EP

United Nations Environment Programme

UNEP(DEPI)/MED WG.359/inf.8 Rev.1
16 May 2011

ENGLISH
ORIGINAL: ENGLISH

MEDITERRANEAN ACTION PLAN

Tenth meeting of the Focal Points for SPAs

Marseilles, France, 17-20 May 2011

Satellite Tracking of Marine Turtles in the Mediterranean Current Knowledge and Conservation Implications

In the framework of a sustainable development approach, this document will be available only in electronic format during the meeting

UNEP
RAC/SPA - Tunis, 2011

The original version of this document has been prepared for Regional Activity Centre for Specially Protected Areas by Flegra Bentivegna & Sandra Hochscheid, Stazione Zoologica Anton Dohrn, Napoli (Italy)
.

Background

Over the past decades satellite telemetry has become extremely popular in the study of marine turtle movements and it is often used not only for scientific reasons but has also become a means of attracting public attention and raising awareness towards the critical status of these charismatic marine reptiles (Godley et al., 2007). It is not always possible to find published information on specific tracking projects and few users of the technique make the effort to publish their results in scientific journals. However, the world wide web offers numerous information sources, since broadcasting of even single movement tracks is much more immediate than the tiresome and time-consuming process of getting a paper through the review process and finally into print. For sea turtles, the most important web-based information platform is undoubtedly the rapidly developing and increasing seaturtle.org (a registered, web-based organisation that supports research and conservation efforts in the world's sea turtle community; www.seaturtle.org). This webpage contains a dedicated section only for satellite tracking and has so far gathered movement data of >3500 animals (mostly turtles, but including also other animals), therefore providing the most comprehensive overview on the dimensions that the tracking of sea turtles has taken to.

Telemetry literally means “measuring from a distance”, allowing to monitor the movements of an animal also in remote and difficult to access habitats such as the open ocean (O'Dor and Webber, 1998). Technically, satellite telemetry involves a platform transmitter terminal (PTT), which is attached to the carapace or head of the turtle, i.e. those body parts that emerge above the water surface when the animals breathes. The PTT sends short messages (<1 s) to the orbiting satellites of the Advanced Research and Global Observation Satellite (ARGOS) system (www.argos-system.org), from where the messages are transferred to ground receiving stations and then to ARGOS Processing Centres. The Processing Centres calculate the position of the transmitters and deliver the results to the users. Locations are calculated by measuring the Doppler Effect on transmission frequency of subsequent messages. For each location for which at least four messages are received during a satellite pass, an estimated accuracy (= location class) is calculated. Location classes 1, 2, 3 and 0 have a radius of error of <250 m, < 500 m, < 1500 m, and > 1500 m, respectively. Additionally, locations classes A and B are assigned to locations calculated from 3 or 2 messages only, respectively, but no accuracy is provided (see AROGS manual for further information: http://www.argos-system.org/documents/userarea/argos_manual_en.pdf).

Because radio frequencies are severely attenuated in saltwater, transmitters for marine animals are usually equipped with a saltwater switch that synchronises transmissions with the time that the animal returns to the water surface for breathing. However, marine turtles spent only short intervals at the surface, and hence time for transmissions and the number of messages sent during one satellite pass are very limited. Additionally, unfavourable environmental conditions (e.g. cloudiness, rough sea state etc) can further impede transmissions and, finally, there may be no satellite overpass at the short time that the turtle stays at the surface. The latter becomes particularly crucial when duty cycles are employed to save battery power and thus prolong the lifetime of the PTT. ARGOS offers satellite overpass forecasts, so that the time window of the PTT's on-state can be synchronised with the interval of maximum satellite encounters. However, even taking all possible precautions, satellite tags often stop transmitting long before battery power is used up. After all, it should always be kept in mind, that the physical properties of seawater and the consequences of the turtles' behaviour form an extremely hostile environment for an electronic device, so that occasional dysfunction can be expected. Saltwater switch failure, antennae breakage, animal mortality and premature detachment of tags were identified as the most commonly encountered reasons for signal loss (Hays et al., 2007).

For above described reasons sea turtle satellite data are dominated by class A and B locations and much less locations with assigned accuracy. It is possible that the users of satellite telemetry can determine the accuracy of locations A and B through trials with PTTs in fixed locations by themselves, but once the PTT is deployed on the turtle differences in diving behaviour may actually affect the accuracy of locations (Hays et al., 2001). At any rate, it is common practice to reconstruct migratory path by applying a filter to eliminate those locations that imply course reversals, unnaturally high swimming speeds (e.g. > 9 kmh^{-1}), or erroneous locations on land (except those where turtles were nesting, e.g. Luschi et al. (1998). However, the determination of speeds of travel requires more prudent estimates of location accuracies, and an analysis of the factors that likely influence turtle movements such as current direction and speed, locations (e.g. oceanic vs neritic) and the turtle's diving behaviour and activity patterns (Hays et al., 2001).

The analysis of the data format provided by ARGOS can be quite tedious and time consuming and hence, apart from the obligatory reconstruction of the migration route, data sets are rarely exploited for all the potential information that they could provide, and even more rarely integrated with other data sets (e.g. remote sensing of environmental factors). Therefore, the freely available Satellite Tracking and Analysis Tool (STAT, www.seaturtle.org.stat) was developed to help researchers downloading, managing, filtering and analysing their tracking data (Coyne and Godley, 2005). Currently, there are >1500 turtle tracks archived in STAT and more than 3900 tags including all animals (M. Coyne, personal communication). These large numbers of users underline the importance of STAT for analysing satellite tracking data and, ultimately, for improving the knowledge on basic life history patterns of sea turtles.

A recent comprehensive review of over 130 scientific papers on sea turtle tracking studies highlighted the knowledge that was gained on temporal and spatial movement patterns, habitat use, post-release survival following fisheries interaction and rehabilitation, and key areas for conservation (Godley et al., 2007). It was also clearly revealed that there are biases in the wealth of data particularly with regard to geographic region, species and life stages. The authors summarised that 82% of the satellite tracking studies included only 3 species (loggerhead, green and leatherback turtles), and >75% were conducted on adult females. About 11% of the worldwide turtle tracking was carried out in the Mediterranean. These figures have likely changed until today, but tracking in the Mediterranean is proportionally well represented with respect to other geopolitical regions. This report summarises the current knowledge on satellite tracking of sea turtles in the Mediterranean Sea and concludes with considerations about management and conservations strategies that can be deduced from the available information.

Sources of Data and Data Summary

The data on satellite tracking of Mediterranean marine turtles were obtained from two principal sources: 1) scientific publications in peer-reviewed journals, and 2) information from abstracts and papers in conference proceedings. A list of scientific papers on the subject was obtained through a literature search using the ISI Web of Science search engine (www.isiknowledge.com). A detailed list of all references used in this report is provided at the end of this document. Additionally, when no other publication was available, data available for viewing in the tracking section of www.seaturtle.org were also considered.

