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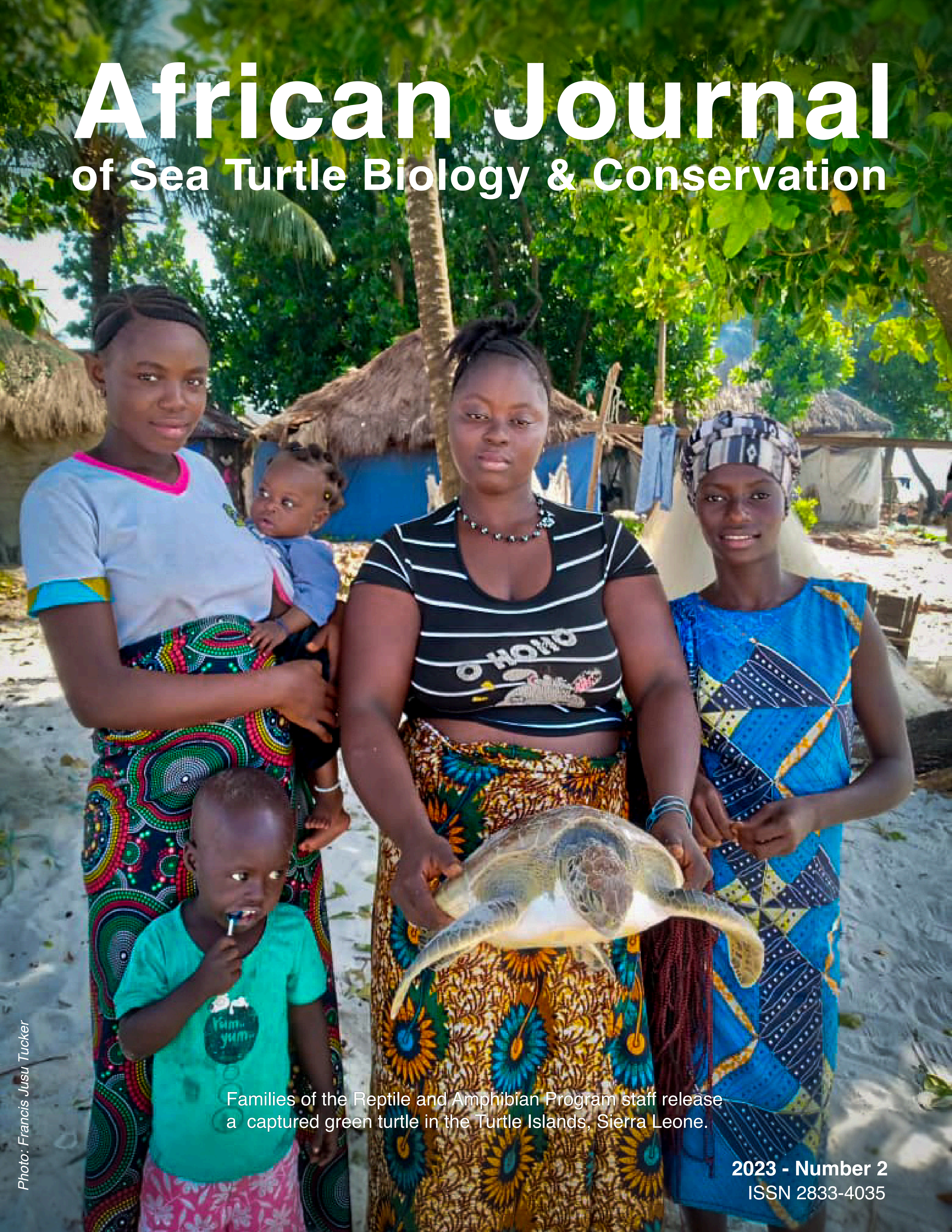

Families of the Reptile and Amphibian Program staff release a captured green turtle in the Turtle Islands, Sierra Leone.

Photo: Francis Jusu Tucker

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Table of Contents

Articles

Short Communications

Technology and Sea Turtle Conservation

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Technological innovations represent human ingenuity in solving practical problems. These innovations, involving the creation of machines and devices grounded in scientific knowledge (Berger-Tal and Lahoz-Monfort 2018), hold the capacity to offer significant and unique contributions to the relationship between humans and nature, enhancing practices and outcomes within the realm of conservation (Mascia 2003). While conservation biologists have progressively integrated technology from various fields (e.g., medicine, military; Berger-Tal and Lahoz-Monfort 2018) into their studies, the future seems to be moving towards a leadership role for technological innovation in conservation. However, there is often resistance to implementing technological changes in conservation programs, particularly when they involve altering familiar and effective practices. Nevertheless, embracing technology can prove advantageous in achieving conservation objectives.

In this paper, we present a case study where technological advancements have been gradually incorporated from 2016 to 2023 in the study and conservation of marine turtles by the Maio Biodiversity Foundation on the island of Maio, Cabo Verde (Fig. 1). Our marine turtle conservation program arose analogously to other national and international programs, driven by local declines and even extinctions of turtle populations, primarily due to mortality in fisheries and the consumption of their meat and eggs in nesting areas (Spotila *et al*. 2000; Jackson *et al*. 2001; Dethmers and Baxter 2011; Fiedler *et al*. 2012), and Cabo Verde has not been an exception (Marco *et al*. 2012; Patino-Martinez *et al*. 2022a).

In our case, technological advances have improved data precision and supported scientifically applied studies in the conservation of loggerhead turtles (*Caretta caretta*). More specifically:

To investigate spatiotemporal variations in incubation temperatures, high-precision (±0.2°C accuracy), tiny (3 cm x 4 cm) programmable temperature data logger (Fig. 2a) have been placed in nesting beaches, within nests, and used to measure air temperature. This information allows us to model the effects of climate change on hatchling production of both sexes, since sex determination in sea turtles is temperature-dependent (Mrosovsky *et al*. 1984).

