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Marine Turtle Nesting Activity Assessment on Libyan Coasts

Phase 3
Survey of the coast to the West of Misratah

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Summary

A first phase to assess nesting activity was conducted in 1995 between Sirte and the Egyptian border, and clearly identified that loggerhead turtle *Caretta caretta* nesting is widespread and abundant in this country (Laurent *et al.* 1995 ; Laurent *et al.* 1997). A second one was carried out in 1996 between Misratah and Sirte (Hadoud & El Gomati 1997).

The last phase completing the Libyan coasts was conducted from 1 to 16 July 1998 between the Tunisian border and Misratah. This coastal zone is 407 km long, representing 22.5 % of the total coasts, and has 160 km of sandy beaches corresponding to 14.7% of the nation's sandy coastline. 23 beaches or beach portions, totalling 105.7 km, were surveyed once on foot and by four wheel motorbike (QUAD). 15 crawl tracks of nesting females were recorded and identified as belonging to the loggerhead turtle *Caretta caretta*. No other sea turtle species were observed. Nesting signs were reported along the whole zone and crawl track and nest (Nesting Crawl Tracks+Nests) densities were low both ranged from 0 to 0.667/km, with an average of 0.113 crawl tracks/km and 0.066 nests/km. Nesting sign densities were reported to be higher between Ras Ajdir-Sabratah, including the beaches of Farwa island, Zuwarah and Tillil. A 45.4% rate of nest predation was measured in 11 nests. Human consumption of eggs appears to be a local tradition along the coastal area of Ras Ajdir-Sabratah, particularly on Farwa island and in Zuwarah. Eggs are usually eaten and sold at the town of Zuwarah.

A comparative analysis among the three phases within the framework of a Mediterranean approach show the following. **(i)** Nesting signs have now been recorded along the whole Libyan coast from the Tunisian to the Egyptian borders. This is an important result demonstrating that loggerhead annual nesting activity is spread over the 1,089 km of sandy shoreline. **(ii)** When considering mean nesting sign density differences the picture is striking since 2.16 crawl tracks/km and 1.24 nests/km were recorded in 1995 during single beach surveys totalling 141.65 km (Phase 1; Laurent *et al.* 1995), whereas 0.563 and 0.310 were observed in 1996 along 87 km (Phase 2; Hadoud & El Gomati 1997). **(iii)** We suspect that the zone between the Tunisian border and Misratah hosts a lower nesting activity, although a methodological explanation is difficult to eliminate. **(iv)** We believe that the apparent global low nesting activity along these wild sandy coasts might be primarily related to incidental captures induced by fishing activity in the bordering country. **(v)** Analysis of variations in loggerhead annual nesting activity in the Mediterranean indicates that nesting sign density difference between the first (1995) and second (1996) phase could reflect a large natural decrease between two seasons rather than a nesting activity difference between two coastal zones. **(vi)** In all, 214 nests were observed along the Libyan coasts during single beach surveys only spread over 24.6% of the 929 km sandy coastline of the zone exhibiting the highest nesting activity, *i.e.* the coasts between Misratah and the Egyptian border. This clear picture shows that the number of nests per season in Libya is undoubtedly very large, exceeding the number of nests in Cyprus and Turkey, and the number might be equal or higher than in Greece. Existence of a large rookery in Libya is totally consistent with a recent loggerhead stock composition assessment in Mediterranean fishery bycatch (Laurent *et al.* 1998). Mediterranean researchers and managers should consider Libya not as an anecdotal nesting ground, as was written in some recent reports, but

as one of the two major nesting grounds in the Mediterranean. **(vii)** Nesting of the green turtle *Chelonia mydas* in Libya should be considered as absent or exceptional. As no historical data supporting the existence of past rookeries are available, and, as fishing activity was not a local tradition, we propose ecological explanations for this result. Our findings therefore demonstrate that the geographical distribution of green turtle nesting activity in the Mediterranean is restricted to the easternmost part of the eastern basin, *i.e.* in Turkey, Cyprus and Israel. **(viii)** As nesting of the leatherback turtle *Dermochelys coriacea* on the long wild sandy coasts of Libya is now considered as absent or exceptional, the existence of a Mediterranean nesting population for this species is thus most improbable.

This synthetic analysis enabled outlines of a marine turtle research programme and conservation strategy for Libya to be proposed. One of the urgent actions is to continue nesting activity assessment, but based on a sound sampling design using multiple surveys and four wheel drive motorbikes QUAD. Prospecting effort should be focused on the zone between Misratah and the Egyptian border where the total beach length not yet surveyed is estimated at 75.4 %.

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INTRODUCTION

Geographical distribution of marine turtle nesting activity in the Mediterranean, as deduced by an analysis of the range of sea turtle rookeries, is primarily structured by ecological conditions and then by anthropogenic factors, i.e. human exploitation. One of the main ecological factor appears to be sea water temperature gradients notably when considering the two Mediterranean oceanographic basins which present two radically different status.

In the western basin, separated from the eastern basin by the channel of Sicily, the situation is similar to the European and north west African coasts of the Atlantic Ocean. In this area, no historical data support the existence of past rookeries nowadays depleted, and nesting activity is known to be absent or to occur only exceptionally as a result of ecological factors. For example, in Morocco and Algeria no nesting sign was found on the very wild long sandy beaches prospected intensively in 1989, indicating that nesting is most likely to be exceptional in these countries (Laurent 1990a). The same conclusion was drawn from marine turtle surveys in Sardinia (Argano *et al.* 1990; Whitmore *et al.* 1991). Finally, within this century the only proof of nesting activity in the western basin is the discovery in Spain in September 1990 of one loggerhead *Caretta caretta* hatchling found dead on a beach located in the south of the Ebro Delta (Filella I Subira & Esteban Guinea 1992; Llorente *et al.* 1992-1993).

