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Monitoring and Conservation of Loggerhead Sea Turtles *Caretta Caretta* Along the Libyan Coast: *A Comparative Study Under the Imap Programme*

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ABSTRACT

The loggerhead sea turtle (*Caretta caretta*), a keystone species in Mediterranean marine ecosystems, plays a pivotal role in maintaining ecological balance. Libya's coastline is a critical nesting habitat for this species, hosting one of the largest nesting populations in the Mediterranean. This study, conducted under the framework of the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria (IMAP) of the Barcelona Convention , assesses loggerhead turtle populations along the Libyan coast during the 2022 nesting season. We monitored nesting success, hatchling production, and juvenile strandings across 13 beaches, observing a 58.93% in nest counts and 45.93% increase in hatchling numbers between 2019 to 2022. However, juvenile strandings remained high, with 21 recorded incidents, likely due to fisheries interactions. This study provides insights into loggerhead population dynamics and proposes targeted conservation strategies, including the implementation of Turtle Excluder Devices (TEDs) and enhanced monitoring efforts, to mitigate threats and ensure the long-term sustainability of loggerhead populations in this crucial Mediterranean region.

رصد وحفظ السلاحف البحرية ضخمة الرأس (*Caretta caretta*) على الساحل الليبي: دراسة شاملة في إطار برنامج الرصد والتقييم المتكامل

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تعد السلاحف البحرية ضخمة الرأس (*Caretta caretta*) ، نوع أساسي في النظم البيئية البحرية في البحر الأبيض المتوسط، وتلعب دورًا حيويًا في الحفاظ على التوازن البيئي. ويُعد الساحل الليبي موطنًا حيويًا لتعشيش هذا النوع، حيث يستضيف واحدة من أكبر تجمعات التعشيش في البحر المتوسط. تهدف هذه الدراسة، التي أُجريت في إطار برنامج الرصد والتقييم المتكامل للبحر الأبيض المتوسط ومعايير التقييم ذات الصلة (IMAP) بموجب اتفاقية برشلونة، إلى تقييم تجمعات السلاحف ضخمة الرأس على طول الساحل الليبي خلال موسم التعشيش لعام 2022م قمنا برصد نجاح التعشيش، ومعدلات الفقس، وحالات جنوح (نفوق) السلاحف البحرية في 13 شاطئًا، ووجدنا زيادة بنسبة 58.93% في عدد الأعشاش وزيادة بنسبة 45.93% في أعداد الفقس بين عامي 2019 و2022. ومع ذلك، بقيت حالات جنوح

اليافعين مرتفعة، مع تسجيل 21 حالة، ويرجح أن السبب هو التداخل مع مصائد الأسماك والصيد العرضي. تقدم هذه الدراسة رؤى حول ديناميكيات تجمعات السلاحف ضخمة الرأس، وتقترح استراتيجيات حماية محددة، بما في ذلك اقتراح استخدام أجهزة استبعاد السلاحف (TEDs) وتعزيز جهود الرصد، للحد من التهديدات وضمان استدامة تجمعات السلاحف في هذه المنطقة المهمة من البحر المتوسط على المدى الطويل.

INTRODUCTION

Loggerhead sea turtles (Caretta caretta) are vital components of Mediterranean marine ecosystems, functioning as keystone species whose presence regulates benthic community structures and nutrient cycling (Mazaris et al., 2017). Their ecological roles extend beyond these immediate functions, contributing to the balance between prey and predator populations, which has cascading effects on the health and stability of the Mediterranean ecosystem as a whole (Bjorndal & Bolton, 2003). Preserving loggerhead populations is, therefore, critical, especially in regions such as the Mediterranean, where human activities continue to intensify pressures on marine biodiversity. The Mediterranean is home to several key loggerhead nesting sites, with Libya emerging as one of the most important countries for this activity (Hamza et al., 2006, Casale et al., 2021, SPA/RAC-UNEP/MAP, 2020).

Early studies identified the Libyan coastline as one of the largest loggerhead nesting grounds in the Mediterranean, second only to Greece (Laurent et al., 1995). This is largely due to Libya's 1,140 km of largely undeveloped sandy beaches, which provide critical nesting habitats for the species. Despite this significance, continuous monitoring of loggerhead populations in Libya has been historically limited due to political instability, logistical challenges, and limited conservation infrastructure (Hamza & Diryaq, 2021), which has hampered efforts to evaluate long-term population trends and threats.

