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*Research Article*

# Tracking *Caretta caretta*: Movement patterns following rehabilitation in Malta

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**Abstract.** GPS tracking through the use of satellite transmitters has proved to be a useful technology in identifying migratory patterns in juvenile and adult sea turtles, despite being a relatively new tool in behavioural biology. This technology has allowed tracking to take place over larger areas and for longer periods of time than previously possible. Loggerhead sea turtles (*Caretta caretta*) are able to travel over large distances throughout their life, being able to travel up to 13,000 km in one year, visiting distant areas and often demonstrating complex patterns of movement both as juveniles and adults. However, information on the tracking of loggerhead turtles rehabilitated and released from the Maltese islands is scarce. This study followed the paths taken by five loggerhead sea turtles, four of which were juveniles while one was a full male adult. All turtles were rescued in Maltese waters and rehabilitated at the Aquaculture Directorate at Fort San Luċjan. The turtles spent between 205 and 1550 days at the rehabilitation centre, depending on the severity of their injuries. Three of these turtles were missing either a front or a hind limb. Turtle movements were recorded as X-Y coordinates using Argos System Applications. This information was gathered using Collecte Localisation Satellite (CLS). Following release, all five turtles were observed to frequent the same main region to the South of the Maltese islands, typically the Libyan and Tunisian neritic coastal zones, with few discrepancies also being recorded. The maximum daily speed recorded ranged between 2.4 and 8.0 km/h. The total distance travelled by the turtles under study ranged between 1375 km and 3273 km in 92 and 292 days respectively. The five turtles covered similar mean distances (11.2–22.4 km/day), despite differences in their life-stages and physical abilities. These results suggest that despite their physical limitations, turtles having missing limbs moved at speeds and covered distances comparable to their fully able counterparts.

**Keywords:** Loggerhead turtle, *Caretta caretta*, GPS, Satellite, Tracking, Mediterranean, Malta

## 1 Introduction

In the Mediterranean Sea, loggerhead turtles (*Caretta caretta*), together with other species of sea turtles, are of conservation interest and have been afforded protection since the late 20th Century. Loggerhead sea turtles are able to travel several thousands of kilometers throughout their lives, visiting distant areas feeding in neritic or oceanic zones, and demonstrating complex patterns of movement both as juveniles and as adults (Luschi et al., 2013). Knowledge of movement patterns of turtles out at sea are required for effective and efficient conservation management of this species (Casale et al., 2018). Accurate data on movement patterns can be obtained through satellite tracking. This is a relatively new technology, and its application for tracking the movement of loggerhead turtles in the Mediterranean Sea started merely three decades ago (Hays et al., 1991). While there were some problems with the earliest attempts at satellite tracking of loggerheads, developments in the technology were made in a relatively short period of time. GPS tracking of sea turtles by satellite transmitters has since proved to be useful technology in assessing migratory patterns in juvenile and adult turtles over large areas and over longer periods of time than previously possible (Bentivegna, 2002). Satellite tracking has also allowed for the identification of various short- and long-distance movements to be recorded and correlated to specific life stages of this species. Different studies (Bentivegna, 2002; Bentivegna et al., 2007; Bradai et al., 2009; Casale et al., 2018) all identified seasonal migratory routes, with loggerheads moving from the