The eastern basin is the Mediterranean nesting area where annual nesting activity takes place along all the sandy coasts except in the northernmost zones, *i.e.* the northern Aegean (Kasparek 1991) and Adriatic Seas (Lazar *et al.* 1998), probably resulting from hydrological conditions. Until recently, the largest nesting areas were known to be located in Greece (Margaritoulis 1980, 1982, 1988; Margaritoulis *et al.* 1995a, b), Turkey (Geldiay *et al.* 1982; Baran & Kasparek 1989a; Canbolat 1991; Erk'akan 1993; Baran & Türkozan 1996; Yerli & Demirayak 1996) and Cyprus (Demetropoulos & Hadjichristophorou 1989, 1995; Broderick & Godley 1996). However, the survey carried out in 1995 in the last Mediterranean country where the distribution of sea turtle remained unknown for a long time, *i.e.* Libya, clearly identified that *Caretta caretta* nesting is widespread and abundant (Laurent *et al.* 19975, 1997). Indeed, during this first survey which focused on the coasts between Sirte and the Egyptian border (Phase 1), 176 nests were recorded along 141.65 km of beach samples surveyed once. This, strongly suggested that the total number of nests laid within the full 1995 nesting season was very high, but no method was available enabling us to infer this number accurately from unique

beach surveys. However, based on the number of nesting crawl recorded during single surveys, and assuming that the remaining nation's shoreline between the Tunisian border and Sirte had a comparable nesting density, an estimation of the total number of nests laid in Libya in 1995 was calculated, suggesting that this country might host the largest loggerhead colony in the Mediterranean (Laurent *et al.* 1995). This high level of nesting is believed to be primarily related to the long sandy coastline which is largely undeveloped, as well as a tradition of low fishing activity.

The discovery of the large loggerhead rookery in Libya and more detailed investigations of previously neglected nesting areas *e.g.* in northern Cyprus (Broderick & Godley 1996) and in Greek Islands (Margaritoulis *et al.* 1995a), enabled the first holistic estimates of the Mediterranean loggerhead nesting population to be made giving a new insight into its population size (Laurent *et al.* 1995). Taken as a whole, Mediterranean may support the third largest loggerhead population in the world, after those of Oman and the United States (Laurent *et al.* 1995). However, on the basis of large past catches in Israel and Turkey (1931; Hornell 1935; Anonymous 1967Hataway 1972Hornell 1935Sella 1982; Geldiay *et al.* 1982), and in Tunisia and Egypt (Argano & Baldari 1983; Laurent *et al.* 1990; Laurent *et al*. Laurent *et al.* 1996), it might be expected that the present Mediterranean nesting population is markedly smaller than in the past, particularly with respect to populations in Israel, Egypt, Tunisia, Turkey, Cyprus and Libya.

Knowledge of loggerhead breeding effort in the Mediterranean is one key to understanding stock composition assessment in fishery bycatch (Laurent *et al.* 1998) and to estimating the impact of fishery-related mortality (Laurent 1998). In order to increase the accuracy of population dynamics analyses conducted on a regional scale and hence effectiveness of marine turtle conservation management program in the Mediterranean, efforts to accurately estimate annual nesting activity in each country should be made. This has been done in Greece (Margaritoulis 1998; Houghton *et al.* 1997), in Turkey (Baran *et al.* 1996; Baran *et al.* 1997; Yerli & Demirayak 1996) and in Cyprus (Broderick & Godley 1996), in 1996 the coasts between Sirte and Misratah were surveyed within the second phase of the assessment of nesting activity (Hadoud & El Gomati 1997).

In this study, we present results of the last phase carried out in July 1998 on the coasts between the Tunisian border and Misratah that completes the Libyan coastline. We compare them with the field data collected during the other phases, giving a new insight into marine turtle nesting activity in Libya within the framework of

an Mediterranean approach. This synthetic analysis enables us to propose outlines of a marine turtle research programme and a marine turtle conservation strategy for Libya.

MATERIALS AND METHODS

Organisation of the mission

Regional activity centre for specially protected areas (rac/spa-map-unep) organised the mission, defined its duration and its main outlines, and constituted part of the team.

General data on Libya and biodiversity

Information dealing with the geography and the fauna of the coastline as well as the marine fisheries in Libya are provided in the report of the first phase (Laurent *et al.* 1995).

Data on coastal and marine biodiversity collected during the survey are presented in a specific report.

Beach sampling design

Sampling strata

a) Date of the survey

The marine turtle nesting activity survey took place from Wednesday 1 to Friday 16 July 1998. These dates were chosen in accordance with the loggerhead nesting period in the Mediterranean. The nesting period extends over 3 months from late May to late August at the Mediterranean level, lasting around 2.5 months locally. Peak nesting generally occurs in late June in Turkey (Geldiay *et al.* 1982; Van Piggelen & Strijbosch 1993; Yerli & Demirayak 1996) and in Northern Cyprus (Broderick & Godley 1996), and in Libya (Hadoud & El Gomati 1997) and during mid-July in Greece (Margaritoulis 1988; Sutherland 1984).

b) Coastal zone and area strata

Two coastal zones were surveyed: (1) the coasts between the Tunisian border and Misratah, and (2) the coasts between Misratah and Sirte (Figure 1). In order to plan both the survey effort and the moving around along the coasts, sub-strata, named coastal areas, were defined on the basis of preliminary data regarding the level of coastal urbanization and geological characteristics of the coastline (Table 1).

Sample allocations and selection

Sampling effort focused on the first zone since it was the last Libyan zone not hitherto surveyed for marine nesting activity. The primary sampling unit was beach or beach portion surveyed one time. Primary sampling units were not selected in a random way. Indeed, wild sandy coastline were preferentially sampled in contrast with developed sandy coastline or beaches frequently used by campers and bathers. Furthermore, so as to be the most efficient during this short mission, in terms of length of beaches surveyed, some small hardly accessible beaches were not prospected.

Beach survey

Beach prospecting method

The team was made up of 5 participants transported by car and a four wheel drive motorbike Yamaha YFM 350 4x4 (QUAD), driven by L.L. The QUAD enabled one or two participants to reach coastlines that were not easily accessible, and to move quickly and comfortably on beaches for efficient and effective surveys.

When moving along the coastal areas by car and QUAD, the different geological structures of the coastline *i.e.* sandy, rocky or saltmarshes, were identified, recorded and located on 1/50,000 maps, and their length measured with the help of a curvimetre. Sandy beaches were inventoried by using natural limits or human installations such as towns, cities, harbours, factories, etc., and only the portion exhibiting no human installations were considered. The geographical coordinates of the beaches or beach portions were determined by using a Global Positioning System instrument (GPS) and were referred to the two extremities for long beaches or the centre for small ones. These coordinates enabled us to precisely locate these beaches or beach portion on 1/50,000 maps and to measure their length by using a curvimetre.

Sandy beaches or portions of sandy beaches were surveyed once by walking and/or QUAD and nesting signs were recorded.

Classifying nesting signs

Observed nesting signs were classified into one of the five following categories:

Crawl tracks:

?? UCT crawl track on the beach without any digging attempt; it generally forms a U on the beach.

?? FCT crawl track with one or more digging attempts but no egg deposition (false nesting attempt).