Loggerhead populations in the Mediterranean face a variety of threats, including coastal development, pollution, illegal harvesting, and bycatch in fisheries, the latter being particularly critical (Casale & Margaritoulis, 2010, Casale et al., 2021), and the impacts of climatic changes on nesting (Jribi et al., 2013) and foraging activities of these endangered populations (Mazaris et al., 2023).

The intensification of fishing activities near loggerhead nesting sites has led to high rates of turtle entanglement in fishing gear, significantly increasing mortality among juveniles and adults. Additionally, the degradation of nesting habitats due to coastal development and light pollution has exacerbated the challenges faced by loggerhead turtles (Hamza & Diryaq, 2021). In Libya, bycatch is considered the most pressing threat, given the overlap of high-density nesting sites and intensive fishing zones (Hamza & Elghmati, 2006, SPA/RAC-UNEP/MAP, 2021).

The Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria (IMAP), initiated under the Barcelona Convention, seeks to address these conservation challenges by coordinating systematic monitoring efforts for key species across the Mediterranean, including loggerhead sea turtles. The IMAP framework provides a standardized approach to data collection on species distribution, population abundance, and demographic characteristics—defined under Common Indicators 3, 4, and 5 (UNEP/MAP-SPA/RAC, 2022). Data from Turtle monitoring and many other biological and environmental data were collectedo feed the second edition of the Quality Status Report for the Mediterranean. The Seaturtles IMAP programme in Libya aims to fill the existing gaps in monitoring loggerhead populations (Fig.1), offering an evidence-based foundation for developing conservation strategies tailored to mitigate key threats, particularly fisheries bycatch and habitat degradation. This study represents one of the first comprehensive assessments under IMAP, providing critical data on nesting success, population trends, and stranding events along Libya's coastline.

This study seeks to address critical conservation challenges related to loggerhead sea turtles along the Libyan coast by conducting a comprehensive assessment of their population dynamics during the 2022 nesting season.

The specific aims are to: (1) monitor nesting success across key sites and assess population trends by comparing data from 2022 with previous surveys, notably from 2019; (2) quantify hatching success to evaluate the effectiveness of ongoing conservation efforts in enhancing reproductive outcomes; (3) investigate juvenile stranding events to identify primary mortality causes, particularly focusing on the impacts of fisheries bycatch; and (4) provide evidence-based recommendations to strengthen conservation strategies, focusing on mitigating fisheries bycatch and preserving critical nesting habitats.

Fig. (1): Tracks nesting females; Adult female laying eggs; Stranded turtle on beach; Egg chamber of Loggerhead turtle.

MATERIALS AND METHODS

Study Area

The study focused on 13 nesting beaches along Libya's extensive coastline, spanning over 115.77 km, which represents more than 10% of Libya's sandy shore (Laurent et al., 1999, Hamza & Elghmati, 2006). The beaches selected for this study have been identified as important loggerhead nesting sites through previous research (Hamza & Diryaq, 2021) and historical monitoring data from the Libyan Sea Turtle Programme (LibSTP). These beaches range from relatively pristine habitats, such as Farwa Lagoon and Ain El Ghazela (both Marine Protected Areas), to heavily disturbed beaches in more urbanised regions, such as Tripoli and Sirte, where anthropogenic pressures from fishing, tourism, and coastal development are most presented.

The nesting season for loggerhead turtles in the Mediterranean typically spans from late May to August (Casale et al., 2021), with peak nesting activity observed in Libya during June and July (Hamza & Elghmati, 2006). Fieldwork for this study was conducted between June and August 2022, with daily patrols of each beach to monitor nesting activities. The beaches in Sirte (Alkhamseen, Alarbaeen-Tamet, West Camp, Algbeba, and Thalateen) were prioritised due to their historically high nesting densities, accounting for over 40% of loggerhead nests recorded in Libya.

Data Collection

Standardised IMAP data collection protocols were employed throughout the study (UNEP/MAP - SPA/RAC, 2022). Nesting data were collected using the IMAP BT1 and BT3 forms, which recorded key parameters such as the number of nests, clutch size, and hatching success rates. Field teams used handheld GPS devices to geo-reference each nest, ensuring accurate spatial data collection.

