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Threats posed to the fragile and pristine marine turtle (loggerhead & leatherback) eggs in the Maputaland coastline: a cross-sectional ecological assessment.

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Abstract

Background
The Maputaland coastline in northern KwaZulu-Natal, South Africa, is a critical nesting habitat for the endangered Loggerhead (*Caretta caretta*) and Leatherback (*Dermochelys coriacea*) turtles. Despite its protected status, this region is increasingly exposed to anthropogenic pressures and environmental stressors that threaten turtle nesting success and egg survival. This study assessed key threats affecting marine turtle reproduction within the Maputaland Marine Protected Area (MPA).

Methods
A cross-sectional ecological assessment was conducted between November 2023 and March 2024, corresponding with the peak turtle nesting season. Data were collected along a 30 km stretch of coastline and included nest counts, hatchling success rates, records of physical disturbances (e.g., erosion and storm surges), observations of human activities (e.g., poaching, tourism, off-road vehicle tracks), and semi-structured interviews with conservation officers and local community members. Quantitative data were analysed using descriptive statistics, while qualitative data were analysed thematically.

Results
The overall hatchling success rate was 58%, with significantly lower success observed in areas experiencing high levels of human disturbance. Illegal poaching was responsible for 23% of recorded nest disturbances. Additional threats included artificial coastal lighting causing hatchling disorientation, dune erosion, and off-road vehicle activity. Qualitative findings revealed low public awareness of conservation legislation and the continued cultural consumption of turtle eggs. Conservation personnel highlighted limited patrol capacity and insufficient community outreach as major constraints to effective protection.

Conclusion
Both anthropogenic activities and natural stressors are undermining marine turtle reproductive success along the Maputaland coastline.

Recommendations
Community-based conservation approaches incorporating environmental education, strengthened enforcement of MPA regulations, turtle-friendly lighting, and sustainable eco-tourism practices are essential. Collaborative co-management involving local communities, conservation authorities, and academic institutions is critical for long-term turtle conservation and ecosystem resilience.

Keywords: *Loggerhead turtles (*Caretta caretta*), Leatherback turtles (*Dermochelys coriacea*), Maputaland coastline, Sea turtle conservation, Nesting success, Marine Protected Areas (MPAs), Turtle monitoring programme, Poaching and human disturbance.*
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Background

The conservation of sea turtles in South Africa has a rich and evolving history, with formal efforts dating back to 1963 when the former Natal Parks Board (now Ezemvelo KZN Wildlife) initiated monitoring and protection measures in response to increasing reports of poaching along the Maputaland coastline. These early interventions focused primarily on two ecologically significant species, the Loggerhead (*Caretta caretta*) and Leatherback (*Dermochelys coriacea*) turtles, which nest on the beaches of northern KwaZulu-Natal. The escalating exploitation of nesting females and their eggs prompted the implementation of the Natal Coastal Fisheries Ordinance, now incorporated into the Marine Living Resources Act, to curb unsustainable harvesting practices (Bachoo, 2018). The first organised survey of turtle nesting activity was launched on 1 December 1963 and covered approximately 60 km of coastline south of the Mozambican border. This initiative has since evolved into one of the world's longest-running and most effective sea turtle monitoring and protection programmes (Bachoo, 2021). Currently led by Ezemvelo KZN Wildlife in collaboration with the iSimangaliso Wetland Park Authority, the Department of Forestry, Fisheries and the Environment (DFFE), and civil society partners such as Wild Oceans, the programme represents a successful model of integrated conservation and community-based eco-tourism. Historically, the protection programme was designed to deter direct exploitation, particularly the poaching of turtles emerging to lay eggs (Hughes, 1967). Over time, regional cooperation has expanded, most notably through the establishment of the Ponta do Ouro–Kosi Bay Transfrontier Marine Conservation Area in 2009 between South Africa and Mozambique (Lombard, 2010). Further strengthening national marine conservation, the declaration of 20 new and expanded Marine Protected Areas (MPAs) in 2018 increased South Africa's ocean protection coverage from 0.4% to 5%. Notably, the iSimangaliso MPA expanded from 886 km² to 10,700 km², substantially enhancing protection for inter-nesting and foraging turtles (Harris, 2011). Despite these achievements, sea turtle populations remain vulnerable. The absence of comprehensive historical population data limits accurate assessment of past population declines. Nevertheless, archaeological evidence, including turtle bone fragments found in Middle Stone Age cave sites, points to a long-standing human–turtle relationship (Hughes, 1998). The amaThonga people traditionally harvested turtle eggs as a protein source, and when combined with emerging markets for turtle products, these practices intensified pressure on nesting populations (Nel et al., 2013).