?? NCT nesting crawl track leading to a nest. This kind of crawl track has an area where the sand has been greatly disturbed and where digging and covering have occurred. The presence of the nest is never 100% certain, and only observation of egg shells on the surface, in the case of a predated nest, or excavation of the eggs, can confirm this.

?? CTold crawl track for which no means of classification is available.

Nests:

?? N nest without crawl track, opened by a predator, and almost always with remains of shells on the surface.

Crawl track identification

Crawl tracks of the loggerhead turtle *Caretta caretta* are typically well under 1 meter in width and present alternating (asymmetrical) marks made by the front flippers. Loggerhead nesting crawl tracks (NCT) exhibit an area of egg deposition with a small degree of associated sand disturbance.

Green turtle *Chelonia mydas* makes larger crawl tracks around 1 meter in width with symmetrical marks made by the front flippers. Green turtle nesting crawl tracks (NCT) show a nesting area with a large amount of sand disturbance; a deep hollowis still evident after the female has left for the sea.

Measuring size of sea turtles

Size of observed sea turtles was determined according to the SCCL method, Standard Curve Carapace Length. The carapace length is measured from the precentral scute (nuchal scute) at carapace midline to the posterior margin of the postcentrals (last marginal scutes).

Comparative analysis with the data collected during the second phase

Results of the phase carried out in 1996 along the coasts between Sirte and Misratah were recently presented in Arabic at an African conference (Hadoud & El Gomati 1997). To make then available to a larger audience and to enable comparison with the other phases, the field data of the second phase are presented in the results of the present final report.

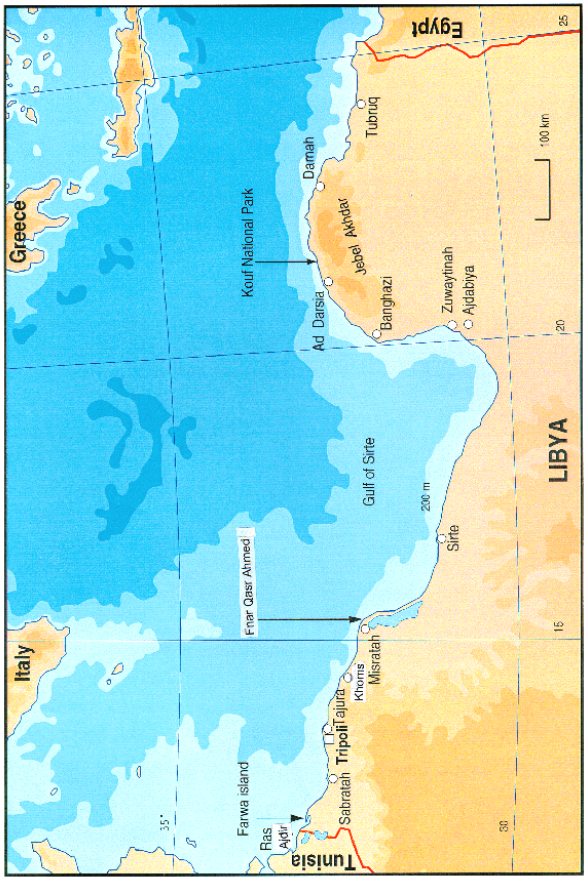

Figure 1 The Libyan coast

RESULTS

Description of the surveyed coasts

Coastal zone between the Tunisian border and Misratah

The coastal zone between the Tunisian border and Misratah (cap Anar Qasr Ahmad) is 407 km long, representing 22.5 % of the total Libyan coasts, and has 160 km of sandy beaches corresponding to 14.7% of the nation's sandy coastline. Four main coastal areas were defined and sampled, and 23 beaches or beach portions were surveyed once, totalling 105.7 km (Table 1; figure 1).

Coastal zone Coastal area	Coastline length km	Sandy beach length km	Number of beach samples	Total length surveyed km (%)
Tunisian border-Misratah				
Ras Ajdir-Sabratah	129.0	71.0	6	57.1 (80.4)
Sabratah-Tajura	90.0	5.0	0	0
Tajura-Khoms	90.0	52.0	8	29.9 (57.5)
Khoms- Misratah	98.0	32.0	9	18.7 (58.4)
Total zone	407.0	160.0	23	105.7 (66.1)
Misratah-Sirte	**209.0**	**186.3**	**1**	**9.3(5.0)**

Table1 Coastline and beach length of the coastal zones and areas, and number and length of beach samples surveyed during the 1998 mission (Phase 3). Percentages of beach length sampled in a coastal zone or area are given in brackets.

Ras Ajdir-Sabratah

This coastal area exhibits a largely sandy coastline (Table 1). From west to east, the coast is structured by a saltmarsh coastline that extends from the Tunisian border to the west end of the Farwa island (Figure 1), including the Farwa lagoon, and then by a sandy coastline which streches to Sabratah, including the north coast of the Farwa island and exhibiting rocky points in certain places. The coasts are largely undeveloped and still in a wild state except around the village and the small port of Abu Kammash, the chemical factory of Abu Kammash and the small town and port of Zuwarah (Figure 1).

A total of 7 beaches or beach areas were inventoried. Length and geographical coordinates of the surveyed beaches are given in Table 2.

Farwa island (1)

Farwa island constitutes a portion of a sand bar recently separated from the continental coast by an artificial channel. The beach, located along the north coast of the Farwa island, is flat and exhibits no dune bar, and is in a wild state, except the presence of an old lighthouse. Human activity appears to be limited to bathers (not observed during our survey).

Abu Kammash (sand bar) (2)

This beach corresponds to the other portion of the sand bar and extends from the channel to the chemical factory. This beach is also in a wild state, but the east part is used for recreational activities (tents, bathers).

Zuwarah (3)

Long wild flat beach (Photo 1) which extends from the chemical factory to Zuwarah. It is intensively used for recreational activities near Zuwarah (temporary holiday camps, bathers).

Al Manqub (4)

Beach in a wild state located between Zuwarah and a small rocky cape named As Sadrah. It is used for recreational activities (temporary holiday camps, bathers) at each end.

Markan (5)

Beach in a wild state. The west end is covered by dense mats of accumulated dead *Posidonia* leaves washed ashore. The east portion is used for recreational activities (tents, bathers).

Millitah area (6)

This portion of the coastline exhibits some rocky plateaux where very small sandy beaches are included. Some of them are intensively used by bathers. These beaches were not prospected.

