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Migration of the Mediterranean sea turtles into the Tunisian waters, importance of the tag recoveries as conservation management method

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Abstract: Data on tag recoveries of 22 loggerhead turtles *Caretta caretta* (Linnaeus, 1758) and one green turtle *Chelonia mydas* (Linnaeus, 1758) along the Tunisian coast are reviewed on the basis of published literature and unpublished records since 1988 to 2008. These data showed coincidentally movement patterns of large juvenile and migratory pathways for loggerhead turtles nesting females, primarily for these coming from Greece. The analysis of epibiont of tagged loggerheads supports the migratory character of these turtles performing long distances from their nesting beach to reach Tunisian waters and mainly the gulf of Gabes, considered as feeding and wintering habitat for this species. This area is therefore an important management sub-unit for loggerhead nesting population in the Mediterranean Sea.

Résumé : *Migration des tortues méditerranéennes dans les eaux tunisiennes, importance du marquage pour la conservation*. Vingt-trois tortues, 22 caouannes *Caretta caretta* (Linnaeus, 1758) et 1 tortue verte *Chelonia mydas* (Linnaeus, 1758) baguées en Méditerranée et récupérées dans les eaux tunisiennes entre 1988 et 2008 sont examinées. Les résultats montrent des déplacements aléatoires pour les tortues juvéniles et des routes de migration spécifiques pour les tortues nidifiantes, principalement les caouannes de Grèce. L'analyse des épibiontes des caouannes récupérées confirme le caractère migratoire de ces tortues sur de longues distances depuis leurs sites de ponte jusqu'a leurs sites d'alimentation dans les eaux tunisiennes et principalement le golfe de Gabès. Le golfe de Gabès, connu comme une aire d'alimentation et d'hivernage pour les caouannes qui nidifient en Méditerranée, représente de ce fait une sous-unité de gestion importante pour cette espèce.

Keywords: Loggerhead turtle ● Green turtle ● Migration ● Gulf of Gabes ● Wintering ● Feeding

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Introduction

Understanding spatial movements of threatened marine species is essential for conservation management (Moncada et al., 2010). This is especially challenging when dealing with large marine migratory animals, such as sea turtles.

The life cycle of this ancient species is unique in many ways. Male sea turtles live entirely at sea, except case of basking. Females come ashore to the same beach where they were born only to lay their eggs. Hatchlings have a pelagic maturation poorly known duration in which they feed and grow into the period of juvenile stage commonly encountered in shallow coastal waters (Carr, 1987). The stage from hatching until first reproduction varies among species but probably ranges and populations from 7-30 years or more (National Research Council, 1990). Once they initiate breeding, mature females travel to breeding beaches every 2-5 years to lay from 2 to 10 clutches of eggs, 9-15 days apart (Buskirk & Crowder, 1994).

Three species of marine turtles: the leatherback turtle *Dermochelys coriacea* (Vandelli, 1761), the loggerhead turtle *Caretta caretta* (Linnaeus, 1758) and the green turtle *Chelonia mydas* (Linnaeus, 1758) are encountered in the Mediterranean. The leatherback turtle is a visitor from the Atlantic and can be found all over the basin, although it does not breed in the Mediterranean (Karaa et al., 2013). The other two species reproduce in the Mediterranean and have evolved local populations with a genetic divergence from the Atlantic populations (Casale & Margaritoulis, 2010, and references therein). The main identified threats at sea to these two Mediterranean populations are incidental catch, collision and intentional killing while the impact of other potential threats like chemical contaminants and debris is not clear yet (Luschi & Casale, 2014).

Green turtles basically reproduce in nesting beaches in Turkey, Cyprus, Lebanon, Israel, Egypt and Syria, and they frequent mainly the Levantine basin with some foraging areas also in Greece and Libya (Casale & Margaritoulis, 2010).

Loggerhead turtles are the most abundant species in the Mediterranean Sea, which frequent the whole basin and nest mainly in Greece, Turkey, Cyprus and Libya; these turtles are common in Tunisian waters and reproduces on some beaches (Jribi & Bradai, 2014).

The Gulf of Gabes (South-East of Tunisia), the most productive marine habitats in Tunisian waters, is likely to be one of the most important areas for loggerhead turtles in the Mediterranean (Casale & Margaritoulis, 2010). These areas should have also a certain importance as a foraging habitat for green turtle (Karaa et al., 2012).

