SOCIETÀ TOSCANA
DI
Scienze Naturali
RESIDENTE IN PISA

ATTI
DELLA
SOCIETÀ TOSCANA
DI
SCIENZE NATURALI

MEMORIE • SERIE B • VOLUME CXXVII • ANNO 2020

Edizioni ETS

INDICE - *CONTENTS*

Atti Soc. Tosc. Sci. Nat., Mem., Serie B, 127 (2020)
pagg. 79-83; figg. 2; *doi: 10.2424/ASTSN.M.2020.16*

Resi Mencacci [1], Yaiza Pozo-Galvan [1], Chiara Caruso [2], Paolo Luschi [1]

LONG-RANGE MOVEMENTS OF THE FIRST OCEANIC-STAGE LOGGERHEAD TURTLE TRACKED IN ITALIAN WATERS

Abstract - R. Mencacci, Y. Pozo-Galvan, C. Caruso, P. Luschi, *Long-range movements of the first oceanic-stage loggerhead turtle tracked in Italian waters.*

No information is currently available on the spatial behaviour of oceanic-stage loggerhead sea turtles (*Caretta caretta*) frequenting the Central Mediterranean Sea. To start filling this gap, we monitored by satellite the movements and diving pattern of a small loggerhead that was released from central Italy after a short rehabilitation period. The turtle was tracked for almost 2 months, during which it quickly left the Italian mainland and reached the oceanic waters west of Sardinia moving first along Corsica eastern coastline. The turtle remained in offshore waters for several weeks, following circuitous paths in an area known to be frequented by juvenile loggerheads arriving from Spanish waters. During the first part of the tracking, the turtle mostly performed short dives spending at least the 85% of time underwater, whereas its successive stay in oceanic waters was characterized by longer periods spent at surface while carrying out more prolonged submergences. Although obtained on a single turtle, these findings shed light on the poorly known movement patterns of oceanic-stage Mediterranean loggerheads and could be useful to inform conservation policies in the area.

Key words - juvenile, satellite tracking, Mediterranean Sea, Italy

Riassunto - R. Mencacci, Y. Pozo-Galvan, C. Caruso, P. Luschi, *Movimenti a lungo raggio in acque italiane di una tartaruga comune in fase oceanica.*

Attualmente non sono disponibili informazioni sui movimenti esibiti dalle tartarughe comuni (*Caretta caretta*) in fase oceanica che frequentano il Mar Mediterraneo centrale. Per iniziare a colmare questa lacuna, abbiamo monitorato tramite satellite i movimenti e il comportamento di immersione di un giovane di tartaruga comune rilasciata dalla Toscana dopo un breve periodo di riabilitazione. La tartaruga è stata seguita per quasi due mesi, durante i quali ha lasciato rapidamente la costa peninsulare italiana e ha raggiunto le acque oceaniche a ovest della Sardegna, muovendosi prima lungo la costa orientale della Corsica. La tartaruga si è trattenuta per diverse settimane in questa zona, che è nota per essere frequentata anche da giovani tartarughe che provengono dalle acque spagnole. Durante la prima parte del suo viaggio, ha compiuto per lo più brevi immersioni, trascorrendo almeno l'85% del tempo sott'acqua, mentre durante la sua successiva permanenza in acque oceaniche ha trascorso lunghi periodi in superficie, effettuando anche immersioni più lunghe rispetto alla prima parte del percorso. Sebbene ottenuti su un singolo individuo, questi risultati forniscono rilevanti informazioni sui poco noti pattern di movimento di tartarughe comuni mediterranee in fase oceanica, che potranno risultare utili per supportare le politiche di conservazione nell'area.

Parole chiave - fase giovanile, tracking satellitare, Mar Mediterraneo, Italia

Introduction

Loggerhead sea turtles face a large number of anthropogenic threats and therefore need specific conservation measures, that should rely on detailed information about their biology (Hays *et al.*, 2019). Specifically, it is crucial to collect information on loggerhead spatial behaviour, given that their life cycle encompasses extended movements at every stage (Mansfield & Putman, 2013).

