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Additional Information

1 **Survival and dispersal routes of head-started loggerhead sea turtle (*Caretta caretta*) post-**
2 **hatchlings in the Mediterranean Sea**

3

4 **Sara Abalo-Morla¹, Adolfo Marco², Jesús Tomás³, Ohiana Revuelta³, Elena Abella², Vicente Marco⁴, José**
5 **Luis Crespo-Picazo⁵, Carolina Fernández⁶, Fernanda Valdés⁷, María del Carmen Arroyo⁶, Susana**
6 **Montero⁷, Cristina Vázquez⁶, Juan Eymar⁸, José Antonio Esteban^{9*}, José Pelegrí¹, Eduardo J. Belda¹.**

7

8 ¹ Research Institute for Integrated Management of Coastal Areas, Universitat Politècnica de València, C/Paranimf
9 nº 1, E-46730, Gandía (Valencia), Spain.

10 ² Doñana Biological Station (CSIC), Sevilla, Spain.

11 ³ Marine Zoology Unit, Instituto Cavanilles de Biodiversidad y Biología Evolutiva, University of Valencia, Aptdo.
12 22085, E-46071 Valencia, Spain.

13 ⁴ Centro de Recuperación de Animales Marinos (CRAM), Paseo de la Playa 28-30, El Prat de Llobregat
14 (Barcelona), Spain.

15 ⁵ Fundación Oceanogràfic, Ciudad de las Artes y las Ciencias, Avanqua Oceanogràfic-Ágora, C/Eduardo Primo
16 Yúfera, 1ºB, E-46013, Valencia, Spain

17 ⁶ Agencia de Medio Ambiente y Agua, Consejería de Medio Ambiente y Ordenación del Territorio (CMAOT),
18 Junta de Andalucía, Spain.

19 ⁷ Aquarium of Sevilla, Muelle de las Delicias s/n, Área Sur, Puerto de Sevilla, Sevilla, Spain.

20 ⁸ Consellería de Medi Ambient, Generalitat Valenciana, Spain.

21 ⁹ Xaloc Asociación para el Estudio y Conservación del Entorno, Valencia, Spain

22

23 * *Present address:* Member of Reserching Group Animal Welfare Science, Humanities, Ethics and the Law.
24 Interdisciplinary Animal Studies (AWSHEL-IAS), Fundación General de la Universidad de Alcalá (FGUA-
25 UAH).

26

27 Corresponding author: S. Abalo-Morla

28 Email: sabalo@epsg.upv.es

29 ORCID: orcid.org/0000-0003-1391-6272

30 **Abstract**

31

32 Several loggerhead sea turtle (*Caretta caretta*) nesting events have been recorded along Spain's Mediterranean
33 coast, outside its known nesting range, in recent years. In view of the possible expansion of its nesting range and
34 considering the conservation status of this species, management measures like nest protection and head-start
35 programs have been implemented. To study the dispersal behavior and survival of head-started loggerheads, 19
36 post-hatchlings from three nesting events were satellite-tracked after their release in three consecutive years
37 (2015-2017). This paper presents the first study of survival probabilities and dispersal movements of loggerhead
38 post-hatchlings in the Mediterranean basin. Monitored post-hatchlings dispersed over large areas using variable
39 routes, mainly off the continental shelf. Nonetheless, post-hatchlings dispersed to high productivity warmer areas
40 during the coldest months of monitoring. These areas might be optimum for their survival and development. We
41 observed differences regarding dispersal orientation and routes among individuals, even from the same nest,
42 release date, and location. Our survival models contributed to improving current survival estimates for sea turtle
43 post-hatchlings. We observed a high probability of survival in head-started individuals during the first months
44 after release, usually the most critical period after reintroduction. The data did not support an effect of habitat
45 (neritic or oceanic) in survival, neither an effect of the region (Balearic sea or Alboran sea) in survival probability.
46 Differences in survival between nests were observed. These differences might be related to parasitic infections
47 suffered during the head-starting period. This study shows that nest management measures may contribute to the
48 conservation and range expansion of the loggerhead turtle population in the western Mediterranean.

49 **Introduction**

50

51 In recent years, several loggerhead sea turtle (*Caretta caretta*) nesting events have been recorded in the western
52 Mediterranean basin, outside the known nesting range in the Mediterranean Sea (Tomás et al. 2008a; Maffucci et
53 al. 2016). Western Mediterranean nests may indicate that the species is exploring new locations to expand its
54 nesting range (Maffucci et al. 2016). However, nothing is known yet about the survival and dispersal of post-
55 hatchlings from these nests.

56

57 There is no evidence of supported nesting events in the past years. Nonetheless, despite the lack of scientific
58 reports and nesting surveys, loggerhead nesting outside its range was sporadically reported in the western
59 Mediterranean during the 20th century (Tomás et al. 2008). The increasing occurrence of these nesting events in
60 the Western Mediterranean may be a consequence of the higher sea temperatures recorded in recent decades (Witt
61 et al. 2010a; Maffucci et al. 2016). Warmer temperatures during interglacial periods also seem to have facilitated
62 the expansion of loggerhead turtles into higher latitudes (Bowen et al. 1993; Clusa et al. 2013). The warmer
63 temperatures may also, hypothetically, imply the disappearance of the traditional nesting areas (Greece, Turkey,
64 Cyprus, and Libya) in future (Hays 2000; Casale and Margaritoulis 2010). Therefore, colonization of new areas
65 may be an important outcome for a threatened species (Wyneken and Lolavar 2015; Abella et al. 2016) like the
66 loggerhead sea turtle, which IUCN considers ‘Vulnerable’ (Casale and Tucker 2015). These new nesting events
67 may contribute to both the Mediterranean subpopulation, and the North Atlantic subpopulations (Revelles et al.
68 2007b; Clusa et al. 2014). Previous genetic analysis shows that hatchlings from the Western Mediterranean basin
69 have Atlantic and Mediterranean genotypes (Carreras et al. 2015).

70

71 Although several western Mediterranean nests have produced successful clutches (Tomás et al. 2008a; Maffucci
72 et al. 2016) nothing is known about the dispersal behavior and survival rates of the post-hatchlings from these
73 nests. After hatching, young turtles crawl into the sea and swim offshore and are rarely observed until they return
74 to coastal waters as larger juveniles. The time gap after young turtles hatch and head to sea, where they remain at
75 a surface-pelagic or oceanic stage before returning to coastal waters as large juveniles, is referred to as the *lost*
76 *years* (Carr 1987; Bolten 2003),

77 Few studies have tracked the dispersal movements of sea turtles during the *lost years*. Recent advances in satellite
78 tags have allowed research in this area. For the rookeries in the Atlantic (Hays and Marsh 1997; Monzón-Argüello
79 et al. 2012; Putman et al. 2012a, b, 2015; Putman and He 2013; Mansfield et al. 2014, 2017; Lamont et al. 2015)
80 and Pacific oceans (Okuyama et al. 2011; Kobayashi et al. 2014; Briscoe et al. 2016; Christiansen et al. 2016)
81 dispersal routes of young loggerhead post-hatchlings (< 2 years old) are starting to be elucidated by tracking,
82 modeling or laboratory-based methods. However, for the Mediterranean Sea this information is lacking. There are
83 some theoretical models for the rookeries at Greece and Italy (Hays et al. 2010; Luschi and Casale 2014; Casale
84 et al. 2015; Maffucci et al. 2016). Cardona and Hays (2018) analyzed the tracks of young pelagic satellite tagged
85 loggerheads (straight carapace length (SCL) ranged 41.2 to 68.5 cm) to assess their movements and the influence
86 of currents in the Mediterranean Sea. Nonetheless, there are no previous studies based on post-hatchling tracked
87 animals with size below 35 cm SCL, that is to say, younger than 2 years old (Bjørndal et al. 2000; Casale et al.
88 2009, 2011). Such information is relevant to assess the dispersal routes of loggerhead turtle post-hatchlings in the

89 Mediterranean Sea since their routes may take them to unsuitable areas for their survival, that is, areas where low
90 temperatures persist (Maffucci et al. 2016). Some authors support that directional swimming, even by small
91 turtles, can influence their oceanic movements and may lead to hatchling distribution patterns that differ from the
92 models (Putman et al. 2011, 2012a, b; Lohmann et al. 2012; Scott et al. 2012; Kobayashi et al. 2014; Mansfield
93 et al. 2014, 2017; Christiansen et al. 2016). Thus, assessing the movement patterns of post-hatchlings would help
94 to understand their behavior and ecology and to design effective conservation strategies (Hays et al. 2016).