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western Mediterranean basin to the eastern parts of the Mediterranean in autumn. Similarly, migrations from the northern parts of the basin to the southern parts have also been observed. Casale et al. (2018) identified several pathways which loggerheads follow throughout their life. Migratory pathways along shallow areas, namely along the southern Mediterranean coast, the northern parts of the Adriatic Sea and along the western coast of Greece were identified. Migratory funnels in open water have also been identified as turtles frequent such areas throughout the reproductive season. Most of the previously identified migratory corridors lie in the East part of the Mediterranean basin (Bentivegna et al., 2007; Casale et al., 2018). The Maltese islands lie within some of the migratory funnels identified by Casale et al. (2018), thus tracking of turtles from the Maltese islands is of interest as one can identify the routes taken by these turtles and whether the routes taken correspond to previously identified migratory corridors. The period of activity of the satellite signalling varies, depending on the life stage of the individual, with younger turtles losing the tracking device earlier, because their shell scutes undergo more frequent developmental changes than adults. The first eleven years of a loggerhead sea turtle are characterised by an increased dependence on oceanographic and meteorological conditions. As the loggerhead grows and develops its muscular apparatus, an increased independence from these factors arises (Bentivegna et al., 2007). Adult females have been observed to perform cyclical shuttling migrations between foraging and breeding sites, thought to be the same routes followed by males (Luschi et al., 2014; Luschi et al., 2013). Their navigational conduct has been attributed to environmental cues, such as thermal fronts and marine currents (Bentivegna et al., 2007). Satellite tracking is also an important tool when following turtles with a disability arising from severe injuries for which they would have undergone treatment and rehabilitation. Turtles easily get caught in derelict fishing lines and nets, as well as large pieces of plastic litter, derelict nylon, twine and ropes, most times becoming severely entangled. As the turtle keeps swimming the entanglement becomes more severe, tightening around the flippers and/or carapace. Often this results in the disruption of the blood flow into the distal part of the limb, resulting in loss of the flipper. It is assumed that this would affect normal activities such as diving and swimming over long distances. It may also effect male *C. caretta* when digging for bivalves and during mating (Schofield et al., 2006). The loss of any flipper shall definitely effect nesting females as they make use of all four flippers in pit preparation, to dig their egg chamber and to direct the eggs from the cloaca into the pit (Hailman et al., 1992). Publication of studies in the recent past have returned differentiating results between rehabilitated loggerhead turtles and patterns recorded for wild unrehabilitated loggerheads (Cardona et al., 2009). Such a comparison has not yet been done on turtles rescued and rehabilitated in Malta, and thus this study will also contribute information towards this knowledge gap. Since the loggerhead, *C. caretta*, is the most abundant sea turtle species in the Mediterranean, it is not surprising that this species is the one that is most encountered in Maltese waters. Occasional nesting events have also been registered on beaches across the Maltese archipelago over the past decade (ERA, 2021; Pace, 2021). Loggerhead turtles in Maltese waters fall victim to both active and derelict fishing gear, boat injuries and ingestion of litter namely plastic and hooks and lines. The associated injuries are the most treated at Nature Trust FEE Malta's Wildlife Rehab Centre. Tracking of turtles in Malta has to date involved mainly rescued, rehabilitated turtles during their release back into the marine natural environment. Sea turtles have a low survival probability, with only 1 in every 100 hatched turtles (Frazer, 1986) reaching maturity. Therefore, understanding the life strategies of these reptiles is important for effective conservation efforts and management. It is also important to understand how these life strategies and survival probability can be affected by injuries and periods of rehabilitation (Baker et al., 2015). Understanding how rehabilitated individuals of *C. caretta* perform following rehabilitation compared to unrehabilitated counterparts, can determine whether rehabilitation efforts are being done in an efficient manner without disturbing the animal's natural instincts. This is in fact what this study aims to contribute, while also comparing migratory routes for juvenile and adult specimens. The first published tracking instances from Malta occurred in 2008 through ERA, formerly Malta Environment and Planning Authority (MEPA) (Hochscheid et al., 2011). This tracking was part of a Regional Activity Centre for Specially Protected Areas (RAC/SPA) project with the collaboration of the Istituto Zoologico di Napoli, MEPA and Veterinary Regulation and Fisheries Conservation and Control Division of Malta. The 2008 tracking involved two rehabilitated turtles which had suffered different injuries. Zeus was the bigger of the two turtles and had suffered mild injuries, thus needed care for a few months. Vicky, which had suffered severe head and neck injuries and had its left front flipper amputated, was released following years at the rehabilitation centre (ERA, 2013). Zeus was recorded as mainly residing in the Malta-Sicily channel during the period of tracking (seaturtle.org, 2013). Unfortunately, the data for Vicky are no longer available on the RAC/SPA website (seaturtle.org, 2013). The present study presents satellite telemetry for five loggerhead turtles which were rescued from different sites and all were rehabilitated prior to release. The turtles were at different stages of their life-cycle with four being juveniles and one adult. Tama, the sole adult male turtle, was missing a front left flipper on release. Doris, one of the juveniles was missing her left hind flipper on release, similarly to Carmine which was also missing one of her rear flippers. Janis and Alison were not missing any flippers on release. Thus, the aim of this study was to assess whether migratory patterns in juveniles and adults overlap, and whether specimens suffering from loss of different flippers behave differently from fully able specimens. This study aims to assess whether turtles that have undergone amputation of one or more of their flippers differ in the migratory routes and speeds from fully bodied, rehabilitated turtles and wild specimens of *Caretta caretta*.