According to Laurent & Lescure (1994), the Gulf of Gabes is a good wintering area for loggerhead turtles in the eastern basin, because the very numerous adult individuals captured in winter in this zone cannot originate all from Tunisian coasts, along where nesting is rare, while not many individuals were captured in the summer. The numerous recaptures in the Gulf of Gabes of adult female loggerheads tagged in Greece support this hypothesis (Margaritoulis, 1988).

In order to enhancing current understanding of the migration patterns of loggerhead turtles into Tunisian Sea, and making clear the importance of the Gulf of Gabes for the loggerhead turtles and green turtles in the Mediterranean Sea, we analyze in the present study the tag recovery of sea turtles in Tunisian waters between 1988 and 2008.

Materials and Methods

The Tunisian coast represents a transition zone between western and eastern Mediterranean basins through the Siculo-Tunisian Strait. The Tunisian littoral topography is highly variable : the northern littoral zone is mainly rocky with reduced continental shelf, while the eastern and southern coasts are sandy to sandy-muddy and with a progressive larger continental shelf to the south; these different features result in the distinction of 3 geographical sub-areas: the northern zone (from the border with Algeria to Kelibia, 300 km length), the Center (from Kelibia to La Chebba 150 km length) and the south (from La Chebba to the border with Libya, 750 km length) in the western basin (Ben Mustapha et al., 2003) (Fig. 1).

Since 1988, the data of first record of the loggerhead sea turtles nesting in Tunisia (Jribi & Bradai, 2014), a Tunisian Sea Turtle Program (TunSTP) included in the activities of the National Institute of Sea Sciences and Technology (INSTM) was launched in order to identify appropriate conservation measures for these species, which are listed in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (del Mar Otero & Conigliaro, 2012); this program include (i) the monitoring of the loggerhead turtles nesting sites, (ii) the by-catch surveys and (iii) the national stranding network (Bradai et al., 2008). Furthermore, fishermen and coastal inhabitants were approached, through a widespread public awareness campaign carried out and were encouraged to provide basic information on sea turtles recoveries such as locality of finding, recovery method, species identification, condition of specimen, and tag code and return address. Other information as a Curved Carapace Length (CCL; Bolten, 1999), the digestive tract (wet mass) and the epibiont samples (removed by scraping the turtles carapace), were also reported within the sea turtle National Stranding Network established in 2004 (Karaa et al., 2012). Loggerheads and green turtles are considered as mature

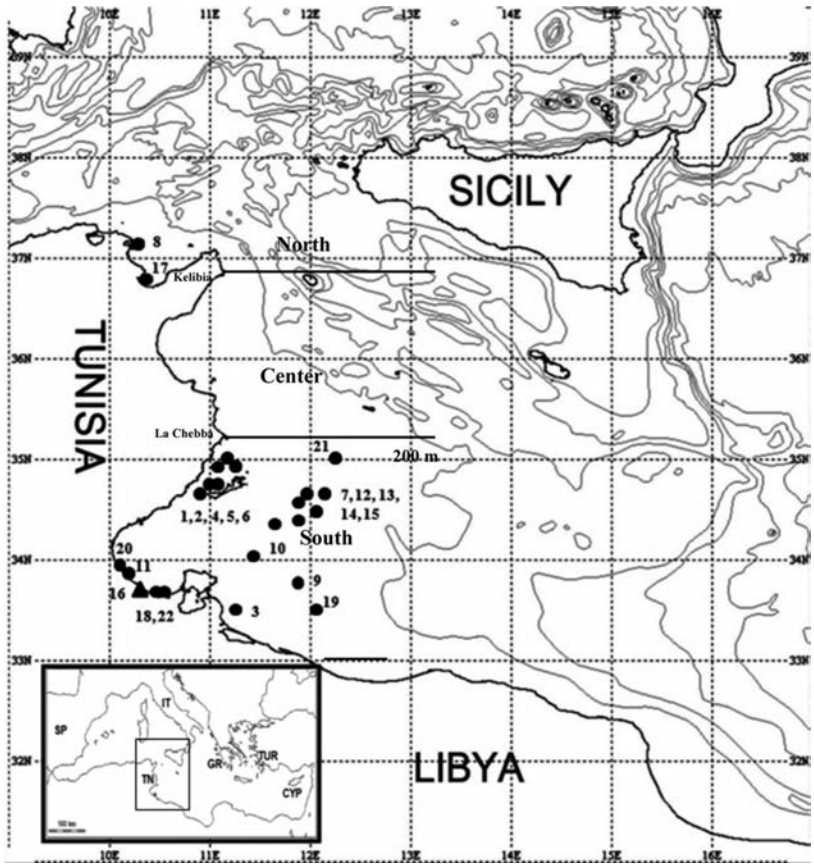

Figure 1. Map showing the recoveries of tagged loggerhead turtles (●) and the green turtle (▲) in the Tunisian Sea between 1988 and 2008. Numbers in boxes refer to respective record numbers (No.); GR: Greece; TUR: Turkey; SP: Spain; CYP: Cyprus; TN: Tunisia; IT: Italy.