The natural behavior of predators, such as ghost crabs (*Ocypode cursor*), on nesting beaches and their effects on turtle nests and hatchlings has been assessed using infrared night-vision cameras (Fig. 2b;

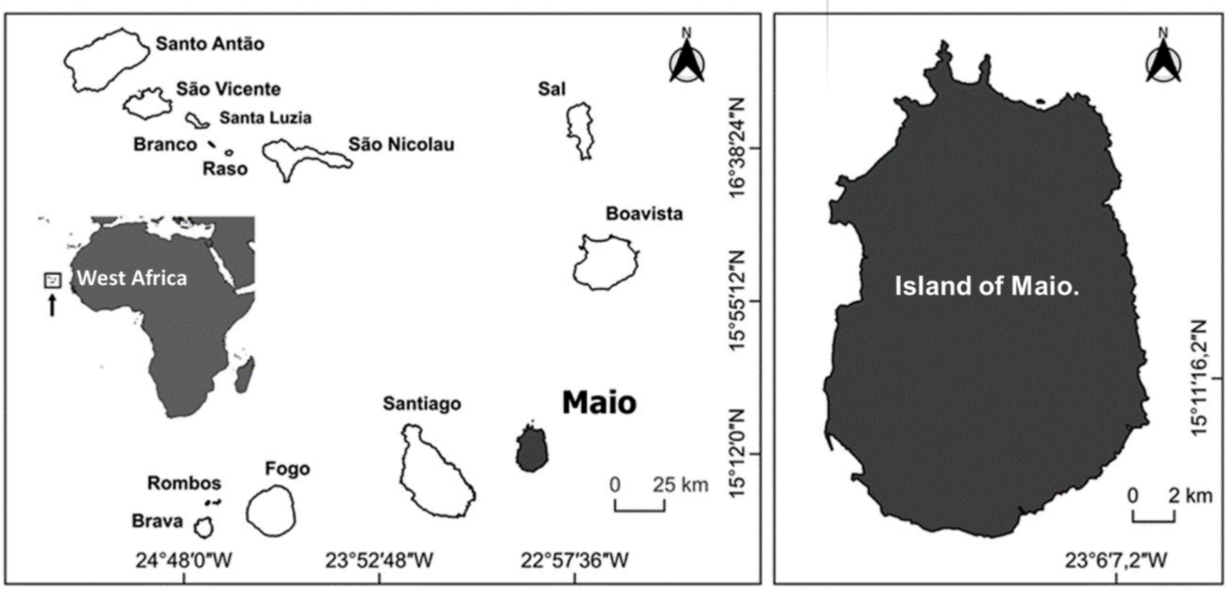

Figure 1. Location of the island of Maio, Republic of Cabo Verde.

Patino-Martínez *et al*. 2022b). The effectiveness of drones (Fig. 2c) has been assessed for monitoring turtle nesting activities in remote or understaffed regions. Drones have proven useful for rapid poaching detection and behavioural studies (Schad and Fischer 2022). The application of the aforementioned technological advancements in sea turtle research have garnered escalating attention, leading to a gradual yet noticeable rise in the publication of related scientific papers.

We have adopted the use of Epicollect 5, a freely available software, for field data collection and database creation through mobile devices (Fig. 2d; Aanensen *et al*. 2009), replacing traditional pen-and-paper methods. This transition has successfully addressed concerns such as empty data fields and entries beyond the specified range, thereby markedly improving the accuracy of the data. Moreover, it has eradicated the errors associated with manual data transcription from paper to computer. The software's real-time data transmission capabilities via an internet connection as well as its offline data collection capability have expedited data availability for analysis. Furthermore, this software not only mitigates the risk of losing paper records but also enables our staff, previously engaged in data entry tasks, to redirect their efforts toward field work and conservation activities.

Access to certain technologies in research projects can be limited by their high costs. This is the case with marine wildlife tracking devices. In our project, we are developing affordable technology to study the mobility of marine species (Fig. 2e; Beuchert and Rogers 2021; Matthes *et al*. *In press*; Beuchert *et al*. 2023) in collaboration with the Arribada Initiative (https://arribada.org), the Department of Computer Science at the University of Oxford (https://www.cs.ox.ac.uk), and with the financial support of the PEW Marine Fellowship (https://www.pewtrusts.org/en/projects/marine-fellows). Through the use of these prototypes, we will obtain valuable information about habitat, threats, and behaviors of sea turtles during their reproductive period.

We employ tracking technology platforms based on Automatic Identification System (AIS; Liu *et al*. 2023) data, such as 'MarineTraffic' (Fig. 2f), to gather information on the routes of semi-industrial and industrial fishing vessels. Low-cost tracking technology has already been implemented to monitor small-scale artisanal vessels (Beuchert 2023). Utilizing the observed overlap, we will model the risk of interaction between sea turtles and both industrial and artisanal fishing vessels.