95

96 Most nesting events recorded in Spain have been found in touristic beaches, and so consequently, egg development
97 and hatchling survival are threatened by human activities, as observed in other Mediterranean areas (Venizelos
98 1989; Demetropoulos 2003). Thus, management measures like nest relocation and head-starting programs were
99 taken to protect Spanish clutches, as recommended in other areas (Kornaraki et al. 2006; Tuttle and Rostal 2010;
100 Burke 2015; Revuelta et al. 2015). The head-starting program is an ex-situ conservation strategy that involves the
101 captive rearing of hatchlings for several months. The objective of this strategy is to avoid the high mortality rates
102 of sea turtle hatchlings in their first year (Burke 2015).

103

104 The head-starting technique is a frequent way of enhancing wildlife populations (Pritchard 1980; Heppell et al.
105 1996; Mestre et al. 2014; Burke 2015). There is evidence that head-started sea turtles can survive to adulthood
106 and contribute to nesting events (Bell and Parsons 2002; Shaver and Rubio 2008). Nevertheless, head-starting
107 programs might not always be as successful as expected, since several constraints like behavioral anomalies, lower
108 growth rates or illness during the captivity period may limit the survival of post-hatchlings before and after release
109 into the wild (Swingle et al. 1994; Heppell 1998; Addison and Nelson 2000; Cardona et al. 2012). Evaluating the
110 success of head-starting programs in sea turtles is challenging due to their long age to maturity (Burke 2015). One
111 approach to assessing the short-term success of these programs is to evaluate the survival rate of reintroduced
112 post-hatchlings during the first few months after release when their prospects of survival are expected to be the
113 lowest (Armstrong and Seddon 2008). However, assessing the survival of post-hatchlings directly is challenging,
114 and one of the major gaps in our knowledge of sea turtle population dynamics (Bolten 2003; Hazen et al. 2012;
115 Casale et al. 2015).

116

117 In this study, we satellite-tracked head-started loggerhead post-hatchlings to analyze and describe their dispersal
118 routes and survival for the first time in the Mediterranean basin.

119

120 **Methods**

121

122 **Turtle data and satellite tagging**

123

124 Loggerhead post-hatchlings were collected from three nests (Clutch A (n = 8), Clutch B (n = 2), Clutch C (n = 9)
125 along Spain's Mediterranean coast (Fig. 1). All hatchlings were reared in a head-starting program (see details in
126 Table 1). Individuals from Clutch A suffered from a parasitic outbreak of the copepod *Balaenophilus manatorum*
127 (Crespo-Picazo et al. 2017; Domènech et al. 2015) and spirorchiid blood fluke *Amphiorchis* sp. (Cribb et al. 2017)
128 infections during the head-starting period. After the head-starting period, which lasted from 9 to 22 months, 19

129 post-hatchlings were selected based on appropriate size for tagging and their swimming and diving activities.
130 Appropriate size is that which ensures that experimental tags do not hinder turtle growth movements, or behavior
131 (Mansfield et al. 2012). Individual sizes ranged between 13.3-29.1 cm straight carapace length (SCL) and weight
132 between 0.490-4.314 kg (Table 1).

133

134 At-sea movements of 19 post-hatchlings were tracked during 2015-2017 (Table 1). Post-hatchlings were tagged
135 with small solar-powered platform transmitting terminals (PTT), model SEATAG-TurtleTag, manufactured by
136 Desert Star S.L, without a duty cycle. We used three tags with similar characteristics but different weights: 18, 21
137 or 26 g (Fig. 2) and an acrylic-silicone-neoprene attachment method modified from Mansfield et al. (2012). The
138 durability of the tag attachment on the carapace was tested in captivity with turtles from Clutch A over four weeks.
139 Tags remained attached for a minimum of 18 days. We also examined the increase in weight of tagged animals
140 over time relative to a control group to test if the tag affected the turtles' growth. The total weight added to the
141 experimental animals ranged 5-12% of the animal weight. There was no significant differences between
142 experimental and control groups (t test, $t = 0.757$, $df = 11.866$, $P = 0.4639$). Prior to attaching the transmitter, the
143 carapace was first cleaned with 70% isopropanol to remove natural oils, and allowed to air dry. Then, the carapace
144 was sanded using mildly abrasive sandpaper (Godley et al. 2003), wiped with 2% chlorhexidine diacetate
145 disinfectant solution, and air dried. The transmitter was attached between the second and the fourth vertebral scute
146 with an acrylic base (Technovit 6091), two neoprene strips (7x0.8 cm, 5 mm thick), and finally aquarium silicone.
147 Aquarium silicone was used in preference to epoxy resin because it is more flexible and allows the carapace to
148 grow without deformations (Mansfield et al. 2012). Neoprene strips provide buoyancy and, with silicone, also
149 provides a flexible base for the satellite tag. In most cases, we secured tags to the turtle's carapace with nylon line
150 (0.4 mm) through a small hole drilled with a 0.6 mm sterilized needle through the keratin part of the crest of both
151 second and fourth vertebral dorsal scutes (modified from Nagelkerken et al. 2003). Nylon was tied in a double
152 knot. Turtles were tagged at least one day before their release so they could get used to the extra weight (except
153 the turtles with identity numbers (ID) 15 to 19). The behavior (including swimming and diving ability) of the
154 turtles tagged in advance was observed. Turtles behaved normally at release. Post-hatchlings were released
155 preferentially on the same beach where the clutch was found. Tag weight was less than 5% of turtle weight,
156 following previous studies (Mansfield et al. 2014). In methods, Mansfield et al. 2014 specify the tag weight (9.5
157 g), but do not provide any explicit information on total tag weight or the weight of the acrylic-silicone-neoprene
158 attachment. The authors only provide information on the epoxy needed to protect the tag from the marine
159 environment (epoxy added weight ranged from 1.5 – 3.5 g) (Mansfield et al 2012). Nonetheless, we can estimate
160 the total weight of the attachment they used from the information provided in Mansfield et al 2012. They used
161 approximately 15-22 mL of aquarium silicone (density = 1.03 g/L) and two neoprene strips (40 x 5 x 5 mm),
162 approximate weight 1.5 g. Adding all these weights shows the total weight of the attached tag would range
163 between 27.95 and 37.16 g. If turtle size in Mansfield were between 300 and 700 g, the added tag weight
164 percentage could range between 3.99 and 12.39 %. This percentage range of total added weight is similar to ours
165 (Table 1). Our total added weight ranged between 31 and 72 g and our turtle size ranged between 489.9 and 4314
166 g, so both weights were heavier than in Mansfield et al. (2014). However, in our case the percentage of added tag
167 weight ranged from 1.29 to 8.81 %. Therefore, our additional weight percentage was similar to Mansfield et al.
168 (2014).

169

170 **Data acquisition**

171

172 Location data (LC) were collected using the Argos system, which classifies seven location classes of decreasing
173 accuracy (3, 2, 1, 0, A, B, Z). LCs 3, 2, and 1 have Argos estimated errors of less than 250 m, 500 m, and 1500
174 m, respectively (CLS 2016). Empirical studies by Hays et al. (2001) and Royer and Lutcavage (2008) found
175 location class A comparable in accuracy to class 1. Witt et al. (2010b) found that LC B had poorer accuracy than
176 LC A, and the worst level of accuracy was found in LC 0, such that $LC3 < LC2 < LC1 < LCA < LCB < LC0 <$
177 LCZ . Facing shortages of LC 3, 2, and 1 locations, some researchers studying sea turtle movements have also
178 included locations of LC 0, A, B and Z after extensive data screening (Mansfield et al. 2014; González et al.
179 2016). Data are stored in Seaturtle.org database. We used all locations except locations that required a high
180 traveling speed, $> 10 \text{ km h}^{-1}$ (González et al. 2016) and land locations (Arendt et al. 2012), which were filtered
181 with Satellite Tracking and Analysis Tool (STAT) (Coyne and Godley 2005). Then, we used the Douglas Argos-
182 filter algorithm (DAF) (Douglas et al. 2012) as implemented in the Movebank tracking database (Wikelski and
183 Kays 2017). We used distance-angle rate filter (DAR), which retains spatially redundant locations and locations
184 that pass movement rate and turning angle tests as the most appropriate approach for studying marine turtle
185 movements (Douglas et al. 2012). Parameters were $KEEP_LC = 2$, $MAXREDUN = 15$, $MINRATE = 10$, and
186 $RATECOEF = 25$.