## 2 Materials and Methods

Malta is located in the South-Central region of the Mediterranean Sea, 80 km south of Sicily and 241 km east of Tunisia. The Maltese coast is mainly rocky, with just 2.4% of the coastline being sandy beaches (Deidun et al., 2004). The high light-pollution on these beaches and the ever-increasing marine traffic in Maltese waters are some of the challenges that loggerheads face when in these waters. In fact, during 2021, Nature Trust FEE Malta, recorded the highest number of rescues for loggerhead turtles ever, since it first started rehabilitating injured *C. caretta* individuals back in 2001. Water temperature in Malta normally falls below 21°C in December, and is back up to this temperature in June, making the release season rather long. This helps with maintaining periods of rehabilitation low, thus rehabilitated turtles are often released soon after they have been declared healthy by the veterinary surgeon in charge.

The five turtles included in this study were rescued between 2015 and 2019, and were released in the years 2018 and 2019 table 1. All turtles were rescued following reports by fishermen, boatmen and the general public of the turtles being in distress, with the main injuries being caused by marine debris and fishing gear. The turtles were rehabilitated at the rehab centre under care for an extensive period of time, depending on the severity of the injuries and the turtle's progress, and were only released once it was determined that the turtles were capable of surviving in the natural environment.

Sandy beaches in Malta are limited and as a result most releases are organised from one of the few beaches present, usually either from Ġnejna Bay or Għajn Tuffieħa Bay in Malta or from Ramla l-Ħamra or Ħondoq ir-Rummien Bay in Gozo (table 1). Prior to release, each turtle in this study was equipped with an ARGOS-linked Satellite transmitter, model SPOT6. The transmitters (Platform Transmitter Terminals, PTTs) were attached to the top of the carapace using epoxy resin in accordance with the 'Attachment Protocol Kit' (Wildlife Computers, 2008). The PTT for each turtle was set to transmit once or twice daily, depending on the satellite route. The period of transmission varied from one specimen to the other, depending on their development and maturity of the specimen as the tracker is lost once the outer carapace layer matures. Each turtle was also equipped with a microchip, which was inserted on the medial margin of the left hind flipper. This would enable identification of the turtle following the loss of the tracker if it is injured once again and/or returns to Maltese beaches (table 1).

Turtle movements were recorded as X-Y coordinates making use of Argos System Applications. Argos system applications allow tracking of organisms as information is relayed over the Argos Satellite system. This information is gathered using Collecte Localisation Satellite (CLS) which is the developer of the processing tools and services which distribute the raw data to the user, Nature Trust Malta in this case (Argos, 2021). Once the trackers stopped generating a daily signal, a notification was received and the data were downloaded in the comma delimited format (.csv). The data were cleaned by removing repetitive geolocation data points that fell along a single straight line on the same day for a given turtle. This was done to ensure that points plotted on the maps were not overcrowded resulting in lack of clarity in travel paths. The clean set of points were imported into ArcGIS software version 10.6.1 (Esri Inc, 2017) for further processing. Position waypoints showing the movement recorded for each turtle were plotted, and a map showing all turtle routes superimposed over each other was also generated to identify any common zones or patterns. Maps were generated using the Management Tools function, which converted the individual geolocation into continuous lines. The daily and total distance travelled by each turtle was also calculated using the formula developed by Vincenty (1975), based on an ellipsoidal model of the Earth (Vincenty, 1975). This formula is accurate to 1 mm on an ellipsoid model, however accuracy is lower when used on a WGS-84 system, as was done in this case. Thus, the results obtained are an indication of the distances travelled by each turtle to around ±1m (Veness, 2019). The distances obtained using this calculation were counterchecked with the distances between points on ArcMap GIS and were reconfirmed using Google Earth. This was carried out, to ensure that the data obtained are accurate and correspond to the distances travelled by the turtles. The raw data recorded for distance travelled daily was used to assess whether any statistically

