Chapter

Sea Turtles in Tunisia: An Overview on their Status and Conservation Effort

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Abstract

Three species of sea turtles occur in Tunisia; the loggerhead is the most common. Tunisian coasts are important for this species in the Mediterranean Sea; the Gulf of Gabes is considered a wintering and foraging area. Among many threats, the bycatch is the most impacting. Many studies were carried out on these species and many measures and mitigations were the monitoring of the nesting sites, the ssuch asundertaken tranding events and the development of ..centerssea turtle rescue Although sea turtles are legally protected in Tunisia, more effort to mitigate bycatch is needed. In this chapter, we focus on the compilation of main data on sea turtles and their analysis, in addition to our own new observations, to propose some recommendations for conservation.

Keywords: sea turtles, nesting, bycatch, mitigation, conservation effort, Tunisia

1. Introduction

1.1 Geographic location of Tunisia

Tunisia is a Mediterranean country in Northern Africa, bordering the Mediterranean Sea. Its geographic coordinates are 34°00′N 9°00′E, and it lies between latitudes 30° and 38°N and longitudes 7° and 12°E (**Figure 1**).

1.2 Coastal length and characteristics

The Tunisian total coastline extends for 2290 km with 1566 km of coastline, 267 km of artificialized linear (Port, Marina, etc.) and a linear of 457 km of islands, islets and archipelagos [1].

The north coasts are under the influence of the Atlantic current. The continental shelf is reduced with the presence of rocky bottoms.

The long of the eastern coasts, the bottom of the sea is homogeneous and the continental shelf is very large, especially at the Gulf of Gabes level. This region is

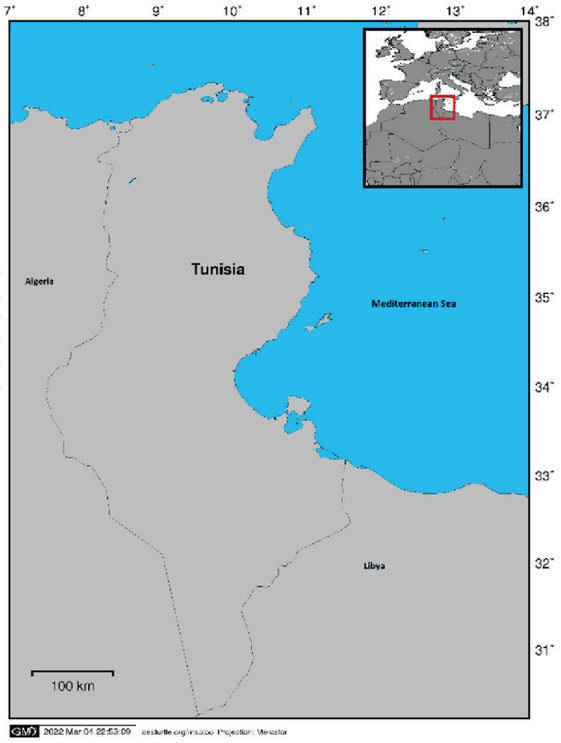

Figure 1.
Map of Tunisia. (The map was created thanks to the Maptool program. Maptool is a product of SEATURTLE.ORG).

characterized by a semi-diurnal tide with a high amplitude (until 2 m). In this sector, the Atlantic current loses its influence. The Gulf of Gabes presents hydro-dynamic and physical and chemical features different from those of the North. The temperature and the salinity are, for example, more elevated.

The important surface of the continental shelf of the Tunisian southeast coasts, the easy access to fishing zones and the presence of the *Posidonia* sea bed that constitutes nurseries for several species of vertebrates and invertebrates made this region an important fishing zone of Tunisia.

From a bio-geographic point of view, the zone Center and especially the South, which is dominated by sandy and muddy funds, have a subtropical affinity characteristic of the oriental basin.

The Tunisian coast presents several well-differentiated landscapes:

- the sandy beaches, which occupy approximately 575 km, constitute the most present landscape on the Tunisian coasts and shelter the major part of the population, essentially in the bays and gulfs of the eastern side of the country;

- the cliff coasts of about 400 km, which are found mainly on the northern facade and to the east of the main capes;

- the coastline with sandy dunes, covered with forest plantations (Zoueraa, Bizerte, Gammarth, Oued Abid, Medfoun, Ghedhabna);

- wetlands.

	North (GSA 12)	Center (GSA 13)	South (GSA 14)	Total
Trawlers	48	98	263	409
Small-scale vessels (With and without engine) including mainly bottom and surface longlines and many kinds of nets.	2272	2745	6451	11,468
Purse-seiners	41	198	151	390
Total	2361	3041	6865	12,267

Table 1.
Fishing effort (total number of vessels in 2022).

1.3 Fishing activities

The Tunisian port chain is made up of 40 ports: 10 deep-sea ports sheltering boats intended for trawling, tuna purse seine and coastal fishing, 22 coastal ports and 8 landing sites: Ten ports north of the country (GSA12: Northern Tunisia), 10 ports in the East (GSA13: Gulf of Hammamet) and twenty ports in the Gulf of Gabes region (GSA 14). (GSA: Geographic sub-area according to the General Fishing Commission of the Mediterranean Sea (GFCM)).

The maritime fishing units active in Tunisia number 12,267 including 11,468 small-scale vessels (**Table 1**) generating a maritime population of around 100,000 fishermen and seafarers.

Several types of fishing are practiced in Tunisia: bottom trawl fishing, purse seine fishing small and large pelagic fish. The smallscale fishery is characterized by a diversification of fishing gears and consequently of metiers. The main ones are: Trammel nets, gillnets, bottom and surface longline.

2. Sea turtles in Tunisia

2.1 Sea turtle diversity

Three species of sea turtles are known in Tunisia; the loggerhead turtle *Caretta caretta*, the green turtle *Chelonia mydas* and the leatherback turtle *Dermochelys coriacea*. The first species is common and nests on some beaches. The green turtle is rarely reported. The leatherback turtle is regularly observed [2].

The Tunisian coasts, mainly the Gulf of Gabès, are of capital importance for the populations of sea turtles in the Mediterranean. The Gulf of Gabès is considered a wintering and foraging area for *C. caretta* [2–10]. This importance has been confirmed by recaptures of tagged female loggerheads after laying on nesting sites in Greece or of ringed juveniles and subadults at sea in the northern Mediterranean. Similarly, satellite monitoring has confirmed such migrations. This migratory gathering is explained by the North-South thermal gradient of the surface waters. The turtles would seek warmer waters. The second reason could be trophic. Turtles feed in winter in southern Tunisia, they eat mainly benthic invertebrates (gastropods, crustaceans and sea cucumbers).

Moreover, regular nesting sites of the loggerhead *Caretta caretta* are known on Tunisian coasts (Kuriat and Chebba) and benefit from regular monitoring

Figure 2.
Sea turtle carapace use (1) Cradle for babies on Kerkennah Island (2) for decoration.

(mainly kuriat islands). Other sites of lesser importance have recently been discovered. It should also be noted that a green turtle nest was reported once on the beach of Rejich (Central East of Tunisia). This nest of the green turtle is the farthest west one discovered in the Mediterranean [11]. The most eastern nesting area occurs principally in Syria [12–14].

2.2 Cultural heritage of sea turtles in Tunisia

Sea turtles were in the past exploited. They are listed among captured species and in the fisheries statistics [15].