187

188 **Dispersion analyses**

189

190 Bathymetry data to analyze the use of neritic and oceanic habitats were obtained from the Satellite Tracking and
191 Analysis Tool (Coyne and Godley 2005). Trajectories were analyzed using ‘adehabitatLT’ package (Calenge
192 2006) in R version 3.3.1 (R Development Core Team 2017). To identify movement phases we segmented
193 trajectory into segments characterized by a homogeneous behavior using the method of Gueguen (2000).
194 Independence of the residuals of this segmentation was tested using the Wald and Wolfowitz test. Orientation
195 analyses were performed using turtle bearing with ‘circular’ and ‘CircStats’ R-packages (Agostellini and Lund
196 2017). The significance of circular mean was tested through Rayleigh’s test. Uniformity of distribution was tested
197 using Watson’s test. Finally, we compared orientation differences among clutches using Mardia-Wheeler-
198 Watson’s test (Batschelet 1981). Dispersion maps were produced using Maptool provided online by
199 SEATURTLE.ORG (www.seaturtle.org/maptool).

200

201 **Survival analyses**

202

203 We assessed the daily survival probability of sea turtles using capture-recapture models for open populations
204 based on the Cormack-Jolly-Seber (CJS) model (Lebreton et al. 1992) using software Mark 7.1 (White and
205 Burnham 1999). In this way, survival probability (Φ) can be estimated independently of recapture probability (p)
206 (Lebreton et al. 1992). Capture-recapture data were obtained from Argos messages and tracks information during
207 90 days from release (day 0). Days with no Argos message were coded as not captured. The goodness-of-fit test
208 (GOF) of the CJS model was performed using U-CARE (Choquet et al. 2009). This was done to explore the fit of

209 the CJS model to the data, and to identify a general model from which to start a suitable model selection. Trap
210 dependence was analyzed following Pradel (1993).

211

212 We used a linear model approach and a logit-link function to evaluate several models. The *a priori* set of models
213 included different effects such as time dependence in survival or recapture, several trends (constant, linear,
214 exponential, logarithmic and half-normal) in survival or recapture, differences in survival between months or trap-
215 dependence effects on recapture. Model selection was based on the corrected Akaike's Information Criterion
216 (AICc) (Burnham and Anderson 1998). We considered that models with a difference in AICc of less than two
217 units were similarly supported by the data (Burnham and Anderson 1998). As we were mainly interested in
218 survival, we first modeled recapture probabilities. Once we had the best model for recapture probability, we
219 modeled survival. In order to compare survival among nests, we started from the best model previously selected.
220 Clutch B was excluded from this analyses due to low sample size ($n = 2$). Nest origin, use of region (Alboran Sea
221 or Balearic Sea) and use of habitat (neritic or oceanic) were included as covariates in these models. Finally, we
222 tested for significant difference in survival estimates between clutches with Contrast software (Hines and Sauer
223 1989).

224

225 **Results**

226

227 **Turtle movements**

228

229 Most locations received were B (32.96%) and Z (25.90%); > 28.80 % of messages received had associated LCs
230 between 0 and 3 (Fig 3). Turtles were remotely tracked on average for 74.2 ± 35.5 days, $n = 19$, and travelled a
231 minimum mean distance of $2,372.45 \pm 1,724.24$ km, $n = 19$, with a resultant mean speed of 2.22 ± 0.94 km h⁻¹, n
232 = 19 (Table 1). Given the low accuracy of locations these swimming values should be considered as estimates.

233 Individuals with few locations were excluded from further movement analyses ($n = 4$, turtle IDs: 3, 7, 8 and 19).

234 On average 75.5 ± 25.1 %, $n = 15$, of locations were off the continental shelf. However, when excluding turtles
235 from Clutch A, 88.0 ± 9.5 %, $n = 15$, of locations were off the shelf (>200 m depth). Turtles from Clutch A have
236 50.4 ± 28.7 %, $n = 5$, of locations within continental shelf waters.

237 The track of each turtle ($n = 15$) showed no directional movement throughout the track duration (Rayleigh's test,
238 Z ; $P > 0.05$, in all cases). Nonetheless, in several instances dispersal movement was consistently directional during
239 certain week periods (Raleigh's test, Z ; $P < 0.05$). Differences in orientation were significant between nests
240 (Mardia-Watson-Wheeler test, $W = 11.736$, $d.f = 4$, $P = 0.019$), and individuals (Mardia-Watson-Wheeler test, W
241 = 64.814 , $d.f = 28$, $P < 0.0001$). Release date did not affect orientation (Mardia-Watson-Wheeler test, $W = 3.291$,
242 $d.f = 2$, $P = 0.193$). Overall, post-hatchlings did not disperse following a similar pattern after release, except during
243 the coldest months. This was true even when considering releases by clutch or date (Fig. 4). The most frequented
244 areas were the Alboran and Balearic Seas. From Clutch A ($n = 5$) two turtles (IDs: 1, 2) moved northwards to the
245 Balearic Islands, Turtle ID 2 traveled south during winter. The other three (IDs: 4, 5, 6) moved southwards to the
246 Alboran Sea, and Turtle ID 4 traveled possibly taking a North African eddie. Turtles from Clutch B (IDs: 9, 10),
247 remained in the Balearic Sea, and Turtle ID 9 travelled northwards to the French coast reaching the Gulf of Lion.
248 From clutch C ($n = 8$), four turtles (IDs: 11, 12, 14, 18) traveled south and moved into the Alboran Sea. One of

249 them, Turtle ID 11, traveled at the end of its monitoring period northwards approaching the Balearic Islands. Two
250 individuals from Clutch C (IDs: 13, 15) traveled northwards from the release point to the Balearic Sea. Finally,
251 only two turtles from Clutch C (IDs: 16, 17) moved eastwards along the north African coast to the Algerian sub-
252 basin approaching the Sicilian Strait (Fig. 4). None of the turtles crossed the Gibraltar or Sicilian Straits or reached
253 the Ligurian Sea during the tracking period. We only observed a common dispersal pattern during the coldest
254 months of monitoring (December and January), when turtle movements were directed southwards to the western
255 Alboran Sea or southeastwards to Sicilian Strait (Online Resource S1 and S2).

256 Track segmentation analyses showed that in all analyzed individuals movements during the first days of
257 monitoring (10-40 days) were slower than in the rest of the trajectory (Fig. 5). Some individuals (IDs: 9, 10, 18)
258 alternated between faster phase movements and slower ones (Fig. 5B). In all cases ($n = 15$) the residuals of these
259 segmentations were independent (Wald and Wolfowitz test $P > 0.05$), confirming the validity of the approach.

260

261 **Survival analyses**

262

263 All post-hatchlings were included to assess survival. We obtained 6235 locations and 887 transmissions without
264 location. Two out of 19 satellite-tagged individuals were recaptured alive. The first one (ID 1), from Clutch A,
265 was found 99 days after release stranded on a beach in Murcia (Spain). The second one from Clutch C (ID 12)
266 was recaptured stranded on a beach in Málaga (Spain) after 83 days from release with its satellite transmitter
267 attached. This individual was found with a high epibiotic colonization, and was taken to a rehabilitation center
268 (CMAOT Junta de Andalucía, unpubl data) and its satellite tag was removed. Both these post-hatchlings died a
269 few weeks later at a rehabilitation center. Necropsy revealed plastic debris in the gastrointestinal track of both
270 animals, but no clear cause of death was found. Therefore, the minimum estimated mortality was 11% after three
271 months of tracking but at least 25% of monitored post-hatchlings were alive three months after release.