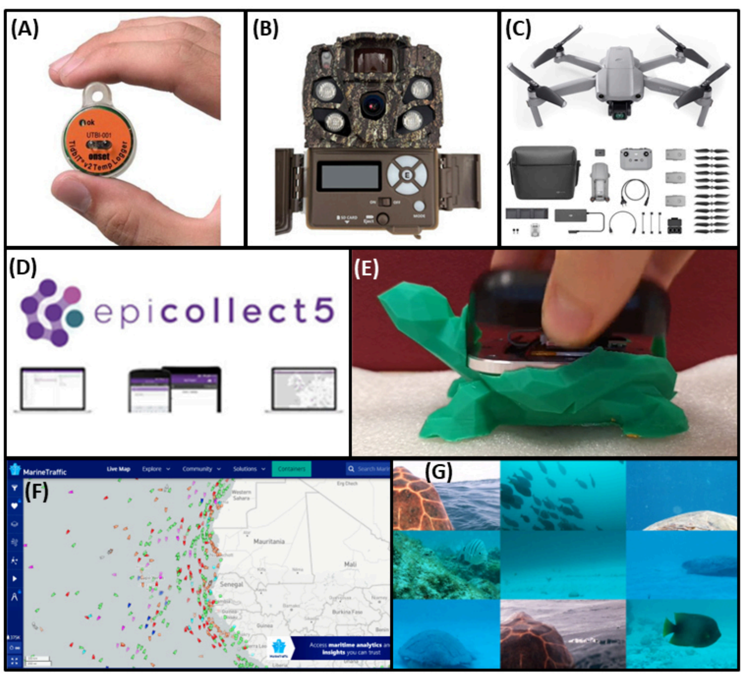

Figure 2. Integration of commercial technology and internal technological innovations in the sea turtle study and conservation program on Maio Island, Cabo Verde, from 2016 to 2023. (a) Automated data loggers (Hobo Stow Away TidbiT v2 Onset) for precise temperature recording (±0.2 °C accuracy) in nesting beaches, nests, air, and water. (b) Infrared cameras (Browning BTC-5HD) featuring automatic activation, motion sensors, and programmability for predator studies on nesting beaches. (c) Drone (Phantom 4 PRO+ V2.0) for quantifying nesting activities, identifying potential poaching, and deterring poachers on beaches without the need for on-site personnel. (d) Open access software (Epicollect 5) for seamless field data collection via mobile devices and online database development. (e) Development of tracking technology utilizing global navigation satellite systems (GNSS) with low cost and open-source hardware and software. (f) Tracking technology platforms leveraging automatic identification system (AIS; MarineTraffic) data to monitor the routes of semi-industrial and industrial fishing vessels and model interaction risks with the studied marine fauna (in this case, sea turtles). (g) In-progress video technology integration with tracking equipment to enhance habitat use research.

The distribution and the type of impacts associated with habitat use in sea turtles and migratory species, in general, can significantly vary from one marine biome to another and from one location to another. To investigate habitat use, we are integrating video technology with tracking devices (Fig. 2g). These data provide a more robust understanding of the relationship between habitat use and its impacts on marine species across different geographic locations. Technological advancements, both in tracking and video devices, will be shared through development platforms and online communities, such as WILDLABS (https://wildlabs.net/) and Github (https://github.com/). The aim is to promote the exchange of ideas, needs, and resources between conservationists and technologists.

In conclusion, through the progressive integration of technological innovations, we have facilitated data acquisition and enhanced data quality, ultimately improving research efficiency and accuracy. We have developed more accessible and efficient technological tools for tracking and observing marine migratory species. The design, implementation, and widespread dissemination of technological innovations applied to conservation will enable global efforts, promoting collaboration within information networks and effective synergy between conservation and technology experts. It is essential to recognize the specific needs of each context, make decisions based on them, and confront the challenges associated with paradigm shifts. Ultimately, it is through the conscious and coordinated adoption of technological tools that we can drive effective and sustainable conservation, ensuring the protection of marine ecosystems for future generations.

Acknowledgments: We would like to thank the FMB local rangers, team leaders, supervisors, and volunteers for their continuing efforts to collect important data. We also thank the environmental national authority, DNA (Direcçao Nacional do Ambiente), for authorisation and their assistance.

Funding for this project has been provided by MAVA Fondation pour la Nature and the US Fish and Wildlife Service. In addition, the PEW Marine Fellows program is currently supporting our research efforts, enabling us to advance studies and technology related to monitoring and video solutions for the conservation of marine migratory species.

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Sea Turtle Interactions with Bottom Trawl and Purse Seine Fisheries in Jebha, Central Mediterranean Morocco

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Fishing activities are responsible for high sea turtle mortality and reduced sea turtle populations worldwide (Gilman *et al.* 2009; Moore *et al.* 2010; Wallace *et al.* 2010; 2011; Stewart *et al.* 2010; Bourjea *et al.* 2014; Casale and Heppel 2016; Arlidge *et al.* 2020). In the Mediterranean, three species of sea turtle are present — the loggerhead turtle (*Caretta caretta*), the green turtle (*Chelonia mydas*) and the leatherback turtle (*Dermochelys coriacea*) (Casale 2011; Casale *et al.* 2018) — and they have all been recorded in Moroccan waters (Benhardouze *et al.* 2012). Artisanal and coastal fishing have led to numerous interactions with sea turtle populations in the Mediterranean (e.g. De Metrio and Megalofonou 1988; Jribi 2003; Casale *et al.* 2004, 2005; Casale *et al.* 2007; Casale and Margaritoulis 2010; Nada and Casale 2011; Benhardouze *et al.* 2012; Lucchetti *et al.* 2016; Casale *et al.* 2018; Hama *et al.* 2020). More than 132,000 catches per year, with over 44,000 accidental deaths per year, have been estimated in the Mediterranean for the green and loggerhead turtles, which are the most affected by coastal fishing, mainly by bottom trawlers, in the eastern basin (Casale 2011). At the western end of the Mediterranean, Morocco forms the southern boundary of the Strait of Gibraltar and occupies a strategic position. It is not only the migration corridor for sea turtles between the Atlantic and the Mediterranean (Brongersma 1982; Camiñas 1997; Casale *et al.* 2003; Revelles *et al.* 2007a), but studies conducted over the last decade have shown that Morocco's Mediterranean coastal zone is mainly used as a foraging habitat (Gerosa and Casale 1999; Margaritoulis *et al.* 2003; Benhardouze 2009; Aksissou *et al.* 2010). The objective of this study was to evaluate the accidental capture of sea turtles in coastal fishing at the port of Jebha in Central Mediterranean Morocco.

Methods: Study area: Port Jebha is located on the Moroccan Mediterranean coast at longitude 04°41' W and latitude 35°12' N and is the only port in the province of Chefchaouen, which stretches over 64 km from Kaa asrass to to the border with the province of Al Hoceima (Fig. 1). It is characterized by the richness and diversity of its fishery resources and their socio-economic importance for the local population.