For this report, only those sources were considered which presented a map showing individual routes of sea turtle movements and where such movements had been monitored through satellite telemetry. Data on mark and recapture were not taken into consideration, since most of this information is not publicly available and remains part of institutional data-bases. The general data summarised for this report referred to species, sex, life stage, dates and total days of tracking, release location, total distance travelled and the name of organisation in charge of the tracking project. However, not all of these parameters were available for each tracked turtle. A summary table of the number of turtles and tracking projects is attached in Appendix I.

To produce the final graphs showing the main migration routes it was convenient to distinguish four groups relative to the movements of A) adult post-nesting female turtles, B) adult female turtles not related to the reproductive season, C) sub-adult and adult male turtles, and D) juvenile turtles. Only group A contained data on both green and loggerhead turtles. Satellite transmitters were deployed during the reproductive season while the turtles stayed on the beach and laid eggs. Subgroups B, C and D contain only data for loggerhead turtles, which were partly obtained from rehabilitated turtles that spent variable periods in a sea turtle rescue facility before being released with a satellite transmitter. The remainder was caught directly from the sea either intentionally for the research purpose or incidentally by fishing gear, and were then released after being equipped with a satellite transmitter.

Tracking Turtles in the Mediterranean – An Overview

This review on satellite tracking of marine turtles in the Mediterranean is based on a total of 164 turtles, released from eleven countries (in order of decreasing number of turtles released: Italy, Greece, Spain, Cyprus, France, Israel, Tunisia, Libya, Malta, Turkey and Syria (Fig. 1)).

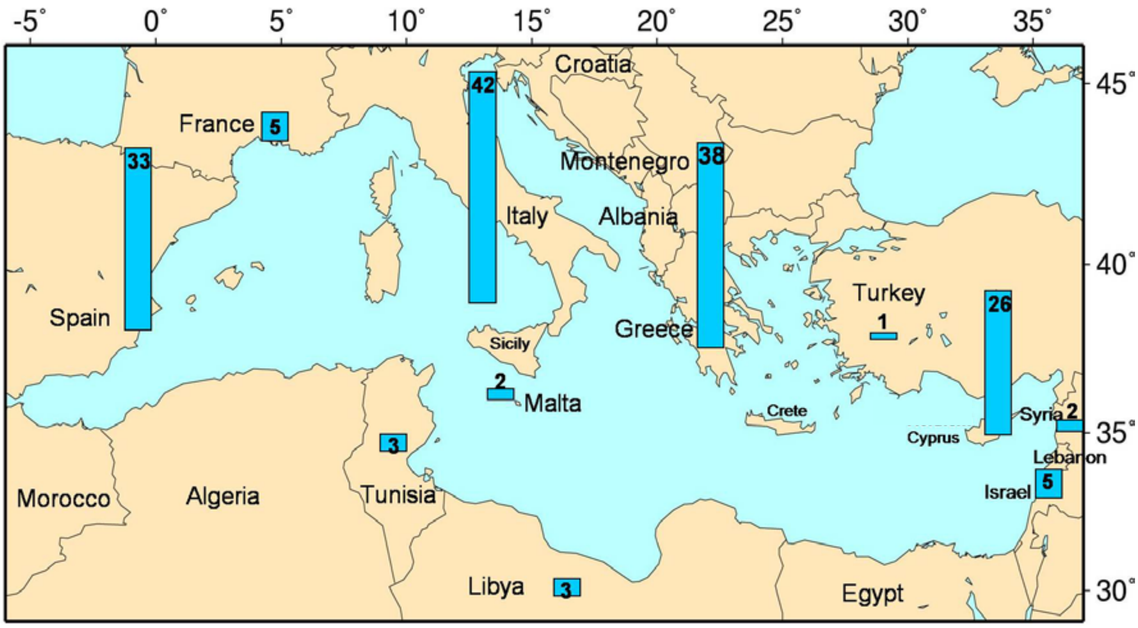

Figure 1: Numbers of sea turtles released with satellite transmitters per country in the Mediterranean.

One-hundred forty-seven of the turtles were loggerhead turtles and only 17 were green turtles, indicating a clear species bias (see ANNEX I). All but one of the green turtles were adult females tracked during their post-nesting migrations. For loggerhead turtles, the adult life stages were slightly better represented than the juveniles (Fig. 2), while twelve percent of the tracked turtles were classified as sub-adults (i.e. either late juveniles which are not mature yet, or small adults for which sexual maturity could not be confirmed).

Regarding the sex of the turtles tracking was female-biased, which was mostly related to the high number of nesting females that come ashore and are thus easier to access for deployment of satellite transmitters. However, for almost half of the turtles sex was not given, most likely due to the difficulties in determining sex in turtles before they develop sexual dimorphism (Fig. 3).

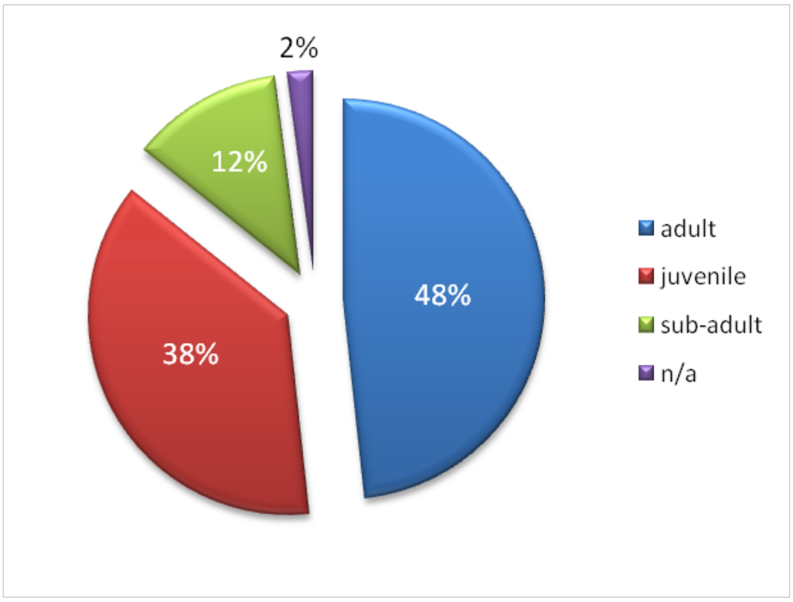

Figure 2: Life stages of tracked loggerhead turtles (n = 147)