Schematically, loggerheads are thought to spend the initial part of their life in oceanic waters before recruiting after some years to neritic areas, where they then remain for the rest of their life, first as late juveniles and then as adults. This general pattern is subjected to large variations in different populations or geographical areas, the main one being that neritic turtles can return to an oceanic lifestyle even during adulthood (e.g.,McClellan & Read, 2007; Varo-Cruz *et al.*, 2016). Regardless of this variability, all loggerhead life history models include an initial stage in which turtles frequent the oceanic environment performing extended movements that derive largely, but not completely, from their passive drift with ocean currents (Mansfield & Putman, 2013). The size at which loggerheads leave the oceanic waters varies among different populations but is thought to be around 40 cm curved carapace length (CCL) at least (Dodd, 1988; Mansfield & Putman, 2013). Smaller loggerheads therefore dwell in offshore areas while moving over large distances: documenting their movement patterns and identifying the area(s) mostly frequented during these years is thus fundamental for their conservation.

Thanks to satellite tracking techniques, knowledge of the movement patterns and migrations of loggerheads is growing (Godley *et al.*, 2008), especially for adult females and late juveniles that are large enough to be tagged with the available transmitter models. Conversely, less information is available about the movements of oceanic-stage juveniles (Godley *et al.*, 2008; Mansfield & Putman, 2013) that are often too small to be equipped with a satellite tag. Tracking studies have

[1] Dipartimento di Biologia, Università di Pisa, via A. Volta 6, I-56126 Pisa, Italy
[2] Parco Regionale della Maremma, via del Bersagliere 7/9, Alberese (GR), Italy
Corresponding author: Resi Mencacci (resi.mencacci@unipi.it)

so far mainly focused on turtles of the central Pacific and western Atlantic Ocean and have revealed quite a large variability in the movement patterns displayed (e.g.,Briscoe *et al.*, 2016; Chambault *et al.*, 2019).
Loggerheads are the most abundant turtle species in the Mediterranean Sea (Casale & Margaritoulis, 2010) with adults breeding in its eastern part and juveniles dispersing throughout the rest of the basin (Luschi & Casale, 2014). A number of studies have tracked medium- or large-sized juveniles, while for small juveniles (< 40 cm CCL), a noticeable lack of knowledge persists, as satellite tracking data are available only for turtles of the western Mediterranean (West of Sardinia Is.) released from Spain, often after capture at sea. These turtles too displayed quite variable movement patterns, usually in offshore waters: most remained in the general area of release making circuitous movements (Abalo-Morla *et al.*, 2018; Cardona *et al.*, 2012; Revelles *et al.*, 2007a), although directed movements towards the central Mediterranean were also recorded (Eckert *et al.*, 2008). No information is available for oceanic-stage loggerheads frequenting other areas of the basin.
In this study, we tracked for nearly two months a small loggerhead that was released after rehabilitation from Tuscany coast (Fig. 1). Loggerheads are quite abundant in western Italian waters, as shown by the large number of turtles incidentally caught or found stranded along the Tuscan coast (Meschini *et al.*, 2007) and, more directly, by aerial surveys (Lauriano *et al.*, 2011). A few large juveniles and adults found in the area have also been satellite tracked, showing a variety of movements that often led them away from Tuscany waters (Luschi *et al.*, 2013; Luschi *et al.*, 2018; Mencacci *et al.*, 2011). The availability of a healthy small turtle, likely still in the oceanic phase, to be released after a short rehabilitation period, offered the unique opportunity to provide novel information about this poorly known life stage.

Materials and methods

The turtle, that was nicknamed Gogoluce, was recovered while floating on the surface in August 2014 and was rehabilitated by Tartnet Rescue Centre in Talamone (GR), southern Tuscany. Radiography showed that the turtle had ingested inert material that was readily expelled, making the turtle ready to be released after 51 days of captivity.
The animal was equipped with a TAM-2638 transmitter (Telonics, USA) linked to the Argos satellite system (www.argos-system.org), which weighed 49 g in air and was attached on the top of the carapace using quick-setting epoxy resin (Powerfast Pure2K). The turtle was released on 11 October 2014 weighing almost 8 kg and with a CCL of 38 cm.
Given the limited battery duration of the unit, a discontinuous duty cycle of 16 hours on/8 hours off, was set. The route was reconstructed by filtering out low-quality locations (Argos location classes 0, A, B) that were on land or which inferred movement speeds above 4 km/h (threshold determined from high-accuracy locations only). Despite the discontinuous duty cycle, a total of 443 locations were obtained, 23 of which were discarded.
The unit additionally relayed the average duration of the turtle submergences and the percentage of the time spent underwater in successive two-hour intervals. Such sensor data were filtered to eliminate repeated and/or clearly erroneous values, and daily averages were calculated.