Tillil (7)

Beach in a wild state exhibiting a dune bar (Photo 2). The beach portion close to Sabratah is intensively used for recreational activities (Photo 3).

Sabratah-Tajura

This rocky coastal area (Table 1) is highly developed since it includes the urbanized capital Tripoli.

Tajura-Khoms

This coastal area exhibits long beaches in its west portion and then mixed sandy-rocky coastline with more diversified habitats including dunes, river estuaries, rocky island and agricultural landscapes. A total of 9 beaches or beach areas were inventoried. Length and geographical coordinates of the surveyed beaches or beach portion are given in Table 2.

Tajura (8)

This long beach which extends from Tajura to Wadi Turghat, is bordered by a road and is intensively used for recreational activities, notably in its west portion. This beach was not prospected.

Wadi Turghat-Wadi Masid (9)

Long wild beach, exhibiting a small sandy-rocky cliff bahind (Photo 4). It is sparsely used by bathers and small houses are located in its east portion.

East Wadi Masid (10)

Wild rocky area with very small beaches not prospected.

Tunnarat al-Qarabulli (11)

Urbanized beach used for recreational activities (Photo 5).

East of Tunnarat al-Qarabulli (12)

Small wild beach located between flat groups of rocks.

Ras el Hallab (13)

Wild beach located west of the lighthouse of Ras ell Hallab, exhibiting a small group of rocks (Photo 6). No human activity was recorded.

Al Jazirah (14)

Long wild beach with two river estuaries (Photo 7). No human activity was recorded except traces of tyres on some dunes.

Ghanimah (15)

Long wild beach located below a rocky shelf, exhibiting sparse small groups of rocks (Photo 8). Some bathers were recorded in some places.

West of Khoms (16)

Long wild rocky coastal area exhibiting agricultural activity. Of numerous small beaches included along this rocky coastline, only one was surveyed *i.e.* Silin.

Khoms- Misratah (Cap fnar Qsar Ahmad)

This coastal area exhibits three parts: a sandy coastline, a long rocky cliff and a mixed sandy-rocky coastline extending to the cap fnar Qsar Ahmad, where the industrial port of Misratah is located (Figure 1).

A total of 8 beaches or beach areas were inventoried. Length and geographical coordinates of the surveyed beaches or beach portions are given in Table 2.

Ras el-Sahal (17)

Long beach bordered by palm groves and other agricultural activities (Photo 9). In many places bathers were observed .

Sidi Ahmad al Maghrabi (18)

Small rocky shelf including some small beaches. None were prospected.

West of Wadi Ka'am (19)

Undeveloped beach bordered by agricultural activities.

Montarha (20)

Undeveloped beach located at the east of Wadi Ka'am and bordered by agricultural fields.

Sidi Ahmad (21)

Small beach bordered by a road and cluttered by various waste.

Wadi Basis (22)

Wild beach with low trace of human activity and bordered by agricultural fields (Photo 10).

Na'imah (23)

Wild beach located at the west end of a long rocky cliff and bordered by agricultural fields with small groups of rocks (Photo 11).

Sidi Abu Madfa (24)

Small beach near agricultural zone.

Tunnarat az Zuraygt (25)

Small beach near tourist zone.

Sidi al Bu Ahmad-Fnar Qsar Ahmad (26)

Long rocky beach area which exhibits numerous small recreational beaches (Photo 12), where small tourist buildings, tents and bathers were recorded. Only one of them was carefully surveyed: Tunnarat ad Dazirah.

Coastal zone between Misratah (Cap fnar Qsar Ahmad) and Sirte

The coastal zone between Misratah (Cap fnar Qsar Ahmad) and Sirte has a 209 km coastline, representing 11.5% of the total Libyan coasts, and has 186.3 km of sandy beaches corresponding to 17.1% of the nation's sandy coastline. This long zone exhibits a very wild sandy coastline with very low human activity since it is bordered by large Sebkha (seasonally flooded saltmarshes) moving the main road from the coastline and making the way to reach the coasts very long and difficult (Figure 1). From the cap Cap fnar Qsar Ahmad the coastline is rocky and then sandy with small groups of rocks (very flat rocky shelf) in some places. Only one beach portion samples of this sandy coastline was surveyed on one occasion during this 1998 mission (Table 1).

South Fnar Qsar Ahmad (27)

This beach portion samples (Photo 13) start from the end of the rocky coastline. At the beginning of this portion bathers were observed.

Sea turtle species observed

A total of 15 crawl tracks of nesting females were recorded during beach prospecting (Table 2). All presented an asymmetrical arrangement of the front flipper marks and a small width largely under one meter. They were identified as belonging to the loggerhead turtle *Caretta caretta*. Based on these findings we considered that all nests inventoried without crawl tracks (N) were laid by the loggerhead turtle.

During the survey, 9 loggerheads were found stranded on the beaches, and two carapaces of this species were observed in a restaurant near Tunnarat az Zuraygt (24). These individuals had a mean size of 57.7 cm (range: 46.0-72.7; SD=7.89; N=11). No other sea turtle species were observed.

Sea turtle species observed during phase 2 (Hadoud & El Gomati 1997)

A total of 66 crawl tracks of nesting females were observed (Table 3) and attributed to the loggerhead turtle *Caretta caretta*. Plastic tags type rototag with the RAC/SPA address marked on it were applied to the trailing edge of one or two front flippers of two nesting loggerhead females. One of 72.5 cm carapace length was tagged F 3022, the other of 83 cm was double tagged F 3101 and F 3121. Seven stranded loggerhead turtle were recorded with size of 72, 74, 72, 71, 67, 63 and 58 cm.

The green turtle *Chelonia mydas* was observed during this phase, since two dead stranded juveniles of 59 and 55 cm in length were recorded on the beach of Abouirat Al Hassoun.

A leatherback turtle *Dermochelys coriacea* of 137 cm long was recorded as being incidentally caught alive in 1996 along the coast of Tajura by a small coastal fishing gear. This individual was subsequently conserved at the Marine Biology Research Centre of Tajura.

Loggerhead nesting sign densities

Coastal zone between the Tunisian border and Misratah

Nesting signs (Photo 14, 15) were reported along the whole zone from the Tunisian border (Farwa island (1)) to the coastal area between Khoms and Misratah (Wadi Basis; figure 1). Crawl track and nest (NCT+N) densities both ranged from 0 to 0.667/km, with an average of 0.113 crawl tracks/km and 0.066 nests/km (Table 2). Nesting sign density as measured by single surveys was reported to be higher in the first coastal area Ras Ajdir-Sabratah, notably on the beaches of Farwa island, Zuwarah and Tillil, and to be particularly low in the two other coastal areas (Table 2). Indeed, no nest (N) and only one crawl track was observed in each of these last two coastal areas, leading to very low densities (Table 2).