272

273 Our starting model to estimate survival was the CJS model which has survival and capture probabilities that vary
274 with time (t ; model $\Phi(t) p(t)$). The overall GOF-test for daily survival was significant ($\chi^2 = 191.20, P < 0.01$).
275 There was evidence for a significant trap dependence effect as revealed by the trap-dependence signed statistic (z
276 $= -11.37, P < 0.01$). The negative sign of the statistic z indicated a trap-happiness effect, that is, recapture was
277 more likely when a sea turtle had been located the day before. As we did not ‘capture’ our turtles, this effect might
278 be due to the likelihood of locating a tag by Argos or due to permanent tag loss or tag malfunction. Therefore, we
279 fitted a model with capture probabilities dependent on time elapsed since last encounter (m) and survival
280 probability dependent on time ($\Phi(t) p(m*t)$; model 10, Table 2).

281

282 In the survival analysis, the model that best fitted the data considered constant survival and trap-dependence in
283 recapture (Table 2, model 11). Model selection supported recapture probabilities being dependent on time elapsed
284 since last encounter, considering three periods: whether capture occurred the day before, two days ago or three or
285 more days ago (model 1, Table 2). The model suggested that recapture probability declined with time since last
286 encounter (Table 2). Models including a trend in survival were not supported (models 12, 14, 15, Table 2). Other
287 competing models had an AICc with a difference of more than two units compared with the selected model.
288 Estimated mean daily probabilities of recapture and survival are shown in Table 4. Extrapolating these minimum

289 survival estimates (Φ days), minimum monthly survival probability was 0.78 (95% CI: 0.63 – 0.87) and minimum
290 survival for the study period was 0.59 (95% CI: 0.40 – 0.76). Similarly, minimum annual survival probability
291 was estimated as 0.05 (95% CI: 0.003 – 0.20).

292 Models where survival differed between nests, habitat association and/or region (models 18, 19, 21, 22, 23 and
293 25, Table 2) were fitted. In models 18 to 26, the two individuals from Clutch B were not included because the
294 clutch size ($n = 2$) was insufficient to compute an adequate estimate for survival rate. In this case, model
295 assessment was started considering trap-dependence in recapture (model 25, Table 2). Thus, model 25 (Table 2)
296 was used as the starting model to compare survival between clutches A and C. Models considering the region,
297 Alboran Sea or Balearic Sea, were fitted (models 19 and 22, Table 2). Model 19 considered the influence of both
298 nest and region. The influence of the region in survival was not clear, since the slope (B) of the linear model
299 included zero ($B = 0.76 \pm 0.83$; 95% Confidence interval (CI): -0.88 – 2.39). Models considering the habitat
300 association, neritic or oceanic habitat, were fitted (models 21 and 25, Table 2). Model 21 considered the influence
301 of both nest and habitat association. The influence of the habitat in survival was not clear, since the slope (B) of
302 the linear model included zero ($B = 1.06 \pm 0.67$; 95% Confidence interval (CI): -0.26 – 2.37). The best model in
303 these analyses included a nest effect (model 18, Table 2). The effect, as determined by the slope (B) of the linear
304 model for the covariate nest, was different from zero ($B = 6.17 \pm 0.95$; 95% Confidence interval (CI): 4.32 - 8.03).
305 Daily survival probabilities were significantly different between nests ($\chi^2 = 5.3011$, $P = 0.0213$). Minimum mean
306 daily survival probability was 0.57 (95% CI: 0.30 – 0.76) for Clutch A and 0.94 (95% CI: 0.67 – 0.99) for Clutch
307 C. Extrapolating these values, minimum annual survival estimates were 0.001 (95% CI: 5×10^{-7} – 0.04) for clutch
308 A and 0.47 (95% CI: 0.01 - 0.89) for clutch C.

309

310 **Discussion**

311

312 **Turtle movements**

313

314 This study provides the first successful satellite tracks for post-hatchlings in the Mediterranean. It is also the first
315 tracking of post-hatchlings from nesting events in the Western Mediterranean, outside the loggerhead sea turtle's
316 known breeding range (Tomás et al. 2008a).

317

318 Monitoring the tracks of post-hatchlings was not easy because 59% of Argos LCs we obtained were B and Z,
319 unlike other studies where $> 70\%$ of Argos LCs obtained where between 3 and 0 (Mansfield et al., 2014; 2017).
320 Given the lower accuracy of Argos LCs we obtained we should consider swim values as estimates. This
321 highlighted that there remains a need to develop more accurate devices to assess sea turtle post-hatchlings
322 movements.

323 Assessing turtles' movements is challenging due to the relative contributions of the unique oceanic conditions
324 encountered by each individual during the monitoring period, such as ocean currents; and the swimming behavior
325 of each turtle, that may influence their fate to passive drift or active dispersal (Putman et al. 2016). Overall, post-
326 hatchlings spent much more time in oceanic zones and, generally avoided neritic areas supporting the loggerhead
327 oceanic nursery paradigm (Carr 1987; Revelles et al. 2007a; Mansfield et al. 2014). Most turtles from Clutch A
328 were an exception because they used the continental shelf extensively. Differences in behavior observed between

329 clutches could be caused by parasitic infections suffered at the rehabilitation center (Cribb et al. 2017). A
330 weakened immune system and secondary lesions and infections caused by parasites could have affected their
331 growing rate and individual size and, therefore, their behavior. Smaller or weaker individuals might not confront
332 coastal currents to reach oceanic zones.

333

334 It has been generally assumed that the distribution of sea turtle hatchlings and small juveniles is the result of
335 passive drifting along prevailing currents, due to their limited swimming capacity (Witherington 2002; Bolten
336 2003). Nevertheless, recent studies also with head-started loggerhead sea turtles, have shown that post-hatchlings
337 dispersal differed from what was predicted by passive drift alone (Mansfield et al. 2014, 2017). In previous studies
338 head-started post-hatchlings were able to disperse over large areas, could travel long distances (Bowen and Karl
339 2007; Mansfield et al. 2014) and exhibited highly variable routes (Okuyama et al. 2010), similarly to our results
340 with loggerhead turtles in the western Mediterranean. In our study, monitored turtles did not show directional
341 movement over the entire track, whether they were from the same nest, release date or location. However, in
342 several instances dispersal movement was consistently directional during certain weeks. This could be explained
343 by the turbulent current system in the Mediterranean Sea (MAGRAMA 2012; Balbín et al. 2014). Consequently,
344 turtles may exhibit more convoluted routes and frequent changes in bearing (Cardona et al. 2009; Cardona and
345 Hays 2018), in contrast to dispersal orientation of small loggerhead juveniles in the North and South Atlantic
346 (Mansfield et al. 2014, 2017) and North Pacific oceans (Briscoe et al. 2016) where strong currents are present.
347 Moreover, some turtles dispersed northwards along the western shore of the Balearic Archipelago, a direction
348 opposite the average surface currents in this area (Balbín et al. 2012). This finding may suggest therefore that
349 active dispersal is more relevant than expected in the at-sea movements of young loggerheads in the Western
350 Mediterranean, as was observed in recent studies in the Atlantic and Pacific oceans (Mansfield et al. 2014, 2017;
351 Putman and Mansfield 2015; Briscoe et al. 2016). Nonetheless, Cardona and Hays (2018) compared drifters and
352 turtles' movements concluding that ocean flows profoundly impact the movements of juvenile loggerhead turtles
353 (40-60 cm SCL), suggesting that surface advection is dominant in determining the trajectories of turtles in the
354 Mediterranean Sea. Our hypothesis is that Mediterranean small juvenile sea turtles present behavioral plasticity,
355 with passive drifting or directional swimming being tuned to local conditions as observed in other studies
356 (Mansfield et al. 2014, 2017; Briscoe et al. 2016). Larger amounts of directional swimming may be required to
357 avoid the less optimum areas as the northernmost part of the western Mediterranean basin during winter. Ongoing
358 studies might confirm this hypothesis.