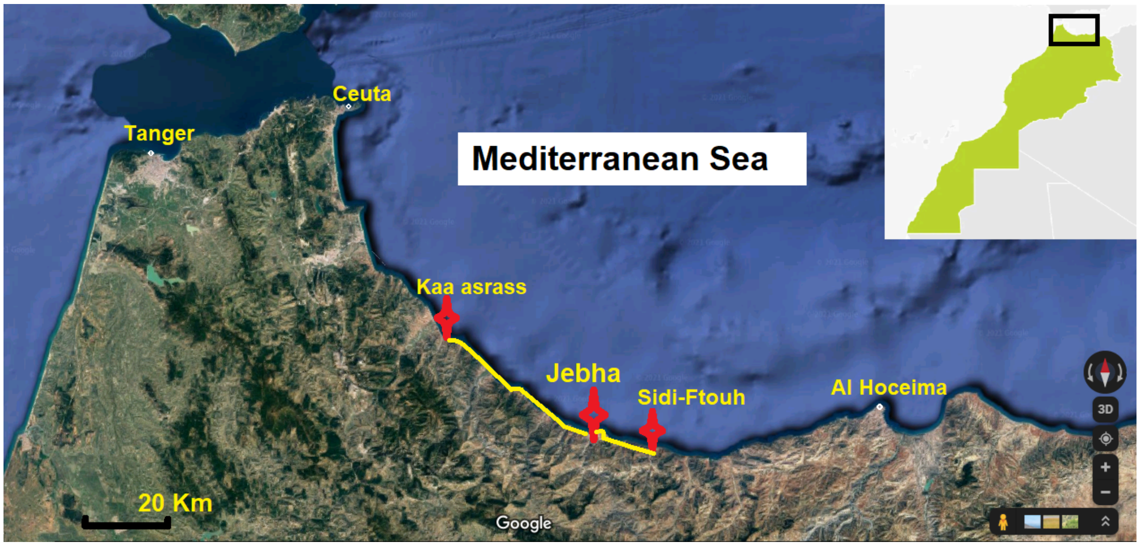

Figure 1. Map of the study area.

The most commonly used fishing gears in the Mediterranean are purse seine, trawl, and longline, which make up the inshore fishery (Chahban *et al.* 2017). Coastal fishing in the study area is characterized by sardine boats that use purse seines. Other vessels, such as trawlers in this area, are registered in the ports of Al Hoceima, M'diq, and Nador. Longline and pelagic trawlers are non-existent in this area, although longlining is practiced in other neighboring areas on the Mediterranean coast (e.g., coast of Al-Hoceima and M'diq).

This research was based on an oral interview of fishermen at the port of Jebha (Fig. 2). The questionnaire included three sets of questions and photos to identify the sea turtle species captured by the fishermen. The first set of questions was about the fishermen (age, type of fishing, seniority in the profession), the second set was about the fishing activity (technique, targeted fish, etc.), and the third set of questions focused on sea turtles in 2020 (sightings at sea, accidental captures, the number captured, the species and size caught, and the variation in the number of turtles in the study area compared with the past).

Twenty-four fishermen, 12 from trawlers and 12 from seiners were interviewed between 31 December 2020 and 12 March 2021 (Figs. 3&4). Two fishermen per boat were selected to interview. For seiners, about 6.3% of all active fishermen were interviewed (12 of 190 active fishermen). No trawler was registered at the port of Jebha. Therefore, all of the trawler fishermen interviewed were considered visitors to the port. We interviewed the fishermen at the port and on board fishing vessels using a single questionnaire, but gave them the freedom to respond and explain as they wished.

Figure 2. Interview with fishermen during the survey (Photo: Y. Ahannach).

Figure 3. The two types of inshore fishing vessels (a: Seiner, b: Trawler; Photos: Y. Ahannach).

Results: Purse seiners work five days a week, with one day off, and do short trips not exceeding 24 hours. Trawlers work every day except on public holidays and during bad weather, and their fishing activity does not exceed five days. Seiners were estimated to have on average 22 fishermen (range = 15–30; n=12) per boat (average boat length = 16.8 m; range = 12.5–20 m; n= 12). However, trawlers have 9.4 fishermen on average (range = 8–11; n=12) on vessels (average vessel length = 15 m; range = 11–20 m; n=12; Table 1).

The dimensions of the gear used at the port of Jebha differ, depending on the gross tonnage of the vessel and/or the depth of the fishing zone. In the case of the purse seine, generally, its length varies from 500 m to 800 m, and its width between 80 m and 160 m. Trawl fishing operations are carried out both during the day and night. Fishing operations for purse seiners are carried out in most cases during the night, using the sounder to detect the shoal of fish, a small boat (lamparo fishing) to group together the shoal, and a rowing boat to help maintain the seine's good shape during the fishing operation (Assabir 1985; Zahri *et al.* 2004).

The trawlers target bottom species, including flatfish (Pleuronectiformes), red mullet (*Mullus surmuletus*), hake (*Merluccius merluccius*), cephalopods such as octopus (*Octopus vulgaris)*, cuttlefish (*Sepia officinalis*) and squid (*Loligo vulgaris*), and crustaceans such as red shrimp (*Parapenaeus longirostris*) and king shrimp (*Penaeus kerathurus*).

The purse seine is the most efficient equipment for catching pelagic species of all sizes — Clupeidae, Engraulidae, Carangidae and Scombridae — but mainly targets small pelagics such as sardines (*Sardina plichardus*), anchovies (*Engraulis encrasicolus*), horse mackerel (*Trachurus trachurus*), and mackerel (*Scomber scombrus*). The first phase of the fishing operation lasts no more than 30 minutes, while the hauling in of the net and recovery of the catch normally takes almost an hour.

According to the interviews, three species of sea turtle have been accidentally caught in this area by fishing activities over one year (2020) (Fig. 5). The results show that the majority of individuals caught were loggerhead turtles (85.7%; n = 36) followed by green turtles (11.9%; n=5), and finally leatherbacks (2.4%; n = 1).

Table 1. Distribution of boat length and number of fishermen on trawlers and seiners.

	Trawlers		Purse Seiners	
	Length (m)	Number of fishermen	Length (m)	Number of fishermen
	17	11	20	25
	15	8	17	20
	16	10	17	26
	20	10	15	15
	11	8	18	25
	16	11	12.5	16
	13	8	13	15
	11	9	20	30
	16	10	19	26
	15	9	15	17
	14	8	20	28
	16	11	15	20
Average	15	9.4	16.8	22.0

Sea turtles were most frequently caught in the trawl net (66.7%; n = 28), followed by the purse seine (33.3%; n = 14). Of the 28 turtles caught in the trawl net, 25 were loggerhead turtles and 3 were green turtles. The14 turtles caught by the purse seine included 11 loggerheads, 2 green turtles, and only one leatherback.