For stranding events, IMAP BT5 forms were used to document species identification, carapace measurements, body condition, and possible causes of death (e.g., bycatch, entanglement in fishing gear). Stranding events were classified based on the turtle's size and the apparent cause of death, with a focus on juvenile strandings, which are often indicative of bycatch mortality. Public reports of stranded turtles were cross-verified with field observations to ensure data accuracy.

Data Analysis

Data from the 2022 nesting season were rigorously compared with those from 2019 to evaluate changes in nesting activity, hatching success, and stranding events. Descriptive statistics and charts, using Julius ai® free version, were employed to examine trends across the monitored sites, with particular focus on differences in nesting success between urbanised and remote beaches, and comparing 2019 and 2022 monitoring data.

Table 1. Monitored nesting beaches during 2022 season

Nesting Beach	Latitude	Longitude	Length (Km)
Farwa	33.104167	11.749722	13
Tripoli	32.896111	13.337222	9.3
Thalateen	31.219444	16.361944	5
Algbeba	31.224167	16.330278	5.67
West Camp	31.230278	16.264444	2.5
Alarbaeen-Tamet	31.238333	16.207222	8.54
Benjawad	30.841111	17.964167	13.07
Ain Alghazala	32.206111	23.334722	3
Karkura	31.445833	20.013333	7.19
Deryana	32.351667	20.297778	4.5
Shat Elbadin	31.188056	20.168333	12
Alkhamseen	31.265833	16.058333	20
Mtefla	31.308889	20.103889	12

RESULTS

Nesting Success

A total of 445 nests were recorded across all monitored sites in 2022, marking an increase from 280 nests in 2019 (58.93%). The Sirte region (Alkhamseen and Alarbaeen-Tamet beaches) accounted for over 40% of the total nests recorded, consistent with historical nesting data that identified Sirte as a high-density loggerhead nesting area (Fig.2). Notably, average hatchling production per site also increased markedly (45.93%), rising from 1598 in 2019 to 2332 in 2022 (Fig.3). The success of nesting and hatching rates varied between sites, with remote beaches such as Deryana showing the highest hatching success. These areas, which are less affected by human activity, had higher rates of hatchling emergence compared to more disturbed beaches, such as those near Tripoli, where artificial light pollution and human disturbance

negatively impacted hatchling orientation and survival (UNEP/MAP-SPA/RAC, 2021).

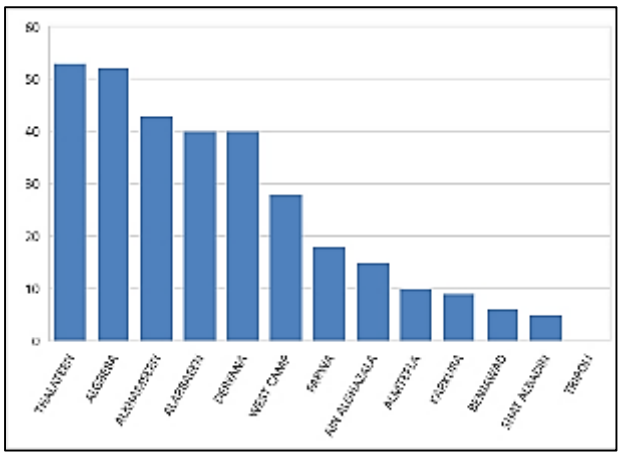

Figure (2) Number of Nests reported at nesting beaches in 2022.

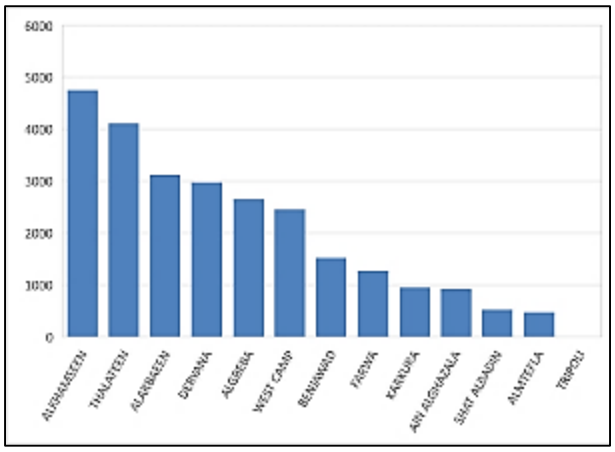

Figure (3) Number of hatchlings produced from nesting beaches in 2022.