| Microchip ID | Name | Date of recovery | Site of recovery | Life stage and gender | Clinical condition on arrival | CCL (cm) | CCW (cm) | Wt (kg) | Veterinary Treatment | Duration of rehabilitation period (days) | Date of Release | Site of Release |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 900182001135067 | Carmine | 16/12/2016 | Marsaxlokk | Juvenile | Injury left hind flipper (swollen with exposed bone). Entangled with a rope, pieces of net and a branch of a tree | 35 | 31 | 3 | Amputated left hind flipper | 738 | 24/12/2018 | Ħofriet, Xrobb l-Għaġin, Marsaxlokk Malta |
| 900182001135300 | Doris | 22/05/2017 | Offshore landed at Kalkara | Juvenile | Severe damage to right hind flipper from restriction with exposed bone. Entangled in nylon bag | 38 | 36 | 5 | Amputated left hind flipper | 568 | 11/12/2018 | Għadira Bay, |
| 990000002586219 | Alison | 27/05/2018 | 2 Km North of St Paul's Bay | Juvenile | Fishing line extending out of mouth and cloaca | 43 | 42 | 7 | Surgical removal of fishing hook | 205 | 18/12/2019 | Ħondoq ir-Rummien Bay, |
| 990000002586433 | Janis | 24/02/2019 | Marsamxett Harbour | Juvenile | Hook in gullet and entanglement with fishing line | 42 | 40 | 8 | Surgical removal of fishing hook | 249 | 31/10/2019 | Għajn Tuffieħa, Mġarr Malta |
| 990000002585436 | Tama | 19/09/2015 | Off Comino | Adult male | Propellor strike – multiple injuries to left front flipper, neck and shoulder | 63 | 58 | 37 | Amputated left front flipper | 1550 | 16/12/2019 | Ġnejna, Mġarr Malta |

**Table 1:** Turtle weight (kg) Curved Carapace Length (CCL; cm) and Curved Carapace Width (CCW; cm) upon arrival at the rescue centre and duration (days) spent at the rescue centre.

| Microchip ID | Name | Tracker Registration Number | Date of end of signal | Days of transmission |
|---|---|---|---|---|
| 900182001135067 | Carmine | Tracker SPOT 6 No84234 | 17/05/2019 | 145 |
| 900182001135300 | Doris | Tracker SPOT 6 No84233 | 21/04/2018 | 130 |
| 990000002586219 | Alison | Tracker SPOT 6 No196950 | 20/03/2020 | 92 |
| 990000002586433 | Janis | Tracker SPOT 6 No195996 | 15/02/2020 | 106 |
| 990000002585436 | Tama | Tracker SPOT 6 No197241 | Still transmitting | 292* |

**Table 2:** Details of the tracker registration number installed on each turtle, the day of release and the number of days for which a signal was generated by the tracker.

*Still transmitting, 292 calculated up to 3rd October 2020 significant difference exists at a 95% confidence interval between the different turtles, whether varying in their life stage or whether they have suffered a disability due to the injuries sustained. This was done through a 'Generalised linear model' using SPSS v.27 (IBM Corp, 2020). The raw data for the 'distances travelled' daily for all turtles throughout the tracking period was tested for normality and following the failing of these tests, the non-parametric Gamma distribution was opted for. The Gamma distribution is very assumption light and can be run on continuous data as was the data format being analysed here. Different turtles were defined as different categories, such that the analysis was based on groups of data pertaining to each individual turtle, rather than considering each value as a different turtle. The mean distance travelled by each turtle was obtained through the 'mean' calculation, based on the summation of all travelled distances, divided by the number of transmission days of the tracker for the respective turtles. For Tama, the 'days of transmission' was taken to be 292 days as the tracker was still generating a signal at the time of writing.

## 3 Results

General patterns were derived for five rehabilitated individuals, after tracking them for at least 92 days. The duration of the tracked period varied for the five turtles under study and this could be due to either loss of tracker by accident or loss of tracker through natural life processes. None of the trackers involved in this study registered malfunction. Two of the turtles spent most of their time in the sea South of the Maltese Islands, while one (Janis) spent most of its time in the Malta-Sicily channel and North East of the Maltese Islands. Alison also deviated from the general pattern, spending a few days in the Malta-Sicily channel, but then headed south soon after the first few weeks of tracking. Carmine headed west towards Tunis immediately after release then proceeded to the North West of the Mediterranean towards Sardinia and continued further towards Spain (figure 1). All five turtles were released during the autumn season, with Janis released in October, while the other four were all released in December, albeit in different years (table 1).