when they reach a size over then 70 cm CCL (Demetropoulos & Hadjichristophorou, 1995; Margaritoulis et al., 2003); adults were sexed on the basis of sexual dimorphic characters (i.e. the large and muscular prehensile tail of males) or by direct observation of the gonads during necropsies (Wibbels, 1999).

The present work based on tag recoveries transmitted to the INSTM and directly reported to the tagging institution and also on some records published on the issue.

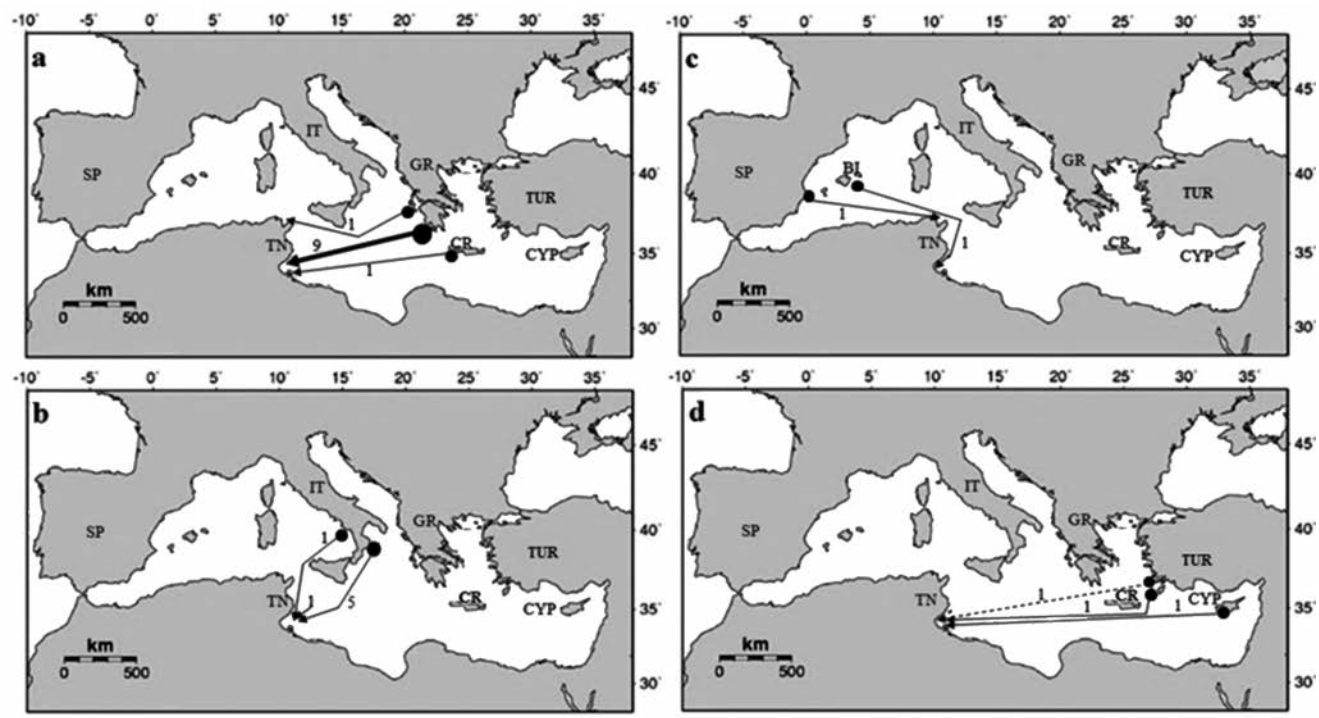

Figure 2. Map showing the route of a loggerhead sea turtle (solid line) and the green turtles (dotted line) connecting release (circles) and re-encounter (triangles) locations in the Tunisian Sea between 1988 and 2008. GR: Greece; CR: Crete; TUR: Turkey; SP: Spain; CYP: Cyprus; TN: Tunisia; IT: Italy; BI: Balearic Islands.