The main use of turtles before its ban was for food: "It is often brought to the markets of all the maritime towns where it is used for food" [16]. Its oil is sometimes used as medicine [17]. André [18] indicated that in the Kerkennah islands, the flesh is little sought after, but that the blood and the heart would be remedies against certain diseases. According to him, above all the carapace interests the Kerkenian to make a cradle of it (**Figure 2**). The use of carapace as a cradle is known also in Djerba island (mainly in Guellala). According to Ref. [19], dried eyes prepared as amulets or very young individuals associated with sponges in a basket hung over the head of a bed to protect fishermen from shark attacks or improve women fertility. According to Ref. [3], A survey was conducted in 1978, and it was found that sea turtles are mainly used for food and tourism (sale of shells) (**Figure 2**).

Despite its prohibition and efforts to protect sea turtles in Tunisia, the trade in a clandestine manner was reported in certain regions. A strategy to combat this phenomenon was developed in 2020 [20]. Currently, sea turtles are well protected in Tunisia.

3. Studies on sea turtles and effort of conservation

Scientific work on sea turtles in Tunisia began in earnest at the end of the 1980s following beach surveys which permitted to report the first nesting in 1988 on the beach located between Ras dimas and Mahdia and on Great Kuriat Island [7]. Surveys in the early 1990s also showed the importance of loggerhead turtle nesting on the Kuriat islands and on Chebba beach where 3 nests on the beach of "Sidi Messaoud"

were discovered [21]. The monitoring of the nesting of the sea turtle *Caretta caretta* on the Kuriat islands and the surveys of the different coasts have shown that the Kuriat islands represent the most important nesting site in Tunisia. Scientific work on sea turtles was then diversified and touched on several themes. Several institutions and organizations have been involved in conservation efforts.

Following the ratification of many international conventions by Tunisian government (**Table 2**), many aspects of conservation were developed and made it possible to improve knowledge of this taxon.

Among the legislative conservation tools adopted by Tunisia, there is the Action Plan for the Conservation of Marine Turtles in the Mediterranean Sea (UNEP/PAM) within the framework of the Barcelona Convention and the recommendations of the GFCM and of ICCAT.

Following the ratification of the international conventions mentioned above, Tunisia has developed national legislation. The protection of sea turtles is ensured, at the national level, by the promulgation of law n°94–13 of July 31, 1994, of the Ministry of Agriculture and its implementing decree of September 28, 1995, which organizes fishing activities and the annual decree of the Ministry of Agriculture organizing hunting. These pieces of legislation prohibit the capture, peddling and trade of sea turtles.

In Tunisia, until 1989 sea turtles were sold to markets and consumed freely. After 1989 and following the ratification of international conventions and the drafting of national legislation to protect these endangered animals, such massacres are no longer seen, and turtles caught accidentally are often released at sea.

In the period 1989–2012, many efforts of conservation were undertaken:

- Launching of the monitoring of the main marine turtle nesting site in 1997;
- Launching of marine turtle's rescue center of Tunisia in 2004;
- the national stranding network, dealing with marine turtles and cetaceans, and the tissues bank of marine endangered species in 2004;

Following political and social problems that appeared in 2011–2012, little illegal trade of loggerheads was observed in some localities. Faced with this situation, Tunisia elaborated:

Convention	Adoption	Ratification	Law n.
CITES	1973	1974	74 - 12 of the 11/05/74
Barcelona	1976	1977	77 - 29 of the 25/05/77
CMS	1979	1986	86 - 63 of the 16/07/86
Bern	1979	1995	95 - 75 of the 07/08/95
SPA Protocol new SPA Protocol (1995) and its Annexes (amendment)	1982 1995	1983 1998	83 - 44 of the 22/04/83 98 - 15 of the 23 /02/98
CBD	1992	1993	93 – 45 of the 03/05/93
ACCOBAMS	2001	2001	2001-68 of the 11/07/01

Table 2.
International conventions and agreement ratified by Tunisia.

- The National Action Plan for the Conservation of Sea Turtles

https://www.rac-spa.org/sites/default/files/doc_turtles_project/pan_totues_2020.pdf

- The national strategy to reduce the illegal trade in sea turtles

https://www.rac-spa.org/sites/default/files/doc_turtles_project/strat_turtles_2020.pdf

Moreover, and within the framework of the implementation of the Action Plan for the Conservation of Marine Turtles in the Mediterranean Sea (UNEP/MAP) and its National Action Plan, Tunisia has undertaken various actions in the field of marine turtle conservation:

3.1 Sea turtles and cetaceans stranding network

The study of cetaceans and sea turtles stranded was reinforced at the beginning of 2004 by the creation of a national stranding network. This program is part of the activities of the INSTM marine biodiversity laboratories.

3.2 Awareness activities

Several educational activities aimed at the general public have been undertaken. The programs have mainly relied on the management of fishing activities targeted at the preservation of stocks, on the protection of threatened species and biodiversity and on the development of guidelines necessary for the management of incidentally caught endangered species. Seminars, leaflets, posters, books, radio and television broadcasts have been implemented for this purpose.

3.3 Monitoring of the Kuriat Islands nesting site

The beaches of Kuriat islands, which represent the most important nesting site, have been monitored since 1997 with a seasonal scientific camp. The activity responds to two concerns:

- Herpetological research;
- The conservation of sea turtles.

This monitoring is done within the framework of an annual convention between mainly the National Institute of Sciences and Technologies of the Sea (INSTM), the Coastal Protection and Layout Agency (APAL), the Special Protected Areas Regional Activity Center (SPA/RAC) and the Notre Grand Bleu association (NGB).

3.4 Sea turtles rescue centres

Given the importance of accidental captures of sea turtles and with the aim of helping those in difficulty, a Sea Turtle Rescue Center was created in 2004 at INSTM Monastir and a first aid centre was recently created in the Sfax Faculty of Sciences (2020). The centres contribute to the treatment of turtles stranded alive or tired after accidental captures.

3.5 Research activities

Several researches on sea turtles are carried out in Tunisia within the framework of the monitoring of nesting beaches and the activities of the rescue centres and the national sea turtle and cetacean stranding network. Other research activities were also carried out such as:

- Study of interactions with several fishing gears and mitigation measures to reduce bycatch;
- Studies of migration by metal tags and by satellite monitoring of turtles caught accidentally or on nesting sites;
- Genetic studies;
- Pollution by heavy metals;
- Studies on the ingestion of marine debris and particularly plastic.

4. Some available data on sea turtles in Tunisia

Under this subtitle, we try to compile data on some research needed for conservation programs nesting activity, bycatch and stranding.such as

4.1 Nesting activities in Tunisia

4.1.1 Introduction

The total length of sandy beaches for the entire Tunisian coastline is estimated at 593 km, 6% of which is bordered by a dune field [1].

An intense nesting activity of the Loggerhead turtle was reported since the mid-twentieth century on Tunisian coasts. Already in 1935, [3] wrote: "The loggerhead lays its eggs in the sand of the islands, islets and deserted shores of Tunisia as well as throughout northern Africa. Many other authors stated also that the eastern coast of Tunisia represented the most important region in North Africa for Loggerhead nesting activity, considering the immense range of uninhabited beaches [3, 22, 23].

This intense and widespread nesting of the Loggerhead turtle *Caretta caretta* mentioned in the literature along the Tunisian coastline, in particular in the southeast of the country, was not based on precise information.