Most turtles in this study were juveniles, whilst Tama was the only adult turtle. The routes taken by the turtles seem to overlap for the most part throughout the tracking period. Carmine was the only turtle that deviated from this general pattern, heading to the NW of the Mediterranean where it spent most of its time throughout the tracking period. The results generated after running the data through a Generalised Linear Model for all turtles, after having defined each turtle as its own category, returned a statistically non-significant difference in the distance travelled by juveniles and adults ($p$-value; $0.545 > 0.05$) (Appendices). This suggests that adults and juveniles are able to cover similar distances throughout their life-cycle. From the Generalised Linear Model using a Gamma distribution, it was also concluded that there was no statistically significant difference in the distance (km) covered daily by fully able turtles and those suffering a disability ($p$-value; $0.566 > 0.05$) (Appendices). The Generalised Linear Model supported the fact that turtles having missing limbs showed similar distances as recorded by fully bodied turtles. Table 3 highlights how Carmine, which was missing a limb, recorded the highest maximum distance (km) travelled in one day and the highest average distance (km) travelled over its tracking period These numbers are comparable to those recorded for Janis, which was not missing any limbs on its release. Similarly, the numbers are comparable for Alison and Doris, although lower than those recorded for Carmine and Janis, reinforcing that there is no difference between fully bodied turtles and ones missing limbs.

## 4 Discussion

Satellite tracking has proved to be the most efficient method presently available to visualise movements of marine organisms, a technology that has been used to study migrations of sea turtles for several years (Nielsen et al., 2009). Until recently, data on the migrations of loggerhead turtles rehabilitated and subsequently released in Malta was somewhat scarce, with information available being restricted to that noted in Hochscheid et al. (2011). The present study aims at filling some of the gaps related to movement of this species, which is currently listed as vulnerable in the IUCN red list. Loggerhead turtles are highly migratory, poikilothermic organisms and their distribution and behaviour are dependent on the surrounding environment. Thus, the migratory routes these reptiles follow are affected by shifting temperatures, currents, habitats and food availability (Mansflield et al., 2013). Warmer Mediterranean waters are found to the South of the Maltese islands due to the natural thermogradient present in the Mediterranean Basin. *Caretta caretta* migration routes are influenced by water temperature and thus it is a common phenomenon that turtles migrate to warmer waters during the colder months (Bentivegna, 2002). The results presented in this study corroborate such findings as most turtles released in Autumn headed southward during the colder months of tracking. However, this was not always the case as Carmine migrated toward the North West of the Mediterranean basin following a few weeks close to Tunisia. Carmine migrated towards the NW colder regions of the Mediterranean in early March, when water temperatures would not have yet star-