Table 1. Recoveries of tagged loggerhead sea turtles and green sea turtle in the Tunisian Sea between 1988 and 2008.

			Data on recovery							Data on the last observation/tagging					
No	**Sp**	**Tag**	**Date**	**Locality**	**Depth at recovery (m)**	**CCL**	**Sex**	**Met**	**Con**	**Date**	**Locality/Return adress of tag**	**CCL**	**MDT (km)**	**ET (days)**	**Ref**
1	Cc	A260	1988: AUG 08	Sfax-S	?	?	?	?	A	1986: JUL5	Leuca - IT	63	960	764	1
2	Cc	A115	1988: OCT 08	Sfax-S	?	?	?	?	?	1985: MAY 28	P. Cesareo - IT	50	940	1228	1
3	Cc	H3379	1989: JAN 08	N 33°55' E11°02'-S	~10	?	F	T	?	?	Kifissia - GR	?	?	?	2
4	Cc	B133	1989: SEP 06	Sfax-S	?	?	?	S	D	1986 : JUL 29	Leuca - IT	57	960	1035	1
5	Cc	TK0117	1990: APR 03	Sfax-S	10	79	F	?	?	?	TUR	?	?	?	2
6	Cc	I39	1990	Sfax-S	?	?	?	?	A	1990 : SEP 01	Lampedusa - IT	44.5	195	?	1
7	Cc	F298	1990: DEC	S	?	?	?	T	?	?	IT	?	?	?	2
8	Cc	F48	1991: JAN 17	Ghar El Melh – N	?	?	?	?	D	1989	Alicante - SP	?	995	?	1
9	Cc	B 2393/ 88	1992: JAN 03	Banc Grigo – S	?	85	F	T	A	?	Peloponnesus - GR	?	?	?	2
10	Cc	A 131	1992: JUN 25	S (N 34°05' E11°42')	50	?	F	?	?	?	Kifissia - GR	?	?	?	2
11	Cc	H3410	1992: OCT 03	Kettana – S	?	?	F	S	D	1992: JUL 12	Rethymno - GR	?	1870	83	3
12	Cc	Y5587	1996: MAR 20	S	?	?	F	T	?	1995: AUG 04	Rethymno - GR	?	?	229	3
13	Cc	H541	2001: APR 18	S	?	79.1	F	T	A	?	GR	?	?	?	2
14	Cc	V 1345	2003: OCT 07	S	?	64	?	T	A	1999: SEP 19	IT	?	?	1102	2
15	Cc	C6805	2003: NOV 06	S	?	?	F	T	?	2003: JUL 18	Rethymno - GR	?	?	121	2
16α	Cm	TRA O718	2005: MAY 10	Zarat – S	?	98.5	F	S	D	2004 : JUL 18	KazanliBeatch - TUR	?	2450	314	2
17	Cc	ZA930/07546	2005: SEP 27	Hammam Lif– N	?	?	F	S	D	2005: JUN 24	Zakynthos - GR	?	1020	95	2
18β	Cc	Re 220	2006: DEC 05	Zarat – S	?	76.5	F	S	D	2004: JUL 15	CRE-GR	76	1245	873	2
19	Cc	ZA667/ZB212	2007: APR 27	Zarzis	45	78	F	G	D	?	Kifissia - GR	?	?	?	2
20γ	Cc	ZA 863	2007: SEP 22	Withref – S	?	84	F	S	D	2007: JUN 10	Zakynthos - GR	?	1050	104	2
21	Cc	AB 1044; AB 1045	2007: SEP 30	Gulf of Gabes– S	?	?	F	T	A	2007: JUN 14	Alagadi - Cyp	82	2030	118	2
22δ	Cc	TTK 975	2008: MAY 14	Zarat – S	?	62	?	S	D	2006: JUN 11	BalearicIslands - SP	58	1200	691	2
23	Cc	FB664	2008: JUL 29	Sfax – S	15	44	?	G	A	2007: OCT 03	SZN Naples- IT	41.5	790	280	2

No: number of the record; Sp: species; S: south; N: North; CCL: Curved Carapace Length; A: adult ; M: male; F: female; Met: method of recovery: Cap: Capture; G, captured in gill net; T, captured in trawl; S, stranded;?, unknown; Con: condition of turtle; D: dead; A; alive; ?: unknown; GR: Greece; TUR: Turkey; IT: Italy; SP: Spain; Cyp: Cyprus; CRE: Crete; LEU: Leuca; MDT (km): minimum distance travelled at sea; ET: elapsed time between the last record of specimen and recovery; Ref: reference; 1: Argano et al., 1992; 2: present work; 3: Margaritoulis & Rees, (2011).