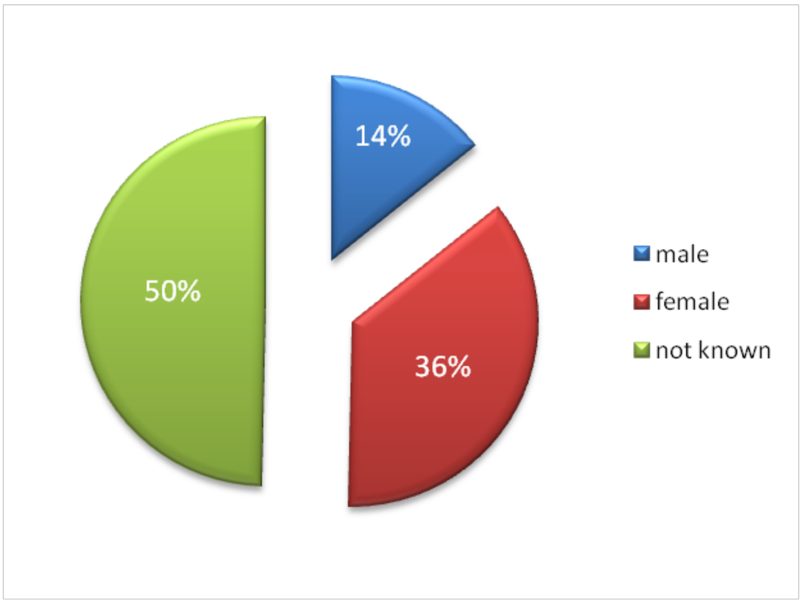

Figure 3: Sex of tracked loggerhead turtles (n = 147)

Due to variability in transmitter performance and other impediments leading to transmission failures (see Hays et al., 2007), the duration of individual tracking periods ranged considerably from just a few days to a maximum of 760 days (Zbinden et al., 2008). This record encompassed a whole remigration period of a female adult loggerhead turtle that left its nesting beach in Zakynthos, Greece, and migrated to the Tunisian shelf and then further along the north African shores to Libya before it returned to Zakynthos for nesting (Zbinden et al., 2008).

The longest beeline distance was covered by a female loggerhead turtle that crossed almost the entire eastern basin and travelled 2020 km from its nesting area in Cyprus to its feeding and wintering grounds in Tunisia (Broderick et al., 2007). However, the actual distances that turtles travel on their migrations cannot always be assessed, because (1) turtles may not have reached their final destination before transmissions ceased, (2) calculating the sum of the minimum distances between successive locations underestimates the real path length, and (3) the location error further confounds distance calculations. It is also worth mentioning that a turtle that moves over 10 km each day but remains within a well defined foraging area, may also covered > 3600 km after one year, but this is hardly comparable to a turtle that migrates from the eastern to the western basin.

Because of the biases mentioned above and since movement patterns vary considerably with life stage in marine turtles, the main outcomes of the satellite tracking studies in the Mediterranean Sea so far will be described and discussed separately for each of the groups in the following sections.

A) Post-nesting movements of female turtles

The majority of adult female loggerhead and green turtles were equipped with satellite transmitters in Greece (mainly Island of Zakynthos) and Cyprus and followed during their post-nesting migration to their feeding and overwintering gounds (Fig. 4). There was a net westward direction in most post-nesting movements. Loggerhead turtles leaving the west coast of Greece either travelled to the Adriatic Sea (n = 6) or to the southern Sicily Strait including waters around Malta, the island of Lampedusa (Italy) and the Gulf of Gabés, Tunisia (n = 7).

Other destinations reached by single individuals were the North Tunisian shelf, the Gulf of Amvrakikos (Greece) and the Aegean Sea, the latter also including a turtle that departed from Crete. These results confirm the general movement patterns identified by mark-and-recapture data previously summarised by (Margaritoulis et al., 2003). Turtles nesting in Cyprus mostly moved to the north African coasts, in particular Tunisia, Libya and Egypt. Most of the green turtles went to Libya, either to the waters off Misurata (western Gulf of Sirte) or the Gulf of Bomba. Turkey and Egypt were also visited by a few individual turtles.

The majority of loggerhead turtles went to western Libya and Tunisia, sharing the foraging grounds with turtles from Greek nesting areas. However, some turtles also went to Turkey, Syria, Lebanon and Egypt or even stayed at Cyprus. The tracking of female turtles after they leave their nesting areas highlights the importance of the north African coast, in particular Tunisian and Libyan waters, and the Adriatic sea as foraging grounds. In general, turtles also overwintered in the areas where they foraged, although small scale migration to off-shore waters or, in the Adriatic Sea, to southern, warmer waters were often observed during the winter (Broderick et al., 2007; Godley et al., 2002; Lazar et al., 2002; Zbinden et al., 2008). Broderick et al. (2007) tracked loggerhead and green turtle individuals twice on their post-nesting migrations and were able to show both high similarity between consecutive migratory routes and a high degree of fidelity to feeding and overwintering sites in these turtles.

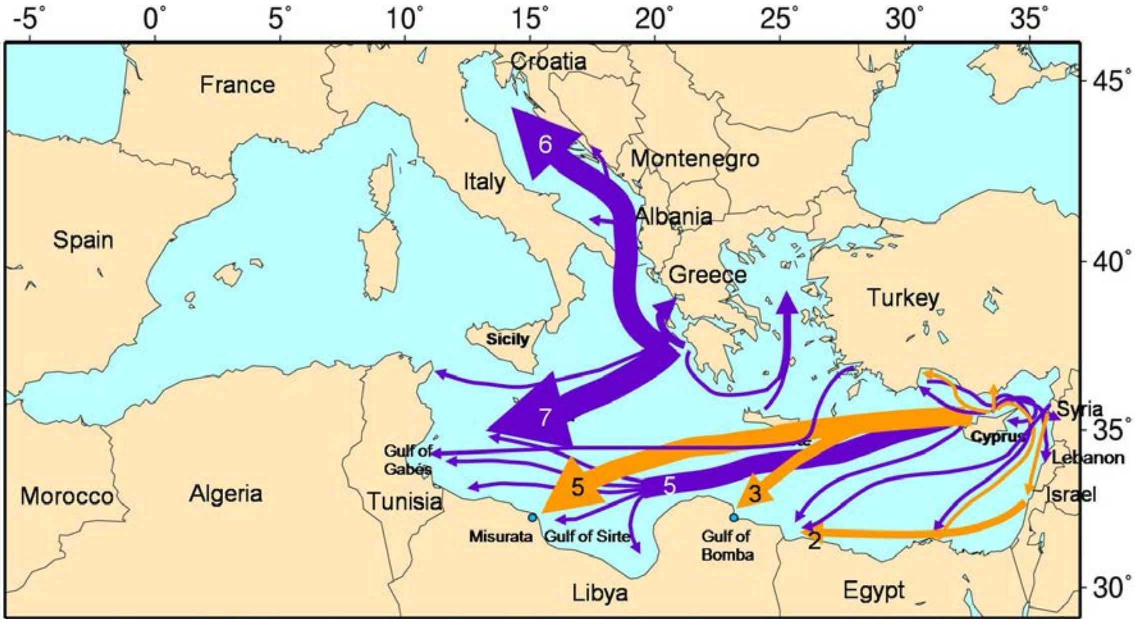

Figure 4: Post-nesting migrations of adult female loggerhead (purple arrows) and green (orange arrows) turtles. Note that the course of the arrows does not reflect the actual route taken, but indicates generally the departure and final destination. The arrow's dimensions are proportional to the numbers of turtles (also indicated by numbers in the arrow heads) that moved to the same destination.