Although legal instruments banning turtle and egg harvesting were established early, enforcement was initially weak. It was only after systematic monitoring began that stricter controls, such as the designation of nesting beaches as sanctuaries, were implemented. Over subsequent decades, conservation approaches evolved to balance ecological protection with socio-economic benefits, transforming turtle conservation into a sustainable livelihood opportunity through eco-tourism. However, illegal exploitation remains a persistent threat. The World Health Organization (WHO) has warned against consuming turtle meat due to risks associated with pathogens and heavy metal contamination, including DDT (Oliver Ridley Project, n.d.). Despite this, cultural traditions and economic hardship continue to drive poaching. Globally, sea turtles have been harvested for both subsistence and international trade, contributing significantly to population declines and endangered status (Frazier, 1980; Lutz, Milton & Musick, 2010). In South Africa, Loggerhead and Leatherback turtles are listed as critically endangered on the IUCN Red List (June 2013). Common causes of turtle strandings include vessel strikes, plastic ingestion, fishing gear entanglement, and disease, all of which significantly reduce survival unless timely rehabilitation occurs (Flint, 2015). Monitoring stranding trends, size classes, and survival rates remains crucial for guiding conservation and rehabilitation strategies (South African Association for Marine Biological Research, 2020). Regionally, fisheries bycatch represents the most significant threat to Leatherback turtles in the southwest Indian Ocean, with consistently high bycatch levels recorded across multiple sites (Wallace, 2011; Nel, 2012). Although conservation efforts in South Africa have reduced threats to eggs and hatchlings, continued illegal harvesting in neighbouring Mozambique poses transboundary challenges, underscoring the need for coordinated regional management strategies. Sea turtles have existed for over 100 million years, yet their survival is increasingly jeopardised by poaching, habitat degradation, and anthropogenic pollution. The recent resurgence of egg poaching along the Maputaland coast highlights the fragility of conservation gains. Importantly, declining turtle populations threaten local livelihoods and eco-tourism benefits that depend on healthy marine ecosystems. Over six decades, the Maputaland turtle monitoring programme has demonstrated that conservation and sustainable development can be

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mutually reinforcing. Through eco-tourism and long-term employment opportunities, local perceptions have shifted, with turtles increasingly viewed as valuable assets rather than solely as a food source. This programme stands as a compelling example of how ecological protection and socio-economic development can align when supported by strong policy frameworks, scientific research, and community engagement. Accordingly, the specific objective of this study was to identify, assess, and document the key anthropogenic and environmental threats affecting the nesting success, egg survival, and conservation outcomes of Loggerhead (*Caretta caretta*) and Leatherback (*Dermochelys coriacea*) sea turtles along the Maputaland coastline, to inform strengthened, community-inclusive conservation strategies.

Methodology

Study Area

The turtle-nesting beaches in South Africa are primarily located within the iSimangaliso Wetland Park, a UNESCO World Heritage Site situated along the northern KwaZulu-Natal coastline. The South African turtle rookery spans approximately 153 km, stretching from Cape Vidal to the border with Mozambique. For this study, monitoring was conducted along a 60 km section of this coastline, extending from the South African-Mozambican border southwards to Sodwana Bay (Figure 1). This specific stretch of beach was surveyed exclusively by trained community-based turtle monitors. Monitoring was conducted on foot, with patrols scheduled for early mornings and evenings to coincide with peak turtle activity. Before deployment, monitors underwent specialized training to ensure standardized data collection. Patrols were carried out daily from 15 October 2021 to 15 March 2022, aligning with the peak nesting season of marine turtles in the region.