Comparative Analysis with 2019

When comparing 2022 data with 2019, several key trends emerged. First, the increase in nesting activity and hatchling production suggests a positive trajectory in loggerhead population recovery (Fig.4). However, the persistent threat of juvenile bycatch, as indicated by the high number of juvenile strandings, remains a major concern. While no significant changes were observed in the geographical distribution of nesting activity, new nesting behaviour was reported in Tripoli, previously considered a low-density nesting area.

The higher hatchling emergence success observed at remote beaches, such as Deryana, compared to urban beaches, underscores the importance of preserving undisturbed nesting habitats (Fig.5). Conversely, beaches near urban centres, where light pollution and human activity are prevalent, showed lower hatchling success, reflecting the well-documented negative impacts of artificial lighting on sea turtle nesting behaviour (Hamza & Diryaq, 2021).

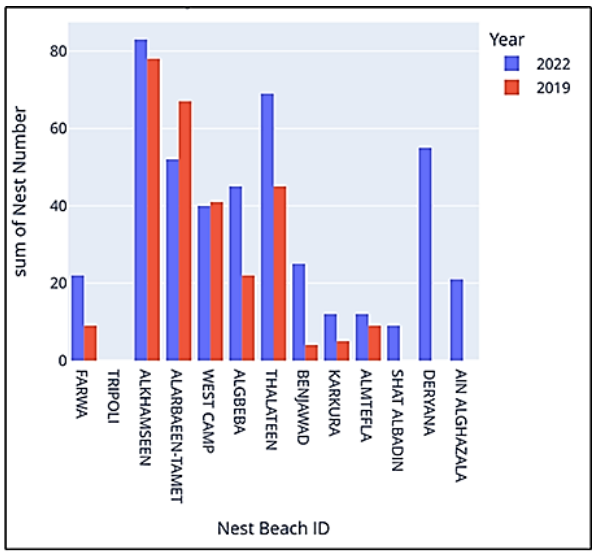

Figure (4) Comparison of Nest numbers across all nesting beaches in 2019 and 2022.

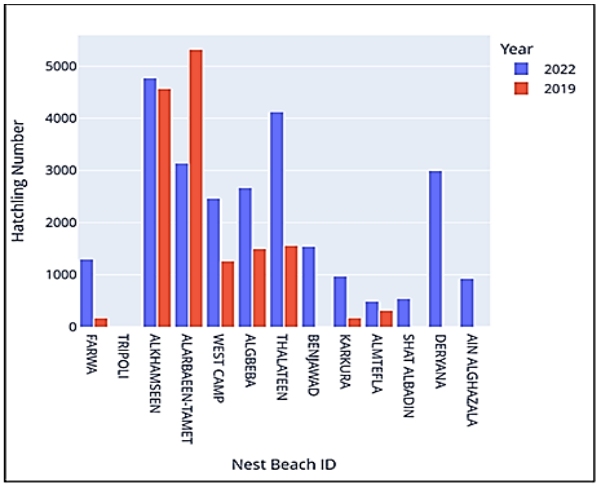

Figure (5) Comparison of hatchling numbers across all nesting beaches in 2019 and 2022.

Stranding Events

Twenty-one juvenile loggerhead strandings were documented during the 2022 monitoring period, with no adult strandings recorded. This contrasts with the 2019 survey, which recorded both adult and juvenile strandings, including rare specimens of leatherback (Dermochelys coriacea) and green turtles (Chelonia mydas). The juveniles stranded in 2022 had an average carapace length of 38.76 cm, with evidence of fisheries operation -related injuries (e.g., net entanglement) present in several cases, while in 2019 more stranded turtles were reported with average carapace length of 64.33 cm (more adult sizes in 2019 data).