α Diet: 750 gr of *Cymnodocea nodosa*; β Diet: Mollusca (81 gr *Hexaplex trunculus*; 46,5 gr *Sepia officinalis*), Crustacea (21 gr *Squilla mantis*); Epibiont: Algae (*Enteromorpha instestinalis*; *Cladophora prolifera*); Amphipoda (*Corophium acherusicum,* n = 8; *Caprella andrea*, n = 22; *Elasmopus rapax*, n = 1); Cirripedia (*Chelonibia testidunaria*, n = 63; *Platylepas hexastylos*, n = 24; *Balanus trigonus*, n = 18); γ Epibiont: *Chelonibia testidunaria*, n = 2; δ Caught by a drifting surface longline targeting blue fin tuna in the southeast of the Balearic Islands, near to Menorca Island and released with a hook in the deep oesophagus in the coordinate 39º37' North, 04º56' East. Stranded dead in Zarat, Gulf of Gabes, Tunisia (33°41' North, 10°22' East) and during the necropsy no fishing hook was detected, and the intestines had a normal shape.

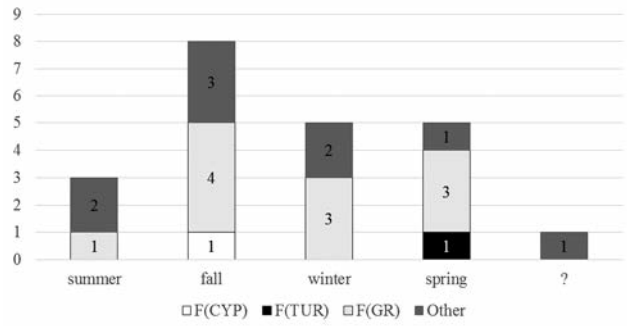

Figure 3. Temporal distribution of tag recoveries of the loggerhead sea turtle in Tunisian Sea F(CYP): female tagged in Cyprus; F(TUR): female tagged in Turkey; F(GR): female tagged in Greece.

Results

We present data on twenty-three recoveries of tagged turtles (22 loggerheads and 1 green turtle) in Tunisian waters (Table 1 & Fig. 1).

Loggerhead sea turtle

Twenty-two loggerhead turtles were reported: of these, two (# 8 and # 17, tagged respectively in Spain and Greece; 9% of cases) were reported in the north of Tunisia; the others, reported in the Gulf of Gabes, were tagged mainly in Greece and Italy (10 and 7 cases respectively), whereas three counted turtles were tagged in Cyprus, Turkey and Spain (Fig. 2).

Findings occurred throughout the whole year; no seasonal movement was noticed in large juvenile, while the lowest proportion of adult females was counted in summer months (Fig. 3).

Size data were available only for ten specimens; on the other hand, three large juveniles (# 14 and # 23 tagged in Italy and # 22 tagged in Spain) and thirteen adult females (presuming that females tagged on the beach during the nesting process and then tracked during the interesting movements) were counted.

Adult females tagged on nesting beaches: one in Turkey, one in Cyprus and eleven (84.6%) in Greece (Table 1). Females coming from Greece were tagged by ARCHELON, the Sea Turtle Protection Society of Greece (STPS), at major nesting areas (e.g. Zakynthos Island, Peloponnesus and Crete).

The time spent by loggerhead turtles between their tagging and their reports are calculated for 14 turtles, this time ranges from 83 to 1228 days and it is variable even if turtles migrate with similar routes (eg. turtles # 11 and # 12 tagged in Rethymno (Greece) and were recorded in the Gulf of Gabes with a difference of 146 days of the elapsed time between the last record of the specimens and its recovery).

The short period elapsed between the last observation of the turtle # 11 on the nesting beach and its recovery suggests the existence of a migratory pathway from the nesting beach in Greece into the Gulf of Gabes (Tunisia).

Among tagged turtles observed, ten were bycatch (46%) and six (27%) were stranded dead on the beach. Out of the ten recoveries reported in fishing gear, eight (80%) were captured in trawls and four of them were certainly alive and released (Table 1), while the condition of others individuals was unknown; it cannot be excluded they were dead, which indicates that at least 50% of turtles caught incidentally by bottom trawling in the Gulf of Gabes remains alive. The mortality in gill nets was 50% in which two recoveries resulted from incidental capture (one individual was found dead and the other was one found alive).