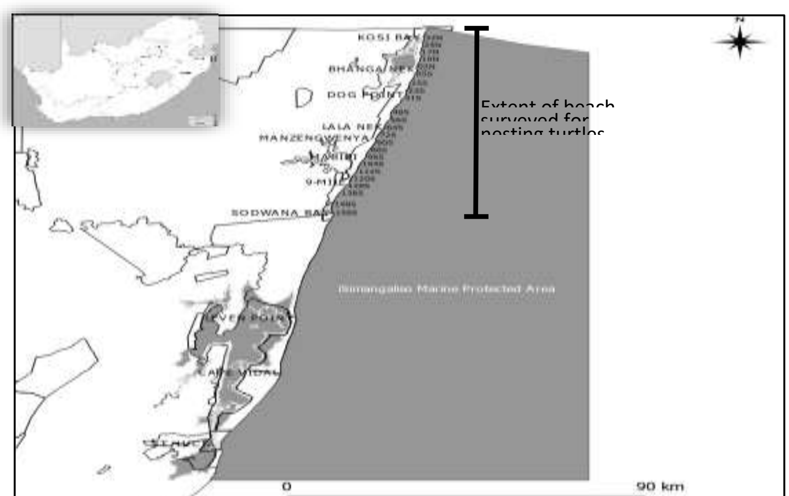

Figure 1: Map of the newly extended offshore extent of the iSimangaliso MPA. The inset provides spatial reference for the study site. The stretch of beach monitored for nesting leatherback and loggerheads is indicated above. The index beach is the stretch from Bhanga Nek north to Kosi Mouth.

Study Design

This study employed a cross-sectional mixed-methods design, integrating quantitative ecological monitoring and qualitative community-based data collection. The ecological component involved field-based nesting observations and biometric data collection, while the social component utilized semi-structured questionnaires to assess local community perspectives on turtle conservation.

Study Setting

The study was conducted along the Maputaland coastline, a protected area within the iSimangaliso Wetland Park, located in northern KwaZulu-Natal, South Africa. The ecological monitoring covered a stretch of coastline from Kosi Mouth (Beacon 32N) to Hulley Point (Beacon 100S). The primary monitoring period occurred between

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November 2023 and March 2024, coinciding with the nesting season for Loggerhead (*Caretta caretta*) and Leatherback (*Dermochelys coriacea*) turtles. Data collection occurred at nine permanent beach camps, with base operations located at Bhanga Nek. Community interviews were conducted across five adjacent rural communities: Mabibi, Mpukane, Mqobela, Novunya, and Kwa-Dapha.

Participants

Ecological participants included nesting Loggerhead and Leatherback turtles encountered during standardized patrols. Only confirmed nesting females were included for biometric data collection and tagging. Human participants for the questionnaire survey were selected through purposive sampling in collaboration with local traditional councils. A total of 50 individuals were interviewed, with 10 participants per community. Eligibility criteria included individuals over 18 years of age who were either long-term residents, traditional leaders, field rangers, former turtle monitors, local fishermen, or tour operators.

Bias

To reduce selection bias, community gatekeepers were consulted to ensure diverse representation of participant roles. Observer bias in ecological data was minimized through standardized training of monitors before the nesting season began, ensuring uniformity in data collection procedures. Recall bias during interviews was addressed by restricting questions to recent events (within the past 5–10 years) and clarifying ambiguous responses in real time.

Study Size

The ecological study size was determined by the geographic span of the turtle monitoring programme, which covered a 68-km stretch of coastline with consistent nightly patrols. A total of nine monitoring camps were operational throughout the season, ensuring near-complete coverage. The social survey sample size was determined based on logistical feasibility and the diversity of community roles, with 50 participants deemed sufficient to identify common themes and capture variability in local knowledge, practices, and attitudes.

Quantitative Component

Inclusion Criteria

Participants were eligible for the quantitative component if they:

- Were 18 years or older
- Resided in communities adjacent to the Maputaland coastline
- Had direct involvement or exposure to sea turtle conservation activities (e.g., community members, former turtle monitors, fishermen, local leaders, tourism operators)
- Provided informed consent

Exclusion Criteria

Participants were excluded if they:

- Were under 18 years of age
- Had no direct interaction or knowledge related to turtle conservation or protected area activities
- Were temporary visitors or tourists
- Declined or withdrew consent

Source of criteria: Eligibility criteria were informed by established community-based conservation research methods and prior socio-ecological studies conducted in protected area contexts in southern Africa.

Qualitative Component

Inclusion Criteria

Participants were eligible for the qualitative component if they:

- Had direct experiential knowledge of turtle conservation (e.g., conservation officers, long-term community members, former monitors, elders)
- Had at least one year of involvement or lived experience related to the study topic
- Were willing to participate in in-depth discussions or interviews

Exclusion Criteria

Participants were excluded if they:

- Had limited or no experiential knowledge of turtle conservation
- Were newly involved (<1 year) in related activities
- Declined consent or were unavailable for extended engagement

Source of criteria: Qualitative inclusion criteria were guided by purposive

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sampling principles commonly applied in ecological and socio-ecological research to ensure information-rich cases.

Participant Flow for Quantitative Component

The quantitative participant flow followed a structured recruitment process:

- 65 individuals were initially identified through community registers and local stakeholder networks
- 55 individuals were screened for eligibility
    - 5 excluded (did not meet inclusion criteria)
- 50 individuals were confirmed eligible and consented
- 50 participants completed the questionnaire
- 50 participants were included in the final quantitative analysis

No incomplete questionnaires or withdrawals were recorded after enrolment.