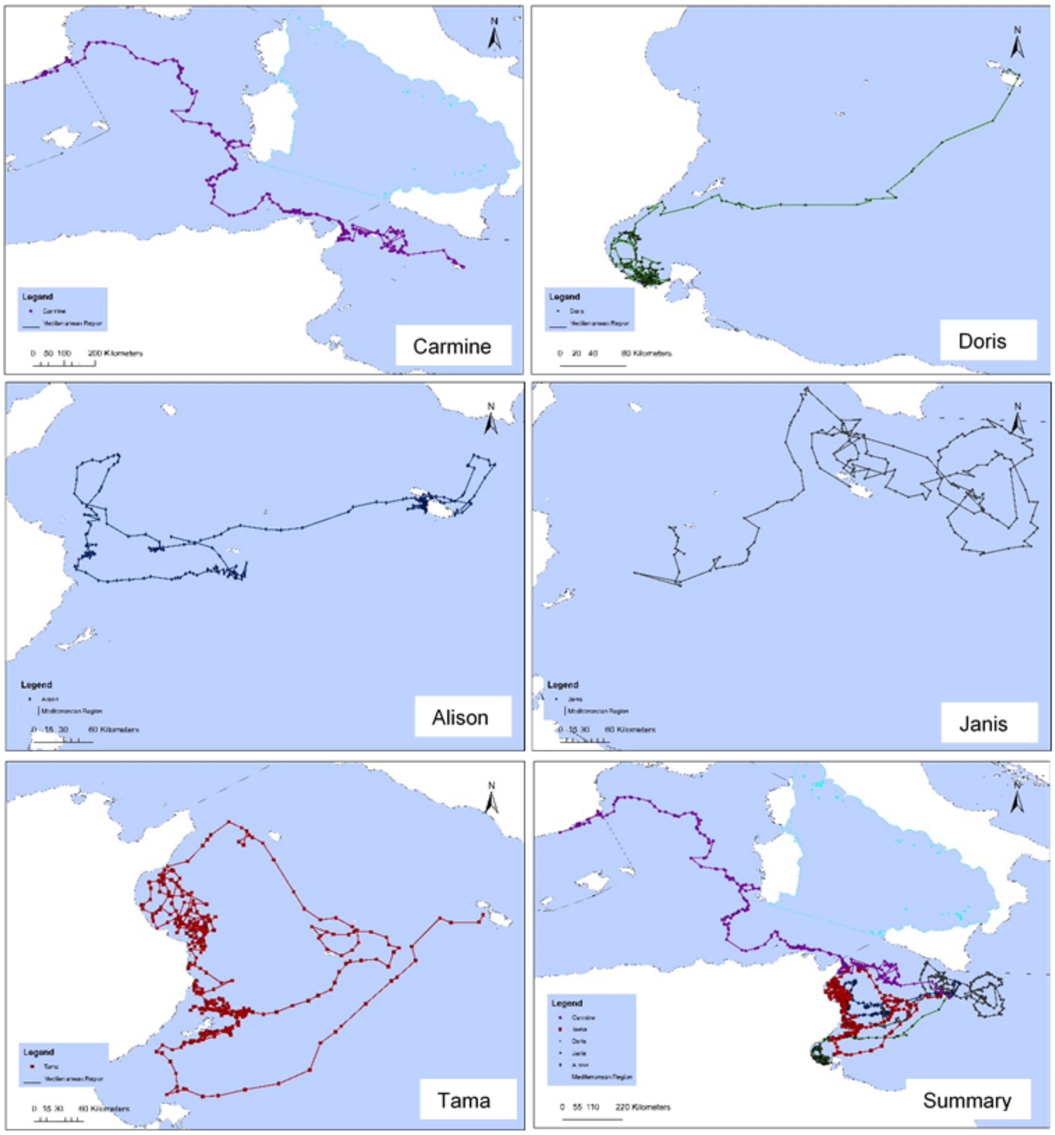


**Figure 1:** Map of the route taken by the five turtles tracked. Carmine was released from Għajn Tuffieħa Bay Mġarr, Malta with the PTT transmitting for 145 days. Doris was released from Għadira Bay Mellieħa, Malta and the signal transmitted for 131 days. Alison was released from Ħondoq ir-Rummien Bay, Qala Gozo, with the PTT transmitting for 92 days. Janis was released from Għajn Tuffieħa Bay Mġarr, Malta with the signal transmitting for 107 days. Tama was released from Ġnejna Bay Mġarr, Malta with the signal still transmitting at the time of paper submission. In the case of Tama the data mapped is for the first for 292 days of transmission. Maps were generated using ArcMap GIS 10.6.1

| Microchip ID | Name | Maximum distance travelled in one day (km) | Minimum distance travelled in one day (km) | Maximum speed recorded (km/h) | Total distance travelled (km) | Total days tracked | Average distance travelled per day of tracking (km) |
|---|---|---|---|---|---|---|---|
| 900182001135067 | Carmine | 191.4 | 0.1 | 8.0 | 3253.9 | 145 | 22.4 ± 24.0 |
| 900182001135300 | Doris | 57.8 | 0.3 | 2.4 | 1879.6 | 130 | 14.2 ± 10.6 |
| 990000002586219 | Alison | 67.0 | 2.0 | 2.8 | 1375.1 | 92 | 14.9 ± 12.6 |
| 990000002586433 | Janis | 101.6 | 2.0 | 4.2 | 2346.1 | 106 | 21.7 ± 18.2 |
| 990000002585436 | Tama* | 61.2 | 0.5 | 2.6 | 3273.1 | 292* | 11.2 ± 10.6 |

**Table 3:** Table showing the distance travelled calculated for each turtle. The table indicates the maximum and minimum distances travelled in a day by each turtle during tracking (km), the maximum speed with which the turtle travelled (km/h), the overall distance travelled by each turtle (km) and the average distance travelled by the turtle during the tracking period (km).

