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Struggles beneath the waves: Unveiling the incidental capture of sea turtles by artisanal fisheries in Angolan waters

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ABSTRACT

The modernization and intensification of fishing practices have raised the threat to sea turtles, with escalating unintentional captures endangering turtles of all life stages. In this study, we examined the impact of artisanal fishing on sea turtles in two coastal regions of Angola, southern Africa. Between August 2015 - March 2016, through participatory monitoring (n = 8) and interviews with fishers (n= 41), we documented unintentional turtle captures occurring year-round during fishing activities. A total of 405 turtles, 403 olive ridley (*Lepidochelys olivacea*) and 2 green (*Chelonia mydas*), were caught in gillnets by fishers engaged in participatory monitoring. Net characteristics, including length and proximity to the shoreline, as reported by the interviewed fishers, correlated with those used by the monitoring group. We estimated approximately 1219 turtles captured by the 41 interviewed fishers over the 8-month study period. Most captures occurred within 100 m from the shoreline. The likelihood of accidental turtle captures increased significantly with proximity to the beach, larger mesh sizes, and greater net lengths and number of hauls. We calculated a survival rate of 41%, and a mortality rate of 59% for captured turtles. Number of turtles caught as bycatch varied throughout the year, with the highest Catch Per Unit Effort (CPUE) reported for Oct. – Dec. Since this period aligns with the nesting season, most captured turtles are likely to be females. The high mortality rate reported in this study emphasizes the immediate threat posed by accidental captures to sea turtle populations, underscoring the critical importance of conservation efforts, particularly in artisanal gillnet fisheries.

1. Introduction

The main driver contributing to the global decline in sea turtle populations is the unintentional capture of these animals in fishing operations (Awabdi et al., 2021). This issue has been exacerbated by the modernization and intensification of both artisanal and industrial fishing methods, resulting in heightened levels of accidental turtle captures, posing a threat to turtles across all life stages,

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including vulnerable juveniles and mature adults (Wallace, 2010; Alfaro-Shigueto et al., 2018).

Around the world, artisanal fishing, characterized by its reliance on family labour and a focus on subsistence, rely on smaller vessels for short coastal expeditions (Santos, 2015). In contrast, industrial fishing embraces advanced technologies and is driven by the ambition of achieving large-scale production (Žydelis et al., 2009). In Angola, although industrial fishing dominates the total volume of landed fish along the coastline, artisanal fishing remains crucial. It plays a vital role in supplying local communities with sustenance, contributing significantly to food security, creating employment opportunities, and supporting livelihoods (March, Failler, 2022). Nevertheless, such fishing activities often operate in the periphery of governmental and regulatory scrutiny, resulting in substantial knowledge gaps regarding fishing efforts and the unintentional capture of non-target species of commercial value. (Carpio et al., 2022). Within the Angolan context, the Institute for the Development of Artisanal Fishing (IPA) oversees all artisanal fishing activities.

Accidental captures occur when non-target, protected, or commercially less significant species become unintended victims of fishing operations (Bjordal, 2005; FAO, 2005). These species, which include sea turtles, fall under the colloquial category of "bycatch" (Awabdi et al., 2021). Sea turtles are prone to get entangled in various types of fishing gear, leading to injuries or even death as they struggle to reach the water's surface to breathe (Wilson et al., 2014).

Globally, certain fishing techniques are known to be major contributors to the inadvertent capture of sea turtles (Dunn et al., 2008). Pelagic longline fishing and drift netting are among the fishing techniques linked to increased rates of accidental marine turtle captures (Kotas et al., 2004; Pinedo & Polacheck, 2004). Trawl fishing, surface longline fishing, bottom longline fishing, and gillnets also contribute to the unintended capture of sea turtles (Alfaro-Shigueto et al., 2018). Trawlers, longliners, and set netters collectively account for an alarming annual estimate of 150,000 sea turtle captures in the Mediterranean alone, potentially resulting in over 50,000 deaths per year (Alessandro and Antonello, 2010). Regions encompassing the Mediterranean, East Pacific, Northwest, and Southwest Atlantic experience the highest bycatch rates of marine turtles (Wallace et al., 2013b).

Angola affords national legal protection to all sea turtle species under Annex I of the Law of Aquatic Biological Resources (LRBA) (Lei nº 6-A, 2004). Offenders caught in possession of marine may face fines and the confiscation of their fishing equipment, which is subsequently returned to the state. In addition to these national measures, international conventions, and protocols, such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), impose a ban on the international trade of all marine turtles. Other agreements, such as the Bonn Convention and the SPAW Protocol, further extend protective measures to these species (Ecker and Abreu-Grobois, 2001; Marcovaldi, 2001). In line with the commitment to strengthen policies aimed at the conservation of biodiversity, Angola has adopted these international conventions and protocols.

Despite numerous studies on sea turtles, significant knowledge gaps exist, particularly concerning certain populations, such as those in Angola. Angola is noteworthy as the southernmost range for nesting sea turtles in the eastern Atlantic, yet it remains relatively underexplored in this regard (Braga-Pereira et al., 2020). Existing studies and reports of sea turtles in Angola indicate the presence of five species: the olive ridley (*Lepidochelys olivacea*), leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), and loggerhead (*Caretta caretta*), with only the first three known to nest in Angola (Morais and Tiwari, 2022).