Coastal zone between Misratah and Sirte

Only one beach sample of 9.3 km in length was recorded in the northern portion of this zone, representing 5.0 % of the total sandy coastline (Table 1). Different nesting signs were observed along this beach portion (Photo 16, 17). Crawl track density was 0.322 tracks/km, whereas the nest density (NCT+N) was 0.430 nests/km (Table 2). Nesting sign density as measured by the once-surveyed beach sample was reported to be higher than in the first zone, but the length of the surveyed beach was particularly smaller (9.3 *vs* 105.7 km), making comparison difficult (see also chapter 4-2 in Discussion).

Loggerhead nesting sign densities recorded during phase 2 (Hadoud & El Gomati 1997)

Nesting sign densities recorded during the second phase by Hadoud & El Gomati (1997) is presented in table 3. Crawl track densities recorded during single surveys ranged from 0 to 3.8 crawl tracks/km, whereas nest densities (NCT+N) varied from 0 to 2.6 nests/km (Table 3). The prospecting method used during this second phase was different from the first and third phases since a car was used to prospect beaches (Table 3). The beach portion number 8 surveyed in 1996 with a length of 3.0 km (Table 3) is included in the 9.3 km coastline of the beach portion Fnar Qasr Ahmad (27) prospected in 1998 (Table 2).

Predation

A 45.4% rate of nest predation was measured in 11 nests (NCT+N) and only refer to N, *i.e.* no NCT was found predated.

Egg consumption

Human consumption of eggs appear to be a local tradition along the coastal area of Ras Ajdir-Sabratah where two NCT were recorded as having been opened by humans. One NCT was reported on the beach of Zuwarah (3) (Photo 2) and its eggs were taken by two fishermen working on the beach near the nest. By discussing with them we learnt that they frequently eat and to sell eggs at the town of Zuwarah. The second NCT was discovered on the beach of Farwa (1), beach known to sustain a high human exploitation of eggs.

Coastal zone	Surveyed beach						Observed nesting signs							
	Reference	Surveyed length km	Coordinates of the middle of beach sample Latitude	Longitude	Period or Date	Method	Crawl tracks UCT	FCT	NCT	Total	Density	Nests N	NCT+N Total	Density
Misratah-Sirte	8	3.0	32°12.13'	15°19.26'	28/5-4/6	W				0	0		0	0
					27/06	W				0	0		0	0
	7	6.0	32°00.42'	15°21.24'	28/5-4/6	C				0	0		0	0
					27/06	C			2	2	0.333		2	0.333
	6	25.0	31°45.21'	15°26.50'	28/5-4/6	C				0	0		0	0
					27/06	C				0	0		0	0
	5	19.5	31°46.16'	15°33.29'	28/5-4/6	C				0	0		0	0
					26/06	C		1		1	0.051		0	0
	4	18.0	31°25.43'	15°42.32'	28/5-4/6	W/C				0	0		0	0
					25/06	W/C	1			1	0.055		0	0
	3	2.0	31°16.00'	16°03.54'	28/5-4/6	W				0	0		0	0
					24/06	W	1	1		2	1.000		0	0
	2	5.0	31°13.56'	16°14.45'	28/5-4/6	W			2	2	0.400		2	0.400
					25/06	W	4	5	10	19	3.800	3	13	2.600
					18-24/07	W				0	0		0	0
					12-15/08	W			4	4	0.800		4	0.800
	1	8.5	31°13.28'	16°22.98'	28/5-4/6	W				0	0		0	0
					23/06	W	1	17	6	24	2.823	6	12	1.412
					18-24/07	W			7	7	0.823		7	0.823
					12-15/08	W			4	4	0.470		4	0.470
	Total zone	87							18	49	0.563		27	0.310

Table 3 Nesting activity recorded in 1996 (Phase 2; Hadoud and El Gomati 1997). Survey method: walk (W), car (C). Density: number per km. Total for the zone is based on compiled shading data.

Coastal zone / Coastal area	Surveyed beach							Observed nesting signs								
	Name and reference	Length	Surveyed length	Coordinates of the beach or beach sample		Date	Method	Crawl tracks						Nests		
															NCT+N	
		km	km	Latitude	Longitude			UCT	FCT	CT	NCT	Total	Density	N	Total	Density
Tunisian border-Misratah																
1 Ras Ajdir-Sabratah	Farwa island (1)	9.0	9.0	33°07.58'	11°41.15'	04/07	W	2	1		2	5	0.555		2	0.222
				33°05.89'	11°46.33'											
	Abu Kammash (2)	4.8	4.8	33°05.89'	11°46.33'	13/07	W					0	0		0	0
				33°04.81	11°48.64'											
	Zuwarah (3)	29.0	26.0	33°04.34'	11°50.51'	04/07	Q/W				2	2	0.077	2	4	0.154
				32°56.60'	12°04.59'											
	Al Manqub (4)	8.0	4.8	32°55.13'	12°07.29'	03/07	Q					0	0		0	0
				32°53.12'	12°11.42'											
	Markan (5)	4.0	3.8	32°53.06'	12°11.82'	03/07	Q					0	0		0	0
				32°51.98'	12°13.83'											
	Tillil (7)	11.7	8.7	32°50.32'	12°17.77'	03/07	Q/W	1	1	1		3	0.345		0	0
				32°49.14'	12°22.78											
	Total coastal area		57.1								4	10	0.175		6	0.105
2 Tajura-Khoms	Wadi Turghat-Masid (9)	11.0	1.2	32°47.51'	13°36.97'	06/07	W					0	0		0	0
				32°47.48'	13°37.76'											
	Wadi Turghat-Masid (9)	11.0	3.8	32°47.46'	13°40.26'	06/07	Q/W					0	0		0	0
				32°47.66'	13°42.36'											
	Tunnarat Qarabulli (11)	1.0	1.0	32°47.52'	13°44.11'	06/07	Q					0	0		0	0
	East Tunnarat (12)	0.1	0.1	32°47.90'	13°45.82'	06/07	Q					0	0		0	0
	Ras el Hallab (13)	2.0	2.0	32°48.00'	13°47.00'	06/07	Q					0	0		0	0
				32°48.00'	13°48.09'	06/07	Q					0	0		0	0
	Al Jazirah (14)	15.0	15.0	32°48.09'	13°48.32'	06/07	Q			1		1	0.067		0	0
				32°46.39'	13°56.75'											
	Ghanimah (15)	6.0	6.0	32°43.92'	14°00.45'	07/07	Q/W					0	0		0	0
				32°43.52'	14°03.82'											
	Selin (16)	0.8	0.8	32°42.69'	14°09.41'	07/07	W					0	0		0	0
	Total coastal area		29.9								0	1	0.033		0	0

Table 2 Nesting activity recorded in 1998 (Phase 3). Survey method: walk (W), QUAD (Q). Density: number per km. Coordinates of the middle are given for small beaches. Beaches are described in the text.