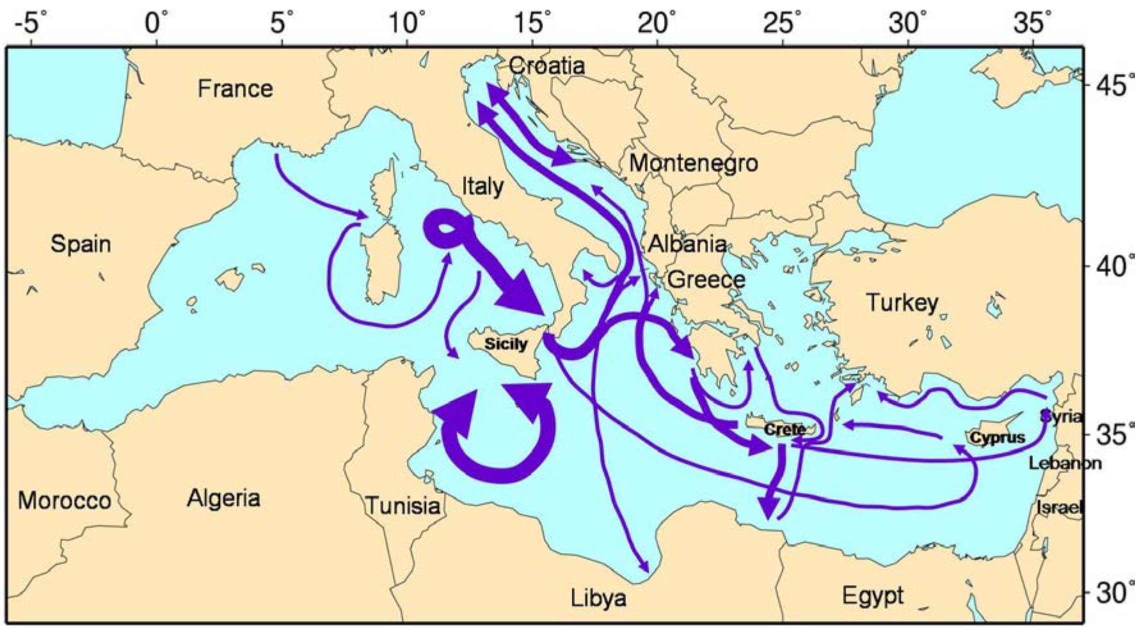

Figure 5: Satellite tracking of female adult and sub-adult loggerhead turtles outside the reproductive season: movements between foraging and wintering habitats and post-rehabilitation movements. Arrows indicate direction of movements and size of arrows is proportional to the number of turtles that took similar routes.

B) Non-reproductive movements of adult female turtles

Most of the turtles in this category were animals that were released again after a rehabilitation period in a marine rescue centre. In addition, the movements of some post-nesting female turtles were continuously tracked also after they had reached their feeding ground and were thus included here as well. The travelled routes are more variable and cover most of the Mediterranean sea with exception of the far western basin. Most frequented areas depend largely on where the turtles were released, and hence there is potential bias towards regions where long-term satellite tracking projects are active (Italy, Greece). This makes it difficult to identify migratory corridors or areas of particular importance. However, there is clear evidence for long-distance movements between the western and the eastern basin and many crossings occur through the Strait of Messina. As for the post-nesting females, the southern Strait of Sicily presents a highly frequented area where turtles do not stay in any particular area but move about in the area between Sicily, Tunisia and West Libya. Likewise, many turtles entered and stayed in the Adriatic Sea to forage. Therefore, the north Ionian Sea and the Strait of Otranto present another important movement corridor.

C) Movements of sub-adult and adult male turtles

Until today no green turtle male has been tracked in the Mediterranean and all results reported here refer to loggerhead turtles. Male turtles are generally underrepresented in tracking studies because unlike females they cannot be accessed and equipped on the nesting beaches. On the other hand, part of the juvenile turtles that have been tracked (see category D below) may have been males at an early life stage that did not present sexual dimorphism yet and thus remained unrecognised. Most of the tracked males remained in the Strait of Sicily, although that might be due to a tracking project specifically targeting male turtle in that area (Fig. 6). A couple of adult male turtles were followed on their migration between the Gulf of Gabés foraging area and the nesting ground in West Greece. Of those male turtles that were tracked through the winter, most stayed in the Gulf of Gabès and the adjacent offshore area to the north. Single individuals overwintered in western Greece, the Aegean Sea and in different places along the Libyan coast. Neither of the males entered the Adriatic Sea or conducted such long-distance movements as observed for the female turtles.

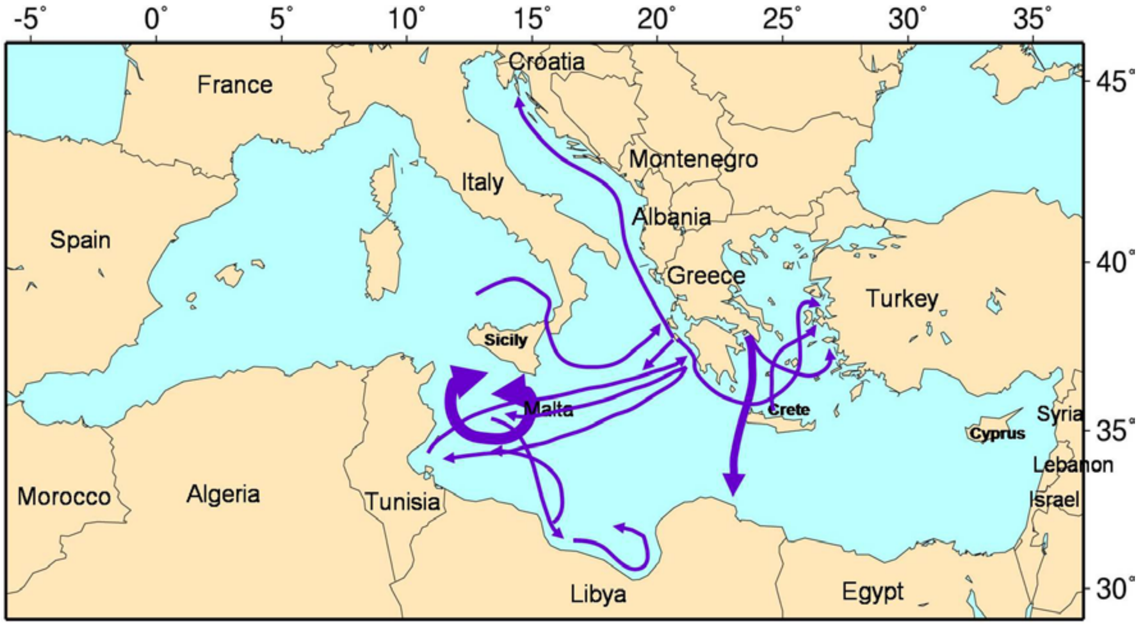

Figure 6: Satellite tracking of adult and sub-adult male loggerhead turtles: post-nesting and post-rehabilitation movements. Arrow heads indicate the direction of the movements. The circular arrow at the south of Sicily indicates that turtles stayed in the general area for the whole tracking period.

