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Transatlantic Migration of Juvenile Loggerhead Turtles (*Caretta caretta* L.) from the Strait of Gibraltar

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One of the most important nesting populations of the loggerhead turtle (*Caretta caretta* L.) in the Atlantic Ocean is situated in the southeastern coast of North America, with a main nucleus located in the Florida Peninsula (*e.g.* Dodd Jr 1988; Ehrhart *et al*. 2003). Hatchlings produced on these beaches migrate to the eastern Atlantic helped by the current systems (Carr 1986; Bolten *et al*. 1992b; Bolten 2003), while the oceanic small juvenile stage of these individuals occurs in the waters off Azores, Madeira and the Canary Islands (Bolten 2003). Larger juvenile loggerheads return to their natal areas in the western Atlantic with an average size of approximately 50 cm SCL (46-64 cm SCL, or 6.5-11.5 years, as reported by Bjorndal *et al*. 2000), where they enter a neritic juvenile stage before reaching maturity (Bolten 2003).

Another important nesting loggerhead population is found in the eastern Mediterranean Sea (Greece, Cyprus and Turkey) (Margaritoulis *et al*. 2003). Oceanic juveniles from this population are distributed all along the Mediterranean basin (Margaritoulis *et al*. 2003). The Strait of Gibraltar separates the Mediterranean Sea from the Atlantic Ocean. Migratory flux of loggerhead turtles near and through this strait has been reported in both directions (Camiñas 1997; López-Jurado & Andreu 1998; Margaritoulis *et al*. 2003). Thanks to this connection, the Atlantic and Mediterranean loggerhead populations share developmental habitats in the western Mediterranean (Margaritoulis *et al*. 2003) and in the northeastern Atlantic.

Oceanic juvenile turtles tagged in the eastern Atlantic have been reported off the North American coast (Bolten 2003), and likewise, individuals from the American coast have been recaptured in the eastern Atlantic and the Mediterranean Sea (Bolten *et al*. 1992a,b; Margaritoulis *et al*. 2003). Nonetheless, over the last years, satellite tracking has been the technique of choice for many researches to more accurately describe migration routes and the feeding grounds of sea turtles

We used satellite telemetry to monitor the migration movements of juvenile loggerhead turtles in the Strait of Gibraltar, an area considered to be very important for the migration of this species (Camiñas 1997;). We fitted satellite-linked transmitters (PTTs) to two juvenile loggerhead turtles, named Centella and Malagueña, that were released in the Atlantic side of the Strait of Gibraltar, one in July 1999 and the other in July 2000. Both animals had suffered injuries related to incidental capture by fishing hooks and were successfully rehabilitated in the Threatened Marine Species Rehabilitation Centre

of Fuengirola in Málaga, Spain (Table I). The transmitters used were Telonics ST-10 (Mesa - Arizona, U.S.A.). These transmitters were 100 x 48 x 20 mm in size and 190 g in weight. Neither PTT exceeded 5% of the turtle's body weight (Aldridge & Brigham 1988). The transmitters were deployed following the procedures proposed by Balazs *et al*. (1996) and by Dr. Alan Bolten (pers. comm.). These PTTs provided only location data; both PTTs were set with an 8 hours on/40 hour off transmission cycle.

Name	Malagueña	Centella
Argos ID	12953	12957
SCL (cm)	65.3	57.0
Mass (kg)	n/a	29.5
Capture date	07 Sept, 1998	09 Feb, 2000
Capture cause	Hook (flipper)	Hook (esophagus)
Release date	18 July, 1999	15 July, 2000
Days in captivity	314	157
Release location	Chiclana (Cádiz)	Tarifa (Cádiz)
	36.25°N, -6.09°W	36.01°N, -5.37°W
Last transmission	08 Jan, 2000	02 June, 2001
Duration of PTT (days)	174	322
No. Transmissions	65	194
Km from release site	4,405.6	4,795.5
Min. distance travelled (km)	4,652.7	7,111.6

Table I. Biometric data of the loggerhead turtles released and performance of their transmitters.

The transmitters successfully sent location data for six to ten months (Table I). We filtered the data by discarding all positions with a location class B (ARGOS 1996) as well as those corresponding to transit speed of > 5 km/h (Godley *et al*. 2003).. We did included positions with location class A, as suggested by Hays *et al*. (2001), since they were apparently quite accurate in our study turtles. Most location points included in the analysis were location classes 1, 0 and A.

Following release in the Strait of Gibraltar, both turtles headed westwards. Centella travelled 4795 km, going 344 km off northeast Bermuda and transmitted its last location at approximately 950 km off Nova Scotia, Canada. Mean latitude for this movement was 35.6º N (Fig. 1, black line). Malagueña moved in a similar fashion, but at a lower latitude and in a southwest direction (towards the Bahamas). It stopped transmitting 4405 km far from the release site, at latitude 32.6ºN (Fig. 1, gray line). Centella travelled at a mean maximum speed of 1.3 km/h (SD = 1.30, N = 67) and Malagueña at 1.4 km/h (SD = 1.21, N = 21). There were no significant differences between the mean maximum speed of both turtles ($X^2 = 0.92$, df = 1, p = 0.33).