Coastal zone / Coastal area	Surveyed beach							Observed nesting signs								
	Name and reference	Length	Surveyed length	Coordinates of the beach or beach sample		Date	Method	Crawl tracks						Nests		
															NCT+N	
		km	km	Latitude	Longitude			UCT	FCT	CT	NCT	Total	Density	N	Total	Density
4 Khoms-Misratah	Ras el Sahal (17)	10.5	5.5	32°36.87	14°20.39'	08/07	Q					0	0		0	0
				32°34.94'	14°22.66'											
	Wadi Ka'am (19)	3.0	3.0	32°32.88'	14°26.21'	08/07	Q					0	0		0	0
				32°31.81'	14°26.91'											
	Montarha (20)	9.0	6.0	32°31.01'	14°28.21'	08/07	W					0	0		0	0
				32°30.23'	14°31.86'											
	Sidi Ahmad (21)	0.3	0.3	32°29.84'	14°34.71'	09/07	Q					0	0		0	0
	Wadi Basis (22)	1.5	1.5	32°29.42'	14°37.52'	09/07	Q				1	1	0.667		1	0.667
				32°29.27'	14°38.25'											
	Na'imah (23)	1.0	1.0	32°28.96'	14°39.17'	09/07	W/Q					0	0		0	0
				32°28.74'	14°39.63'											
	Sidi Abu Madfa (24)	0.1	0.1	32°26.44'	14°53.24'	09/07	Q					0	0		0	0
	Tunnarat az Zuraygt(25)	0.1	0.1	32°26.15'	14°55.03'	09/07	Q					0	0		0	0
	Tunnarat ad Dazirah(26)	1.2	1.2	32°25.17'	15°00.24'	10/07	Q					0	0		0	0
				32°25.06'	14°59.62'											
	Total coastal area		18.7								1	1	0.053		1	0.053
	Total zone		105.7								5	12	0.113		7	0.066
Misratah-Sirte																
	Fnar Qasr Ahmad (27)		9.3	32°12.87'	15°19.07'	10/07	Q/W	1		1	1	3	0.322	3	4	0.430
				32°08.48'	15°21.57'											

Table 2 Nesting activity recorded in 1998 (Phase 3). Survey method: walk (W), QUAD (Q). Density: number per km. Coordinates of the middle are given for small beaches. Beaches are described in the text.

DISCUSSION

Nesting sign density differences among phases

In 1998 between the Tunisian border and Misratah, single beach surveys have recorded crawl track and nest (NCT+N) densities both ranging from 0 to 0.667 per km (Table 2). In 1996, between Misratah and Sirte (Phase 2; Hadoud & El Gomati 1997) ranges of crawl track and nest densities were 0-3.8 and 0-2.6, respectively (Table 3). This is in marked contrast with the zone between Sirte and the Egyptian border, surveyed in 1995 using the same method, where crawl track densities varied from 0 to 5.8, whereas nest densities ranged from 0 to 3.8 (Phase 1; Laurent *et al.* 1995). When considering mean densities the comparison is more striking: 0.113 crawl tracks/km and 0.066 nests/km along 105.7 km of beaches surveyed in 1998 (Phase 3; table 2), 0.563 and 0.310 along 87 km in 1996 (Phase 2; table 3; Hadoud & El Gomati 1997) as opposed to 2.16 and 1.24 along 141.65 km in 1995 (Phase 1; Laurent *et al.* 1995).

Inferences regarding nesting activity differences

Given what has been presented above we might be tempted to infer that nesting activity is low between the Tunisian border and Misratah, medium between Misratah and Sirte, and high between Sirte and the Egyptian border.

However, inherent bias in our exploratory methodology make quantitative comparative analysis among phases regarding nesting activity differences among coastal zones theoretically unfeasible. The main bias comes from the fact that nesting activity is not constant among years; large fluctuations in annual nesting activity are widespread and reported in numerous nesting areas (Davis & Whiting 1977; Talbert *et al.* 1980; Williams-Walls *et al.* 1983; Owen *et al.* 1992; Bagley *et al.* 1996; Erhart *et al.* 1996). In the Mediterranean, nesting sites which are monitored annually over a long period are Zakynthos and Kyparisia bay (Margaritoulis 1998), Mounda beach in Cephalonia (Houghton *et al.* 1997) and in northern Cyprus (Broderick *et al.* 1997). These long term nesting activity censuses show large variations in annual nesting activity. For example, on Zakynthos the number of nests per season ranges from 2,018 to 857 with an average of 1.295 (Margaritoulis 1998).

Another important bias results from intra-annual variability in nesting activity. Temporal nesting distributions on a weekly basis and particularly on a daily basis recorded on monitored Mediterranean nesting sites indeed show large fluctuations of number of nests laid. Such situations can explain differences in observed nesting

sign densities as much among phases as within phases. Other serious bias also interfere: differences in lifetime of nesting signs resulting from distinct meteorological and granulometric conditions, differences in predation activity, and differences in the survey vehicle such as the use of a car and walk in the second phase. This shows that the single survey method is by far more of a qualitative method than a quantitative one, but remains an efficient approach for exploring long coastline during short missions, as was the case in Libya.

As regards comparison between the first (1995) and second (1996) phase, we note that on Zakynthos the largest amplitude between two consecutive seasons occurred between 1995 and 1996 (Margaritoulis 1998). 1995 was a very high Mediterranean loggerhead nesting season, it being the highest season ever reported on Zakynthos and Kiparisia bay (Margaritoulis 1998), the highest within the last eleven seasons on Monda beach (Houghton *et al.* 1997), the highest alongside the 1994 season in northern Cyprus (Broderick *et al.* 1997), and the highest within 5 consecutive seasons monitored on Fethiye beach, the only Turkish nesting site surveyed in 1995 (Baran *et al.* 1997). In contrast, 1996 was a very low season in the Mediterranean. 1996 was the lowest within 5 consecutive seasons monitored in Turkey (Baran *et al.* 1997), and was one of the lowest ever recorded in Zakynthos. Together these data indicate that nesting sign density differences between the first (1995) and second (1996) phase could reflect a large natural decreasing variation in annual nesting activity at a Mediterranean level rather than a nesting activity difference between two coastal zones: Sirte-The Egyptian border and Misratah-Sirte.