Study Size Determination

Quantitative Sample Size (n = 50)

The quantitative sample size was determined based on:

- The size of the target communities
- The exploratory nature of the socio-ecological survey
- Logistical feasibility and time constraints
- Consistency with similar community-based conservation studies, which typically use sample sizes of 30–60 participants for descriptive analysis

The sample size was sufficient to generate descriptive statistics and identify trends in community knowledge, attitudes, and perceptions.

Qualitative Sample Size

The qualitative component included:

- Conservation officers
- Former turtle monitors
- Community elders and leaders

Participants were selected purposively until thematic saturation was reached, meaning no new themes emerged from additional interviews. Saturation was achieved after repeated patterns were observed across participant narratives, consistent with qualitative research standards.

Integration of Mixed-Methods Components

Both quantitative and qualitative components were integrated at the interpretation stage. Quantitative findings provided breadth and pattern identification, while qualitative data offered depth and contextual explanation of observed trends. This complementary approach strengthened the validity and interpretability of the findings.

Statistical Analysis

Quantitative ecological data were analysed using Microsoft Excel and Statistica 8 software. Nesting trends were assessed using LOWESS smoothing techniques to identify temporal patterns. Data on carapace measurements, tag returns, and nest success rates were summarized using descriptive statistics.

For the social survey, qualitative responses were thematically analysed and tabulated. Responses were coded according to recurring themes (e.g., conservation awareness, poaching practices, cultural beliefs). Missing data from incomplete questionnaires were treated as "Not Applicable" and excluded from thematic frequency counts but noted in the final dataset for transparency.

Ethical Consideration

Ethical approval for the study was granted by the Ezemvelo KZN Wildlife Research Ethics Committee in accordance with its conservation research protocols. The research activities involving human participants were reviewed and approved by the Mangosuthu University of Technology on 15 January 2020. All participants provided verbal informed consent before participation, and data confidentiality was maintained throughout.

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Results

Table 1: Nesting parameters for the loggerhead turtles over 8 seasons

LOGGERHEAD TURTLES	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
NUMBER OF TRACKS	6490	5958	5020	4654	5749	6077	4381	7088
NUMBER OF TAGS	1054	851	935	1002	1217	1019	827	1377
NUMBER OF DISTINCT INDIVIDUALS	658	606	670	632	843	735	578	801
NUMBER OF NEW INDIVIDUALS	412	241	407	382	511	462	457	545
NUMBER OF REMIGRANTS	218	365	263	250	332	273	121	256
NUMBER NESTED	3890	3591	2951	2629	3352	3644	2361	4551
NUMBER NOT NESTED	2515	2165	2045	1999	2366	2342	1694	2442
NUMBER OF NESTS NOT SPECIFIED	85	200	20	26	31	91	326	295
NUMBER OF CALLOUSES	138	112	104	153	113	151	96	13
NUMBER OF PIT TAG (REPEATS)	226 (63)	345	28(1)	16(4)	31	N/A	N/A	
NUMBER OF NOTCHES (actual codes reported)	55(50)	45	32(30)	31(55)	74(71)	46(31)	49	57 (46)
MEAN LENGTH	912±42.5	908±55.7	900.9±43.8	903.6±43.3	909.2±37.4	897.8±44.6	892.8±49	902.21±44.8

Table 2: Nesting parameters of leatherback turtles for the past 8 seasons

LEATHERBACK TURTLES	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22
NUMBER OF TRACKS	431	456	609	491	402	387	394	531
NUMBER OF TAGS	96	92	105	111	100	104	76	156
NUMBER OF DISTINCT INDIVIDUALS	54	63	76	74	73	60	57	96

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NUMBER OF NEW INDIVIDUALS	36	30	51	49	40	45	44	81
NUMBER OF REMIGRANTS	18	33	25	25	33	15	13	15
NUMBER NESTED	414	423	558	471	393	374	372	493
NUMBER NOT NESTED	16	27	50	18	9	10	20	31
NUMBER OF NESTS NOT SPECIFIED	1	5	1	2	0	3	2	7
NUMBER OF CALLOUSES	5	12	5	12	16	6	8	26
NUMBER OF PIT TAG (REPEATS)	6	22	2	0	0	0	N/A	N/A
MEAN LENGTH	1638.2 ±79.3	1610.38 ±119	1572.04 ±149.6	1591.81 ±138.5	1614.00 ±62.78	1616.97 ±78.92	1601.84 ±93.7	902.21 ±44.8

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Table 3: Comparison of the results of the 2020/2021 and 2021/2022 nesting season along a 60km stretch of beach being surveyed.