Nevertheless, such activity of nesting was truly discovered for the first time in 1988 on the beach located between Ras Dimas and Mahdia and on the Great Kuriat island off Monastir [7], at Sidi Massaoud beach in Chebba [21] and at Zouaraa beach (Beja) in 2016 [24].

Currently, nesting activity of the Loggerhead turtle *Caretta caretta* occurs principally in Kuriat islands [25–30] and Chebba beaches [31–33] which are monitored. The first site is the most important in Tunisia. The two sites are located in the eastern coasts. Since 1997, an annual report is elaborated on the monitoring of the Kuriat nesting sites.

Although the smallness of the two nesting sites, Kuriat islands and Chebba, at the Mediterranean scale, the nesting activity is regularly registered, and the nests number increases since respectively 1997 and 1994.

Besides these documented loggerhead nesting sites in Tunisia, several testimonies mention the presence of other nesting sites. Inquiries about this phenomenon and an exploration of sandy beaches, along Tunisian coasts carried out in 2018 and 2019 confirmed such testimonies and discovered more nesting sites [33, 34].

An exceptional nesting event of green turtle was also recorded in the summer of 2019 in Rejich beach (Mahdia – Eastern coasts) [11, 33]. This nest represents the western most nesting record of the green turtle in the Mediterranean.

Tunisian beaches represent the westernmost nesting grounds for Loggerheads in the southern Mediterranean [7] before the new nesting site recorded recently in Algeria [35].

4.1.2 Monitoring of the sea turtle Caretta caretta nesting on the Kuriat Islands

The Kuriat or Qûrya Islands (35° 48′ 05″ N, 11° 02′ 05″ E) are two small emergences, 2 km away from each other, located east-northeast of Cape Monastir, in front of the bay of Khnis at 11 nautical miles, or about 20 km. These are two small uninhabited islets, characterized by a flat and low morphology not exceeding 4.5 m with several low-pressure areas (**Figure 3**).

The largest one, the Great Kuriat called also Qûrya El Kbira, has an ovoid shape, it is 3.5 km long by 2 km wide and covers about 270 ha.

Almost one third of the Great Kuriat shoreline is rocky and large deposits of sea grass (*Posidonia oceanica*) detritus further restrict the accessible nesting sites particularly in the south and the south-western beaches. The principal nesting beach lies on the western coast and it is almost 900 m in length.

The smallest one, Qûrya Sghira also known under the name of Cogniliera (the island of the rabbits), has an area of 50 ha, most of which is made up of flat and low

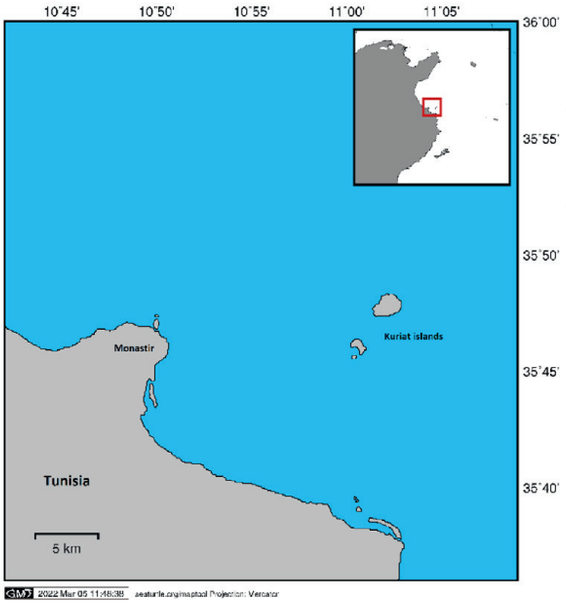

Figure 3.
Geographic position of Kuriat islands off the coast of Tunisia. (The map was created thanks to the Maptool program. Maptool is a product of SEATURTLE.ORG).

land exceedingly very rarely 0 m in the North and in the Northeast, as well as intertidal plains corresponding to the oscillation zone of the marshes. Small Kuriat has a total of 800 m of sandy beach situated in the north-eastern part of the island whereas the rest of the coastline is rocky or marshy. These two sites have been monitored regularly since 1997.

4.1.2.1 Nesting period

The monitoring of nesting on Kuriat islands since 1997 permits to locate the egg-laying period of *Caretta caretta* mainly during months of June, July and August of each year with a pic during the first half of July [29]. The laying during the month of August was registered for the first time during the nesting season of 2003 indicating a spreading of this period especially during the last years. The distribution of laying dates on the Kuriat Islands is found in the range of dates observed in the Mediterranean. Indeed, the loggerhead *Caretta Caretta* begins to lay at the end of May until the end of August, however some individuals continue to lay until early September [36]. This parameter is very important to know for the implementation of any conservation activity. Indeed, its knowledge makes it possible to reduce anthropogenic disturbances, especially when the nesting phenomenon coincides with the frequentation of nesting beaches by summer visitors and tourists [36].

The average number of nests deposited on the Kuriat Islands since 1993 is 21.4 (SD = 13.45; N = 30) (**Figure 4**). The average number of nests deposited on the Great Kuriat and on the small Kuriat are respectively 15.03 (SD = 8.87; N = 30) and 6.37 (SD = 7.02; N = 30). It should be noted that the number of nests has recorded a marked increase over the past 5 years (Mean = 45.4, SD = 3.65, N = 5), which would be the result of the protection effort deployed since the start of monitoring.

It should be noted that last 10 years nesting was recorded in May in Tunisia and in the Mediterranean countries. This early nesting activity could be related to climate change.

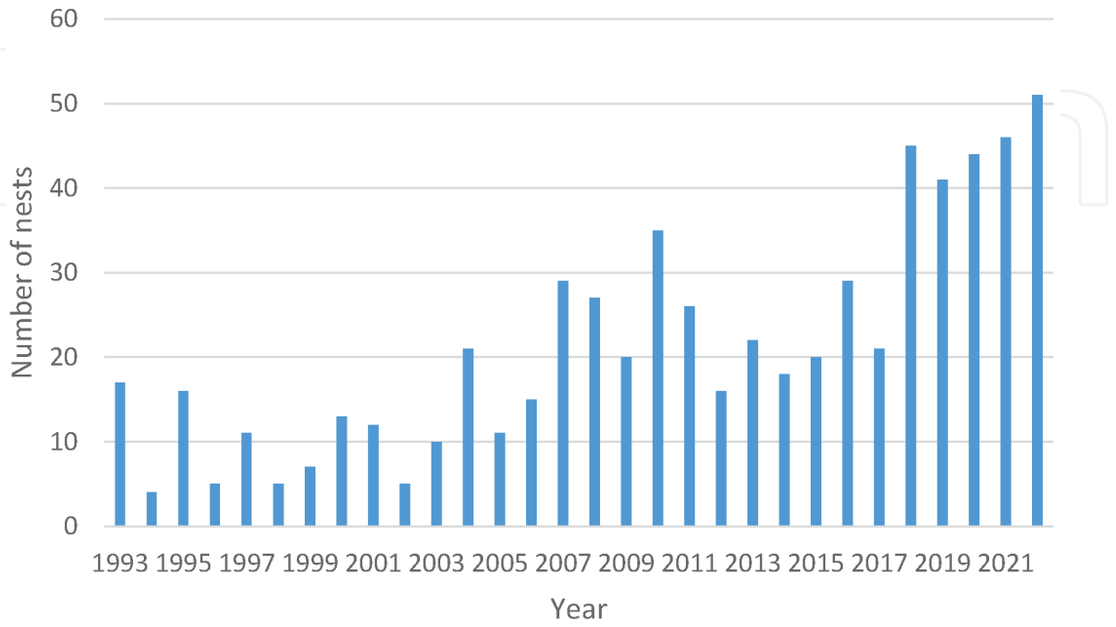

Figure 4.
Number of nests yearly deposited on Kuriat islands.