Results

During the 58 days of tracking, Gogoluce travelled 1468 km (approximately 25 km per day), initially moving towards northwest to reach Capraia Island, about 120 km from release location. Then it turned south along the eastern coast of Corsica until the Straits of Bonifacio, where it arrived 12 days after release (Fig. 1). The mean travel speed in this initial segment was 1.5 km/h. After crossing the strait, the turtle continued to proceed south along the west side of Sardinia, still moving quite fast (mean speed between 23 Oct. and 3 Nov., 1.6 km/h). Gogoluce subsequently performed two loops at lower speed (mean 1.1 km/h): first at the boundary of the Sardinian continental shelf, and then in waters deeper than 2500 m (Fig. 1). The turtle was returning to the shallower waters of the Sardinian continental shelf when transmissions ended on 8 December. The reasons why the PTT stopped working are unknown, considering that the batteries were expected to last at least 5 months.
Satellite-relayed sensor data showed that the turtle alternated periods characterised by short submergences (daily averages usually below 3 min) with periods with longer dives (Fig. 2). Initially the turtle mostly made short submergences, either when moving north-westward or during the successive southward leg. Only for a few days while moving along the Corsica coast, the turtle made long dives, which typically exceeded 5 minutes and peaked on 19 October with an average duration of 16.2 minutes. In this period, the underwater percentage was always above 85% (Fig. 2).
From 28 October, Gogoluce changed its behaviour, spending more time at the surface and carrying out longer submergences while moving west of Sardinia (Fig. 2). During the first loop (3-13 Nov.), the turtle remained underwater for 71.7% of time on average, making long dives, up to over 22 minutes on 5 and 6 November (Fig. 2). During the second loop (13-28