*The data for Tama was calculated based on the first 292 days of tracking as the tracker is still generating a signal on submission of this paper for publication.

ted to rise. This study shows that within the central Mediterranean rehabilitated loggerhead sea turtles with missing appendages (*Caretta caretta*) travel long distances that are comparable to those travelled by full able-bodied specimens. Such distances and areas in which the tracked individuals travelled all fall within the main migratory corridors identified by Casale et al. (2018). It is also evident that some of the turtles tracked in this study followed similar routes to turtles tracked under the RAC/SPA project as outlined in Hochscheid et al. (2011). When referring to the map showing the route taken by 'Zeus' (Mifsud, 2020; seaturtle.org, 2013) similarities are apparent with the route taken by Janis, both residing in the Malta-Sicily channel for most of their tracked days. Comparison with the data for Vicky, the second turtle released during the RAC/SPA project, is not possible as data for this turtle are no longer available. With the exception of Carmine, all turtles travelled and resided for long periods of time within the neritic regions in Tunisian and Libyan waters (figure 1). Neritic areas are areas corresponding to the continental shelf and are generally delimited by the 200m isobath (Casale et al., 2018). The neritic regions identified in Casale et al. (2018) have been identified as foraging and wintering areas, thus providing possible explanations to the migratory routes undertaken by the five turtles tracked in this study, despite Carmine migrating to the Spanish coast soon after its arrival at the Tunisian coast. However, this is not necessarily an anomaly as the Spanish continental shelf shows the same neritic characteristics as the Libyan and Tunisian coasts (Cardona et al., 2009), despite temperature variations between the western and southern coasts of the Mediterranean. Carmine was also released on the 24$^{\text{th}}$ December 2018 and travelled to the South of the Mediterranean towards Tunisia and as temperatures rose towards the end of the tracking duration for this turtle, it migrated towards the NW, were temperatures tend to be cooler for a longer period of time. These findings support the findings by Cardona et al. (2009), with the latter having identified that the majority of rehabilitated turtles tracked in their study, spent their time in the neritic regions, with just one of the tracked turtles migrating into oceanic waters. This identifies a fidelity between rehabilitated turtle and neritic feeding areas. Whether this is a result of rehabilitation has not yet been investigated experimentally, however several findings have suggested this behaviour not being an artefact of rehabilitation. Aerial surveys by Cardona et al. (2009) and Gómez de Segura et al. (2006) identified a higher density of loggerhead sea turtles in different neritic regions across the Mediterranean.

Carmine and Janis registered the highest maximum distances travelled in one day and also the highest mean distance travelled per day during the tracking period (table 3). Tama, Alison and Doris recorded similar mean distances to one another (table 3). The lowest overall mean daily distance travelled was observed for Tama, the only adult. However, when analysed for statistical significance through a Generalised Linear Model, the difference between distances recorded by the different turtles at different life-stages, were observed to not be statistically significant. These findings are comparable to results recorded for *Caretta caretta* adult individuals previously tracked within the Mediterranean (Bentivegna, 2002). Bentivegna (2002) recorded mean distances between 10 km and 23 km for adult *C. caretta* fully-bodied individuals which were released following rehabilitation for a few months after being rescued from trawl nets. However, out of the five turtles tracked in this study, only Tama was a full adult with the rest being juveniles (table 1). Comparable results for the overall mean daily distance travelled, were also recorded for Tama when considering the first 145 days of tracking, which is equivalent to the maximum number of days of tracking undertaken for the other four turtles (mean distance/day based on 145 days of tracking = $10.2 \pm 10.9$). The present results indicate that juvenile individuals reflect the behaviour and capabilities of adult specimens. Moreover, three of the five turtles considered during the present study had missing limbs and, despite their physical limitation, these turtles moved with speed and covered distances comparable to their fully bodied counterparts. Therefore, the comparison of the mean distance travelled does not show distinctive differences between specimens with loss of hind flippers and fully bodied ones. Tama an adult, missing a front flipper, recorded a maximum travelling speed comparable to Alison, a full-bodied juvenile and Doris a juvenile turtle missing one of its hind flippers. Carmine, who was also missing a rear hind flipper, recorded the maximum travelling speed and showed the highest mean distance travelled per day over the tracking period. The maximum distance recorded for this turtle was not a one-off, it actually travelled almost an equal distance also on the day after registering the maximum distance travelled. This could also be explained by the fact that the turtle was in open waters where speeds achieved are much higher than those in neritic areas (Casale et al., 2018). Some studies show that after long periods of rehabilitation, turtles were returned with success in their natural environment (Robinson et al., 2020). The outcome of this study supports this theory. The tracking records obtained for the five turtles subject of this paper are strong evidence of the distance and speed capabilities of rehabilitated turtles. Further tracking data, particularly on adult individuals will serve to provide more information on the migrations undertaken by this species. Releases in different seasons will allow for the comparison of travel patterns between seasons.