4.1.2.2 Reproductive parameters

The clutch size (the total number of eggs laid in a nest) on Kuriat Islands varies between 25 to 164 with a mean of 88.95 (N = 375). The hatching and emergence rates for nests under normal conditions exceed usually 60%, which reveals the suitability of the beaches of Kuriat islands [2, 25, 27, 29, 37].

The females' remigration interval (years between breeding migrations) on Kuriat islands is of the order of 2 years, however, intervals of 1 year have been recorded, which shows the importance of satellite monitoring to see if there are turtles who do not migrate too far to come the following year to lay. In fact, this parameter and the clutch frequency (nests per breeding season), are associated with feeding conditions and related environmental factors.

Since 1997, 81 nesting females were tagged. They had a mean CCLn-t (Curved Carapace Length) of 75.97 cm (SD = 4.13; N = 81; individual range: 68–87 cm) and a mean CCW (Curved Carapace Width) of 67.5 cm (SD = 3.86; N = 81; individual range: 61–77 cm). These data confirm that nesting females in the Mediterranean have generally curved lengths greater than 70 cm [10].

4.1.2.3 Genetic

Genetic analysis has been undertaken on the nesting site of Kuriat. Freshly dead Hatchlings of loggerhead have been analyzed for the long mtDNA control region sequences. Only the widespread Mediterranean haplotype CC-A2.1 has been detected when analyzing the long sequence of 800 bp. Anthropogenic impact linked mainly to fishing and touristic activities resulted in the observed reduced genetic diversity of the nesting population [38].

4.2 Monitoring of sea turtles *C. caretta* nesting sites of Chebba

Chebba is located off Cape Ras Kaboudia which is the most easterly point of the Tunisian coasts (**Figure 5**). It has the particularity to spread like a peninsula and the sea surrounds it on three sides. It has 29 km of coastline with some islets.

Two nesting sites are known in Chebba "Essir" and "Sidi Messaoud" beaches (**Figure 6**)."Essir" is the main beach of Chebba. It has a length of approximately 600 m and spreads between the two points with GPS coordinates: 35°14.386′N/011°08.557′E and 35°14.268′N/011° 08.892′E. This beach is very busy during the summer, day and night.

The beach of "Sidi Messaoud" is contrary to "Essir" and less crowded. It is a small beach of about 200 m in length located behind the fishing port and adjacent to the Roman archaeological site "Borj Khdija". It spreads between the two GPS points: 35°14.108'N/011°09.442′ E and 35°13.998′N/011°09.604′E.

The history of the nesting activity in the two nesting sites of the Chebba area can be summarized as follows (**Table 3**).

The available information on the studied nests deposited in Chebba beaches (N = 10) shows that the clutch mean is 87 eggs by nest and hatching and emergence rates are respectively 66.5 and 66.2. These rates are within the range of what is registered in the Mediterranean indicating that beaches of Chebba are suitable for nesting activity.

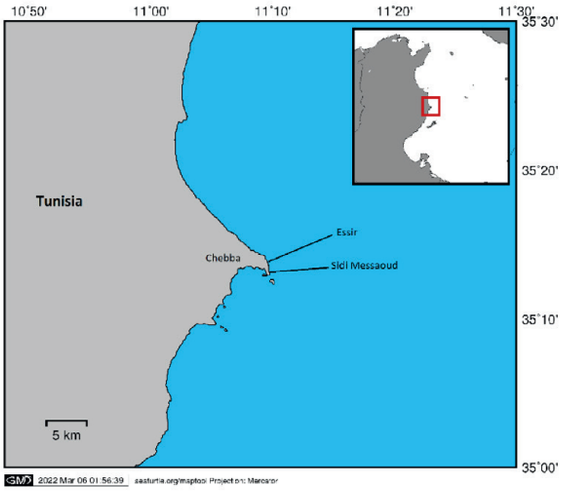

Figure 5.
Geographic position of Chebba and nesting beaches.

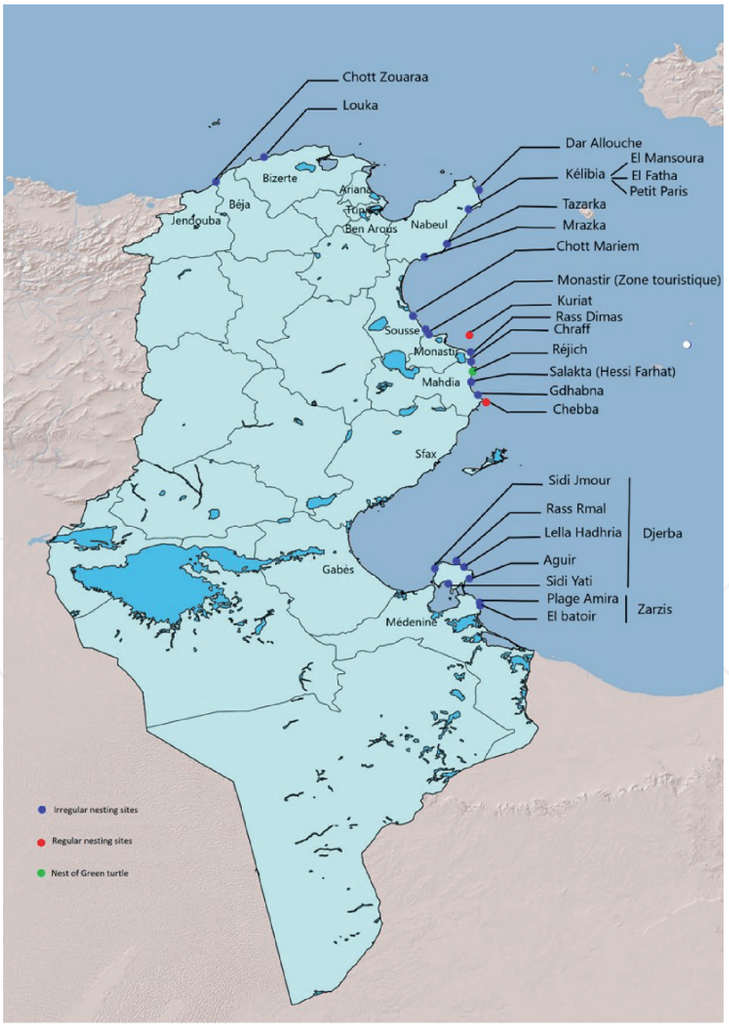

Figure 6.
Map of Tunisia with locations of nesting beaches known and discovered in 2018–2020.

Year	Nesting activities
1994	First record of 2 nests of Loggerhead on Sidi Massaoud beach [21]
1995	One nest deposited on Sidi Massaoud beach [21]
1996–2000	No nesting activity recorded.
2003	Hatchlings recorded close to Essir Beach.
2004–2012	Nesting activity recorded each summer in Essir Beach.
2013	Six nests deposited at Sidi Messaoud Beach and four at Essir Beach.
2019	Four nests were deposited in 2019; two on the beach of "Essir", one at "Sidi Messaoud" and one on another beach called "El Koucha".
2023	Seven nests deposited on different beaches

Table 3.
Historic loggerhead nesting activities in Chebba sites.