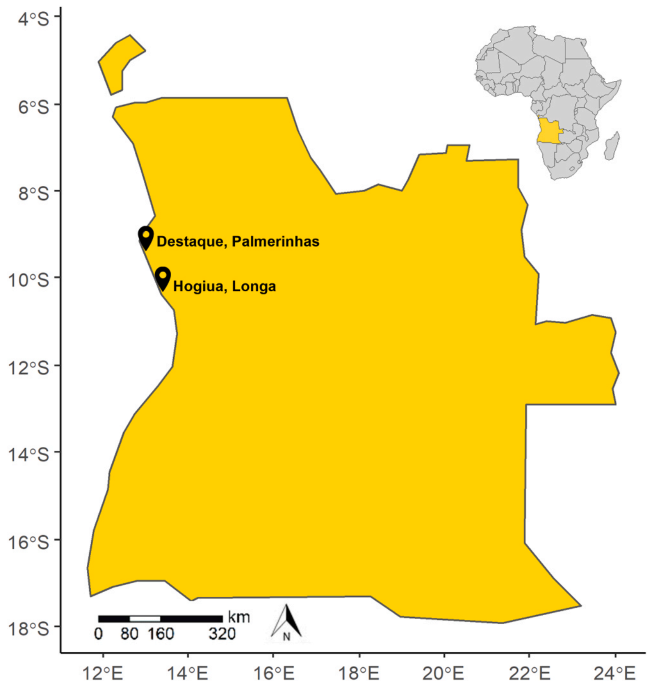

Fig. 1. Map of Angola, highlighting the study area Destaque in Palmeirinhas and Hogiua in Longa. The country boundaries are depicted in a darker shade of yellow. This visualization was created using the 'sf,' 'rnaturalearth,' and 'ggplot2' packages in R.

There is a pressing need to assess the impact of artisanal fishing on marine turtle populations along Angola's coastline. In this study we present new information on the interplay between artisanal fishing and sea turtles in two sites off the Angolan coast. We provide quantitative data on accidental turtle captures and identify the multifaceted factors that may contribute to these incidents. Through this effort, our goal is to catalyse the development of more efficacious conservation measures and management strategies. In doing so, we aspire to contribute significantly to broader mission of preserving global marine biodiversity.

2. Material and methods

2.1. Study area

The study encompasses two distinct coastal communities: The first one is the Destaque in the Palmeirinhas region, southern coast of Luanda city, Belas Municipality, at coordinates 9°09'38.14"S and 13°02'54.07"E. The second community, Hogiua, is located on the northern coast of Cuanza-Sul Province, in the Longa Municipality, at coordinates 10°15'22.01"S and 13°33'08.18"E (Fig. 1).

Both Destaque Beach and Hogiua Beach are sandy shores, a defining characteristic of Angola's coastline. These sandy beaches are narrow expanses of land wedged between the sea and the mainland. Typically, they do not exceed a width of approximately 100 m (Morais et al., 2006). These coastal features serve a multitude of purposes, including their role as attractions for tourism, habitats for various crustaceans and mollusks, and as potential nesting grounds for marine turtles (Silva, 2015).

Most fishers in these regions are Umbundu. The Umbundu are one of the largest Bantu ethnic groups in the country, primarily residing in the central and southern regions of Angola. Other ethnicities, namely Chokwe, Ganguela, and Bakongo are present (Coelho, 2015). Fishing practices and knowledge are passed down from generation to generation and as a result most fishers inherit their parents' boats to continue this activity. Fishing constitutes a primary subsistence sector in the region, though it is not the sole activity among the local fishers (Abreu et al., 2020). After fishing, livestock, agriculture, and commerce are also important activities in these regions (Abreu et al., 2020).

Most fishers are locally organized in cooperatives. At a governmental level, these cooperatives are linked to the Institute for the Development of Artisanal and Aquacultural Fisheries. In the Longa region, fishers collaborate with Biology students at the Faculty of Natural Sciences of the Agostinho Neto University. The latter raise awareness on current fishing legislation and contribute to environmental education. In the Palmeirinhas region, fishers engage with students from the Faculty of Natural Sciences of the Agostinho Neto University and the Instituto Politécnico das Pescas Cefopescas.

The Kitabanga Project, dedicated to the study and conservation of sea turtles in Angola, is the sole project near the study areas. Established in the Palmeirinhas region since 2003 and in the Longa region since 2010, the project has been actively contributing to sea turtle conservation (Morais et al., 2022). Additionally, approximately 50 km away from the Palmeirinhas region, theProject for Mangrove Restoration and Protection Project in Angola has been operational since 2020. In Palmeirinhas, where there are currently over 200 fishers, the coexistence of these projects underscores the collective effort to promote sustainable fishing practices. Addtionally, in Longa, with about 50 fishers, fishing activities are restricted, especially during the turtle nesting season from September to April.

2.2. Data collection

We collected data from two separate groups of artisanal fishers, all men, Cuanza-Sul province, with aged 19 – 62 years. The first group were individuals who willingly engaged in the monitoring of accidental sea turtle captures (n=8). The second group included other fishers from the study sites who, while not directly involved in the monitoring effort, took part in semi-structured interviews (n=41). Among those interviewed, 68% (13 in Destaque and 15 in Hogiua) had more than three years' experience, while 32% (3 in Destaque and 3 in Hogiua) had less than three years of experience. Despite the predominance of fishers with over three years experience, few owned their own boats.

2.2.1. Participatory monitoring

In July 2015, we consulted the traditional authorities in both study communities to identify artisanal fishing operators willing to participate in the study. We provided training to participants to ensure accurate recording during their fishing activities of: net features (length and mesh size), fishing locations (distance from the coast and depth), fishing frequency per month, types of fishing gear used, net submersion time (in hours) as well as the number of turtles caught per catch, species, turtle physical characteristics (curved carapace length, CCL and width CCW), and the physical condition of the animals (alive, injured, inanimate, dead). Recording sheets were filled in by the fishers and followed data collection procedures used by other authors (Barbiere, 2009; Silva, 2006; Bolten, 1999). Participatory monitoring occurred from August 2015 to March 2016. During this time, we conducted inspection visits to observe the recorded fishing activities without interfering with the fishers' choices, including their decisions about fishing gear use.