359

360 Post-hatchling movements appear to have been constrained by environmental variables such as sea surface
361 temperature. Overall, we observed that during the coldest months of monitoring (December and January) turtles
362 moved in two directions: (1) southwards to the western Alboran Sea where the surface temperature is warmer due
363 to the inflow of Atlantic waters (Skirris and Beckers 2009), or (2) southeastwards probably on the Algerian Current
364 with its frontal systems of enhanced productivity (Pinaridi and Masetti 2000; MAGRAMA 2012). This fact may
365 be related to the habitat selection hypothesis (Christiansen et al. 2016), probably in order to avoid zones with low
366 temperatures (Coles and Musick 2000). Furthermore, we observed that individuals from Clutch B moved
367 northwards to the Gulf of Lion during the strong upwelling season in October (MAGRAMA 2012). Track
368 segmentation analyses suggest that phases of lower speed at the beginning of the monitoring period may be related

369 to an adjustment period to the new environment. Although oceanographic information was not assessed,
370 alternation of faster and slower velocity phases may illustrate migration phases (direct swimming) and foraging
371 phases (convoluted swimming), respectively (Cardona et al. 2005), or they might be a consequence of different
372 speed currents.

373

374 None of the tagged individuals crossed the Gibraltar Strait during the monitoring period, even though three of the
375 turtles spent most of the tracked time near the Strait area. This fact agrees with previous studies which suggest
376 that small loggerheads (< 36 cm) are unable to pass the Gibraltar Strait from the Mediterranean basin towards the
377 Atlantic basin (Revelles et al. 2007b). It is assumed that most of small juvenile loggerheads found in this area
378 come from the Atlantic Ocean (Bolten 2003; Revelles et al. 2007b), because transport of small juvenile turtles
379 from eastern to western Mediterranean seems to be very unlikely (Putman and Naro-Maciel 2013; Casale and
380 Mariani 2014; Maffucci et al. 2016). Our results suggested that the small juveniles frequenting the surrounding
381 area of Gibraltar Strait might also come from western Mediterranean nests laid in Spain, France, Italy (Delaugerre
382 and Cesarini 2004; Sénégas et al. 2009; Maffucci et al. 2016) and even from Algeria and the western
383 Mediterranean coast of Morocco and Tunisia, though there were no recorded nesting events (Casale and
384 Margaritoulis 2010). If we observe the prevailing currents in agreement with Millot (1999) we can notice that the
385 Algerian current moves eastwards but its convoluted as well, presenting a large number of gyres. This might
386 permit hatchlings from north African coast to travel to the Alboran Sea by shifting passive drift and active
387 swimming behavior. The lack of recent studies in the southern part of the western Mediterranean Sea impeded to
388 confirm this hypothesis. We did not observe any tracked loggerhead crossing the Sicilian Strait from western
389 Mediterranean to eastern Mediterranean during the monitoring period but we lost satellite transmission when two
390 turtles were moving towards the Sicilian Strait, probably directed by the Algerian current. There is evidence of
391 two southward conveyors connecting the south Tyrrhenian Sea with the Strait of Sicily, and therefore, with the
392 favorable Eastern Mediterranean developmental habitat (Casale and Mariani 2014; Maffucci et al. 2016).

393

394 We did not observe a common dispersal pattern, however; two confluence areas in the Western Mediterranean
395 were distinguished: The Balearic and Alboran Seas. The Alboran Sea is a high-productivity area in comparison
396 with the rest of the oligotrophic Western Mediterranean basin due to the input of rich Atlantic waters (Pinardi and
397 Masetti 2000; MAGRAMA 2012) and the permanent upwelling zone in the northwestern part of the Alboran Sea
398 along the Spanish coast (Skirris and Beckers 2009). We observed that our post-hatchlings do not frequent the
399 Ebro's Delta area, in contrast to previous studies on juveniles (Cardona et al. 2009), although our tracked
400 individuals were younger, head-started and from a different rookery. Distribution in more productive areas like
401 the Balearic and Alboran Seas may be related to directional swimming in young sea turtles to select more favorable
402 habitats based on ambient temperatures, foraging conditions, decreased predation or other reasons (Christiansen
403 et al. 2016; Gaube et al. 2017).

404

405 **Survival analyses**

406

407 Estimating survival in the wild it is a difficult task, particularly when studying marine animals as it is not easy to
408 find recoveries. One approach is the use of satellite locations to obtain capture and recapture data. Previous studies

409 have suggested that head-started marine turtles may present low survival probabilities (Cardona et al. 2012) as
410 has been observed in other species of turtles, especially during the first weeks after release (Burke 2015). Our
411 results show that the minimum daily survival probability of head-started turtles during the first three months after
412 release is high (0.98 - 0.99). Additionally, we need to consider that we may have underestimated survival due to
413 tag loss or tag malfunction (Lebreton et al. 1992). Therefore, if a tagged post-hatchling stopped transmitting we
414 did not know whether it had lost the tag or died. Regarding our results, we can assume that at least within the first
415 month, the likelihood of tags remaining attached was high, with decreasing likelihood in the next months of
416 monitoring. Consequently, our estimates might be upper biased and should be considered conservative estimates
417 due to an unknown, though not negligible, tag loss and failure rate, which increases substantially from the second
418 month of monitoring after release. Nonetheless, estimated survival using capture-recapture methods is less biased
419 than only using return rates.

420

421 We did not find real survival estimates for loggerhead turtle post-hatchlings to compare with. The only available
422 estimates are found in status reviews and are broadly applied to all post-hatchlings worldwide. Hence, there is a
423 need to assess the survival of loggerhead turtle post-hatchlings specifically. Conant et al. (2009) assumed that the
424 oceanic survival rate during the first year was 0.4, however; this value was used for another species (*Lepidochelys*
425 *kempii*) and, moreover, it was not empirically estimated. This assumed survival value is lower than the reported
426 in our results when considering just Clutch C. Mansfield et al. (2014) present tracking data for satellite tagged
427 post-hatchlings in the North Atlantic. Although they did not analyze survival particularly, they tracked neonates
428 for more than 80 days on average, which was similar to our results. Additionally, we need to consider whether
429 tagging could have an effect on post-hatchling survival due the added weight or increase in drag. We used a
430 similar attaching method and the proportional added weight was within the range used by Mansfield et al. (2012,
431 2014). These studies showed that the tagging method did not affect the growth of monitored individuals
432 (Mansfield et al. 2012). We obtained the same results for differences in growing between captive tagged
433 individuals and a control group. Moreover, our turtles were tagged in advance to the release and behavior observed
434 was normal for all individuals after a habituation period (usually 24 hours). In any case, even considering this
435 possible effect of tagging on survival or behavior, our survival estimates support that reintroduced head-started
436 loggerhead turtle post-hatchlings were able to survive in the wild, at least during the most critical period after
437 release (Armstrong and Seddon 2008). Although we cannot evaluate the long-term success of head-started turtles,
438 our results support the short-term success of reintroduction into the wild (Armstrong and Seddon 2008).

439

440 Casale et al. (2007, 2015) estimate annual survival probability of juvenile loggerheads in the Mediterranean Sea
441 using the capture-mark-recapture and the catch-curve method, respectively. They obtained survival estimates that
442 ranged between 0.71-0.86. Sasso and Epperly (2007) estimate monthly and annual loggerhead survival rates (SCL
443 ranged 43-60 cm) with the known-fate model, which upper biases survival estimates when fate is unknown.
444 Although our minimum mean estimates are lower than these previous studies, our range of estimates include these
445 values. These previous studies focused on older individuals (> two years), whereas our study focuses mainly on
446 younger individuals which are expected to have a lower survival probability. Additionally, Sasso and Epperly use
447 a known-fate model instead of a Comarck-Jolly-Sebel model. This implies that they did not consider tag
448 detachment probability, and therefore, the survival estimate was upper biased. The method we used to extrapolate

449 minimum annual survival estimates is highly sensitive to small variations in daily survival. Our estimates,
450 however, only cover a period between June to January, but do not include survival during the period of the year
451 with the lowest sea surface temperature (March) in the Western Mediterranean, when the survival of small
452 loggerheads may be compromised (Maffucci et al. 2016). Further studies covering this cold period should be
453 conducted to obtain annual survival probabilities for one-year-old individuals. Moreover, annual changes in
454 oceanic circulation could impact post-hatchling survival rates (Putman et al. 2013). Therefore, possible annual
455 changes in oceanic circulation should be considered in next studies in order to elucidate the more favorable periods
456 and places to release head-started post-hatchlings, as this may influence their dispersal and survival.