Sea turtles interacted with fishing gear throughout the year, but with the majority of interactions taking place in the Summer (Fig. 6).

In the Summer, 30 individuals (24 by trawl and 6 by purse seine) were caught whereas 7 individuals (4 by trawl and 3 by purse seine) were caught in the Spring.

The majority of turtles reported to have been caught were between 50 and 100 cm long. Among 14 individuals, the purse seine recorded 13 individuals between 50–100 cm and only one individual greater than 100 cm, which was the leatherback. However, in the trawl, 22 out of 28 individuals were estimated to be between 50–100 cm in length, 4 individuals smaller than 50 cm and 2 larger than 100 cm.

Figure 4. The two inshore fishing gears at the Port of Jebha (a: Purse seine, b: Bottom trawl; Photos: Y. Ahannach)

In the purse seine, no dead turtles were reported, whereas in the trawls 27 captures were released alive, and only one individual was brought up dead on deck.

All fishermen interviewed were male with an average age of 42 years (range = 28–64 years; n = 24). The majority of the fishermen were over 36 years of age (70.8%; n = 17) and 29.2% (n = 7) were between 23 and 36 years of age (Table 2).

Of the 24 fishermen surveyed, 22 (91.7%) said that fishing is their main source of livelihood. Only two fishermen (8.3%) had other secondary occupations to supplement their income. Farming was the main secondary occupation (Table 2).

Twenty-one fishermen (87.5%) interviewed had been fishing for between 5 and 30 years, 2 fishermen (8.3%) had been fishing for between 31 and 40 years, and only one fisherman (4.7%) had been fishing for more than 40 years. Eight fishermen (33.3%) had primary level education, seven fishermen (29.2%) had secondary school education, five fishermen (20.8%) had never studied, and 4 fishermen (16.7%) declared that they had completed Koranic studies (the Msid).

The majority of fishermen have been active for more than ten years (95.8%, n = 23), and 73.9% (n = 17) declared that the number of sea turtles captured had decreased over time and a minority felt that the accidental capture of sea turtles had increased (26.1%; n = 6).

Table 2: Demographics and economics of surveyed fishermen.

	Age (Years)		Active years as a professional fisherman			Source of livelihood	
	23-36	37-64	5 -30	31-40	>40	Fishing is the only source	Other sources
Number of fishermen interviewed	7	17	21	2	1	22	2

Discussion: The type and length of fishing vessels and the number of people on board are similar to results reported from the port of Al-Hoceima (Keznine *et al.* 2021).The species most frequently caught at Jebha is the loggerhead. Similar results have been reported in the Tangier region (Benhardouze *et al.* 2012), in Al-Hoceima and Beni Nser regions (Chahban *et al.* 2017), and in the M'diq-Martil region (Kaddouri *et al.* 2018), as well as more generally in the Mediterranean (Casale 2011). It is important to note that the fishermen reported capture events and not individual turtles, and the same turtle may have been captured more than once. In this study, trawling was the main threat to sea turtles in this region, however, in the M'diq-Martil region, Kaddouri *et al.* (2018) found that purse seiners were a bigger threat to sea turtles.

Mortality caused by trawling is due both to the physical stress exerted on the animal (e.g., Hare 1991), as the net can remain submerged for several hours and the turtle is unable to rise to the surface to breathe. The mortality rate is linked to three operational parameters (Gerosa and Casale 1999): trawling time, intensity of fishing effort in a given area, and water temperature.

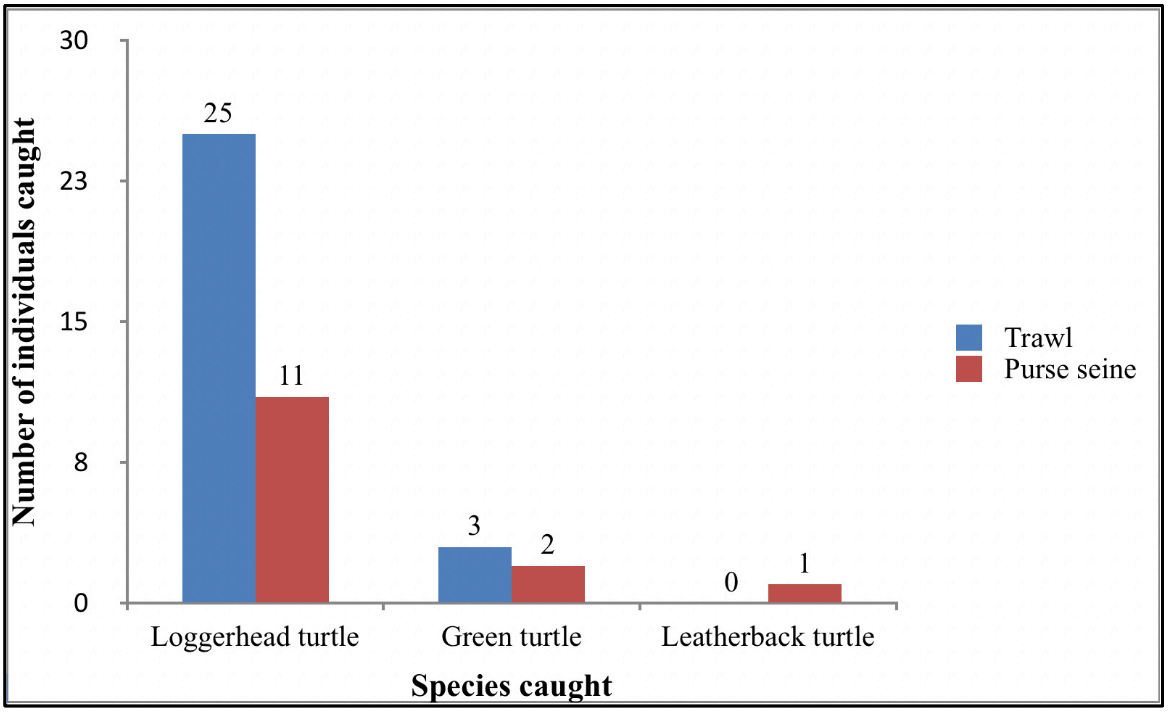

Figure 5. Total number of different sea turtle species reported to have been caught accidentally in the study area in 2020.