Concerning the comparison between the third (1998) and the two other phases, we have to take into consideration the fact that the 1998 loggerhead nesting season is considered as medium in Greece (Margaritoulis *pers. comm.*) and poor in northern Cyprus (Broderick & Godley *pers. comm.*), it being higher than 1996, but far from having the same 1995 intensity. However, as the mean nesting sign density of phase 3 (1998) is lower than phase 2 (1996) (0.113 *vs* 0.563 crawl tracks/km), and so lower than phase 1 (1995) (0.113 *vs* 2.16 crawl tracks/km), it is difficult to imagine that the zone between the Tunisian border and Misratah does not show a lower nesting activity, although methodological bias could explain such a difference.

Loggerhead nesting activity distribution along the Libyan coasts

As in any country where nesting occurs, there is likely to be a spatial variability in nesting activity in Libya. We thus suspect that low nesting sign densities recorded

between the Tunisian border and Misratah reflect a spatial variation in nesting activity and do not totally result from bias of our survey methodology, although this methodological explanation is difficult to eliminate (4-2). We have to mention that within this zone, the coastal area of Ras Adjir-Sabratah could nevertheless host substantial nesting sites on Farwa, Zuwarah and Tillil beaches (Figure 1).We believe that this apparent global low nesting activity along these westernmost coasts from the Tunisian border to Misratah, and equally along the eastern ones from Tubruq to Egyptian border (Phase 1; figure 1), might be primarily related to incidental captures due to the fishing activity in the bordering countries. Indeed, in contrast with Libya, the fishing industry is highly developed in Egypt and Tunisia, leading to large fishery bycatch and marine turtle fishery related mortality (Laurent *et al.* 1996), notably of adults (Laurent *et al.* 1998), probably inducing immediate decrease in nesting activity. We also suspect low nesting activity along the 35.0 km of the Zuwaytinah area (Phase 1) and maybe in the centre of the zone between Sirte and Misratah (Phase 2; figure 1). Ecological factors might explain such situations, although the methodological explanation is once again difficult to eliminate (4-2).

In the other hand, the first and second phases clearly identified numerous large nesting grounds along the long coastline between Misratah and the Egyptian border, notably from the west of Sirte to Tubruq (Phase 1; table 2, 3; figure 1). Others should be discovered when prospecting long sandy beaches not surveyed during the first phase, *e.g.* the beaches located in the south and north of Banghazi (Figure 1).

Libyan loggerhead nesting population size

Our study shows that nesting activity has now been recorded along the whole Libyan coast from the Tunisian to the Egyptian borders. This is an important result demonstrating that loggerhead annual nesting activity is spread over the 1089 km of sandy shoreline of this country, as was estimated on 1/50,000 maps. We suspect that the zone between the Tunisian border and Misratah, exhibiting 160 km of sandy beaches and corresponding to 14.7 % of the nation's sandy coastline, host a low nesting activity in contrast with the zone between Misratah and the Egyptian border totalling 929 km of sandy beaches (85.3 %). As nest density data of the Libyan nesting ground are based on a methodology which is different from those of the three other main Mediterranean nesting grounds, *i.e.* Greece, Turkey and Cyprus, this theoretically prevents us from comparing Libya from the three countries.

We can assume however that a full nesting season which spread over more than 2.5 months in the nesting grounds of Greece, Turkey and Cyprus, lasting for example 98 days on Zakynthos in 1994 (Margaritoulis & Dimopoulos 1995), has the same duration in Libya starting end of May (Hadoud & El Gomati 1997). In these three nesting grounds, moreover, beach monitoring through observation of crawl tracks starts at the beginning of the nesting season (late May-beginning of June) and continues until October through observation of nests, predated or hatched, not recorded during the nesting period..This means that the number of nests (NCT+N) detected in Libya by using a single day survey method does indeed represent a tiny proportion of the total number of nests which would be detected by daily surveys carried out during the nesting and hatching seasons *i.e.* around 4.5 months from the beginning of June to mid October.

By assuming that the number of nesting crawl tracks (NCT) recorded during single surveys represented 11.0% of the nests laid during the full nesting season, and that variability of nesting activity was similar along the whole Libyan sandy shoreline, Laurent *et al.* (1995) estimated the total number of nest laid in Libya in 1995 to be 9,000. We now know that the second assumption is wrong since nesting activity is suspected to be lower between the Tunisian border and Misratah. However this zone represents a low proportion of the nation's sandy shoreline (14.7 %). Therefore, results of the 1998 survey would not significantly alter the estimate made for the 1995 season, although this estimate should be considered as a maximum, since 1995 was a particularly high Mediterranean loggerhead nesting season, and total length of the nation's sandy shoreline is now estimated at 1,089 km instead of the 1,144 used in Laurent *et al.* (1995).

By compiling the three phases, the number of nests (NCT+N) actually recorded in Libya during single surveys along 343.65 km of beach samples (31.6 % of the nation's sandy shoreline) is 214 nests. By considering some multiple beach surveys made during the first and second phases we obtain a total of 245 nests. In comparison, the maximum number of loggerhead nests per season recorded during daily surveys spread over 4.5 months was 5,287 in Greece in 1995 (Margaritoulis 1998), 884 in Turkey in 1994 (Yerli & Demirayak 1996), and 519 (1994) and 518 (1995) in northern Cyprus (Broderick & Godley 1996).

In conclusion, Libya exhibits 1089 km of sandy beaches used by loggerheads for nesting. In all, 214 nests were observed along the Libyan coasts during single beach surveys only spread over 24.6% of the 929 km sandy coastline of the zone

exhibiting the highest nesting activity, *i.e.* the coasts between Misratah and the Egyptian border. This clear picture shows that the number of nests per season in Libya is undoubtedly very large, exceeding number of nests in Cyprus and Turkey, and the number might be equal or higher than in Greece. Existence of a large rookery in Libya is totally consistent with the recent loggerhead stock composition assessment in the large Mediterranean fishery bycatch which shows that all captures from bottom trawl fisheries and 53-55% in drifting longline fisheries originated from the Mediterranean stock (Laurent *et al.* 1998). Mediterranean researchers and managers should consider Libya not as an anecdotal nesting ground, as was written in some recent reports, but as one of the two major nesting grounds in the Mediterranean.