The growth of loggerhead turtles from the date of their tagging and the date of their recoveries was calculated for three turtle's (# 18, # 22 and # 23). The first turtle (# 18) was an adult female tagged in Greece and spend 873 days to reach the Gulf of Gabes area; during this period of time the turtle increase with 0.5 cm in CCL, the calculated growth rate was approximately 0.21 cm.year^{-1}. Similarly, the calculated growth rate of the two subadult turtles (# 22 and # 23; CCL = 62 cm and 44 respectively) were 2.06 and 1.91 cm. year^{-1}.

Epibiont sampling was performed on 2 turtles (# 18 and # 20) in which 8 different epibiont species was recorded: two species of algae (*Enteromorpha instestinalis* and *Cladophora prolifera*), three species of amphipoda (*Corophium acherusicum*, *Caprella andreae* and *Elasmopus rapax*) and three barnacles: *Chelonibia testidunaria*, *Platylepas hexastylos* and *Balanus trigonus*) (Table 1). All identified epibiont are cosmopolitan and are for the most part subtidal species in the Mediterranean (Kitsos et al., 2005).

The digestive contents collected from turtle # 18 indicate that predominant preys, composed by benthic invertebrate, are from shallow waters (El lakhrach et al., 2012).

Green sea turtle

Only one green turtle, tagged in the final phase of the nesting season in Kazanly beatch in Turkey (turtle # 16 in Table 1), was found stranded dead in Zarat beach (South-East of Tunisia) in May 2005 (Fig. 2). The elapsed time between tagging and recovery was 314 days (Table 1) and calculation of the minimum distance travelled at sea (2430 km) show a speed of travel in the order of 0.3 km.h^{-1}.The necropsy of this turtle did not give details about the causes of mortality, however it indicate its diet composition which is composed only by 750 g of *Cymnodocea nodosa*.

Discussion

Loggerhead sea turtle

The report of 22 recoveries of tagged loggerhead turtles in Tunisian waters, which correspond to a migration rate of 1.1 individuals.year^{-1} between 1988 and 2008, clearly shows that numerous loggerhead turtles, coming from various sites of the Mediterranean, spend some period in Tunisian waters. The number of tag recoveries of loggerhead turtles in Tunisia can be considered as a minimum; in reality, there recovery of tagged turtles can be considered as hazardous and depend mainly on the effort of fishermen and coastal inhabitants reports. Interviews with fishermen reflect the difficulty of treating the subject of these endangered species with people who feel culpable even if the catch is incidental.

Moreover, the availability of sea turtles is absolutory casual; it depends mostly on professional fishing activities that are developed with different methods in various areas and in different periods. Capture of sea turtle disturbs normal fishermen activities on board and generally it is not rescued, especially if it is too big, while smaller individuals escape many type of fishing devices (Echwikhi et al., 2011) therefore, our sample is not representative. Others mark-release-recapture studies of loggerheads sea turtles has shown that tag-return data typically account for just 1-3% of the total tagged population (e.g. Margaritoulis, 1988; Argano et al., 1992).

Even if we consider that many data were omitted, the present results give more information on the migration of the loggerhead sea turtles and problems encountered during the journey.

Adults

The majority of the available information about movement patterns of adult loggerheads concerns nesting females (63.6% of individuals, N = 14). This is not surprising, since this class of individuals is the only one that comes ashore for extended periods at predictable times and locations during the long and laborious egg-laying process, thus offering an easy way for researchers to approach and tag (Luschi & Casale, 2014). Information's are more available for turtles nesting in Greece than those coming from Turkey and Cyprus. The recapture in the Gulf of Gabes of numerous adult's females tracked during their inter-nesting migration and the lacks of regular nesting sites in this area demonstrate that the turtles were non-random dispersal and point out the value of the Gulf of Gabes as feeding zone for adult's loggerhead in the Mediterranean.