4.3 New nesting site discovered

We consider in this study the nesting site definition of Girondot and Fretey [39]: "A marine turtle nesting site is considered to be any surface where at least one female of any species of sea turtle has laid eggs in historical times".

Global warming is affecting habitat quality and availability on our planet and some species are predicted or already being observed to change their distribution range. Marine turtles are a particularly interesting case to study in this respect since they have already survived and adapted to several important climate change events throughout their >1 million years of evolutionary history and they colonized tropical and subtropical nesting habitats around the world notwithstanding their natal philopatry. However, current climate change is happening at a much faster rate and is expected to have profound effects on the adaptability of sea turtles whose life history is characterized by longevity, late age of maturity and temperature-dependent sex determination. It seems that in the Mediterranean, loggerhead turtles have already started to expand their nesting range from the eastern to the western basin, which has only been known to host sporadic nests but reports of nesting activity have been increasing since the 2010's [40].

In Tunisia, many testimonies and observations confirm this tendency and many nests were deposited even in sites not considered before by nesting activities.

In the frame of the project "Conservation of sea turtles in the Mediterranean region" coordinated by SPA/RAC and financially supported by MAVA (2018–2019), exploration of sandy beaches, along Tunisian coasts, looking for new and potential sea turtles nesting sites, was done.

Primarily results show that about 20 sites were identified as nesting sites for the loggerhead turtle, where previous or current nests were detected (**Figure 6**).

Moreover, the study of the quality of beaches patrolled indicates that the majority of them are favorable for nesting activity which allows us to consider them as potential nesting sites.

As noticed, surveys on Mediterranean coasts and especially on the coasts of the western basin show that nesting activity has increased recently from 1 year to another in many Mediterranean countries. Global warming phenomenon and increase of observation effort, mainly in the frame of science citizen, could be responsible for the extension of the nesting areas.

In Tunisia 65 nests were registered in 2020; 44 in Kuriat islands and 21 nests in other beaches of Tunisian coasts. **Figure 6** shows all nesting sites known in Tunisia for the moment.

Besides Kuriat islands and Chebba beaches, those considered nesting sites during 2016–2020 and where nests were really observed are presented in **Table 4**.

It is also noticeable that many other sites were discovered last 5 years in Tunisia.

4.4 First record of *Chelonia mydas* nesting in Tunisia

Following a testimony reported to NGB (association Notre Grand Bleu) on the discovery of a sea turtle nest on Rejich beach in summer of 2019, an expedition of experts and volunteers discovered that it is a nest of green turtle *Chelonia mydas*, hatchlings (**Figure 7**) gave more confirmation [11].

The nest was laid on August 03, 2019, on the beach of Rejich, 35.449871°N; 11.044676°E. Sea-nest distance was 19.5 m and cavity depth was 70 cm from the surface.

Sixty hatchlings reached the sea securely, while no hatchlings were found dead either inside or outside the nest. Hatching success was calculated as 54.5%

Year	Governorate	Nesting activities
Beach name: Zouaraa (Nefza)		
2016	Beja	*One nest deposited* [24]
2018	Beja	*One nest deposited*
2019	Beja	Two nests
2020	Beja	Four nests
Beach name: Louka 2		
2018	Bizerta	Nesting activity detected
Beach name: Fetha (Kelibia)		
2018	Nabeul	Flooded nest
2020	Nabeul	Nesting activity detected
Beach name: Mansoura (Kelibia)		
2018	Nabeul	One nest
2020	Nabeul	One Lost nest
Beach name: Petit Paris		
2020	Nabeul	Nesting activity detected
Beach name: Dar Allouche		
2020	Nabeul	Nesting activity detected
Beach name: Echraff		
2020	Mahdia	Two nests [41]
Beach name: Chott Mariem		
2020	Sousse	One nest [41]

Table 4.
Nesting sites recorded and number of nest-laid during 2016–2020.

Figure 7.
Green turtle newborn hatching in Tunisia (Rejich Beach, 2019).

(Eggshells/clutch size X 100). The remaining 50 eggs (unhatched eggs) were identified and included 14 early embryony stages (12.73%), 2 late stages (1.82%) and 34 unfertilized eggs (30.91%) [11].

4.5 Main threats on nesting beaches

- The nesting sites of small Kuriat and Chebba are highly frequented by swimmers during nesting season (**Figure 8**). The beaches are heavily used by humans and disturbance of the sand may have impeded the detection of turtle tracks or nests [2, 37].

- The black rat *Rattus rattus*, abundant on small Kuriat attacks hatchlings after emergence (**Figure 8**). Deratization undertaken by " Notre Grand Bleu " association in 2016 has resolved the problem.

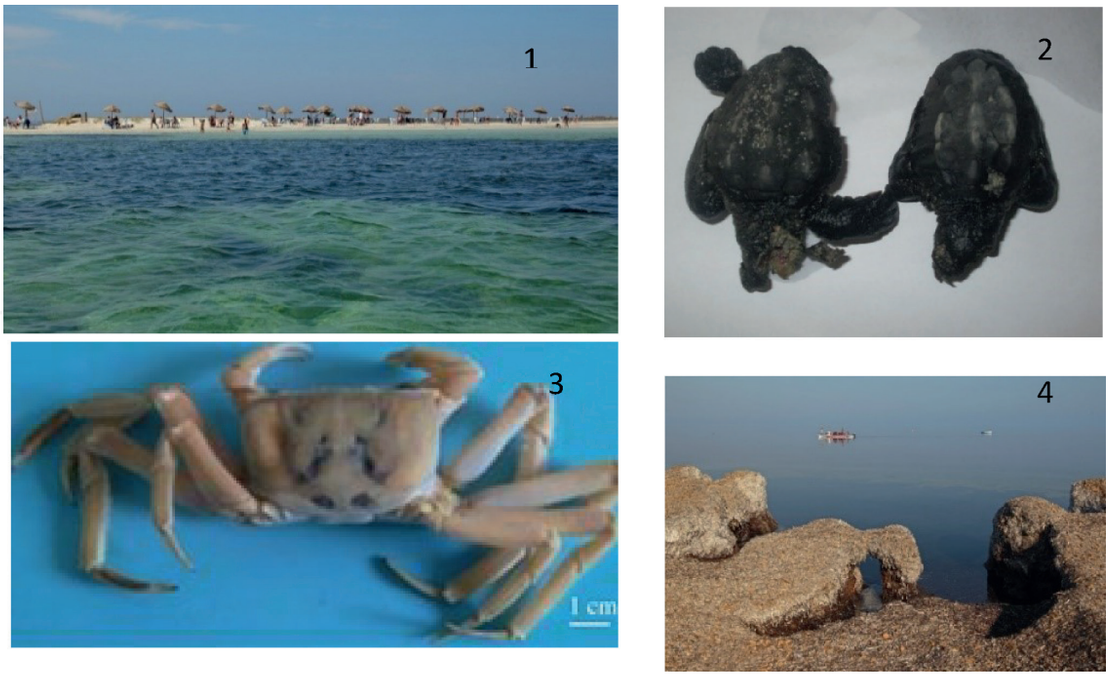

Figure 8.
*Threats on nesting beaches: (1) Beaches of small Kuriat highly frequented (2) Hatchlings on the small Kuriat attacked by rat on their heads (3) Specimen of Ocypode cursor from the south of Tunsia 340] (4) Large deposits of seagrass (*Posidonia oceanica*) on the beaches of great Kuriat.*

- Sea gulls *Larus carchinans*, common on the Kuriat islands, seem to engender predation of hatchlings, mainly of those that emerged during daytime.