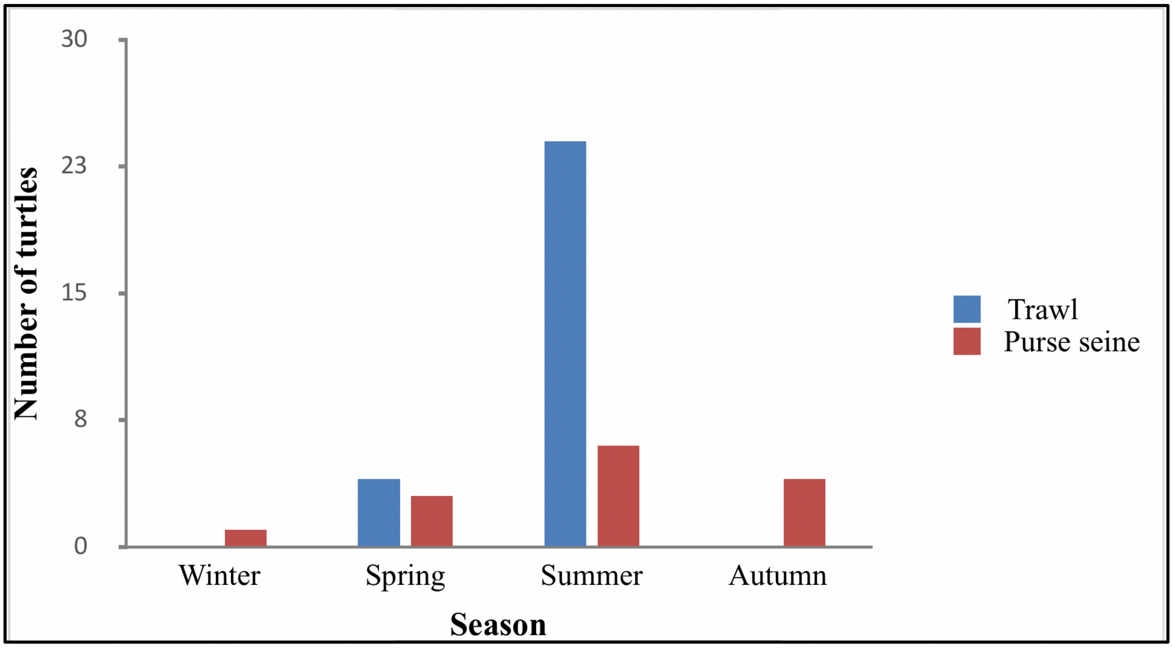

Figure 6. Seasonal distribution of reported sea turtle bycatch.

The low frequency of purse seine bycatch can be explained by the short haul duration (less than one hour) and the low fishing effort. At the scale of the Jebha maritime district, we can conclude that this type of gear and technique does not seem to pose a major problem for marine turtle populations. The small mesh size and the presence of floats minimize the risk of turtles becoming entangled and drowning and the turtles are released alive.

The turtles caught in the nets were mainly juveniles and subadults and represent the size classes migrating between the Atlantic and the Mediterranean (Camiñas 1997; Revelles *et al.* 2007a; 2007b). The low numbers of adults and smaller individuals are probably due to the absence of nesting beaches in the Moroccan-Spanish region (Tiwari *et al.* 2001; Tomas *et al.* 2002).

The majority of fishermen who have been active for over ten years declared that the number of sea turtle captures had decreased compared to the past. This same finding was reported by Kaddouri *et al.* (2018) in the M'diq-Martil region of northwest Morocco. Most fishermen explained that the decline in captures was due to marine pollution while others explained that the increase in turtles was due to the ban on the drift gillnets for swordfish.

The information obtained on the interaction between sea turtles and fishing activities in Jebha has improved our knowledge of these interactions and has enabled local stakeholders to reflect on the methods to be adopted to mitigate the impact of fishing on sea turtles. Overall, the probability of interaction between sea turtles and fisheries in this area appears generally low, due to low fishing effort and low availability of turtles in the area. Despite the low impact of coastal and artisanal fisheries on marine turtles in this area, awareness and education as well as bycatch mitigation measures need to be implemented to protect these species.

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A Case of Bicephaly in a Loggerhead (*Caretta caretta*) Hatchling from Ponta do Ouro, Maputo National Park, Mozambique

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Bicephaly (or dicephaly) refers to a physical malformation, with an individual having two heads. Malformations can range from the duplication of some structures of the head to the occurrence of conjoined twins (Ingle *et al*. 2021). Bicephaly may be the consequence of the incomplete separation of the zygote of identical twins (conjoined twins) or may occur by the terminal bifurcation of the axis of development of the embryo, the notochord, during the gastrulation process (Ingle *et al*. 2021; Martín-del-Campo *et al*. 2021). In general, bicephaly is a rare, although widely known, phenomenon. It has been documented in all major vertebrate groups: sharks and rays (e.g., Galván-Magaña *et al*. 2011; Guida *et al*. 2013; Prado *et al*. 2020), amphibians (e.g., Velo-Antón *et al*. 2007; Tanaka and Nishikawa 2021), reptiles (e.g., Matz 1997), and in marine (e.g., Kompanje *et al*. 2017) and terrestrial (e.g., Hampson 2016) mammals, including humans (e.g., Harma *et al*. 2005).

In reptiles, bicephaly has been reported in geckos (e.g., Ruiz-Villanueva *et al*. 2018), crocodiles (e.g., Matz 1997), marine turtles (e.g., Martín-del-Campo *et al*. 2019; 2021), non-cheloniid testudines (e.g., Palmieri *et al*. 2013), and particularly frequently in snakes (e.g., Wallach 2007). Here, I report on a case of bicephaly in a loggerhead *(Caretta caretta)* hatchling found dead at the Ponta do Ouro-Ponta Malongane section of the Maputo National Park (Fig. 1) in January 2019. The marine turtle program in the Park (formerly Ponta do Ouro Partial Marine Reserve) was initiated in 1994 and has been growing since (see Pereira *et al*. 2014a). Apart from regular systematic monitoring and tagging of nesting females, other activities pertaining to the biology, ecology, and conservation of marine turtles have been conducted in the area (e.g., Pereira *et al*. 2014b; Fernandes 2015; Fernandes *et al*. 2016; Louro *et al*. 2016).