2.2.2. Interviews

Between Sept. 2015 and Jan. 2016, we interviewed another group of fishers (n = 41, 20 in Destaque and 21 in Hogiua, all men) to gather additional data on accidental turtle captures. During these interviews, we inquired about various aspects, including the specifics of the fishing nets in use (such as net length and mesh size), fishing locations (comprising net distance from the coast and depth), use of fishing gear, duration for which nets were submerged, and species captured.

2.3. Analysis

2.3.1. Accidental turtle capture rate over the year

To assess the temporal variation in accidental turtle captures, we first calculated the Capture per Unit of Fishing Effort (CPUE) for each month using the following formula:

$$CPUE = \text{Number of captured turtles} / \text{Mesh Size} \times \text{Hours of net in water} \times \text{Net length} \times \text{Number of hauls}$$

To assess the relationship between the independent variable "Months" and the dependent variable "CPUE", we employed an analysis of variance (ANOVA). If the result of this analysis was significant (indicating that accidental captures varied significantly across different months), we then used a Tukey test to identify which specific months showed statistically significant differences in CPUE. We assumed a statistically significant difference between the compared months if the p-value <0.05.

2.3.2. Characteristics of fishing activities influencing turtle accidental captures

To analyse the impact of various factors (mesh size, net length, distance from the net to the coast, depth of the net, and the number of hauls) as predictor variables on the number of accidentally captured turtles (the response variable), we employed generalized linear mixed models (GLMMs). In our modelling, we treated the fisher and location as random factors. Given that the response variable is continuous, we utilized a negative binomial distribution. Notably, we identified collinearity ($p > 0.05$) among specific predictor variables: mesh size and net length, distance and number of hauls, and depth concerning all the mentioned predictor variables (Supplemental Material, Fig. 1). Consequently, we established three separate sets of models with these variables isolated. We conducted residual checks to ensure the suitability of our models. The Akaike information criterion was employed for model selection. The model with the lowest AIC was retained, and we ranked the remaining competing models based on their Akaike differences (ΔAIC) relative to the best model (the one with the lowest AIC) (Harrison et al., 2018; Burnham and Anderson, 2002). The final selected models were:

Fullmodel <- (Number of captured turtle ~ Depth + (1 | Fishers/City)

Fullmodel <- (Number of captured turtle ~ Distance + log10(Mesh Size) + (1 | Fishers/City)

Fullmodel <- (Number of captured turtle ~ Number of Hauls + Net Length+ (1 | Fishers/City)

2.3.3. Total number of turtles captured

To estimate the number of turtles captured by the interviewed fishers and those involved in the participative monitoring, we employed the following statistical approach:

i) Calculation of Correlation Coefficients:

We first examined the relationship between the number of answers in the monitored fishing expeditions and the number of interviewed fishers using the follow three fishing characteristics: a) different mesh sizes; b) net lengths; and c) distances from the coast. We focused on these three fishing characteristics which had a significant impact on the accidental capture of turtles during monitored fishing expeditions (see Section 2.3.2).

ii) Estimation of Turtle Captures:

- Next, we calculated the average (55.14) and standard deviation (45.66) of turtle captures per fishers in the participative monitoring, and so using three correlation coefficients firstly calculated for each fishing characteristics, we separately proceeded to estimate the number of turtles captured by the interviewee fishers using the formula:

$$Estimation = Mean\_Captures\_Monitored + (Correlation * (Std\_Deviation\_Captures\_Monitored / \sqrt{Num\_Captures\_Monitored}) * \sqrt{Num\_Fishers\_Interviewed - \sqrt{Num\_Fishers\_Monitored}})$$

where:

Mean_Captures_Monitored represents the mean number of turtles captured per monitored fisher. The correlation is the coefficient between the monitored and interviewed fishers obtained for each correlation conducted.

Std_Deviation_Monitored is the standard deviation of turtle captures among the monitored group. Num_Fishers_Monitored is the number of monitored fishers (n = 8). Num_Fishers_Interviewed is the number of interviewed fishers (n = 41).

iii) Finally, an average value was calculated based on the three estimated values of each fishing characteristics and assumed as the final estimate.

3. Results

3.1. Number of expeditions and sea turtle captures of the 8 fishers in the participative monitoring

A total of 1357 fishing trips were recorded in the Destaque (n = 805) and Hogiua communities (n = 552). Within these, sea turtles were caught in 147 fishing trips (11%; 54 in Destaque, and 93 in Hogiua). Gillnets were the only fishing gear used in both study sites and these were typically submerged for 24 hours.

As many as 405 sea turtles were caught (117 in Destaque and 288 Hogiua); 403 were *Lepidochelys olivacea*, and two were *Chelonia mydas*. During October 2015 to January 2016, the capture rate, representing sets involving accidental captures, exhibited a notable increase when comparing the number of sets per fisher (Fig. 2). The ANOVA and Tukey's test revealed a statistically significant difference in CPUE means, with more turtles captured in November compared to February, March, and August ($p < 0.05$) (Supplementary material, Fig. 2).

3.2. Conditions of sea turtles captured

Out of the captured turtles, 140 (35%) were found alive, 28 (7%) displayed injuries, 18 (4%) were motionless, and a significant number, 219 (54%), were dead. In Destaque, the highest counts of live, lifeless, and deceased turtles were observed in December, closely followed by November. Additionally, the highest number of injured turtles were recorded in November. In Hogiua, the highest figures for live, injured, motionless, and deceased turtles were found in November, with October being the second-highest month (Fig. 3). There was an overall survival rate of 41% and a mortality rate of 59%.

