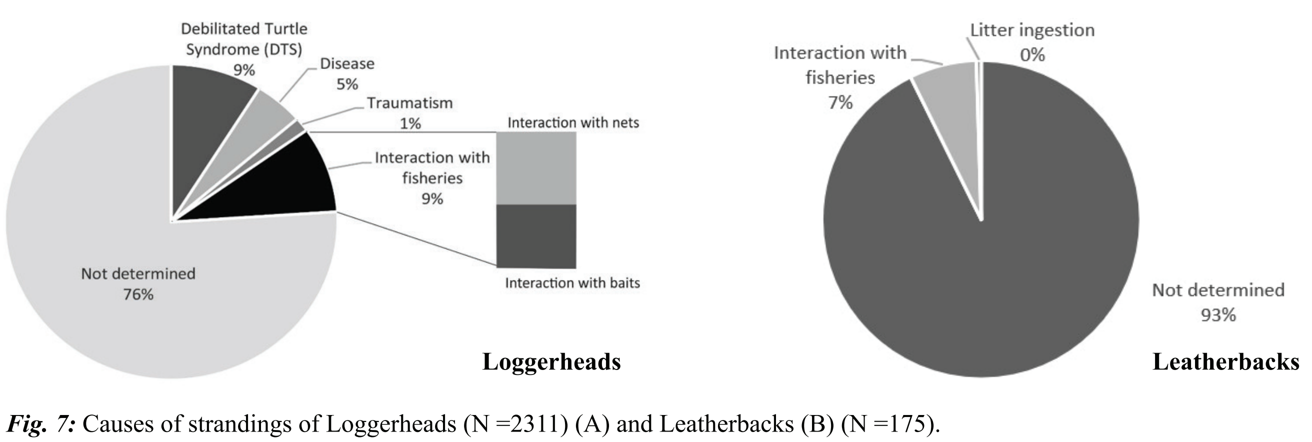

Fig. 7: Causes of strandings of Loggerheads (N =2311) (A) and Leatherbacks (B) (N =175).

of Straight Carapace Length –SCL- respectively). This measurement corresponds to 60.6 and 59.4 cm of CCL respectively, according to a conversion carried out using the formula developed by Báez *et al.* (2010). The north Adriatic Sea, with a large continental shelf, is an important neritic foraging area for Loggerhead sea turtles in the Mediterranean Sea (Casale *et al.,* 2010). The north of the Ibero-Moroccan Gulf also has a large continental shelf and a high primary productivity near the coast (Luque & Templado, 2004). Bellido *et al.* (2010a) found that Loggerheads stranded in the Atlantic coast of Andalusia were larger than Loggerheads stranded in the Alboran and Mediterranean Sea areas, which suggests that adults and larger juveniles preparing to migrate to Atlantic breeding grounds concentrate in the Atlantic waters of Andalusia. Furthermore, in the Andalusian coast, as in Italy, turtles stranded alive tend to be smaller than the dead stranded turtles (Bellido *et al.,* 2010a; Casale *et al.,* 2010).

Dead Loggerheads strandings are more frequent on beaches in the Atlantic coast than in the Mediterranean (Bellido *et al.,* 2010a). For Leatherbacks, the incidence of live specimens is almost imperceptible, with only few cases recorded in the Atlantic area. This pattern possibly shows that negative interactions with human activities are more acute around the Gulf of Cadiz. Fishing-induced mortality has been shown to be by far the most important threat for sea turtles in the Mediterranean Sea (Casale *et al.,* 2010) where they are not only subject to capture by Mediterranean longliners but also by bottom trawlers (Carreras *et al.,* 2006). However, there is a differential distribution of fisheries along the Andalusian coast. The analyses of causes of stranding show that interactions with net fisheries are more frequent in the Atlantic than in the Mediterranean waters. On the other hand, interactions with baits have a major effect in sea turtles in the Mediterranean basin. These results are consistent with the existence of a traditional artisanal trammel net fishing fleet operating in the Gulf of Cádiz and an important longline fleet fishing from Mediterranean waters (Báez *et al.,* 2006, 2007).

Our results in the Gulf of Cadiz seem to agree with those of Cardona *et al.* (2009), who found that an important portion of the immature Loggerheads found off the eastern coast of mainland Spain used the continental shelf and exhibited fidelity to neritic feeding grounds, where they suffer incidental by-catch in fishing gear. Monzón-Argüello *et al.* (2009) reported that young turtles, after reaching a suitable feeding area, may stay there for a long period of time, which is perhaps also the case in Gulf of Cadiz (Báez *et al.,* 2006). On the other hand, our results confirmed the previous finding by Báez *et al*. (2011). Thus, according to these authors and our work, when conditions are not adequate for migration due to causes related to the North Atlantic Oscillation (NAO), Loggerhead sea turtle abundance could increase along the Atlantic coast. Drinkwater *et al.* (2003) argued that a positive NAO phase, which was prevalent during the study period, results in stronger-than-average westerly winds across northern midlatitudes, and lower sea surface temperature between the equator and 30°N, an area crossed by tagged adult Loggerheads travelling to nesting beaches (e.g., see Eckert *et al.,* 2008). Thus, we hypothesised that during a positive NAO, winds favour migration of immature turtles born on American beaches, and others attempting to reach the Mediterranean feeding areas, which could explain the stranding pattern of small Loggerheads with an increase along the Atlantic coast during springtime which shifted to the Mediterranean areas in summer. Young Loggerheads coming from Atlantic areas, mainly in spring and summer (Witt *et al.,* 2007), spend little but measurable time in this neritic habitat before being affected by the prevalent currents that drag them into the Mediterranean Sea. These same westerly winds are difficult to overcome by Loggerhead sea turtles returning to nesting areas in the Western North Atlantic. This would lead to Loggerhead accumulation around the Strait of Gibraltar, which is both the receiving area for newcomers, mainly in spring, and the starting point for returning Loggerheads, possibly in late summer and autumn (Camiñas & De la Serna, 1995). Thus we hypothesise that the probability of a Loggerhead stranding would consequently also increase in relation to the higher Loggerhead sea turtle abundance.

In conclusion, the north Ibero-Moroccan Gulf may represent a neritic habitat for the Loggerhead sea turtle in the Mediterranean threshold. Atlantic Andalusian and Portuguese waters could be used by Atlantic Loggerhead sea turtles arriving for first time to the Mediterranean Sea and by those either feeding or resting before returning to their nesting beaches in the Atlantic Ocean. It is crucial to test the previous hypothesis to improve the management of the sea turtle in the region and adjacent waters.

Acknowledgements

We are grateful to Consejería de Medio Ambiente y Ordenación del Territorio de la Junta de Andalucía, Programa de Gestión del Medio Marino, for providing data of strandings. E. Torreblanca was supported by a grant of Soroptimist International Europe. We also thank to two anonymous referees for their useful comments. Finally, we would like to thank Nathalie Yonow for revising the manuscript.

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