## 5 Conclusion

The routes taken by all turtles led to areas, in particular the neritic regions in Tunisian and Libyan waters, which were common to all, suggesting grounds of importance, possibly as foraging and mating grounds within the regions highlighted in previous publications. It appears that loss of any one flipper does not affect the activity of the turtle and foraging for food and general movement seem to follow the capabilities of the fully bodied specimens. Our results highlight that the rehabilitation of these five marine turtles and their return to their natural environment, seems to have been a success in particular for Tama, Carmine and Doris in spite of the long period of rehabilitation.

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# Appendices

## Generalised Linear Models

| Model Information | |
|---|---|
| Dependent Variable | Distance |
| Probability Distribution | Gamma |
| Link Function | Identity |

| Case Processing Summary | | |
|---|---|---|
| | *N* | *Percent* |
| Included | 735 | 100.0% |
| Exluded | 0 | 0.0% |
| Total | 735 | 100.0% |

| Categorical Variable Information | | | | |
|---|---|---|---|---|
| | | | *N* | *Percent* |
| Factor | Disability | Disability | 545 | 74.1% |
| | | No Disability | 190 | 25.9% |
| | | Total | 735 | 100.0% |
| | Life Stage | Adult | 286 | 38.9% |
| | | Juvenile | 449 | 61.1% |
| | | Total | 735 | 100.0% |

| Categorical Variable Information | | | | | | |
|---|---|---|---|---|---|---|
| | | *N* | *Minimum* | *Maximum* | *Mean* | *Std. Deviation* |
| Dependant Variable | Distance | 735 | 10 | 191.40 | 16.4785 | 16.29504 |
| Covariate | Turtle | 735 | 1 | 5 | 3.37 | 1.567 |

| Goodness of Fit[a] | | | |
|---|---|---|---|
| | *Value* | *df* | *Value/df* |
| Deviance | 571.388 | 731 | .782 |
| Scaled Deviance | 817.154 | 731 | |
| Pearson Chi-Square | 630.528 | 731 | .863 |
| Scaled Pearson Chi-Square | 901.731 | | |
| Log Likelihood[b] | -2743.348 | | |
| Akaike's Information Criterion (AIC) | 5496.695 | | |
| Finite Sample Corrected AIC (AICC) | 5496.777 | | |
| Bayesian Information Criterion (BIC) | 5519.694 | | |
| Consistent AIC (CAIC) | 5524.694 | | |

**Omnibus Test**[a]

| *Likelihood Ratio Chi-Square* | *df* | *Sig.* |
|---|---|---|
| 69.317 | 3 | .000 |

**Test of Model Effects**

| | | Type III | |
|---|---|---|---|
| *Source* | *Wald Chi-Square* | *df* | *Sig.* |
| (Intercept) | 6.859 | 1 | .009 |
| Disability | .330 | 1 | .566 |
| Life Stage | .366 | 1 | .545 |
| Turtle | .435 | 1 | .510 |

**Parameter Estimates**

| | | | 95% Wald Confidence Interval | | Hypothesis Test | |
|---|---|---|---|---|---|---|
| *Parameter* | *B* | *Std.Error* | *Lower* | *Upper* | *Wald Chi-Square* | *df* |
| (Intercept) | 24.042 | 6.8979 | 10.522 | 37.561 | 12.148 | 1 |
| [Disability=1] | -2.714 | 4.7275 | -11.980 | 6.551 | .330 | 1 |
| [Disability=2] | 0[a] | . | . | . | . | . |
| [Life Stage = 1] | -4.052 | 6.6947 | -17.173 | 9.070 | .366 | 1 |
| [Life Stage = 2] | 0[a] | . | . | . | . | . |
| Turtle | -1.178 | 1.7855 | -4.677 | 2.322 | .435 | 1 |
| Scale | .699[b] | .0331 | .637 | .767 | | |

**Parameter Estimates**

| | Hypothesis |
|---|---|
| *Parameter* | *Sig.* |
| (Intercept) | .000 |
| [Disability=1] | .566 |
| [Disability=2] | |
| [Life Stage = 1] | .545 |
| [Life Stage = 2] | |
| Turtle | .510 |
| Scale | |