3.2.1. Relationship between fishing characteristics and turtle captures

Fishing vessels employed net mesh sizes of 28 mm, 30 mm, 40 mm, and 200 mm. The Destaque community used a greater mesh size diversity, including 28 mm, 30 mm, and 40 mm, while in Hogiua a 200 mm mesh size was used. The 40 mm mesh size in Destaque captured most turtles, followed by the 30 mm mesh size. Conversely, in Hogiua, where only the 200 mm mesh size was used, this size captured the highest number of turtles.

The fishers used nets of three different lengths: 200×8 (14.9% of all fishing trips and used only in Hogiua), 300×10 (26.8% and used only in Hogiua), and 80×6 (56.3%, only in Destaque). Spanning distances were 100 m, 300 m, and 500 m from the shoreline. Most of all turtle captures (80%, n=325) occurred at 100 m distance from the shore, 18% (n=73) at 300 m, while only 2% (n=7) at 500 m. Our GLMM results indicate that placing nets closer to the shoreline (Fig. 4A), greater mesh size (Fig. 4B) and greater number of hauls (Fig. 4C) net length (Fig. 4E) significantly increases the likelihood of turtle captures (Table 1).

Interviews

Interviewed fishers used net length (correlation=0.99) and position the net regarding the distance from the coast (correlation=0.98) similarly to those participating in the monitoring. However, the mesh sizes used by the two groups were dissimilar (correlation=0.02). Based on our correlation results, we estimate that the number of turtles captured by the 41 interviewed fishers would approximate 1218 turtles. This value represents the average obtained considering the correlation coefficient obtained in net length (1797); net distance (1773), and mesh size (83).

4. Discussion

Among the five marine turtle species reported along Angolan coasts, only *L. olivacea* and *C. mydas* were recorded in this study as accidentally captured in fishing nets, with *L. olivacea* being mentioned more frequently in both monitoring and interviews. In our study, 1624 sea turtles were probably incidentally captured over the 8-months survey in only two communities. For comparison, a more extended study in Portugal recorded 177 sea turtles incidentally caught, including loggerhead and leatherback turtles (Parra

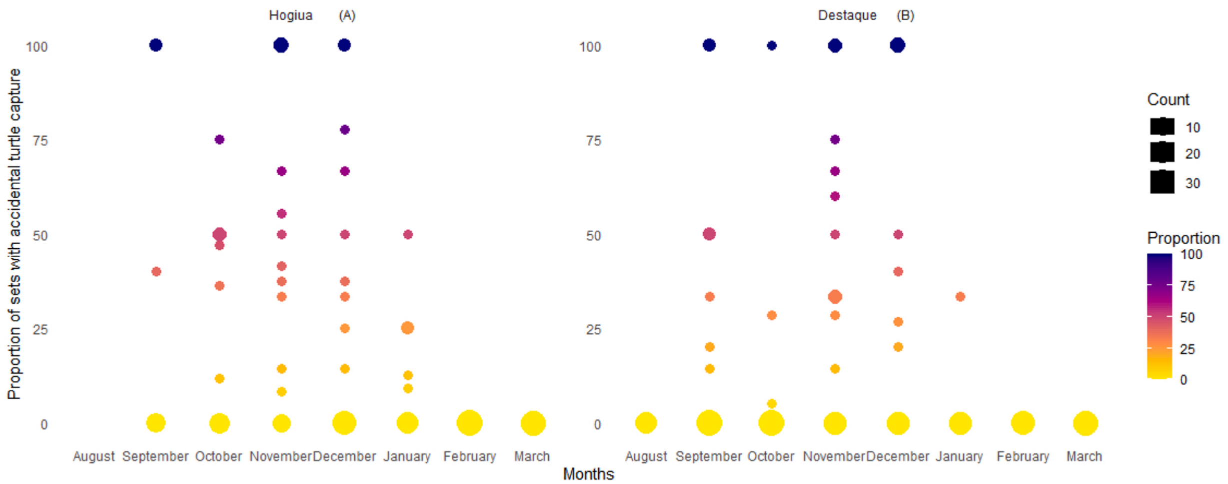

Fig. 2. Monthly variation in the proportion of sets involving accidental sea turtle capture in Hogiua (A) and Destaque (B), Angola. The proportion was calculated by dividing the number of sets with accidental captures by the total number of sets. Count caption: Point size represents the frequency of each proportion, with larger points indicating a more frequent proportion of capture.