D) Movements of juvenile turtles

Most of the juvenile loggerhead turtles that were tracked via satellite telemetry were caught and remained in the western Mediterranean, especially in the Balearic, Algerian and Alboran Sea (Cardona et al., 2005; Eckert et al., 2008; Revelles et al., 2007a) (Fig. 7). Movements of juvenile turtles lack the periodicity typical for adult migrations between well defined feeding and nesting areas, and also reflect behavioural differences between oceanic and neritic stage juveniles. Combined results from the recorded movement trajectories and analysis of oceanographic features revealed a size dependent divergence in juvenile behaviour (Eckert et al., 2008). Smaller turtles that are less accomplished swimmers are closely associated with the major surface current system and generally prefer deep oceanic waters where they exhibit intensive movements in search of prey (Revelles et al., 2007a). Size-effects also lead to asymmetric exchange of turtles through the Strait of Gibraltar, because turtles require a minimum size of 36.0 cm (straight carapace length) to overcome the prevailing current velocities (Revelles et al., 2007b).

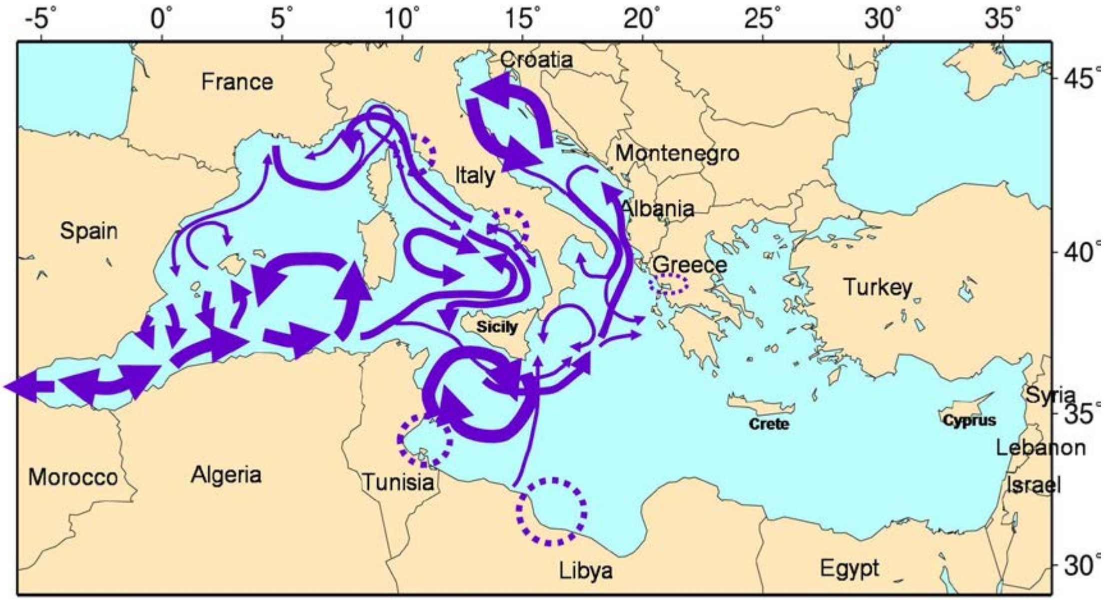

Figure 7: Movements of juvenile loggerhead turtles. Hatched circles indicate neritic foraging areas of turtles that did not engage in long-distance movements.

While some of the tracked turtles entered the Ionian and Adriatic Sea, juvenile movements in the central Mediterranean are scarcely known and up to date nothing is known on the movements and dispersal patterns of oceanic stage juveniles (<45 cm CCL) in the far eastern Mediterranean, in particular those that hatched on regional beaches. Most of the individuals followed by satellite in the central Mediterranean were relatively large juveniles (>45 cm CCL), some of which showed fidelity to specific neritic feeding areas (e.g. Tunisian shelf, Gulf of Sirte (Libya), SW Italy (Hochscheid et al., 2007)). Others (>55 cm CCL) engaged on long-distance migrations between the eastern and the western basin and were able to travel counter-current for great lengths of the path towards their destination (Bentivegna, 2002; Bentivegna et al., 2007).

Despite the more erratic nature of juvenile movements, there are more frequented areas that overlap with foraging areas preferred by adult turtles, in particular the southern Strait of Sicily and the Adriatic Sea. Moreover, physical bottlenecks such as the Straits of Sicily, Messina and Otranto, also present important passages for juvenile turtles. Those juveniles that were presumably already in the neritic stage overwintered in coastal areas of SW Italy, Tunisia, and the Adriatic Sea. Most of the tracked juveniles, however, remained in oceanic regions also during the winter, including the Alboran Sea, the Algerian Sea, the Tyrrhenian Sea and the Ionian Sea.

Current Gaps and Recommendations for Future Tracking Studies

The results obtained from satellite tracking of marine turtles in the Mediterranean so far have revealed some important biases that indicate substantial gaps in the knowledge of some species and life stages. These can be summarised as follows:

1. Movements of green turtles are only known for some post-nesting females leaving Cyprus, and there is certainly great scope for further studies of the foraging and overwintering grounds and preferred migratory routes of this species. No data are available on the movements of male or juvenile green turtles.
2. The study of small-sized juvenile turtles has only recently been made possible due to the development of small light weight satellite transmitters. There is urgent need to identify juvenile nursery areas and oceanic foraging habitats and how juvenile movements are affected by meso-scale oceanographic features.
3. The least known movements and dispersal patterns are those of male turtles, and efforts have to be made to determine the migratory connectivity between breeding and non-breeding populations.
4. There are also considerable gaps in the knowledge of turtle movements at the population level, deriving from the fact that some populations have received much research focus while others are clearly underrepresented. In fact, post-nesting movements are mostly known for the breeding populations of Cyprus and Western Greece, while many more breeding sites are known and monitored and first genetic studies have begun to reveal independent management units.