Status of green turtle in Libya

The three phases of this study demonstrate that the only marine turtle species nesting in Libya is the loggerhead turtle *Caretta caretta*. Nesting of the green turtle *Chelonia mydas* in this country should be considered as absent or exceptional. As no historical data supporting the existence of past rookeries are available, and as fishing activity was not a local tradition, we propose ecological explanations for this result. Our findings therefore demonstrate that the geographical distribution of green turtle nesting activity in the Mediterranean is restricted to the easternmost part of the eastern basin *i.e.* in Turkey (Geldiay *et al.* 1982; Baran & Kasparek 1989a; Coley & Smart 1992; Gerosa *et al.* 1998; Yerli & Canbolat 1998), Cyprus (Demetropoulos & Hadjichristophorou 1989, 1995; Broderick & Godley 1996) and Israel (Ashkenazi & Sofer 1988; Silberstein & Dmi'el 1991; Kuller 1995). A very small number may also nest annually in Syria (Kasparek 1995), Lebanon and on the eastern Mediterranean Egyptian coasts, but nesting activity in this country has yet to be surveyed.

However, this species was recorded in Libya through observations of immatures. The first record was made in 1992 in Ayn al Ghazalah by Hadoud & Assigier 1995). Two other juveniles (length 29.0 and 29.3 cm) were reported as having been caught in Ayn al Ghazalah lagoon (Phase 1; Laurent *et al.* 1995). Last records concern two individual immatures (length 59 and 55 cm) found in 1996 stranded on the beaches between Sirte and Misratah (Phase 2; Hadoud & El Gomati 1997). This suggests that Libya may host feeding grounds for juvenile green turtles coming from distant nesting populations.

Status of leatherback turtle in Libya

The leatherback *Dermochelys coriacea* is known to have nested at least at one time in the Mediterranean at the end of the 19th Century, but such an event has never been recorded since (Lescure *et al.* 1989). As nesting of this species on the wild sandy coasts of Libya is now considered as absent or exceptional, the existence of a Mediterranean nesting population is thus most improbable. Individuals using Mediterranean pelagic feeding grounds originate from Atlantic populations. Records of this species in Mediterranean fishery bycatch are regular, as reported, for example, along the Tunisian coasts by Bradai & El Abed 1998). At the present time, three captured individuals were reported in Libya. Two were caught in Tuna traps, in 1927 in Benghazi and in 1928 in Tripoli (Capra 1949); the other in 1996 in a small fishing gear near Tajura (Hadoud & El Gomati 1997).

RECOMMENDATION

Define a marine turtle research programme for Libya

A comprehensive marine turtle research programme should be defined for the coming years in order to efficiently increase the demographic knowledge of the Libyan loggerhead nesting population within the framework of a comparative approach among other Mediterranean nesting grounds. It is not the aim of this present study to determine such a scientific programme that requires a sound and large reflection, but the following serve as guidelines:

a) The continuation of nesting activity assessment in this country needs to be based on a sound sampling design using multiple surveys and several four wheel drive motorbikes QUAD. Efforts should be focused on the zone between Misratah and the Egyptian border where the total beach length not yet surveyed is estimated at 75.4 %, in contrast with 33.9 % for the coasts between the Tunisian border and Misratah (Table 1). In this eastern portion of Libya, some coastal areas should be totally surveyed during the full nesting season, notably the sandy shoreline of the gulf of Sirte from Misratah to Ad Darsia and the beaches of the Kouf National Park (Figure 1), using a method based on a 4-to-7 day basis. Such surveys are urgent.

b) The Gulf of Sirte from Misratah to Ad Darsia (Figure 1), may constitute a crucial area for marine turtle conservation management in Libya and in the Mediterranean and should be investigated notably in relation to fishery bycatch. Indeed, the coasts of this Gulf host a large proportion of the loggerhead nesting activity in Libya, and thus in the Mediterranean. Moreover, this Gulf presents a large area of shallow coastal waters resulting from a wide continental shelf (Figure 1), where benthic feeding grounds for large immatures and adults of Libyan and other Mediterranean nesting populations may exist. Such a coastal area, presenting both large marine turtle nesting activity and large shallow water area, appears to be unique in the Mediterranean.

c) The only Mediterranean monitored nesting sites are located in the east of this Sea, *i.e.* Greece, Turkey, Cyprus, Israel and Egypt. Reference nesting sites for the Libyan nesting populations should be quickly chosen and annually monitored on a daily basis. Concerning the number of nesting sites, it would be better to focus the available monitoring effort on two or three nesting sites so as to increase the quantity and the quality of demographic data, rather than multiplying the number of nesting sites with a low level of monitoring.

d) On these nesting sites demographic parameters should be measured according to standardized methods and within the framework of saturation tagging methods.

Define a marine turtle conservation strategy for Libya

Libya clearly hosts a substantial proportion of the loggerhead nesting that takes place in the Mediterranean each year, and the country is duty bound to protect this heritage. This exceptional situation should be used to facilitate the creation of a Libyan Conservation Strategy for the Loggerhead Sea Turtle. Since most of the coast is completely unspoilt by human development, since fishing is only slightly developed and that the tourism sector is practically non-existent, there is potential for Libya becoming a model for conservation, management and planning with regard to its diverse coastal zone. It is not the aim of this present study to determine such a strategy, but the following actions should be included:

a) The fishing community should be educated in sea turtle biology and conservation, including gear technology and other measures to reduce incidental catches. Advantage should be taken of the relatively undeveloped nature of the national fishing industry, and a serious policy of informing fishermen and involving them in conservation practices should be established as a priority. With assistance from different sources, this policy should operate at all levels in the fishing sector, including vocational schooling and administration. Materials should be distributed in markets, ports, landing areas, etc. Such a program might serve as a pilot scheme for later adaptation throughout the Mediterranean. Investigation on sea turtle interaction with trawls, gill nets, fishing with dynamites, etc. should be carried out and is imperative in fixing priorities.

b) Several nesting areas along the Libyan coasts should be declared as protected areas.

c) Effective protection of the physical characteristics of sea turtle nesting beaches should be taken into account in all future planning for the coastal areas. These efforts should be carried out (not only as sea turtle conservation action), but as part of an integrated approach for protecting marine coastlines, whether they are hosting nesting beaches or not, and for safeguarding their biodiversity.

d) An educational programme to reduce human egg exploitation should be defined for the area between Ras Ajdir and Sabatrah.

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