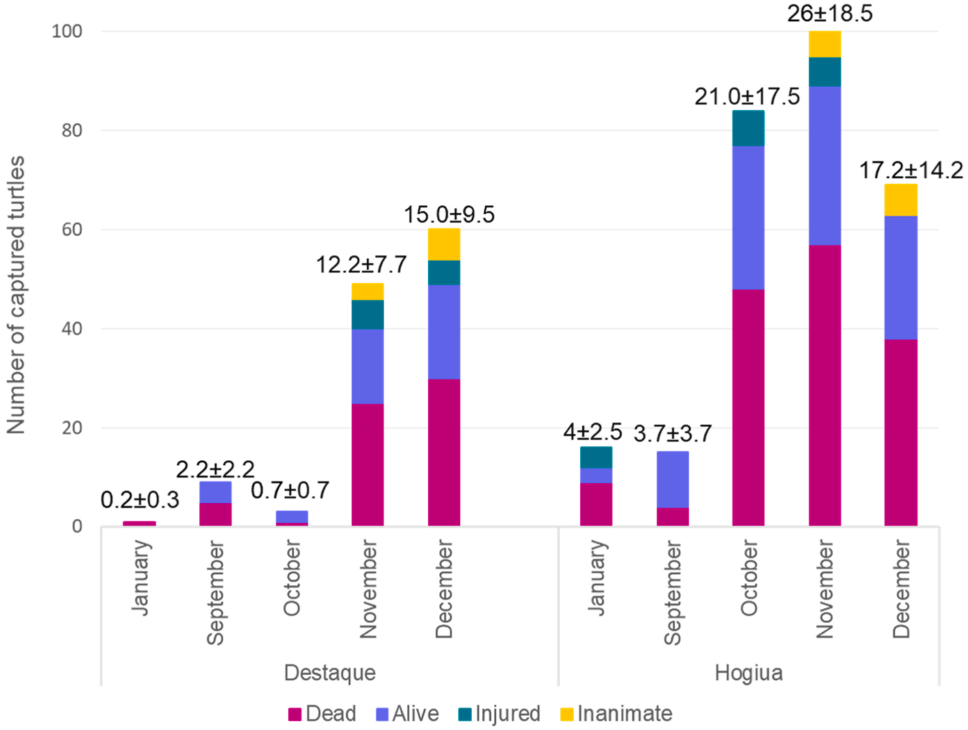

Fig. 3. Monthly Variation in the Condition of Captured Turtles in Destaque and Hogiua, Angola.

et al., 2023). The global bycatch rates are a cause for concern, with estimates ranging from thousands to tens of thousands of sea turtles annually (14,000–90,000 turtles/year/country), particularly in gillnets, longlines, bottom trawl nets and handlines (Belhabib, Greer & Pauly, 2018; Jabado, 2021; Bourjea et al., 2008; Casale, 2011; Wallace et al., 2013a; Lewison et al., 2014). Our study further underscores the challenge posed by gillnets in artisanal fisheries, primarily due to their extended soak times, which often lead to sea turtles drowning. While gillnets and longlines are well-documented threats, limited information exists on the impact of trawling on sea turtle populations, despite its widespread practice in Northwest Africa (Gascuel et al., 2007; Emanuelsson, 2008). With a substantial number of licensed trawlers in the nearby region (Jabado, 2021), urgent research is needed to assess their potential impact on sea turtle populations along the Angola coast.

We show that the variation in turtle captures between our studied communities, Destaque and Hogiua, can be attributed to several factors. Firstly, disparities in fishing practices and larger mesh nets being more used in Hogiua community, because larger mesh sizes tend to reduce escape opportunities of marine turtles (Moore et al., 2010; Mancini et al., 2012). Secondly, turtle nesting density in the Hogiua community was much higher than in Destaque, with 115.7 nests per kilometre, compared to 47.5 nests per kilometre, respectively (Morais, 2022). While the Angolan coastline is the most important site in the Atlantic for olive ridley turtles (nest annually estimated in 83,000), Hogiua has the highest population density of marine turtles in Angola.

The highest number of captures occurred in November and December, coinciding with the peak nesting period when a significant number of turtles approach the beaches to nest (Casale et al., 2004). During this period, the increased presence of turtles near the shores results in a higher likelihood of entanglement in fishing nets. To address this issue, reducing the duration of net deployment during these critical months could lead to a decrease in accidental turtle captures, as suggested by Lima et al., (2010) and Paulo Catry et al., (2010), in a similar study in Guinea-Bissau. Additionally, the utilization of LED lights in fishing nets has demonstrated an impressive 81% reduction in sea turtle capture rates (Allman et al., 2020).

Our observations revealed a survival rate of 41% (n=166) of turtle captures and a corresponding mortality rate of 59% (n=239). This high mortality rate is concerning and demonstrates a profound negative impact of gillnets fishing on turtle populations. The substantial number of turtle deaths has significant implications for population dynamics, particularly given the lengthy time required for these animals to reach maturity and the extremely low survival rate to adulthood (Morais, 2014). Even worse, considering that the period of the highest CPUE coincides with the nesting period, it is expected that most of the captured individuals were female. This is a cause for concern, as capturing female sea turtles mainly during their nesting season reduces their ability to contribute to the next generation, potentially leading to a substantial decline in hatchling numbers and, subsequently, the overall population. Indeed, studies have shown that the average mortality rate of *L. olivacea* ridleys was significantly higher (range 11–45%, average 32%) compared with other sea turtle species caught in regional longline fisheries or longline fisheries elsewhere (Swimmer et al., 2006; Whoriskey, Arauz & Baum, 2011).

The annual bycatch estimates do not consider potential post-release mortality or multiple exposures to fishing gear stress, both of