For this report much information has been used that is only available for viewing on the dedicated tracking section at seaturtle.org but which has not yet been published. At the time of writing of this report the tracking site contained information on the movements of 70 turtles in the Mediterranean, part of which addressed less known populations and male turtles. Future studies should focus particularly on underrepresented geographic regions, on green turtles, on male turtles and on less known life stages. Preference should also be given to increase sample size in these studies and refrain from single transmitter deployments that are unlikely to reveal significant results on the behaviour at the population level.

Finally, it is always important to consider the fate of tracking data, and plan publication well ahead of deploying transmitters on turtles. In their comprehensive review, Godley et al. (2008) commented on the responsibilities that donor organisations and researchers share. In essence, it should be an ethical obligation to minimise the disturbances for the animals subject to transmitter deployments, to extract maximal benefit from tracking data and to disseminate them in a sound and scientific manner.

Recommendations for Conservation Measures

Many tracking studies intend to reveal conservation hot spots that need management plans and urgent mitigation of the threats posed on the turtles in these areas. However, many fail to produce significant data sets with representative sample sizes, that may highlight the importance of one area above another. Indeed, despite the 164 tracked turtles included in this report, only few areas can be identified which merit priority attention for conservation measures. Most of these were already indicated by the hereafter cited publications.

Migratory corridors

Some routes are more often travelled by turtles on their breeding migrations or during movements that either connect different habitats or are dictated by physical properties (e.g. straits or surface currents). Thus, the extension of so-called migratory corridors may be well defined in the through-passage between physical barriers, but less clearly recognisable when in the open sea.

Satellite tracking revealed that both juveniles and adult turtles cross over between the western and the eastern basin, and hence inevitably pass either of the three physical bottlenecks present at the Straits of Sicily, Messina and Otranto. It is not yet clear whether there are certain periods that these straits are more often used or if passages of turtles occur all year round. However, post-nesting movements of loggerhead turtles leaving Zakynthos and travelling into the Adriatic sea suggest that the Strait of Otranto may be highly frequented during late summer/early autumn season (Schofield et al., 2009; Zbinden et al., 2008). Likewise, some turtles leave the Adriatic at the onset of the winter, and hence this may be another period where particular attention should be given to the Strait of Otranto. Finally, the Strait of Gibraltar which connects important developmental habitats for juvenile loggerhead turtles from the Atlantic and the Mediterranean (Carreras et al., 2006; Eckert et al., 2008; Laurent et al., 1998). Protection of this passage may be particularly crucial for the Atlantic loggerheads that, once they have entered the Mediterranean, have to cross the Strait of Gibraltar again to return to western Atlantic coasts for recruitment into neritic foraging habitats (Eckert et al., 2008; Laurent et al., 1998;).

An oceanic corridor instead has been identified by Broderick et al. (2007) along a south-westerly route connecting Cyprus with the North African coast, particularly in to central and western Egypt. This route was repeatedly travelled by most loggerhead and green turtles that continued along the North African coast to foraging and overwintering habitats further west. Another seasonal corridor for turtles travelling from and to their breeding sites may be present in the Ionian sea, although this has not yet been shown by the tracking studies on males and females leaving Zakynthos (Schofield et al., 2009; Zbinden et al., 2008). However, since the connection between feeding grounds in Tunisia and the Greek nest sites has been well documented, it can be expected that turtles follow similar post-nesting and remigration routes.

Oceanic feeding grounds

The monitoring of juvenile behaviour during the oceanic stage is still in its infancy and while satellite tracking revealed large scale area use by juvenile loggerhead turtles in the western Mediterranean, it was not possible to identify key pelagic habitats that are manageable and protectable in size. The Alborán sea presents an exception, since this small sea between the European and African continent is an important developmental area for juvenile and sub-adult loggerhead turtles (Carreras et al., 2006; Laurent et al., 1998) from both Atlantic and Mediterranean origins. Hence, the reduction of fishing induced mortality in this area should be of priority. Turtle by-catch is also very high in the Algerian Sea, but loggerhead dispersal is so widespread, that protection of concrete oceanic areas unlikely solves the problem (Revelles et al., 2007a, and references cited therein). There is strong evidence that the pelagic foraging habitats in the southern Sicily Channel may be of importance for turtles at various life stages, since many tracked juveniles, adult females and males prevailed for extended periods in this large area, particularly in the waters around Malta and the Pelagic Islands. This area should be of primary interest, not only because it includes oceanic foraging grounds and a migratory bottleneck, but also because of the thread posed by the intense fishing activities in this area.

Single tracks also revealed oceanic foraging sites in the Ionian Sea off Sicily and South Italy and in the southern Tyrrhenian sea, but these areas require further studies. At this stage the importance of the Ionian sea as juvenile developmental habitat can only be assumed because of its central position in the Mediterranean and its proximity to major nesting areas in Greece and Libya.

Neritic foraging and overwintering grounds

Due to the recently shown high degree of fidelity to specific neritic foraging habitats, it is now possible to indicate some areas where protection of the reproductively valuable adult green and loggerhead turtles would be most effective (Broderick et al., 2007). The importance of the North African coasts in general was highlighted in the work done by Broderick, Godley and their collaborators (Broderick et al., 2007; Godley et al., 2003b). These authors identified inshore waters in Libya (Gulf of Bomba, western Gulf of Sirte) as foraging and overwintering areas for green turtles that nest in Cyprus, and the Gulf of Gabés and the Nile Delta as important areas for the loggerhead turtle which are also impacted by significant fishing activities in these areas. The Gulf of Gabés also hosts turtles that nest in Greece (Bradai et al., 2009; Schofield et al., 2009; Zbinden et al., 2008) and hence, effective protection of this area potentially contributes to the conservation of multiple nesting populations. An equally important foraging area is located in the northern Adriatic Sea, that receives both adult and juvenile loggerhead turtles.

Many overwintering habitats overlap with these foraging grounds and Figure 8 provides an overview of the areas identified so far. During the winter period turtles spend most of their time resting on the sea floor and are thus especially susceptible to demersal fisheries (Broderick et al., 2007; Hochscheid et al., 2007). Such areas include the Gulf of Gabés, the western Gulf of Sirte, the Campanian coast in southwest Italy, Gulf of Bomba (East Libya), southern Croatia, western Greece and southern Albania.