457

458 Survival differences between clutches were most likely due to the condition of individuals. Lower survival
459 probability of Clutch A was probably a consequence of parasitic infections caused by *Amphiorchis spp.* at the
460 rehabilitation center (Cribb et al. 2017), although all infected individuals received proper veterinary treatment.
461 Head-starting programs may have some constraints that limit their success (Burke 2015), especially during the
462 initial years of implementation. Another condition that would contribute to different survival rates between
463 clutches would be caused by a potential genetic bias, since turtles came from three different clutches. We did not
464 observe any effect of the influence of region (Alboran Sea or Balearic Sea) or habitat association (oceanic or
465 neritic habitat) on survival estimates.

466

467 Although fisheries by-catch is considered a major threat for juvenile and adult sea turtles in the Mediterranean
468 Sea (Casale 2011; Baez et al. 2013; Casale and Heppell 2016), we have no evidence of interaction with fisheries
469 of our monitored individuals during the monitoring period. Mortality induced by pelagic longline and bottom
470 trawling gears is the most significant in the Mediterranean Sea (Casale 2011; Echwikhi et al. 2012). This threat
471 becomes greater for larger juveniles (> 30 cm) because larger juveniles in the Western Mediterranean exploit
472 neritic habitats, therefore their main threat are the fishing gears typically deployed in this habitat (bottom trawls,
473 set nets, demersal longlines). Pelagic longline is also a threat for larger juveniles because hooks used by longlines
474 are smaller than turtles' mouth, increasing their chances of accidental capture. In contrast, the hooks are too big
475 for small juvenile loggerheads, preventing their capture (Echwikhi et al. 2012; Casale et al. 2015). Several authors
476 highlight the ingestion of debris and plastics as a major threat for immature turtles (Margaritoulis et al. 2003;
477 Carreras et al. 2004; Cardona et al. 2009). Indeed, two of our satellite tagged turtles were found stranded after
478 almost three months of tracking with several plastic items in their gastrointestinal track, but in these cases the
479 significance remains unknown. One of these turtles also had a severe colonization of epibiotic barnacles in the
480 Alboran Sea (CMAOT Junta de Andalucia, unpubl data). Epibiotic colonization have been described in the
481 Adriatic basin, Aegean basin and, particularly, in the Alboran Sea (Vallini et al. 2011; Domènech et al. 2015).
482 This phenomenon may be significant in certain areas and years, but this remains unclear. Further studies may
483 highlight the importance of these threats for small loggerhead juveniles.

484

485 In conclusion, the present study provides the first results on dispersal areas of head-started loggerhead post-
486 hatchlings in the Mediterranean Sea and contributes to a better understanding of loggerhead post-hatchling
487 survival and habitat use. These results are relevant for the management of potential new breeding areas in the
488 Western Mediterranean. Our survival estimates could be applied to model loggerhead sea turtle populations

489 (Richards et al. 2011) or anthropogenic impacts (Putman et al. 2015). Management measures like nest
490 translocation and head-starting programs for loggerhead hatchlings were successful when considered in terms of
491 short-term survival. There was a high probability of survival of head-started individuals in the wild, and probably
492 head-started turtles had the ability to forage natural prey and growth normally in its natural environment.
493 Furthermore, post-hatchlings from the Western Mediterranean may contribute not only to the Mediterranean
494 subpopulation stock but also to the North Atlantic's, which are endangered. Further understanding of the
495 movement ecology of post-hatchling loggerheads in the Western Mediterranean is crucial for more effective
496 conservation strategies. Nonetheless, as we said before, there remains a need for smaller, lighter and more accurate
497 devices to help drive the science forward, especially about the monitoring of sea turtle post-hatchlings.

498

499 **Compliance with Ethical Standards** The authors declare that there is no conflict of interest and that consent was obtained
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524

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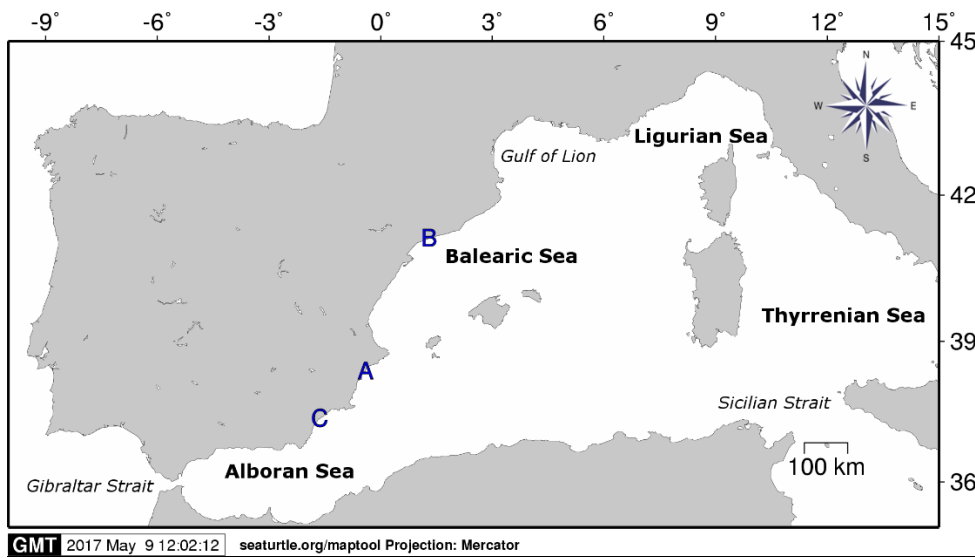
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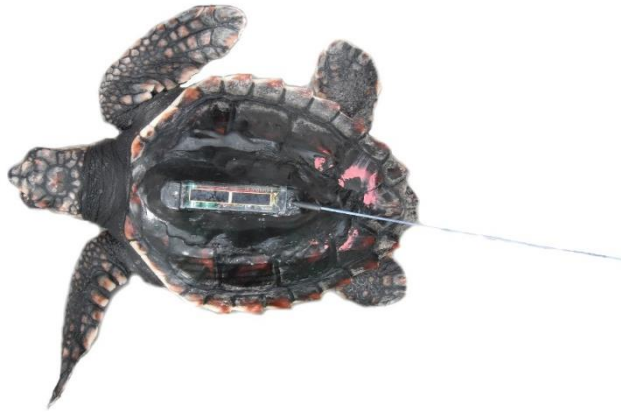
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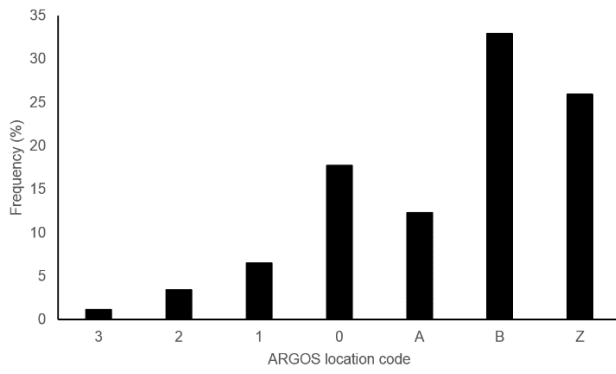
823 **Figures**