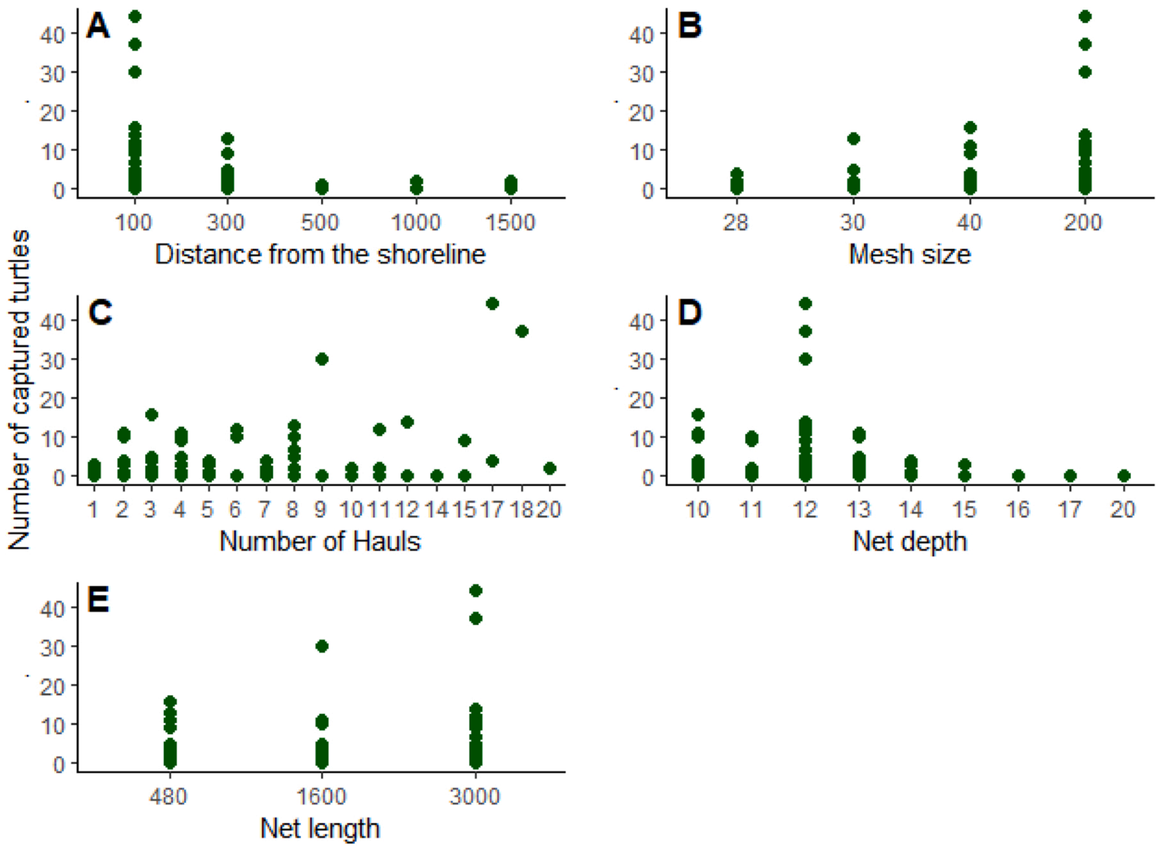

Fig. 4. Scatterplots illustrating the relationship between different variables and the number of captured turtles. (A) Distance from the shoreline, (B) Mesh size, (C) Number of Hauls, (D) Net depth, and (E) Net length. The x-axis represents different factors, while the y-axis indicates the number of captured turtles.

Table 1
Factors influencing turtle captures in fishing nets.

	Predictor variables AIC	Estimate	Std. Error	z value	Pr(>|z|)		AIC	AIC Null model	ΔAIC
Model 1	Distance from the shoreline	-0.00463	0.000604	-7.669	1.74E-14	***	914.2	1035.8	121.6
	Mesh size	1.580116	0.68689	2.3	0.0214	*			
Model 1	Depth	0.04508	0.06329	0.712	0.476		1037.3	1035.8	-1.5
Model 3	Number of Hauls	0.276996	0.026065	10.627	<2.00E-16	***	853.9	1035.8	181.9
	Net length	0.000488	0.000243	2.01	0.044	*			

which can further affect sea turtle survival. In this study, some fishers have reported that avoiding incidental captures is challenging, and sea turtles often do not die immediately. Even when fishers release captured animals, regardless of their condition, it's possible that turtles may succumb later (Casale et al., 2004; Garcia-Parraga et al., 2014). Sea turtles incidentally captured may experience conditions like drowning, fainting, or suffering from decompression sickness (gas embolism), often associated with prolonged submersion. These turtles may perish after being returned to the sea in such conditions (Garcia-Parraga et al., 2014). Consequently, the practice of immediate release by fishers inadvertently contributes to increased turtle mortality. Training and regular monitoring of fishers on the best practices for incidentally captured sea turtles are potential alternatives to reduce mortality (Awabdi et al., 2018).

Regarding the species distribution and nesting patterns in the Atlantic, the major rookeries are in Gabon and Angola (Metcalfe et al., 2015; Morais and Tiwari, 2022), but smaller breeding populations exist from Guinea–Bissau southwards (Fretey & Malaussena, 1991; Barbosa, Broderick & Catry, 1998). Angola holds the largest olive ridley turtle nesting population globally, with the species being the most abundant in the country and outnumbering other major nesting sites, such as Brazil, Suriname, French Guiana, and the Republic of the Congo (Silva et al., 2007).

Despite a relatively stable population, land-based threats like turtle and egg consumption and threats at sea, such as fishing gear entanglement, demand a comprehensive management plan, strengthened legislation, and conservation efforts for all sea turtle species in Angola. Data from 2016 in this paper has uncovered the high occurrence of turtle drownings in fishing nets and disruptions to nesting caused by the presence of fishers and their equipment. Based on the results obtained in this research, together with other information collected over the years, about sea turtles in this region, the Ministry of Culture, Tourism, and Environment issued Decree 1487/21 in March 2021, which regulates unauthorized presence and movement, has imposed restrictions on fishing gear placement in monitored beaches, and prohibits trawl fishing in the Hogiua area to address these challenges. In our study area in Angola, sea turtle populations are continuously monitored throughout the nesting season during September - April. These monitoring efforts have increased in these regions due to the escalating threats from artisanal fishing, nest predation, egg collection, and turtle hunting for meat (Primo et al., 2022). Furthermore, hatcheries have been strategically set up in locations where natural hatching may pose risks to the eggs. Additionally, the introduction of a nest sponsorship program provides an avenue for citizens to voluntarily contribute to sea turtle conservation. These initiatives play a pivotal role in safeguarding vulnerable sea turtle populations and ensuring the sustainability of their habitats (Primo et al., 2022).