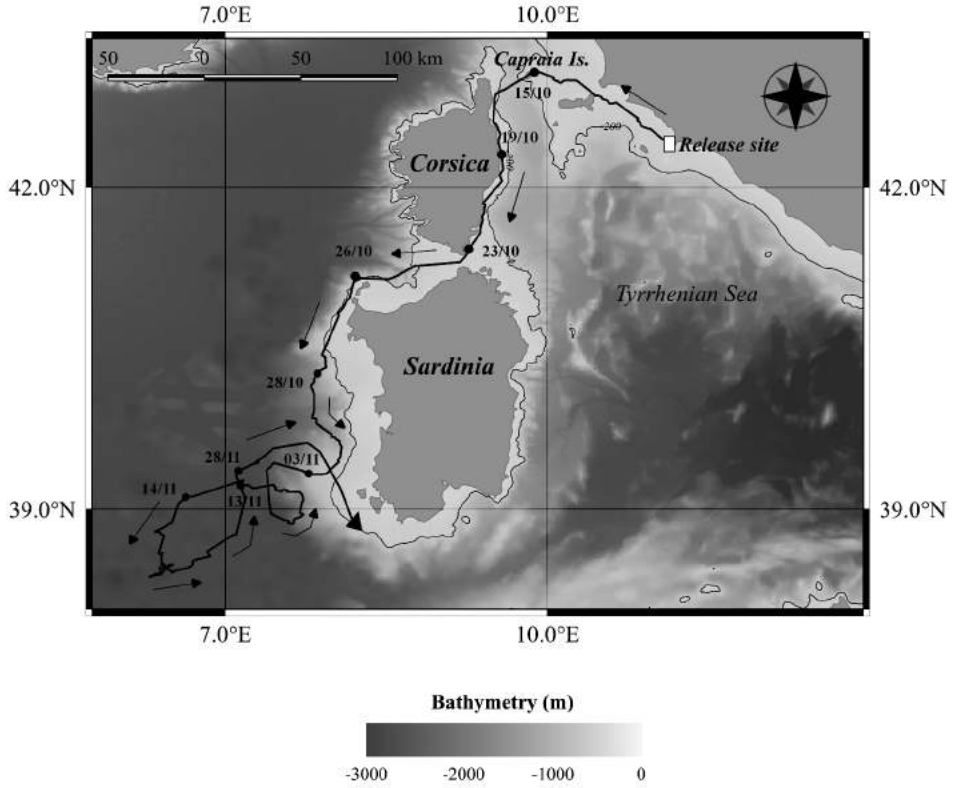

Figure 1. Reconstructed movement path of the turtle. The square indicates the release site, the triangle the tracking endpoint. The dates of relevant localizations (circles) are also shown. Bathymetry was obtained from Natural Earth (http://naturalearthdata.com).

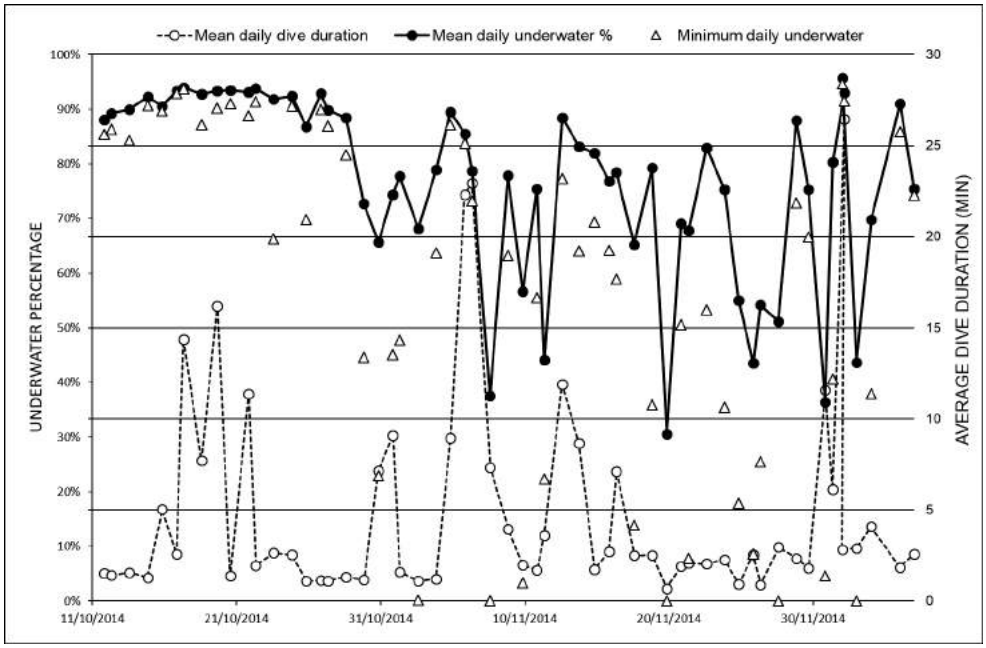

Figure 2. Gogoluce submergence pattern throughout the tracking period as derived from satellite-relayed sensor data. Dotted line: daily average dive duration, continuous line: mean daily underwater percentage. Empty triangles show the minimum underwater percentage recorded each day.

November) it performed shorter dives, generally of less than 2 minutes on average, still with 60-70% of time submerged. In this phase, several periods with underwater percentages below 40% were recorded, indicating that the turtle spent extended times on the surface, up to two continuous hours in 5 occasions (Fig. 2). During the final days, the time spent underwater showed again an increase as did the mean dive duration that reached 26.4 minutes on 2 December.