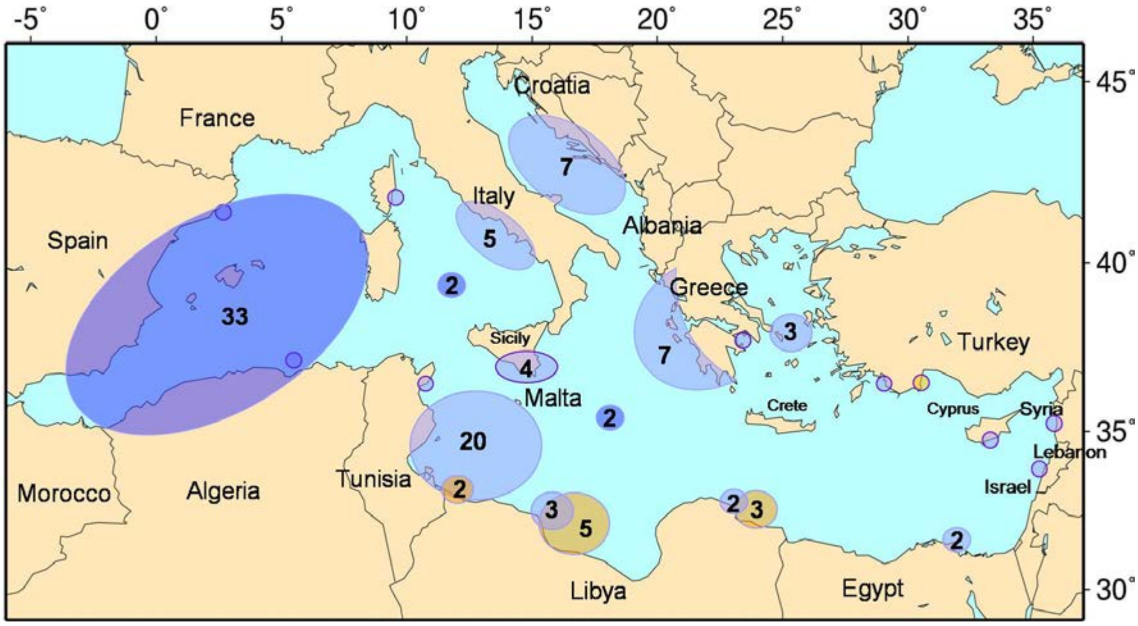

Figure 8: Overwintering sites for green (orange) and loggerhead (blue) turtles. Areas in darker blue indicate oceanic overwintering of turtles that did not remain in a well defined area, but continued to move over larger spatial scales. The numbers represent the numbers of turtles that were observed to use a given overwintering site.

Inter-nesting habitats

Two recent studies have highlighted the use of satellite linked telemetry to identify small scale area use during the breeding season (Schofield et al., 2009; Zbinden et al., 2007). High accuracy locations revealed that both female and male loggerhead turtles actually prefer areas outside the existing protected zone in Laganas Bay, Zakynthos. Such results have important implications for the management of protected areas and future studies should aim at obtaining more small-scale habitat use data for those areas that have already been identified as important sites for protection.

Cited References

Bentivegna, F. (2002). Intra-Mediterranean migrations of loggerhead sea turtles (Caretta caretta) monitored by satellite telemetry. *Mar. Biol.* **141** 795-800.

Bentivegna, F., Hamza, A., Saied, A., Elghmati, H., Elsharif, E., Hays, G. C. and Hochscheid, S. (2008). Movements of juvenile loggerhead turtles accidentally caught by fishermen in the Libyan Sea. In *Third Mediterranean Conference on Marine Turtles*. Hammamet, Tunisia.

Bentivegna, F., Valentino, F., Falco, P., Zambianchi, E. and Hochscheid, S. (2007). The relationship between loggerhead turtle (Caretta caretta) movement patterns and Mediterranean currents. *Mar. Biol.* **151**, 1605-1614.

Bradai, M. N., Bentivegna, F., Jribi, I., El Quaer, A., Maatoug, K. and El Abed, A. (2009). Monitoring of a loggerhead sea turtle, Caretta caretta, in the Central Mediterranean via satellite telemetry. In *Second Mediterranean Conference on Marine Turtles*, eds. A. Demetropoulos and O. Turkozan), pp. 54-57. Kemer, Turkey: Barcelona Convention - Bern Convention - Bonn Convention (CMS).

Broderick, A. C., Coyne, M. S., Fuller, W. J., Glen, F. and Godley, B. J. (2007). Fidelity and over-wintering of sea turtles. *Proceedings of the Royal Society B* **274** 1533-1538.

Cardona, L., Revelles, M., Carreras, C., San F,lix, M., Gazo, M. and Aguilar, A. (2005). Western Mediterranean immature loggerhead turtles: habitat use in spring and summer assessed through satellite tracking and aerial surveys. *Mar. Biol.* **147** 583-591.

Carreras, C., Pont, S., Maffucci, F., Pascual, M., Barceló, A., Bentivegna, F., Cardona, L., Alegre, F., SanFélix, M., Fernández, G. et al. (2006). Genetic structuring of immature loggerhead sea turtles (*Caretta caretta*) in the Mediterranean Sea reflects water circulation patterns. *Mar. Biol.* **149** 1269-1279.

Coyne, M. S. and Godley, B. J. (2005). Satellite Tracking and Analysis Tool (STAT): an integrated system for archiving, analyzing and mapping animal tracking data. *Marine Ecology Progress Series* **301**, 1-7.

Eckert, S. A., Moore, J. E., Dunn, D. C., Sagarminaga van Butten, R., Eckert, K. L. and Halpin, P. N. (2008). Modelling loggerhead turtle movement in the Mediterranean: Importance of body size and oceanography. *Ecological Applications* **18** 290-308.

Godley, B. J., Blumenthal, J. M., Broderick, A. C., Coyne, M. S., Godfrey, M. H., Hawkes, L. A. and Witt, M. J. (2007). Satellite tracking of sea turtles: where have we been and where do we go next? *Endangered Species Research* **3**.

Godley, B. J., Blumenthal, J. M., Broderick, A. C., Coyne, M. S., Godfrey, M. H., Hawkes, L. A. and Witt, M. J. (2008). Satellite tracking of sea turtles: where have we been and where do we go next? *Endangered Species Research* **3**.

Godley, B. J., Broderick, A. C., Glen, F. and Hays, G. C. (2003). Post-nesting movements and submergence patterns of loggerhead marine turtles in the Mediterranean assessed by satellite tracking. *J. Exp. Mar. Biol. Ecol.* **287** 119-134.

Godley, B. J., Richardson, S., Broderick, A. C., Coyne, M. S., Glen, F. and Hays, G. C. (2002). Long-term satellite telemetry of the movements and habitat utilisation by green turtles in the Mediterranean. *Ecography* **25**, 352-362.

Hays, G. C., Åkesson, S., Godley, B. J., Luschi, P. and Santidrian, P. (2001). The implications of location accuracy for the interpretation of satellite-tracking data. *Anim. Behav.* **61**, 1035-1040.

Hays, G. C., Bradshaw, C. J. A., James, M. C., Lovell, P. and Sims, D. W. (2007). Why do Argos satellite tags deployed on marine animals stop transmitting? *Journal of Experimental Marine Biology and Ecology* **349**, 52-60.

Hays, G. C., Webb, P. I., Hayes, J. P., Priede, I. G. and French, J. (1991). Satellite tracking of a loggerhead turtle (Caretta caretta) in the Mediterranean. *Journal of the Marine Biological Association of the UK* **71**, 743-746.