In conclusion, our study highlights the urgent need to reduce the impact of gillnet fishing impacts on marine turtles in Angola. We propose a multifaceted approach, starting with ongoing impact studies at Angolan nesting beaches, aiding in the development of medium-term conservation strategies. Implementing comprehensive registration for artisanal fishers will enhance monitoring and environmental impact assessments. Reducing net deployment duration, especially during peak nesting seasons, similar to successful models in Australia and the United States, can minimize accidental turtle captures. Enhanced beach monitoring during nesting seasons by relevant authorities is essential for marine turtle conservation. Additionally, ongoing protection efforts, exemplified by the Kitabanga project, through awareness campaigns and information dissemination in fishing areas and nesting sites, will raise awareness about ecosystem balance and foster local support for conservation initiatives. Stricter regulations on net deployment, seasonal restrictions during peak nesting months, the exploration of LED technology in nets, and the promotion of turtle-friendly practices through collaboration with local fishing communities are crucial. Educating fisherson turtle conservation's significance and their role in safeguarding these species is fundamental for long-term success. These measures will contribute to preserving both adult and juvenile turtle populations and ensuring their survival amid ongoing fishing threats.

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CRediT authorship contribution statement

Franciany Braga-Pereira: Writing – original draft, Supervision, Formal analysis. **Julia E Fa:** Writing – review & editing. **Miguel V. de Morais:** Supervision, Methodology, Funding acquisition, Conceptualization. **Juelma Lisandra Domigos dos Santos:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2024.e02898.

References

Abreu, J.S., Beneditto, A.P.M.D., Martins, A.S., & Zappes, C. (2020). Artisanal fishing in the municipality of Guarapari, state of Espírito Santo, Brazil: An approach to the perception of fishermen working in small-scale fishing. Brazil.

Alessandro, L., Antonello, S., 2010. An overview of loggerhead sea turtle (Caretta caretta) bycatch and technical mitigation measures in the Mediterranean Sea. Rev. Fish. Biol. Fish. 20, 141–161. https://doi.org/10.1007/s11160-009-9126-1.

Alfaro-Shigueto, J., Mangel, J.C., Darquea, J.M., Donoso, M., 2018. Untangling the impacts of nets in the southeastern Pacific: Rapid assessment of marine turtle bycatch to set conservation priorities in small-scale fisheries. Elsevier.

Alfaro-Shigueto, J., Mangel, J.C., Darquea, J., Donoso, M., Baquero, A., Doherty, P.D., Godley, B.J., 2018. Untangling the impacts of nets in the southeastern Pacific: Rapid assessment of marine turtle bycatch to set conservation priorities in small-scale fisheries. Fish. Res. https://doi.org/10.1016/j.fishres.2018.04.013.

Allman, P., Agyekumhene, A., Stemle, L., 2020. Gillnet illumination as an effective measure to reduce sea turtle bycatch. Conserv. Biol. https://doi.org/10.1111/cobi.13647.

Awabdi, D.R., Pestana, I.A., Bondioli, A.C.V., Zappes, C.A., Di Beneditto, A.P.M., 2021. Incidental Capture of Sea Turtles in Southeast Brazil: Assessment of the perceptions of artisanal fishers. Oceano Gest. ão Coste. https://doi.org/10.1016/j.ocecoaman.2021.105696.

Barbiere, E., 2009. Concentration Of Heavy Metals In Tissues Of Green Turtles (Chelonia mydas) Sampled In The Cananéia Estuary, Brazil. Braz. J. Oceanogr. 57 (3), 243–248.

Bjordal, A. (2005). Uso de medidas técnicas en la pesca responsable: Regulación de artes de pesca.

Bolten, A.B., 1999. Techniques for measuring sea turtles. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A., Donnelly, M. (Eds.), Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication, pp. 110–114.

Bourjea, J., Derville, S., Berzins, R., Hays, G.C., 2008. Diving behaviour of green turtles at Mayotte Island. Mar. Biol. 155 (2), 237–249.

Braga-Pereira, F., Peres, C.A., Campos-Silva, J.V., et al., 2020. Warfare-induced mammal population declines in Southwestern Africa are mediated by species life history, habitat type and hunter preferences. Sci. Rep. 10, 15428 https://doi.org/10.1038/s41598-020-71501-0.

Burnham, K.P., Anderson, D.R., 2002. Model selection and multimodel inference: A practical information-theoretic approach. Springer-Verlag, New York, New York, p. 488.

Carpio, A.J., Álvarez, Y., Serrano, R., Vergara, M.B., Quintero, E., Tortosa, F.S., Rivas, M.L., 2022. By-catch of sea turtles in Pacific artisanal fishery: Two points of view: From observer and fishers. Front. Mar. Sci. https://doi.org/10.3389/fmars.2022.936734.

Casale, P., 2011. Conservation strategies for sea turtles: past, present, and future. In: Mrosovsky, J.C., Kamel, A., Richardson, A.J. (Eds.), Sea turtles of the Atlantic and Indian Oceans: Status and conservation. CRC Press, pp. 53–68.

Catry. P., Barbosa, C., Indjai, B. (2010). Marine Turtles of Guinea-Bissau. Guinea-Bissau.

Coelho, V. (2015). A classificação etnográfica dos povos de Angola (1.ª parte). Angola.

Dunn, D.C., Kot, C.Y., Halpin, P.N., 2008. A comparison of methods to spatially represent pelagic longline fishing effort in catch and bycatch studies. Fish. Res. https://doi.org/10.1016/j.fishres.2008.01.006.

Ecker, K.L, Abreu-Grobois, F.A, 2001. Status and distribution of the oliva ridley turtle, (Lepidochely olivacea), in the westerns Atlantic Ocean. Proceedings of the Regional Meeting: Marine Turtle Conservation in the wilder Caribbean Region. A Dialogue for Effective Regional Management.