Discussion

This study provides the first data on the movements of small, oceanic-stage loggerheads in the central Mediterranean Sea. During its journey, Gogoluce displayed two main types of behaviour: directed, transiting movements made at sustained speed, and prolonged stays in limited, often oceanic, areas where circuitous, slower paths were followed. On the whole, this pattern is similar to those recorded in loggerheads of similar size tracked in the Western Mediterranean, which often displayed complex paths with alternated looping and straight segments, apparently not directed towards specific sites (e.g.,Abalo-Morla *et al.*, 2018; Eckert *et al.*, 2008; Revelles *et al.*, 2007a). This overall similarity with patterns shown in wild-caught individuals, suggests that Gogoluce behaviour was not affected by the rehabilitation process, that was however quite short and did not involve invasive treatments like surgery.
In the first 20 days of tracking, the turtle moved quickly, making short submergences and spending a high percentage of time underwater, a behaviour that is typical of turtles undertaking directed movements and swimming actively (e.g.,Hays *et al.*, 1999; Papi *et al.*, 1997). This behaviour led the turtle to leave the capture/release area in the Tyrrhenian Sea to quickly reach Corsica and Sardinia Islands. A similar response was observed in a rehabilitated, adult-sized turtle released in Tuscany that reached Corsica soon after release, before however returning to mainland Italy afterwards (Luschi *et al.*, 2013).
After this initial directed movement, Gogoluce started to move in a circuitous path, making counterclockwise loops at lower speed in waters outside the continental shelf, while carrying out dives of longer duration and spending less time underwater. Such a pattern is typically associated with foraging activity in loggerheads and other turtles (e.g.,Chambault *et al.*, 2019; Lambardi *et al.*, 2008) as well as in other marine predators (Bailleul *et al.*, 2010; Bauer *et al.*, 2015; Gaube *et al.* 2018). Given that the turtle mostly frequented deep waters it is probable that it fed on epipelagic prey found at the surface or in the upper water column, as already shown in other loggerheads (Casale *et al.*, 2008; Luschi *et al.*, 2018). This interpretation is in line with the turtle tendency to spend less time submerged in this period (Fig. 2), when it even surfaced for 2 consecutive hours (at least) on several occasions. Similar extended surfacing periods lasting tens of minutes have been recorded in other Mediterranean loggerheads (Hochscheid *et al.*, 2010), but their functional significance is unclear.
The area where the turtle remained is known to be frequented by juvenile loggerheads arriving from the western Mediterranean (Revelles *et al.*, 2007b) and even by adults from the Eastern basin (Mencacci, unpublished data; Rees & Margaritoulis, 2019), that often display short-scale circular paths (Eckert *et al.*, 2008; Revelles *et al.*, 2007a). This oceanic area is characterised by the presence of wind-induced mesoscale eddies (Robinson *et al.*, 2001) that may provide foraging opportunities for offshore-dwelling turtles.

Acknowledgements

We thank the personnel of the Maremma Regional Park, and in particular Drs. Lucia Venturi and Laura Tonelli. This research was supported by Regione Toscana (Gogreen funds 2014) and authorized by the Italian Ministry of the Environment (prot. 0024513/PNM, 28/11/2014).

References

Abalo-Morla S., Marco, A. Tomas, J. Revuelta, O., Abella E., Marco V., Crespo-Picazo J., Fernandez C., Valdes F., Del Carmen Arroyo M., Montero S., Vasquez C., Eymar J., Esteban, J.A., Pelegri J., Belda E.J., 2018. Survival and dispersal routes of head-started loggerhead (*Caretta caretta*) posthatchlings in the Mediterranean Sea. *Marine Biology* 165: 51. https://link.springer.com/article/10.1007/s00227-018-3306-2

Bailleul F., Cotté C., Guinet C., 2010. Mesoscale eddies as foraging area of a deep-diving predator, the southern elephant seal. *Marine Ecology Progress Series* 408: 251-264. https://www.int-res.com/abstracts/meps/v408/

Bauer R.K., Fromentin J.-M., Demarcq H., Brisset B., Bonhommeau S., 2015. Co-occurrence and habitat use of fin whales, striped dolphins and Atlantic bluefin tuna in the Northwestern Mediterranean Sea. *PlosONE* 10(10): e0139218. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0139218

Briscoe D.K., Parker D.M., Bograd S., Hazen E., Scales K., Balazs G.H., Kurita M., Saito T., Okamoto H., Rice M., Polovina J.J., Crowder, L.B., 2016. Multi-year tracking reveals extensive pelagic phase of juvenile loggerhead sea turtles in the North Pacific. *Movement Ecology* 4: 23. https://movementecologyjournal.biomedcentral.com/articles/10.1186/s40462-016-0087-4/

Cardona L., Fernandez G., Revelles M., Aguilar A., 2012. Readaptation to the wild of rehabilitated loggerhead sea turtles (*Caretta caretta*) assessed by satellite telemetry. *Aquatic Conservation: Marine Freshwater Ecosystems* 22: 104-112. https://onlinelibrary.wiley.com/doi/abs/10.1002/aqc.1242