The predominance of juvenile strandings in 2022 aligns with findings from other Mediterranean regions, where juvenile loggerheads are disproportionately affected by bycatch in trawlers and other commercial fishing operations (Casale & Margaritoulis, 2010). The absence of adults strandings may indicate their improved survival rates, although the limited geographical coverage of the study may have contributed to this observation. Further investigation is required to determine whether adult loggerheads are simply stranded in less-monitored areas or during non-nesting seasons.

DISCUSSION

Conservation Implications

The results of this study highlight the positive impact of ongoing conservation efforts in Libya, particularly those facilitated by the Libyan Sea Turtle Programme (LibSTP) and UNEP/MAP - SPA/RAC, which have improved local capacity for sea turtle monitoring and conservation (Hamza & Diryaq, 2021). The increase in nesting success and hatchling production across multiple sites is an encouraging sign that regional and national conservation strategies implementation, such as habitat protection and human disturbance mitigation, are yielding positive tangible outcomes.

However, the data on juvenile strandings are concerning, as they indicate that bycatch remains a major threat to loggerhead populations in Libya. Previous studies have demonstrated the high mortality rates of juvenile turtles due to entanglement in fishing gear, particularly trawlers (Casale & Margaritoulis, 2010; Wallace et al., 2010). Addressing this issue is critical for ensuring the long-term survival of loggerhead turtles, particularly in areas with high fishing activities near nesting sites.

One proven mitigation measure for reducing bycatch is the use of Turtle Excluder Devices (TEDs) in fishing gear, which has been shown to significantly reduce the number of turtles caught in trawls (Wallace et al., 2010). Despite the success of TEDs in other Mediterranean countries, their adoption in Libyan fisheries remains limited. Encouraging the use of TEDs in Libyan fisheries, particularly in regions with high juvenile bycatch rates, should be a priority for conservationists and policymakers alike.

POLICY AND MANAGEMENT RECOMMENDATIONS

Several key policy and management recommendations emerge from this study:

Adoption of TEDs in Libyan Fisheries: TEDs have been proven effective in reducing bycatch in several Mediterranean countries. Introducing TEDs in Libyan trawl fisheries could substantially reduce juvenile loggerhead mortality. This should be accompanied by outreach and training initiatives for local fishermen to promote the widespread adoption of TEDs (Wallace et al., 2010).

Increased Beach Patrols and Monitoring: Expanding the coverage and frequency of beach patrols, particularly in remote areas such as Ain El Ghazela and Farwa, would improve data accuracy and ensure the protection of critical nesting sites. Additionally, increasing the duration of monitoring to include non-nesting seasons may provide more comprehensive data on adult loggerhead mortality rates.

Protection of Remote Nesting Habitats: Preserving undisturbed beaches, where hatchling success is highest, is crucial for sustaining loggerhead populations. Designating these areas as protected zones or limiting human activity during nesting seasons would help safeguard turtle habitats.

Community Engagement and Public Awareness: Engaging local communities in conservation efforts, through education and participation in nesting and stranding monitoring activities, would foster a culture of conservation. Public awareness campaigns, particularly in urban areas, could help mitigate the negative impacts of artificial lighting and human disturbance on nesting beaches.

Conducting At-Sea Surveys: While this study focused on nesting and stranding events, at-sea surveys to monitor loggerhead distributions in Libyan waters would provide valuable data on the turtles' foraging grounds, migration routes, and interaction with fisheries. These surveys would be crucial for identifying and mitigating bycatch hotspots, particularly in areas frequented by juvenile turtles (Casale et al., 2010).

CONCLUSIONS

This study provides valuable insights into the status of loggerhead turtle populations along the Libyan coast, with data showing positive trends in nesting success and hatchling production. However, the high incidence of juvenile strandings underscores the ongoing threat of fisheries bycatch, which remains a significant cause of mortality. Implementing proven and targeted conservation measures, including the use of TEDs, expanding monitoring efforts, and protecting critical nesting habitats, as defined within the national and regional Action plans, will be essential for ensuring the long-term survival of loggerhead turtles in Libya.

Given the regional importance of Libya as a key loggerhead nesting ground in the Mediterranean, sustained efforts from government agencies, conservation organisations, and local communities will be necessary to mitigate threats and enhance the conservation of this keystone species. Through the continued implementation of the IMAP programme, Libya can contribute significantly to national, regional and global sea turtle conservation initiatives.

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