- The tufted ghost crab *Ocypode cursor* (**Figure 8**) is the only Ocypode species present in the Mediterranean Sea. The first observation of this crab, known to be a predator of sea turtles' hatchlings and eggs, in the Tunisian coasts was made by a hazardous observation of specimens emerging from their burrows in June 2018 near a nest of loggerhead turtle in the Kuriat Islands [42].

- The large deposits of phanerogam (*Posidonia oceanica*) on the beaches of Great Kuriat (**Figure 8**) mainly restrict the accessibility of nesting females to the site. These deposits of *Posidonia* hinder also the return of hatchlings to the sea after their emergence. However, the deposits constitute a natural protection of the beaches from waves and inundation.

- Light pollution concerns the two nesting beaches of Chebba [31, 32]. The light of the cornice and the port attract the hatchlings after their emergence. Hatchlings, disoriented, finish on the road behind the cornice where they are crushed by cars.

5. Bycatch of sea turtles

5.1 Bycatch and mortality rates

Bycatch of sea turtles in commercial fisheries occurs along Tunisian coasts but it is more important and more assessed in the Gulf of Gabès. This area is the most important fishing area that comprising about 50% of the Tunisian fishing fleet [48].

The high concentration of the fishing effort in the Gulf of Gabès has led to overexploitation of fish stocks and is contributing to bycatch of several threatened species as well as of many fish species. Besides, other pressures such as pollution and the spreading of alien species have contributed to the degradation of the ecosystems [48].

In this region, a large fishing fleet using many kinds of fishing gear operates during different seasons and targets a wide variety of commercially important species. These fisheries constitute the main threats to the sea turtles, through the direct mortalities and injuries associated with incidental bycatch. Although observations show that both species; the loggerhead turtle *Caretta caretta* and the leatherback turtle *Dermochelys coriacea* were captured by fishing gear in the Gulf of Gabès, the occurrence of the latter is very sporadic. Several studies have quantified the bycatch of sea turtles from various gears in the Gulf of Gabès (**Table 5**). The bycatch rates observed varied between the different gears and studies and were highest in gillnet fishery and pelagic longlines (**Table 5**). In terms of mortality, the highest rates were recorded by gillnet followed by bottom longlines (**Table 5**). The high mortality rates associated with gillnets, targeting sharks, it may be a result of the long soak time [48, 49]. In these fishing gear captured sea turtles might not be able to reach the surface to breathe and eventually die of asphyxia. In the Gulf of Gabès, sea turtles are bycaught because of the high degree of spatial overlap between the fishing grounds and the habitats of this species [43, 45, 49].

Although some studies exist on the impact of fishing gears on the *Caretta caretta* in the Gulf of Gabes region, the data remains fragmentary and the level of interaction of sea turtles with fisheries remains poorly assessed. Indeed, they are limited to

Fishing gear	Observed catch rate	Estimated total captures	Recorded mortality	Reference
Pelagic longline	0.823 (0.568–0.158) turtle/1000 hooks	486 (335–683)	0%	[46]
	0.806 (0.802–0.810) turtle/1000 hooks	437 (299–609)	12.1%	[44]
	0.25 turtle/1000 hooks	100	3.44%	[45]
Bottom longline	0.278 (0.179–0.415) turtle/1000 hooks	733 (470–1090)	33%	[43]
	0.333 (0.236–0.591) turtle/1000 hooks	142 (100–167)	43.7%	[45, 47]
	0.26 turtle/1000 hooks	688	9.41%	[45]
Trawl	0.0114 (0.0085–0.0143) turtle/ haul	5458 ± 1652	3.3%	[52]
Gillnet	0.527 (0.403–0.649)/ km^2/day	444 (358–501)	69.4%	[43]
	0.63 (0.355–0.893)/ km/day	3756 (1908–5902)	92.06%	[49]
Trammelnets	0.92 turtles day^{-1} km^{-1}	2000		

Table 5.
Observed catch rates (95% C.I), estimated yearly captures (in numbers), and mortality rates of loggerhead turtles registered by different gears in the Gulf of Gabès.

restricted areas in the Gulf of Gabès and concern only some metier. Furthermore, some discrepancies in the results regarding capture and mortality exist (**Table 5**). This could be due to the study period and the metier.

Recent Interviews conducted with fishermen in 19 ports along the Gulfs of Gabes and Hammamet revealed that sea turtle bycatch per unit effort (BPUE) was the highest for Gillnet (0.73 turtles/vessel/day), followed by pelagic longlines (0.6 turtles/vessel/day) (**Figure 9**). However, due to the trawlers' high fishing effort, the cumulative impact of the trawl nets was the highest with an estimated number of 11,740 (0–41,525.75) turtles caught per year in Tunisia [50]. These results corroborate the previous ones in that they show the same conclusions: Gillnets and pelagic longlines are the most gears impacting sea turtles.

Investigations made in the frame of the Medbycatch project (March 2019–January 2022) indicated that all fishing gears operating in the Gulf of Gabès affect sea turtles because of the overlap of their areas of activity with the feeding and wintering grounds (**Figure 10**). Overall, small-scale fisheries including nets and longlines are the main threats of sea turtles followed by trawlers.

The mortality at haul back of sea turtles is higher in small-scale fisheries (**Figure 11**). Among small-scale fisheries, gillnets have the highest mortalities (**Table 6**, **Figure 11**). However, fishermen are aware of the status of this species along the Tunisian coasts and all alive individuals at retrieval are generally released.

Considering the Tunisian coasts, MedBycatch project surveys showed that more than 70% of sea turtle catches occurred in the Gulf of Gabès followed by the Gulf of Hammamed (GSA13) where more than 27.5% of bycatches were reported. However, Sea turtle captures along the northern coasts (GSA, 12) were very scarce.

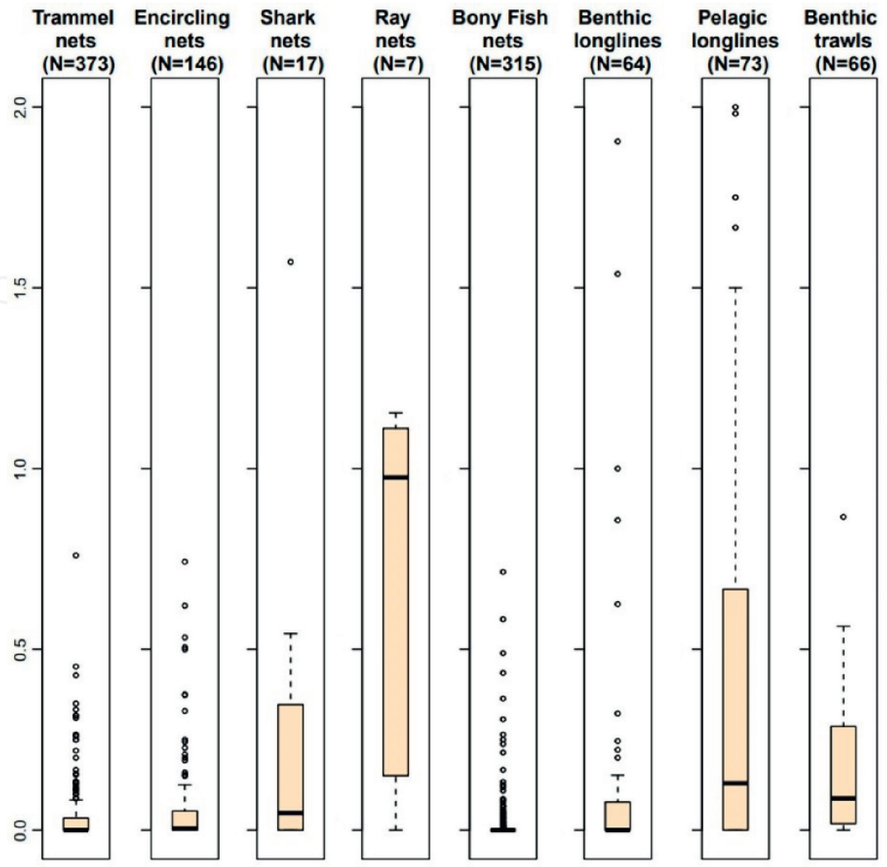

Figure 9.
Sea turtle bycatch per day of fishing (BPUE) [50].