Casale P., Abbate G., Freggi D., Conte N., Oliverio M., Argano R., 2008. Foraging ecology of loggerhead sea turtles *Caretta caretta* in the central Mediterranean Sea: evidence for a relaxed

life history model. *Marine Ecology Progress Series* 372: 265-276. https://www.int-res.com/abstracts/meps/v372/p265-276/

Casale P., Margaritoulis D., 2010. Sea turtles in the Mediterranean: Distribution, threats and conservation priorities. IUCN, Gland, Switzerland. https://www.iucn.org/es/content/sea-turtles-mediterranean-distribution-threats-and-conservation-priorities-0

Chambault P., Baudena A., Bjorndal K.A., Santos A.M.R., Bolten A.B., Vandeperre F., 2019. Swirling in the ocean: Immature loggerhead turtles seasonally target old anticyclonic eddies at the fringe of the North Atlantic gyre. *Progress in Oceanography* 175**:** 345-358. https://www.sciencedirect.com/science/article/abs/pii/S0079661118303458

Dodd C.K., 1988. Synopsis of the biological data on the loggerhead sea turtle *Caretta caretta* (Linnaeus 1758). Rep. 88, U.S. Fish and Wildlife Service, Washington D.C.

Eckert S.A., Moore J.E., Dunn D.C., Sagarminaga van Buiten R., Eckert K.L., Halpin P.N., 2008. Modeling loggerhead turtle movement in the Mediterranean: importance of body size and oceanography. *Ecological Applications* 18: 290-308. https://esajournals.onlinelibrary.wiley.com/doi/10.1890/06-2107.1

Gaube P., Braun C.D., Lawson G.L., McGillicuddy Jr D.J., Della Penna A., Skomal G.B., Fischer C., Thorrold S.R., 2018. Mesoscale eddies influence the movements of mature female white sharks in the Gulf Stream and Sargasso Sea. *Scientific Report* 8(7363). https://www.nature.com/articles/s41598-018-25565-8

Godley B.J., Blumenthal J.M., Broderick A.C., Coyne M., Godfrey M.H., Hawkes L.A., Witt M.J., 2008. Satellite tracking of sea turtles: Where have we been and where do we go next? *Endangered Species Research* 4: 3-22. https://www.int-res.com/abstracts/esr/v4/n1-2/p3-22/

Hays G.C., Bailey H., Bograd S.J., Bowen W.D., Campagna C., Carmichael R.H., Sequeira A.A., 2019. Translating marine animal tracking data into conservation policy and management. *Trends in Ecology & Evolution* 34: 459-473. https://www.sciencedirect.com/science/article/abs/pii/S0169534719300242

Hays G.C., Luschi P., Papi F., Del Seppia C., Marsh R., 1999. Changes in behaviour during the inter-nesting period and post-nesting migration for Ascension Island green turtles. *Marine Ecology Progress Series* 189: 263-273. https://www.int-res.com/abstracts/meps/v189/p263-273/

Hochscheid S., Bentivegna F., Hamza A., Hays G.C., 2010. When surfacers do not dive: multiple significance of extended surface times in marine turtles. *Journal of Experimental Biology* 213: 1328-1337. https://jeb.biologists.org/content/213/8/1328

Lambardi P., Lutjeharms J.R.E., Mencacci R., Hays G.C., Luschi P., 2008. Influence of ocean currents on long-distance movement of leatherback sea turtles in the Southwest Indian Ocean. *Marine Ecology Progress Series* 353: 289-301. https://www.int-res.com/abstracts/meps/v353/p289-301/

Lauriano G., Panigada S., Casale P., Pierantonio N., Donovan D.P., 2011. Aerial survey abundance estimates of the loggerhead sea turtle *Caretta caretta* in the Pelagos Sanctuary, northwestern Mediterranean Sea. *Marine Ecology Progress Series* 437: 291-302. https://www.int-res.com/abstracts/meps/v437/p291-302/

Luschi P., Casale P., 2014. Movement patterns of marine turtles in the Mediterranean Sea: a review. *Italian Journal of Zoology* 81**:** 478-495. https://www.tandfonline.com/doi/full/10.1080/11250003.2014.963714