Figure 1. Map showing the Maputo National Park and locations mentioned in the text (Source: Maputo National Park Management Plan).

The loggerhead hatchling was dug out of a nest as part of the monitoring protocol where nests are occasionally excavated to determine clutch size and assess hatching success. The hatchling had four limbs, five lateral scutes, and normal pigmentation, and apart from the two fully developed heads and a slightly more rounded carapace, no other morphological abnormalities were immediately apparent (Fig. 2).

With a straight carapace length of 34 mm, the hatchling was within the interval estimated for the Developmental Stage 30 (32.5 mm ± 1.90; Miller *et al*. 2007). However, the specimen was considerably smaller in comparison to other dead hatchlings from the same clutch (Fig. 3) and to average sizes reported for South Africa in iSimangaliso Wetland Park, Kwa-Zulu-Natal (43.9 mm ± 0.08; n = 412 hatchlings; Le Gouvello *et al*. 2020), and to worldwide average sizes (40.0 – 45.8 mm; LeBlanc *et al*. 2014).

As highlighted by Martín-del-Campo *et al*. (2021), bicephaly may occur early in the development of the embryo. Therefore, the exact nature of the deformity and origin of the split could potentially indicate its causes. However, in this case, an X-ray analysis failed to provide a clear-cut picture of the origin of the split (Fig. 4), although it appeared to be centred in the lower cervical region (C6-C8), similar to bicephalic loggerhead hatchlings reported by Ingle *et al*. (2021).

Figure 2. Normal and bicephalic loggerhead hatchlings from the same clutch (Photo: M.A.M. Pereira).

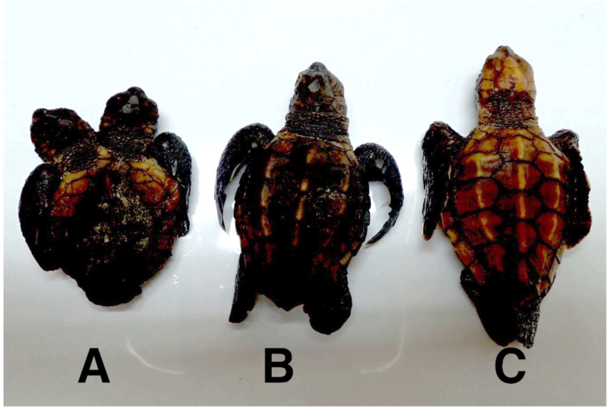

Figure 3. Straight carapace length comparison between hatchlings from the same clutch. A = 34 mm; B = 41.5 mm; C = 43.5 mm (Photo: M.A.M. Pereira).

Bicephaly in marine turtles is very rare, and individuals with this abnormality do not normally survive long after hatching (Piovano *et al*. 2011; Sönmez *et al*. 2017; Ingle *et al*. 2021; Martín-del-Campo *et al*. 2021). No internal post-mortem was performed, and the specimen has been kept in 95% ethanol at the Maputo National Park (MNP) headquarters. During the 2018/19 season, a total of 690 confirmed loggerhead nests (out of 1,875 recorded tracks) were reported for the MNP covering a total of ca. 90 km (Fernandes *et al*. 2020).

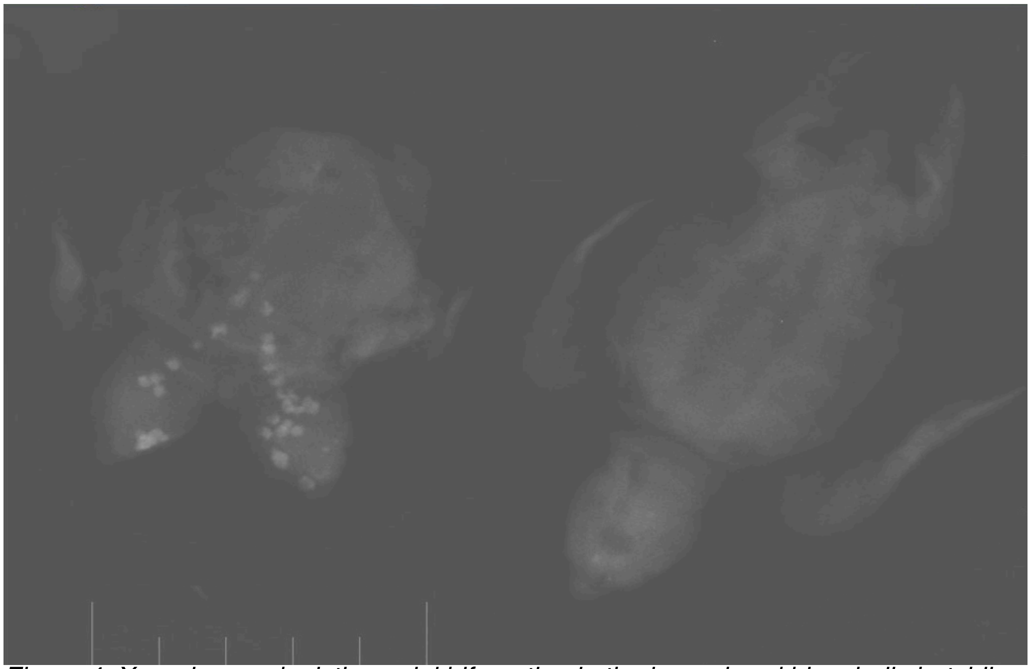

Figure 4. X-ray image depicting axial bifurcation in the loggerhead bicephalic hatchling. A normal hatchling from the same clutch is shown for reference (Photo: M.A.M. Pereira).