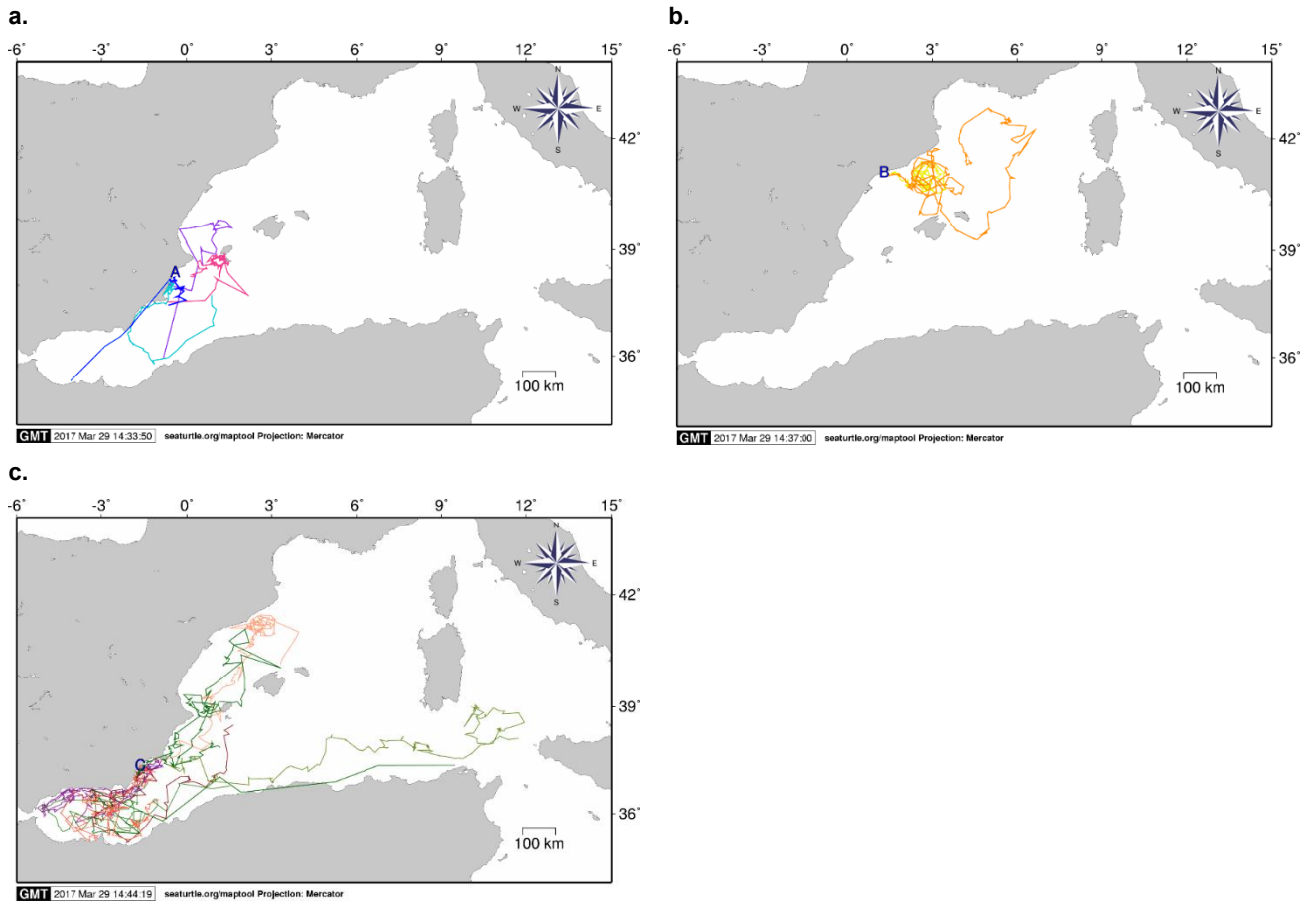
824 **Fig 1.** Nesting locations. Clutch A, n = 8, (Alacant, Spain) [38.37 ° N, 0.41 ° W], Clutch B, n = 2, (Tarragona, Spain) [41.13
825 ° N, 1.30 ° E] and Clutch C, n = 9, (Almería, Spain) [37.38 ° N, 1.64 ° W]. Map obtained with SeaTurtle Maptool
826 (www.seaturtle.org/maptool)



827 **Fig. 2** Post-hatchling identity number (ID): 21 satellite-tagged with a solar-powered platform transmitter terminal (PTT) by
828 Desert Star S.L. a few moments after release

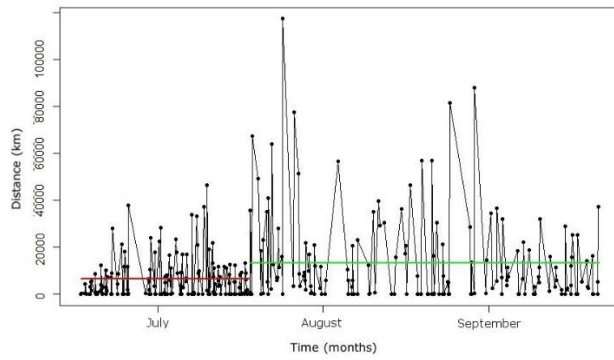


829 **Fig. 3** Frequency (%) of Argos location codes reported with satellite track locations from loggerhead sea turtle post-
830 hatchlings released in the Western Mediterranean.

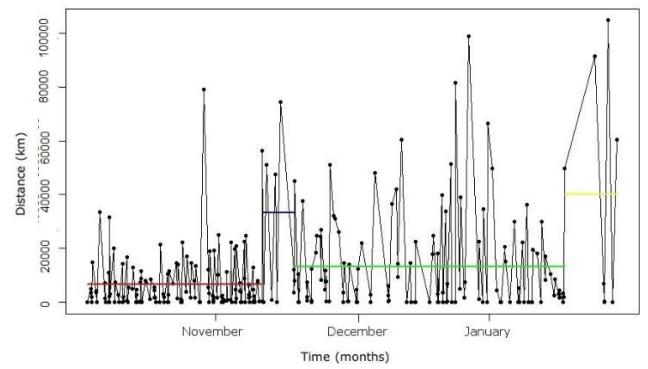


831 **Fig. 4** Dispersion patterns for loggerhead sea turtle (*Caretta caretta*) post-hatchlings in the Western Mediterranean. Release
 832 point is marked by clutch letter (A, B or C). Therefore, figures 4a, 4b, and 4c represent the dispersion routes for clutches A (n
 833 = 8), B ($n = 2$) and C ($n = 9$), respectively. Track colors represent different turtles. In 4c green colors represent post-hatchlings
 834 released in September and the other colors represent post-hatchlings released in June. Maps obtained with SeaTurtle Maptool
 835 (www.seaturtle.org/maptool)

a.



b.



836 **Fig. 5** Movement segmentation analyses. Straight lines indicate mean travel distance through time, red (slower travel
837 distance), green (low medium travel distance), blue (high medium travel distance), yellow (higher travel distance). Different
838 mean travel distances point to different types of movement. Figure 5a: Turtle identity number (ID): 14; Figure 5b: Turtle ID:
839 18

840 **Table 1** Post-hatchling loggerhead data information. Hatchlings were kept in a head-starting program. Head-starting locations were: ARCA del mar (Área de Recuperación y Conservación de
841 Animales del mar, Oceanográfico de València, Spain); CRAM (Centro de Recuperación de Animales Marinos, Tarragona, Spain); CEGMA (Andalusian Marine Environment Management Center,
842 Consejería de Medio Ambiente y Ordenación del Territorio, Junta de Andalucía, Algeciras, Spain); and Aquarium of Sevilla (Spain). Several post-hatchlings from Clutch A were head-started at
843 ARCA (8 months) and at CEGMA (5 months). Clutch C was incubated at Doñana Biological Station (EBD-CSIC, Sevilla, Spain). Total tag weight includes both the Platform Transmitter Terminal
844 (PTT) tag and attachment material. Days transmitted include all transmissions received with or without location. Distance traveled is the sum of the minimum distance between all consecutive
845 locations of each turtle. Release location was on the beach: Clutch A in Elx, Alacant (38.234 N, 0.513 W), Clutch B in Tarragona, Barcelona (41.129 N, 1.302 E) and Clutch C in Pulpí, Almería
846 (37.375 N, 1.636 W).