Luschi P., Mencacci R., Cerritelli G., Papetti L., Hochscheid S., 2018. Large-scale movements in the oceanic environment identify important foraging areas for loggerheads in central Mediterranean Sea. *Marine Biology* 165: 4. https://link.springer.com/article/10.1007/s00227-017-3255-1

Luschi P., Mencacci R., Vallini C., Ligas A., Lambardi P., Benvenuti S., 2013. Long-term tracking of adult loggerhead turtles (*Caretta caretta*) in the Mediterranean Sea. *Journal of Herpetology* 47: 227-231. https://doi.org/10.1670/11-173

Mansfield K.L., Putman N.F., 2013. Oceanic habits and habitats. *Caretta caretta*. In Wyneken J., Lohmann K.J., Musick J.A. (eds), *The Biology of Sea Turtles. Vol. III*, 189-210. CRC Press, Boca Raton.

McClellan C.M., Read A.J., 2007. Complexity and variation in loggerhead sea turtle life history. *Biology Letters* 3: 592-594. https://royalsocietypublishing.org/doi/10.1098/rsbl.2007.0355

Mencacci R., Ligas A., Meschini P., Luschi P., 2011. Movements of three loggerhead sea turtles in Tuscany waters. *Atti Società toscana Scienze naturali, Memorie Serie B*. 118: 117-120. http://www.stsn.it/it/memorie-serie-b/13-stsn/49-memorie-serie-b-anno-2011.html

Meschini P., Luschi P., Mancusi C., 2007. On the presence of sea turtles along the Tuscany coast. In Bologna M.A., Capula M., Carpaneto G.M., Luiselli L., Marangoni C., Venchi A. (eds), *Atti del VI Congresso Nazionale della Societas Herpetologica Italica.* Edizioni Belvedere, Latina.

Papi F., Luschi P., Crosio E., Hughes G.R., 1997. Satellite tracking experiments on the navigational ability and migratory behaviour of the loggerhead turtle *Caretta caretta*. *Marine Biology* 129: 215-220. https://link.springer.com/article/10.1007/s002270050162

Rees A.F., Margaritoulis D., 2019. The longest migratory distance recorded for a loggerhead nesting in Greece. *Marine Turtle Newsletters* 158: 10-11. http://www.seaturtle.org/mtn/archives/mtn158/mtn158-2.shtml

Revelles M., Cardona L., Aguilar A., San Felix M., Fernandez G., 2007a. Habitat use by immature loggerhead sea turtles in the Algerian Basin (western Mediterranean): swimming behaviour, seasonality and dispersal pattern. *Marine Biology* 151: 1501-1515. https://link.springer.com/article/10.1007%2Fs00227-006-0602-z

Revelles M., Isern-Fontanet J., Cardona L., San Felix M., Carreras C., Aguilar A., 2007b. Mesoscale eddies, surface circulation and the scale of habitat selection by immature loggerhead sea turtles. *Journal of Experimental Marine Biology and Ecology* 347: 41-57. https://www.sciencedirect.com/journal/journal-of-experimental-marine-biology-and-ecology/vol/347/issue/1

Robinson, A.R., Leslie, W.G., Theocharis, A., Lascarotos, A., 2001. Mediterranean Sea circulation. In Steele J., Thorpe S., Turekian, K. (eds), *Encyclopaedia of Ocean Sciences. Vol. 3*, 1689-1705. Elsevier.

Varo-Cruz N., Bermejo J.A., Calabuig P., Cejudo D., Godley B.J., Lopez-Jurado L.F., Pikesley S.K., Witt M.J., Hawkes L.A., 2016. New findings about the spatial and temporal use of the Eastern Atlantic Ocean by large juvenile loggerhead turtles. *Diversity and Distribution* 22: 481-492. https://onlinelibrary.wiley.com/doi/full/10.1111/ddi.12413

(ms. pres. 19 maggio 2020; ult. bozze 15 dicembre 2020)

Edizioni ETS
Palazzo Roncioni - Lungarno Mediceo, 16, I-56127 Pisa
info@edizioniets.com - www.edizioniets.com
Finito di stampare nel mese di dicembre 2020