Currently, the marine turtle program at MNP does not include systematic monitoring of hatchlings, so monitoring of nest contents occurs incidentally. While Louro and Pereira (2009) reported a case of twinning of loggerhead hatchlings (i.e., fully developed embryos sharing a common yolk sac) in the same section of the MNP, this constitutes the first report of bicephaly for the MNP. A few cases of bicephaly have been observed in Kwazulu-Natal (South Africa), over the many years of the South African marine turtle monitoring program, but these represent a very small fraction of the total hatchlings (R. Nel, *pers. comm*). It is thus recommended that hatchlings are monitored more regularly (or at least be the focus of a targeted study) to assess the prevalence of such phenomena in the area.

There is general consensus within the literature that bicephaly may be caused by environmental conditions (e.g., temperature and humidity), teratogens associated with pollution such as heavy metals (e.g., mercury), and/or polycyclic aromatic hydrocarbons (e.g., Bárcenas-Ibarral *et al*. 2015), as well as defective genes, while multi-factorial causes cannot be excluded (Martín-del-Campo *et al*. 2019; 2021). There are not enough data to determine the exact cause of the malformation observed in this case. However, studies have shown that the coastal habitats of the Western Indian Ocean are not pristine. Bioaccumulation of metallic elements has been reported in leatherback and loggerhead turtle eggs (du Preez *et al*. 2018) and soft corals (van der Schyff *et al*. 2020) in Kwazulu-Natal, immediately to the south of the MNP.

Porter *et al*. (2018) reported organochlorine pesticides (potentially from agricultural runoff and coastal groundwater) in reef organisms (soft corals and sponges) at the iSimangaliso Wetland Park (South Africa). Given the proximity of MNP and iSimangaliso and that the two conservation areas share the same population of marine turtles, attention from both managers and scientists to pollution loads and sources, as well as potential management or mitigation measures, is warranted. Further research into the frequency and distribution of malformations in marine turtles must also be undertaken. If deemed necessary, potential causes should be investigated through an analysis of nest conditions (e.g., temperature, humidity), pollutants concentration (e.g. in specific habitats, eggs), and hatchling genotypes.

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Minutes of the Africa Regional Meeting, 41st Annual Symposium on Sea Turtle Biology and Conservation, Cartagena, Colombia

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The Africa Regional Meeting took place on 20 March 2023 and was attended by ~30 people.

PRESENTATIONS:

(1) New challenges for the conservation of loggerhead turtles in Cape Verde in the face of a huge population increase — Adolfo Marco

Discussions focused on the extraordinary increase in loggerhead nesting on all the islands, saturation of the beaches similar to an arribada, potential reasons for this increase, future predictions for this population, and the strategies and challenges for the conservation of this population. It is too early to change the current IUCN Red List designation of "Endangered" for this population.

(2) Super-quick overview of marine turtles along the African East coast — Casper van de Geer

This presentation has been published: Casper van de Geer *et al.* (2022). Marine turtles on the African east coast: current knowledge and priorities for conservation and research. Endangered Species Research 47: 297-331. https://doi.org/10.3354/esr01180

(3) Sea turtle research and conservation in Gabon — Angela Formia

Post-presentation discussion focused on: average number of leatherback nests laid annually; the uncertainty in the nesting trend; fisheries and bycatch work; size of the Gabon olive ridley population compared to theAngola olive ridley population; monitoring of index beaches; standardization and centralization of the work; why turtles are not tagged; and threats on the beaches and within the MPA shared with Equatorial Guinea,

(4) Sea turtle research and conservation in West Africa — Rita Patrício

Questions following the presentation focused on the monitoring of the large green nesting population in Poilão, how nest numbers are estimated, and dispersal patterns of juveniles.

(5) Kitabanga Project: A 20-year approach to sea turtle study and conservation in Angola — Michel Morais

Questions were asked about the genetic sampling of green turtles in the Cunene River and the length of the marine protected area, which covers 10 km of coastline and extends out 5 miles from the coast for fish protection.

(6) Sea turtle CSO networks in Africa: Rastoma and its brother networks —Alexandre Girard

Discussion focused on strategies to reduce plastics, the challenges of dealing with different languages among countries, and what limits African participation at the Symposium (visa obstacles that cannot be overcome by the Symposium or the International Sea Turtle Society).

(7) The Côte d'Ivoire Sea Turtle Project — Angela Formia

The study site, threats, conservation activities on the beaches and at sea, and engagement with the communities were discussed.

ADDITIONAL DISCUSSION TOPICS/COMMENTS

- Brazil would like to collaborate with Africa as these Atlantic countries share populations.
- “Best practice” techniques for conservation vary among countries.
- Greater benefits are obtained from reallocating grants from research equipment to the local communities for improving the monitoring of nesting populations. The most important thing besides collecting data is giving the local community what they need for schools and infrastructures – one cannot tell a starving person to stop eating turtles, one needs to look at the bigger picture.
- Religious leaders and conservation-related religious text can be used to promote conservation.
- Approaches need to consider understanding communities rather than criticizing them for what they don’t know. Progress requires patience and understanding.
- Education messages for the youth should not say “turtles are good and poachers are bad” because often the poachers are their parents.
- Challenges of tourism as a conservation tool include: language, behavior impact locally, distribution of tourism money, incentives, and livelihoods. Some suggested publications for review are:
    - Ferraro, P. J., & Gjertsen, H. (2009). A global review of incentive payments for sea turtle conservation. Chelonian Conservation and Biology, 8(1), 48-56. https://doi.org/10.2744/CCB-0731.1
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Instructions for Authors

The African Journal of Sea Turtle Biology and Conservation (AJST) is a free, bi-annual electronic publication about the biology and conservation of sea turtles and their habitats in Africa and wherever its turtles migrate.

We accept a diversity of contributions that ranges from the biology of sea turtles to the geographical, cultural, social, economic, political, and spiritual aspects of sea turtle conservation and management in Africa.
Contributions can include original scientific articles, natural history observations, opinion pieces, field experiences, project activities, workshops, announcements/news, Master's/PhD summaries, etc. We also welcome photo essays and the stories and observations of people who work with sea turtles on this vast and diverse continent and its offshore islands.

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