Emanuelsson, A., 2008. Review of the shrimp fishery on the St. Mary's Bank, Gulf of Gabes, Tunisia. In Status and trends of the fisheries and associated environment of the Mediterranean. Studies and Reviews. Gen. Fish. Comm. Mediterr. vol. 86, 38–50.

FAO. (2005). Informe de la Consulta Técnica sobre la Conservación de las Tortugas Marinas y la Pesca.

Gascuel, D., Merigot, B., Rouyer, T., Pinnegar, J.K., Vermard, Y., Shin, Y.J., Huret, M., 2007. Coexistence of small pelagics: a major hypothesis to explain fluctuations of sardine and anchovy in the North-Western Mediterranean. J. Appl. Ecol. 44 (1), 232–241.

Harrison, X.A., Donaldson, L., Correa-Cano, M.E., Evans, J., Fisher, D.N., Goodwin, C.E., et al., 2018. A brief introduction to mixed-effects modelling and multi-model inference in ecology. PeerJ 6 pmid:29844961.

Jabado, R.W., 2021. Conservation status and key threats of chondrichthyan fishes in the Arab region. Rev. Fish. Biol. Fish. 31 (4), 637–649.

Kotas, J.E., dos Santos, S., de Azevedo, V.G., Gallo, B.M.G., Barata, P.C.R. Incidental capture of loggerhead (Caretta caretta) and leatherback (Dermochelys coriacea) sea turtles by the pelagic longline fishery off southern Brazil.2004.

Lei nº 6-A (2004)/04 de 8 de Outubro – Lei dos Recursos Biológicos Aquáticos (LRBA).

Lima, E.H.S.M., D, Melo, M.T. & Barata, P.C.R. (2010). Incidental Capture of Sea Turtles by the Lobster Fishery off the Cear Coast. Brazil.Marine Turtle Newsletter.

Mancini, A., Koch, V., Holland, K.N., 2012. Evidence of partial migration in a large marine vertebrate: the estuarine crocodile. Integr. Comp. Biol. 52 (3), 374–387.

March, A. & Failler, P., (2022). Small-scale fisheries development in Africa: Lessons learned and best practices for enhancing food security and livelihoods. *Marine Policy*.

Marcovaldi, M.A. (2001). Status and distribution of the olive ridley turtle, Lepidochely olivacea, in the western Atlantic Ocean.

Moore, J.E., Dutton, P.H., Read, A.J., 2010. Effect of fishery bycatch on loggerhead sea turtles in the western North Atlantic. Endangered Species Res. 7 (3), 239–250.

Morais, M., Tiwari, M., 2022. Surveys of the Angolan coast uncover the largest olive ridley sea turtle nesting population in the Atlantic and the largest non-arribada population globally. Oryx *56* (5), 789–797. https://doi.org/10.1017/S003060532100065X.

Morais, M.V, Torres, M.O., Martins, M.J. (2006). Biodiversidade Marinha e Costeira em Angola. Ministério do Urbanismo e Ambiente (MINUA). Offsert, Lda.Luanda, Angola.

Morais, M.V. (2014). Projecto Kitabanga - Conservação de Tartarugas Marinhas. Relatório de actividades e resultados do Projecto Kitabanga. UAN/Faculdade de Ciências. Luanda.

Parra, H., Machete, M., Santos, M., Bjorndal, K.A., Vandeperre, F., 2023. Incidental capture of sea turtles in the Northeast Atlantic Portuguese pelagic longline fishery. Fish. Res. *263*, 106673 https://doi.org/10.1016/j.fishres.2023.106673.

Pinedo, M.C., Polacheck, T., 2004. Sea turtle by-catch in pelagic longline sets offsouthern Brazil. Biol. Conserv. 119, 335–339.

Primo, R.A., Santos, J.L.D., Russo, V. & Morais, M.V. (2022) Um Património da nossa Biodiversidade. O que Devemos saber para as Proteger. Angola.

Santos, A.N., 2015. Fisheries as a way of life: Gendered livelihoods, identities and perspectives of artisanal fisheries in eastern Brazil. Mar. Policy. https://doi.org/10.1016/j.marpol.2015.09.007.

Silva, M.I., 2006. Etnoecologia sobre a Tartaruga Marinha e a sua Captura Incidental na Pesca de Pequena Escala: Estudo de Caso na Praia da Canoa (Barra Velha/SC). 102 f. In: Trabalho de Conclusão de Curso (Curso de Oceanografia). Universidade do Vale do Itajaí, Itajaí.

Silva, M.J. (2015). VII Congresso sobre Planeamento e Gestão das Zonas Costeiras dos Países de Expressão Portuguesa, Aveiro, Portugal.

Wallace, B.P. (2010). Global research priorities for sea turtles: informing management and conservation in the 21st century.

Wallace, B.P., Tiwari, M., & Girard, Y. (2013a). Dermochelys coriacea. In The IUCN Red List of Threatened Species 2013.

Wallace, B.P., Kot, C.Y., DiMatteo, A.D., Lee, T., Crowder, L.B., Lewison, R.L., 2013. Impacts of fisheries bycatch on marine turtle populations worldwide: toward conservation and research priorities. Ecosphere 4 (3), 1–49. https://doi.org/10.1890/ES12-00388.1.

Wilson, S.M., Raby, G.D., Burnett, N.J., Hinch, S.G., Cooke, S.J., 2014. Looking beyond the mortality of bycatch: sublethal effects of incidental capture on marine animals. Biol. Conserv. https://doi.org/10.1016/j.biocon.2014.01.020.

Żydelis, R., Wallace, B.P., Gilman, E.L., Werner, T.B., 2009. Conservation of marine megafauna through minimization of fisheries bycatch. Conserv. Biol. https://doi.org/10.1111/j.1523-1739.2009.01172.