Hochscheid, S., Bentivegna, F., Bradai, M. N. and Hays, G. C. (2007). Overwintering behaviour in sea turtles: dormancy is optional. *Mar. Ecol. Prog. Ser.* **340**, 287-298.

Laurent, L., Casale, P., Bradai, M. N., Godley, B. J., Gerosa, G., Broderick, A. C., Schroth, W., Schierwater, B., Levy, A. M., Freggi, D. et al. (1998). Molecular resolution of marine turtle stock composition in fishery bycatch: a case study in the Mediterranean. *Molecular Ecology* **7**, 1529-1542.

Lazar, B., Borboroglu, P. G., Tvrtkovic, N. and Ziza, V. (2002). Temporal and spatial distribution of the loggerhead sea turtle, Caretta caretta, in the eastern Adriatic Sea: a seasonal migration pathway?, (ed. J. A. Seminoff), pp. 283-284. Miami: NOAA Technical Memorandum NMFS-SEFSC-503.

Luschi, P., Hays, G. C., del Seppia, C., Marsh, R. and Papi, F. (1998). The navigational feats of green turtles migrating from Ascension Island investigated by satellite telemetry. *Proc. R. Soc. Lond. B.* **265** 2279-2284.

Margaritoulis, D., Argano, R., Baran, I., Bentivegna, F., Bradai, M. N., Cami¤as, J. A., Casale, P., De Metrio, G., Demetropoulos, A., Gerosa, G. et al. (2003). Loggerhead turtles in the Mediterranean sea: present knowledge and conservation perspectives. In *Loggerhead Sea Turtles*, pp. 175-198. Washington: Smithsonian Books.

O'Dor, R. K. and Webber, D. M. (1998). Marine animal telemetry tags - A brief history of marine fish and invertebrate tagging. In *Aquatic Forum Series*, eds. G. S. Stone H. C. Tausig and J. R. Schubel), pp. 17-27. Boston: New England Aquarium.

Rees, A., Jony, M., Margaritoulis, D. and Godley, B. J. (2008). Satellite tracking of a green turtle, Chelonia mydas, from Syria further highlights importance of North Africa for Mediterranean turtles. *Zoology in the Middle East* **45**, 49-54.

Rees, A. and Margaritoulis, D. (2009). International migrations of non-nesting loggerhead turtles from Greece to Turkey and Libya. In *Second Mediterranean Conference on Marine Turtles*, eds. A. Demetropoulos and O. Turkozan), pp. 151-154. Kemer, Turkey: Barcelona Convention - Bern Convention - Bonn Convention (CMS).

Revelles, M., Cardona, L., Aguilar, A., San Félix, M. and Fernández, G. (2007a). Habitat use by immature loggerhead sea turtles in the Algerian basin (Western Mediterranean): swimming behaviour, seasonality and dispersal pattern. *Mar. Biol.* **151**, 1501-1515.

Revelles, M., Carreras, C., Cardona, L., Marco, A., Bentivegna, F., Castillo, J. J., De Martino, G., Mons, J. L., Smith, M. B., Rico, C. et al. (2007b). Evidence for an asymmetrical size exchange of loggerhead sea turtles between the Mediterranean and the Atlantic through the Straits of Gibraltar. *J. Exp. Mar. Biol. Ecol.* **349**, 261-272.

Schofield, G., Lilley, M. K. S., Bishop, C. M., Brown, P., Katselidis, K. A., Dimopoulos, P., Pantis, J. D. and Hays, G. C. (2009). Conservation hotspots: implications of intense spatial area use by breeding male and female loggerheads at the Mediterranean's largest rookery. *Endangered Species Research*.

Zbinden, J. A., Aebischer, A., Margaritoulis, D. and Arlettaz, R. (2008). Important areas at sea for adult loggerhead sea turtles in the Mediterranean Sea: satellite tracking corroborates findings from potentially biased sources. *Mar. Biol.* **153**, 899-906.

APPENDIX I Summary of Satellite Tracking Projects in the Mediterranean and number of turtles tracked per species and life stage. Notes on abbreviations: 1f = 1 female, 1m = 1 male, number without letter indicates sex unknown.

Species	*Adult*	*Sub-Adult*	*Juvenile*	*n/a*	*Release location*	*Organisation*	*Seaturtle.org*	*Other source*
C. mydas	1f	-	-	1	Israel	MTRG Exeter, UK	Yes	-
	13f	-	-	-	North of Cyprus	MTRG Exeter, UK	Yes, in part	(Broderick et al., 2007; Godley et al., 2002)[a]
	2f	-	-	-	Syria	ARCHELON, GR	Yes	(Rees et al., 2008)
C. caretta	1	4	-	-	France	CESTMED, FR	No	www.cestmed.org
	3f,3m	2f,3m	-	3	Greece	ARCHELON, GR	Yes, in part	(Rees and Margaritoulis, 2009)
	1f	-	-	-		Univ. Aberdeen, UK	No	(Hays et al., 1991)
	7f	-	-	-		Univ. of Bern, CH	Yes	(Zbinden et al., 2008)
	11f	-	-	-		MTRG Exeter, UK	Yes	-
	5m	-	-	-		University of Swansea, UK/University of Ioannina, GR	No	
	2f,1	-	-	-	Israel	MTRG Exeter, UK	Yes	-
	2f,1m,2	3	12	-	Italy	ISLAMETA Pisa, IT	Yes	-
	2f	1f,2	6	-		SZN Napoli, IT	No	(Hochscheid et al., 2007)
	3f	1m	-	-			No	(Bentivegna, 2002)
	-	-	1	-			No	own unpubl. data
	6m	-	-	-		WWF IT	Yes	-
	1m	1	1	-	Libya	EGA/RAC-SPA/SZN	Yes, in part	(Bentivegna et al., 2008)
	-	1	1	-	Malta		Yes	-
	17f	-	-	-	North of Cyprus	MTRG Exeter, UK	Yes	(Broderick et al., 2007; Godley et al., 2003)
	-	-	5	-	Spain	Univ. Barcelona, ES	No	(Cardona et al., 2005)
	-	-	10	-			No	(Revelles et al., 2007a)
	-	-	18	-		WIDECAST NC, US	No	(Eckert et al., 2008)
	1m	-	-	-	Tunisia	INSTM/RAC-SPA/SZN	No	(Bradai et al., 2009)
	1f	-	1	-			No	(Hochscheid et al., 2007)

	1f	-	-	-	Turkey	MTRG Exeter, UK	Yes	-

[a]Note that according to Broderick these authors equipped 26 turtles with satellite transmitters, six of them (three green and three loggerhead turtles) twice after consecutive breeding years. For the summary statistics in this report we have included only those turtles that could be clearly identified in the publications and the tracks on seaturtle.org, to avoid repeated counts. Figure 4, however, reports the maximum tracking effort as reported in Broderick et al. 2007.