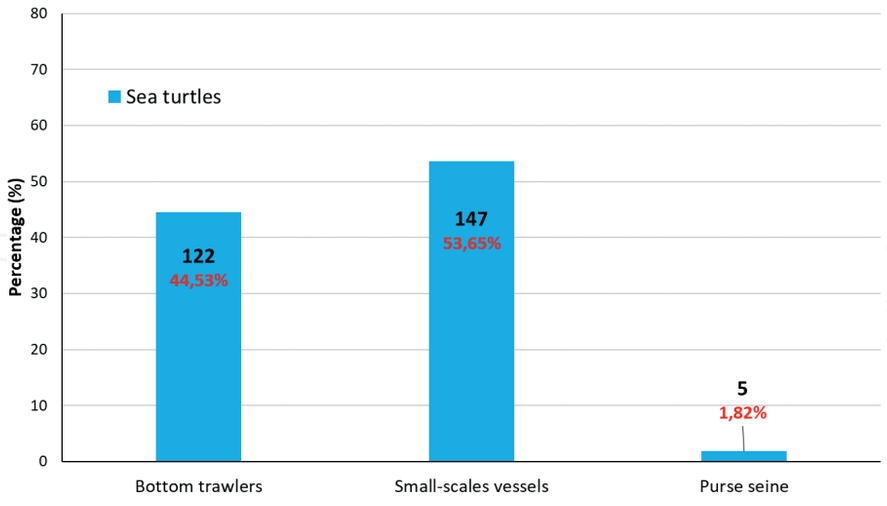

Figure 10.
Percentage in number of individuals caught accidentally by gear type in GSA 14.

5.2 Mitigation measures

In Tunisia, as in the rest of the Mediterranean basin, certain mitigation measures have been experimented with to reduce the capture and mortality of sea turtles. These measures include the use of circle hooks for longlines, soak time and depth. These studies remain preliminary and require further experiments for consolidation. On the

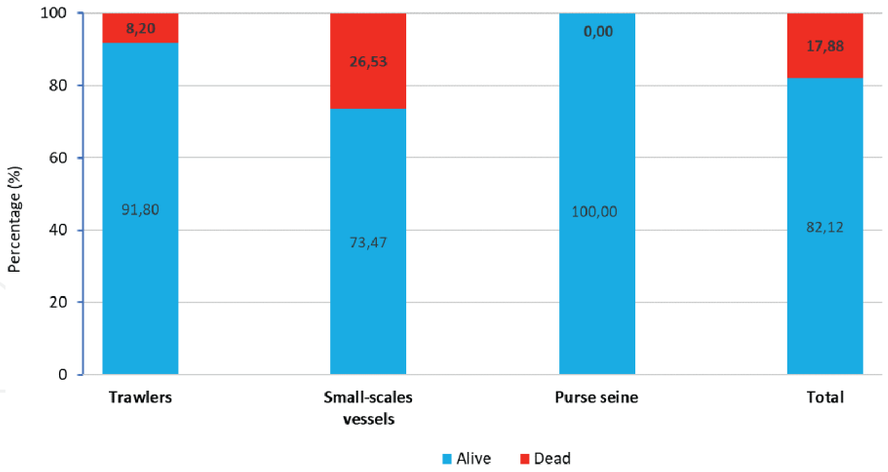

Figure 11.
Mortality at haulback of Caretta caretta *in percentage by gear type in GSA 14.*

Species	GSA 12	GSA 13	GSA 14	Total
Caretta caretta	46	116	575	737
Chelonia mydas	0	0	2	2
Dermochelys coriacea	2	1	11	14
Undetermined	2	9	39	50

Table 6.
Distribution of sea turtle strandings by GSA (2020–2022).

other hand, no requirements to use these have been put in place, and the results are still controversial.

The use of circle hooks as a mitigation measure in pelagic longline fishery appear not promoting indeed it increases the catch rates of Sea turtles [45]. However, in the frame of Medbycatch project, reducing soak time to less than 12 hours for gillnets appears encouraging, in fact, the mortality rate decreases significantly when reducing the soak time. In the other hand, investigation showed that the bycatch rates of sea turtles decrease significantly with depth in gillnets, longlines and trawls suggesting that excluding fishery activities from coastal waters would reduce the impact of these fisheries on sea turtles. Fishing at depth beyond 30 m reduces largely the bycatch of sea turtles. Besides, increasing fishers and administration's awareness about sea turtles may help to improve the conservation of this species in Tunisia.

6. Sea turtle stranding

The study of stranded marine turtles was strengthened in the beginning of 2004 through the creation of the National Stranding Network (RNE). This program was included in the activities of the National Institute of Sciences and Technologies of the Sea (INSTM). Mainly three groups (researchers, veterinary doctors and students) have been set up to this effect, one based in the north, a second group based in the center and a third one in the south.

Many other actors are also involved in the records of stranding such as:

- The Sfax Faculty of Sciences (FSS);
- NGOs: The Notre Grand Bleu association, AJEM association, TunSea and many others;
- The World Wildlife Fund-North Africa.

For each stranding event, many data were registered, such as dates, Global Positioning System coordinates or location, kind of coast (sandy, rocky), body measurements, sex and species identification. Animals' conditions were reported as live animals, freshly dead, moderately decomposed (organs basically intact), advanced decomposition (organs not recognizable) and mummified/skeletal remains. Necropsy was performed on fresh and moderately decomposed animals. Tissues were taken for histopathology, toxicological and genetic analyses; they were frozen at −20°C or preserved in ethanol and stored at INSTM; the presence and nature of parasites and epibionts were noted.

In this chapter, we present the analyze of stranding data 2020–2022 (RNE commission report, 2023).

During this period, 806 stranding events were recorded including 740 (92%) loggerhead turtles *Caretta caretta*, 14 (1.73%) leatherback turtles *Dermochelys coriacea* and 2 (0.25%) green turtles *Chelonia mydas*. These results confirm that the loggerhead turtle is the most common species on the Tunisian coasts, the green turtle is, in fact, rare while the leatherback turtle is regularly observed in Tunisian waters [51]. 50 specimens have not been determined.

6.1 Sizes of stranded turtles

Among the 529 loggerhead turtles measured, the Curved Carapace Line of the smallest stranded is less than 20 cm, the largest was a female of 91 cm. The most represented size classes are those of juveniles to sub-mature (SCCL between 60 and 70 cm) (**Figure 12**).

This bell-shaped distribution (**Figure 12**) would be due to the fact that large juveniles are the most affected by accidental captures [43, 47], which would increase the number of stranding cases.