Clutch	Name	Turtle identity number (ID)	Weight (g)	SCL (cm)	% Total tag weight	PTT tag weight (g)	Total tag weight (g)	Head-starting locations	Age at release (months)	Release date	Days transmitted	Distance traveled (km) ± s.d.	Mean speed (km/h) ± s.d.
A	Sali	1	970.6	17.5	4.07	26.0	39.5	ARCA / CEGMA	13	14/09/2015	98	2076.53 ± 17.97	1.91 ± 2.48
	Daniel	2	854.2	15.8	4.73	26.0	40.4	ARCA / CEGMA	13	14/09/2015	91	1429.58 ± 32.57	1.37 ± 1.83
	Espaikel	3	867.1	16.3	4.26	26.0	37.0	ARCA / CEGMA	13	14/09/2015	23	313.92 ± 2.94	1.28 ± 1.95
	Maya	4	718.3	15.3	5.35	21.0	38.5	ARCA / CEGMA	13	14/09/2015	43	1173.98 ± 11.18	1.50 ± 1.76
	Contxi	5	716.8	15.1	5.34	21.0	38.3	ARCA / CEGMA	13	14/09/2015	54	993.99 ± 31.58	1.70 ± 2.03
	Samy	6	700.4	15.0	5.18	21.0	36.3	ARCA	13	14/09/2015	42	262.73 ± 9.95	0.84 ± 1.13
	Lusi	7	489.9	13.6	8.81	21.0	42.2	ARCA	13	14/09/2015	34	383.86 ± 18.90	1.60 ± 1.62
	Carla	8	496.2	13.3	7.19	21.0	35.7	ARCA	13	14/09/2015	11	117.49 ± 15.26	1.23 ± 2.20
B	Seis	9	4314	25.6	1.29	26.0	72.0	CRAM	22	31/08/2016	123	3916.68 ± 12.15	2.23 ± 1.97
	Nueve	10	3381	29.1	2.17	26.0	56.0	CRAM	22	31/08/2016	37	1908.18 ± 15.99	3.51 ± 2.55
C	Cocedora	11	1012.8	17.5	NA	26.0	26+	CSIC / CEGMA	9	16/06/2016	82	3626.64 ± 22.68	3.27 ± 2.67
	Rabiosa	12	1096.7	17.5	NA	26.0	26+	CSIC / CEGMA	9	16/06/2016	83	3743.38 ± 13.84	3.34 ± 2.68
	Pichirichi	13	952.6	16.6	NA	26.0	26+	CSIC / CEGMA	9	16/06/2016	79	4107.8 ± 17.64	3.85 ± 2.72
	Serena	14	879.2	16.8	NA	26.0	26+	CSIC / CEGMA	9	16/06/2016	102	4163.46 ± 24.82	2.84 ± 2.59
	Toby	15	940	16.97	3.72	18.0	35.0	CSIC / Aq. of Sevilla	12	28/09/2016	106	4381.07 ± 52.49	3.18 ± 2.91
	Dora	16	1000	17.52	3.10	18.0	31.0	CSIC / Aq. of Sevilla	12	28/09/2016	115	2574.49 ± 85.76	1.70 ± 1.82
	Vendetta	17	1102	18.11	3.72	26.0	41.0	CSIC / Aq. of Sevilla	12	28/09/2016	108	5580.33 ± 48.00	3.31 ± 2.80
	Bonita	18	1030	17.47	3.79	26.0	39.0	CSIC / Aq. of Sevilla	12	28/09/2016	123	3981.24 ± 43.66	1.85 ± 1.69
	Morla	19	1308	18.65	3.29	26.0	43.0	CSIC / Aq. of Sevilla	12	28/09/2016	105	341.25 ± 38.20	1.58 ± 1.76

847 **Table 2** Model selection for recapture and survival probabilities of loggerhead post-hatchlings. For each model, the values for deviance, the number of estimable parameters (Np), corrected
848 Akaike's Information Criterion (AICc), differences between the first model and the model with the lowest AICc (Δ AICc) and AICc weights are shown. Model notation is as follows: Phi: post-
849 hatchlings survival probability; p: recapture probability; c: constant; t: time dependence (days); linear trend: linear dependency, month: monthly dependency, ln trend: logarithmic dependency,
850 exp trend: exponential dependency (positive or negative), half normal trend: half-normal dependency, age model for recapture (m2: considering two ages or m3: considering three ages), m*t:
851 interaction recapture probability and time. Bold face denotes the selected models.

	Models	AICc	ΔAICc	AICc weight	Np	Deviance
Modeling Recapture probability	1. {Phi(t) p(m3)}	1125.53	0.00	1.00	92	382.06
	2. {Phi(t) p(m2)}	1146.21	20.68	0.00	91	405.16
	3. {Phi(t) p lineal trend}	1343.82	218.29	0.00	91	602.77
	4. {Phi(t) p ln trend}	1349.36	223.83	0.00	91	608.30
	5. {Phi(t) p(c)}	1352.28	226.75	0.00	90	613.63
	6. {Phi(t) p exp positive trend}	1353.25	227.72	0.00	91	612.19
	7. {Phi(t) p exp negative trend}	1354.33	228.80	0.00	91	613.28
	8. {Phi(t) p half normal trend}	1354.33	228.80	0.00	91	613.28
	9. {Phi(t) p(m*t)}	1418.76	293.23	0.00	264	166.66
	10. {Phi(t) p(t)}	1479.36	353.83	0.00	177	510.20
Modeling Survival probability (considering all clutches)	11. {Phi(c) p(m3)}	974.10	0.00	0.88	4	424.86
	12. {Phi(month) p(m3)}	978.14	4.04	0.11	6	424.85
	13. {Phi(c) p(m)}	996.02	21.92	0.00	3	448.79
	14. {Phi(linear trend) p(m2)}	996.73	22.63	0.00	4	447.49
	15. {Phi(month) p(m2)}	1000.05	25.95	0.00	5	448.79
	16. {Phi(t) p(m3)}	1125.53	151.43	0.00	92	382.06
	17. {Phi (c) p(c)}	1199.44	225.35	0.00	2	654.23
Modeling Survival probability (considering nest origin and or region)	18. {Phi(nest) p(m3)}	918.52	0.00	0.60	5	908.46
	19. {Phi(region+nest) p(m3)}	919.62	1.10	0.35	6	907.53
	20. {Phi(c) p(m3)}	924.15	5.62	0.04	4	916.10
	21. {Phi (nest+habitat association) p(m3)}	925.24	6.71	0.02	6	913.15
	22. {Phi(region) p(m3)}	925.98	7.46	0.01	5	915.92
	23. {Phi(nest) p(m2)}	942.60	24.07	0.00	4	934.55
	24. {Phi(c) p(m2)}	947.14	28.62	0.00	3	941.11
	25. {Phi (habitat association) p(m3)}	948.89	30.37	0.00	5	938.83

25. {Phi(t) p(m3)}	1081.05	162.52	0.00	92	876.00
26. {Phi(c) p(c)}	1131.51	212.99	0.00	2	1127.50

852

853 **Table 3** Real estimate of daily survival parameters and 95% confidence intervals (CI), in brackets, for all covariates of the selected model. Model notation is as follows: Phi: post-hatchling
854 loggerhead survival probability; c: constant, p: recapture probability (note that recapture probabilities are dependent on time elapsed since last encounter, thus, we considered three periods and
855 therefore three recapture probabilities: capture the day before (p1), two days ago (p2) or three or more days (p3), nest: nest intrinsic influence on survival rates, m3: model age for recapture for
856 three ages. Regarding nest influence, we show real estimate parameters for clutches A and C.

Model	Daily survival	p1	p2	p3
All clutches {Phi(c) p(m3)}	0.991 ± 0.003 (0.984 -- 0.996)	0.911 ± 0.009 (0.892 -- 0.928)	0.625 ± 0.052 (0.519 -- 0.719)	0.280 ± 0.044 (0.201 -- 0.375)
Considering nest influence for Clutch A {Phi(nest) p(m3)}	0.981 ± 0.007 (0.961 -- 0.991)	0.901 ± 0.010 (0.879 -- 0.919)	0.622 ± 0.052 (0.516 -- 0.718)	0.264 ± 0.0428 (0.189 -- 0.356)
Considering nest influence for Clutch C {Phi(nest) p(m3)}	0.998 ± 0.002 (0.987 -- 1.000)			