The fact that most of adult females from breeding sites in Greece were reported in cold seasons (63, 3% of individuals, N = 11) even if the significant presence of coastal inhabitants and the high fishing effort in summer, shows a possible cyclic migration of theses turtles which leave their breeding in summer, arrive to the Tunisian shelf during autumn and winter and moved towards to their native habitat in the end of spring. These conclusions confirm the numerous recaptures in the cold season of adult female loggerheads tagged in Greece after the end of the nesting season (Margaritoulis, 1988). Indeed, Mediterranean loggerhead turtles have been observed to maintain some level of activity at low temperatures (as low as 11.8°C) adopting a specific behavioral strategy known as overwintering; This behavior allows some turtles migrate southwards in the coldest months of the year (Hochscheid et al., 2007). In our case, the digestive contents collected from turtle # 18, which is tagged in Greece July 2004 and stranded dead in Zarat in December 2006 (Table 1) demonstrate that this turtle continue to feed during the cold period. This hypothesis was also suggested by Laurent & Lescure (1994) thanks to data based on accidental catches by trawlers in the region.

Adults males did not appear in the tag recoveries recorded in Tunisian waters due to the difficulty to approaching of these animals to tag since they very rarely leave the aquatic environment (Luschi & Casale, 2014 and references therein). On the other hand, the migratory pattern between Greece and Tunisia is also checked by an adult male accidentally caught in a bottom trawl in the Gulf of Gabes on January 21st 2001 and released equipped with satellite transmitters (Bradai et al., 2009). This turtle moved towards Greece, arrived on the 27th of April 2001 in the vicinity of Kyparissia Bay, and turned up to the Gulf of Gabes five months later when the water temperatures had risen to 27°C showing some loyalty between the neritic areas of the Gulf of Gabes and Greek waters (Bradai et al., 2009). Several authors suggest a certain loyalty to marine habitats (Godley et al., 2003; Casale et al., 2007).

All identified epibionts from turtles # 18 and 20 are cosmopolitan; this figure is quite high, since in the Mediterranean cosmopolitan benthic species do not generally exceed 22-35% as percentages of the total macrobenthic fauna (Koukouras et al., 2001). This high percentage of cosmopolitan epibiont species should be attributed to the migratory character of these turtles (Kitsos et al., 2005). In fact, adult loggerheads periodically migrate between feeding and nesting areas which are often hundreds of thousands of kilometres distant (Bowen et al., 1993). This figure was demonstrated in the Gulf of Gabes that hosts turtles that nest in Greece (Bradai et al., 2009; Schofield et al., 2009).

Juveniles

Three large juveniles' (40 < CCL < 70 cm, Bolten, 2003; Margaritoulis et al., 2003), two of which were tagged in Italy

and one was tagged in Spain, were reported in the Gulf of Gabes with no seasonal movements differences. The migration of juvenile's loggerhead sea turtles into the Tunisian Sea depend for the most part on the combination of surface circulation patterns in the Mediterranean than the turtles' active swimming as recommended by Bentivegna (2002).

The turtle # 22 was tagged in Spain with a hook in the deep esophagus and then stranded dead in Zarat (Gulf of Gabes) with no fishing hook detected after necropsy; this case (i) demonstrates that the loggerhead turtle can survive after being released with a hook attached to the deep esophagus and that it can be able to spontaneously expel it in wild and (ii) shows the difficulties of estimating post-release mortality as suggested by Chaloupka et al. (2004). Bjorndal et al. (2003) and Casale et al. (2007) analysed the survival probabilities of loggerhead sea turtles estimated from capture-mark-recapture data in the Greater Caribbean and Mediterranean Sea, respectively; according to both papers, there are low probabilities of dead loggerhead recoveries. Casale et al. (2007) obtained low estimates of annual survivorship, although this result should be considered with prudence, due to an unknown tag loss rate. In our case the turtle was injured, released and died for unknown causes. Thus, in two years the turtle travelled in minimum distance of 1200 km approximately and had a very eventful life. The movement of the turtle # 22 verifies the hypothesis that juveniles frequenting oceanic areas may either show fidelity to an area or move across multiple areas (Luschi & Casale, 2014).

Two tagged loggerhead turtles in Italian waters (# 14, CCL = 64 cm and # 23, CCL = 44 cm) were captured alive by a bottom trawl and gillnet respectively in the Gulf of Gabes providing evidence of benthic behavior and survival probabilities of theses turtles after these tag-releases. The Gulf of Gabes is, therefore, a good neritic area where larger juveniles feed range throughout the entire water column, from the bottom to the surface. Actually, data from bycatch and stranding of loggerheads sea turtles inhabiting the Gulf of Gabes, demonstrate the abundance of large juvenile size-classes (Bradai et al., 2008; Echwikhi et al., 2011). Knowing that residence of juveniles seems more common in neritic foraging grounds than in oceanic areas (Casale et al., 2007) and shows the importance of this zone for large juvenile loggerhead in the Mediterranean Sea.