The low percentage of strandings of small turtles (SCCL <30 cm) would be due to the absence of interaction with fishing gear, especially during the first years of their life (Lost Years) when they seem to disappear. Before reappearing again 2 or 3 years later.

The low percentage of adults in the strandings seems to confirm the smallness of the nesting population in Tunisia.

For the 11 leatherback turtles *Dermochelys coriacea* measured, the Curved Carapace Line (CCL) of the smallest stranded is 138 cm, the largest was a female of 180 cm. The most represented sizes are between 140 and 160 cm) [52].

6.2 Sexes of stranded loggerheads

91.19% of the 227 adult turtles recorded are female

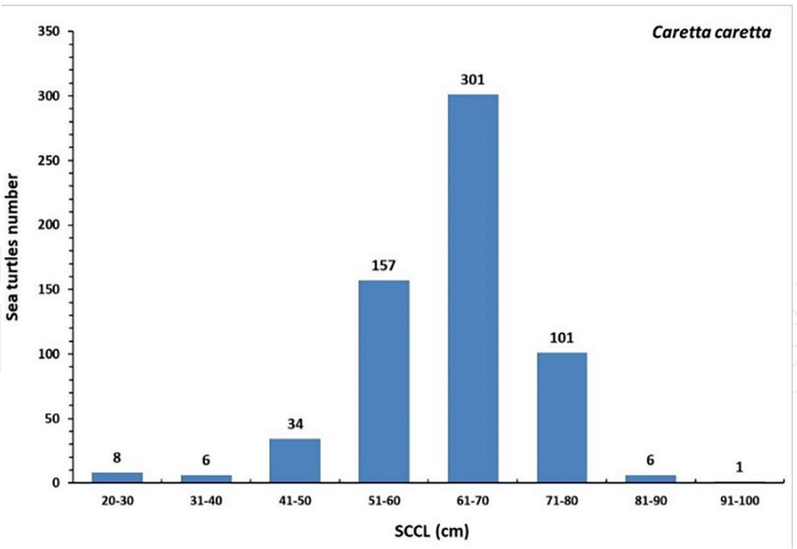

Figure 12.
Number of stranded loggerheads by size classes 2020–2022.

6.3 Spatio-temporal distribution of strandings

Strandings are more concentrated in southern Tunisia (GSA 14) (**Table 6**; **Figure 13**). This result confirms that:

- The Gulf of Gabès (GSA 14) is a foraging and wintering area for marine turtles in the Mediterranean [3, 6, 8]

- Turtle strandings are believed to be caused mainly by fishing. Indeed, the Gulf of Gabès area is an important maritime fishing area in Tunisia and is home to most of the country's fleet.

It should be noted, however, that the effort to prospect for strandings is not uniform for the three regions considered. It is more important in the Gulf of Gabès.

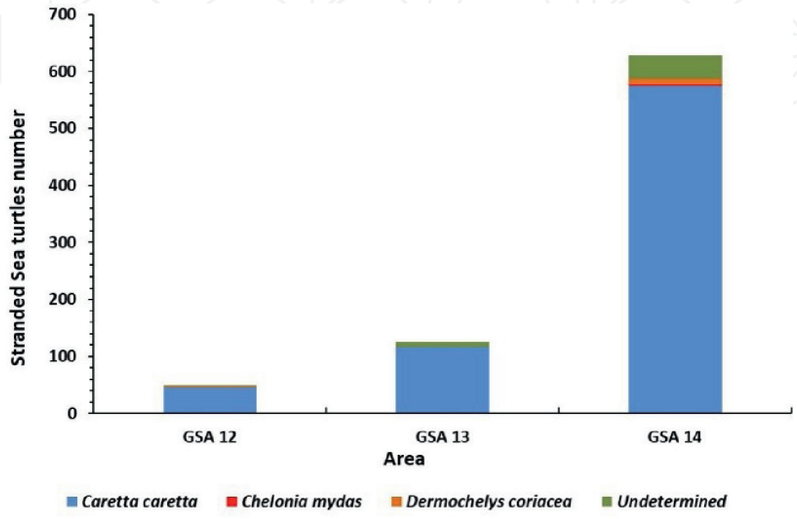

Figure 13.
Spatial distribution of sea turtle strandings (2020–2022).

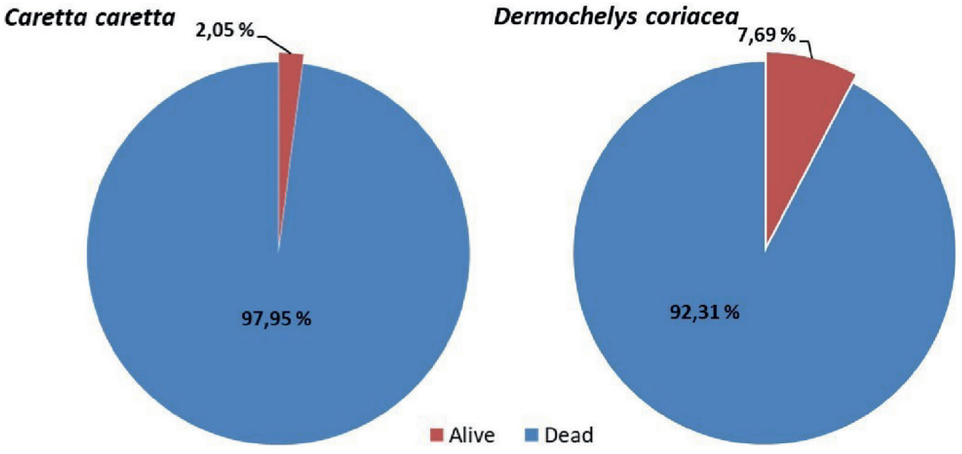

Figure 14.
Distribution of strandings between dead and alive (2020–2022).

Concerning the temporal distribution, strandings are more observed in spring and summer for the period 2020–2022 with a peak in May.

6.4 Causes of death

The majority of stranded turtles are dead, in fact, approximately 98% of loggerhead turtles and more than 92% of leatherback turtles arrive dead on the beach (**Figure 14**).

The interaction with fishing appears to be the major cause of marine turtle mortality when the mortality factor is known. Among the most impactful fishing gear, gillnets targeting elasmobranchs should be noted.

7. Conclusion

Sea turtles, once abundant in Tunisia at sea and on nesting beaches, were marketed for several uses. These uses are anchored in the collective memory of the population, especially islanders (food, shells for decoration and as cradles for babies, medicines, etc.). Faced with the unprecedented acceleration of the collapse of their global populations following several anthropogenic threats, they have become threatened with extinction and their conservation has become urgent. Bycatch seems to be very threatening. The available data on the assessment of bycatch clearly show that sea turtles are among the taxa most affected by accidental fishing on all Tunisian coasts and that several gears bring them back with different rates.

Several mitigation measures have been tested. We mainly cite the reduction in loggerhead catches in gillnets targeting elasmobranchs "Garracia" by implementing spatio-temporal solutions (depth, soak time). Similarly, catches of this species in trawls decrease with increasing depth. In addition, several conservation tools developed in Tunisia (legislation, rescue centers, stranding network, monitoring of nesting sites, etc.) have contributed to the protection of sea turtles in Tunisia, and even in the Mediterranean Sea. Fishers automatically release turtles caught accidentally at sea and even intervene in the release of turtles entangled in nets and in informing the authorities and care centers.

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