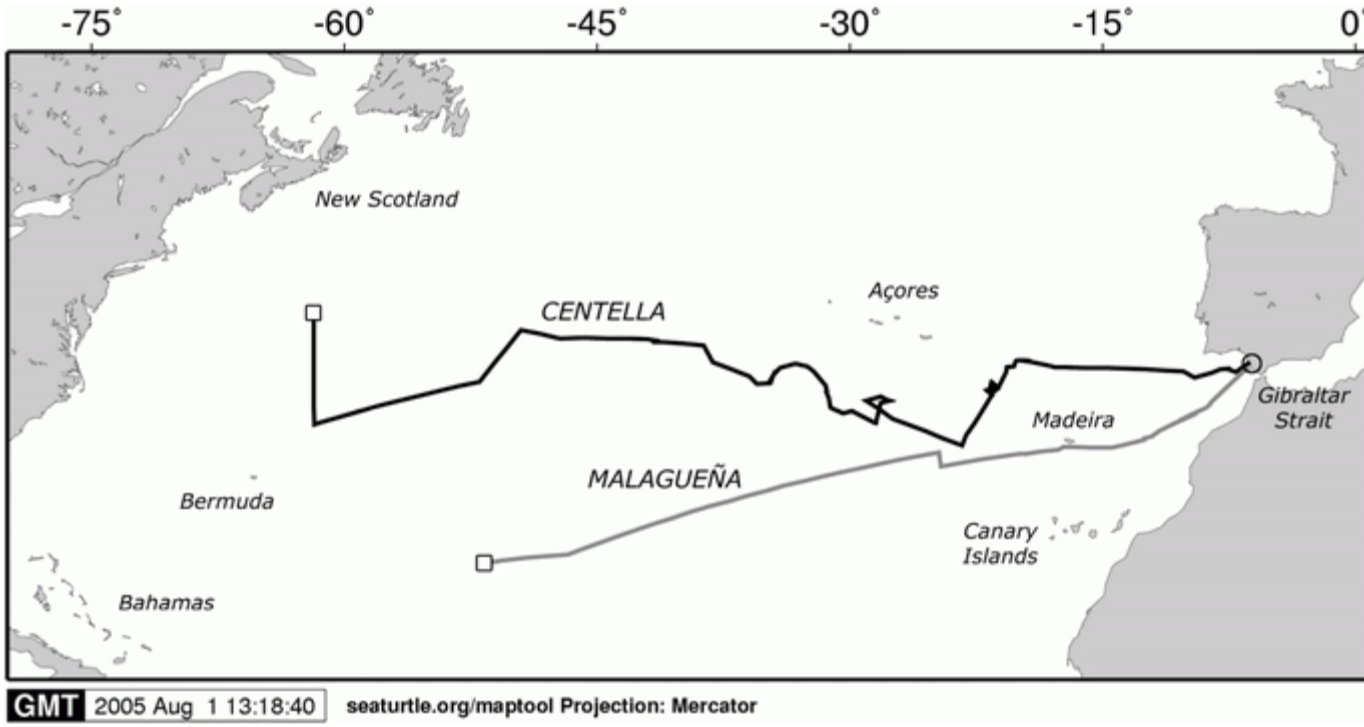

Figure 1. Migratory routes of two juvenile loggerhead turtles released with satellite tags (Centella, black line; Malagueña, gray line). Circle shows the release location, and squares show the last location for each transmitter.

There are several reports of transatlantic migrations of flipper-tagged loggerheads (*e.g.* Bolten *et al*. 1992a). Nonetheless, satellite tracking data of our study individuals provide more detailed information on the migration route followed, as well as the time and speed employed. Although the transmitters failed before the turtles likely reached a final destination, this is one of the few published records of east-west Atlantic migration of loggerheads using satellite telemetry (see Bolten *et al*. 1996). Centella's last location was along the 40º N parallel, in late spring. It is possible that this turtle was traveling to the foraging areas off the coast of northeastern North America (Ehrhart *et al*. 2003). In contrast, Malagueña was located at a lower latitude when its transmitter failed in December, suggesting it was moving to warmer zones. It should be noted that both turtles were held in captivity for several months, and thus their behavior after release might have been affected. Nonetheless, the injuries for which these turtles were admitted to the rehabilitation centre were judged slight.

The transatlantic movement of both turtles was carried out counter to the prevailing currents in the North Atlantic (Lópes-Ferreira 2005), though a more detailed analysis could reveal small scale currents that may have helped these turtles in their migration. It is likely that warm surface counter-currents occur during the summer time. Both sea turtles traveled at similar swimming speeds, suggesting that they could have been affected by the currents in the same way.

The two turtles tracked in this study fall within the stage that Bolten (2003) defined as the oceanic-neritic transition. The mean size of loggerheads found in the Strait of Gibraltar is similar to that reported from the Canary Islands (50 cm SCL, A. Liria, *in prep.*) and the coast of Morocco (Benhardouze 2004). Because of their size, there is a possibility that these two tracked turtles belonged to the group of loggerhead turtles that

spend part of their oceanic stage in the western Mediterranean Sea. Note that there appears to be an influx of loggerhead juveniles from the Mediterranean to the Atlantic in warm summer months, starting in July (Camiñas 1997), when these two turtles were released.

The different latitudes of the two migration routes may reflect that the turtles belong to different sub-populations. It may also be the case that there is no tightly defined migration corridor from the eastern to western Atlantic; rather, the trajectories undertaken reflect not only the prevailing marine currents but also other factors such as time of year, local currents, and the final destination (neritic habitat). Regardless of the reasons, the variation in migration routes highlights a conservation concern related to incidental capture by fisheries. Both study turtles traversed an area near the fishing grounds off Madeira and Azores, where the impact of fishing activities on sea turtles is considered to be serious (Lópes-Ferreira 2005).

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