Time of migration

Bentivegna (2002) and Godley et al. (2003) recorded average travel rate of 1.2 and 1.3-1.7 $km.h^{-1}$ for loggerheads during pelagic crossings. Calculated speeds of travel in our case are lower (e.g. turtle's # 11, 17 and 20 with travel rates of 0.94, 1.07 and 0.42$km.h^{-1}$ respectively), but they are based on three assumptions: (i) that these turtles started their migration at the day of their tagging; (ii) that they were recovered in the Gulf of Gabes at the day of their arrival; and (iii) that they have followed the shortest route. However, it is more likely that the periods of migration were shorter than the calculated elapsed times (Table 1), which could explain the lower speeds of travel in our study. Moreover, long-distance movement of loggerhead turtles in the Mediterranean basins followed a seasonal pattern and reflects different nutritional status (may be different feeding strategies in relation with the stability of their food necessity (Bentivegna, 2002). Knowing the plasticity of behavior of the loggerhead turtles (Hatase et al., 2002), it is possible that loggerhead turtles oscillate between feeding periods and periods of inactivity during their migration which has implications for the elapsed time between the last record of specimen and its recovery in the Tunisian waters. Others different behaviors can be observed in loggerhead turtles in relation with their maturity and the type of habitat (Casale et al., 2007). Therefore, information's about sea turtle tag recoveries should take into account not only the tagging point of the turtle and of its recapture but different others environmental factors as the period of breeding, the temperature, the abundance of diet and the sea current.

Green sea turtle

The occurrence of the adult green turtle in Tunisian waters could be explained by the migration of some individuals from nesting areas in the eastern side of the Mediterranean Sea to the feeding grounds along the North African coastal. Luschi & Casale (2014) and Godley et al. (2002) analysed the post-nesting migration of the green turtles equipped with satellite transmitters in the Mediterranean Sea. According both papers, the post-nesting movement of the green turtles shows a direct and quick migration away from their breeding site (Cyprus, Turkey and Syria) to reach individually specific neritic foraging areas in Turkey, Egypt and North Africa. If we suppose that the speed of migration of green turtles was significantly greater during the open-sea crossing than during the period were they feed in the coastal waters of their final destination, the reduced speed of travel calculated for turtle # 16 (0.3 $km.h^{-1}$), shows that this turtle could spend a certain time in the Tunisian waters to meet their feeding requirements particularly in the Gulf of Gabes where they find a local large coverage of *Cymnodocea nodosa* and the most extensive and continuous *Posidonia oceanica* meadows of the Mediterranean (Hattour & Ben Mustapha, 2013).

Conclusions

Data from by-catch and tagging projects in the Mediterranean Sea confirms the importance of Tunisian

shelf for the loggerhead and the green sea turtles. Long-range recoveries of loggerheads tagged in Greece show a post-nesting wide dispersion in the Mediterranean with preference areas the Gulf of Gabes and the Adriatic Sea (Margaritoulis, 1988; Lazar et al., 2000). In Italy, a total of 1,047 loggerheads, mostly juveniles, were tagged after their capture in fishing gear; among these, 4.8% have been recovered at both the eastern and western Mediterranean basins; the ones in the eastern basin exhibiting, more or less, the same preference areas as the post-nesting females from Greece (Argano et al., 1992).

The Gulf of Gabes and the Adriatic are the two most extensive shallow (< 200 m) regions in the Mediterranean, with approximate areas of 77.000 km^2 and 102.000 km^2, respectively (Margaritoulis et al., 2003). Such a high number of tag recoveries coinciding with these two regions, suggests that the Gulf of Gabes and the Adriatic Sea host major neritic habitats for loggerheads in the Mediterranean.

Population model studies have suggested that a reduction of turtle mortalities in subadult and adult stages is crucial to their survival and recovery (Heppell et al., 2003). Our results show that the viability of the loggerhead population nesting in Greece is partially dependent on the mitigation of 'at-sea' threats in the Gulf of Gabes. This area can be considered as an important management sub-unit for loggerhead nesting population in the Mediterranean Sea as we know that the rookeries in Greece account for the largest loggerhead nesting population in the Mediterranean Sea (Casale & Margaritoulis, 2010).

To confirm our results and to provide a more detailed picture of migration of the loggerhead and the green turtle in the Tunisian water, systematic awareness programs among professional fishermen and local coastal inhabitants at national level are essential.

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