NESTING PARAMETER	SEASON 2020/2021		SEASON 2021/2022	
	LEATHERBACK TURTLES	LOGGERHEAD TURTLES	LEATHERBACK TURTLES	LOGGERHEAD TURTLES
NUMBER OF TRACKS	394	4381	531	7088
NUMBER OF TAGS	76	824	156	1377
NUMBER OF DISTINCT INDIVIDUALS	57	578	96	802
NUMBER OF NEW INDIVIDUALS	44	457	81	545
NUMBER OF REMIGRANTS	13	121	15	256
NUMBER NESTED	372	2361	493	4551
NUMBER NOT NESTED	20	1694	31	2442
NUMBER OF NESTS NOT SPECIFIED	2	56	7	295
NUMBER OF CALLOUSES	8	96	26	13
NUMBER OF NOTCHES (actual codes reported)	N/A	49	N/A	57(46)
MEAN LENGTH	1601.84±93.7	892.85±49	1610.8±70.65	902.21±44.8

Figure 2 highlights persistent traditional beliefs regarding the uses of sea turtle eggs along the Maputaland coastline. A majority of participants (over 50%) still believe in the myth that turtle eggs enhance livestock reproduction, indicating a strong cultural narrative that remains influential despite conservation education. Additionally, 22% of respondents regard turtle eggs as a food source, reflecting subsistence or culinary motivations, while 19% associate them with libido enhancement, a belief common in some traditional medicinal practices. Only a small fraction (6%) of participants reported no such belief or held alternative views. These findings underscore the need for targeted awareness campaigns that address specific cultural myths while promoting the ecological importance of turtle conservation.

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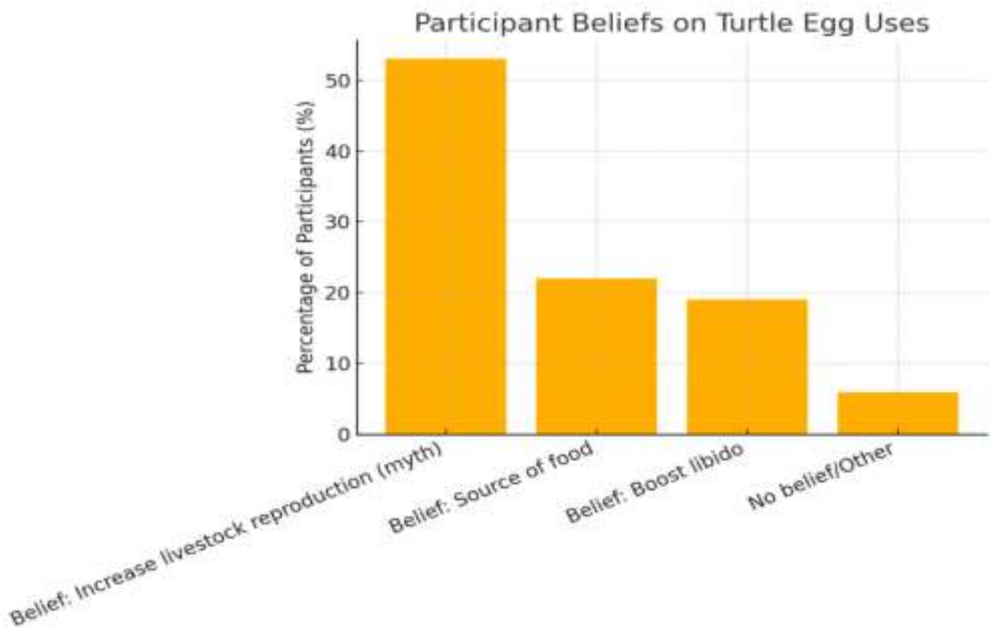

Figure 2: Percentage of participants' feedback on the uses of Turtle eggs at the Maputaland Coastline

Figure 3 illustrates the age distribution of community members who participated in the study, with the highest representation (16 individuals) falling within the 60–69 age group. This age cohort was specifically targeted due to their deep historical knowledge of the area and longstanding interactions with the environment and turtle populations. Their contribution is particularly valuable for understanding changes in community practices, local ecological knowledge, and the evolution of human-turtle interactions. The inclusion of participants across younger age brackets (18–59) also ensures intergenerational perspectives, although their numbers were relatively lower. This highlights the importance of documenting elder knowledge while also fostering conservation dialogue with younger generations.

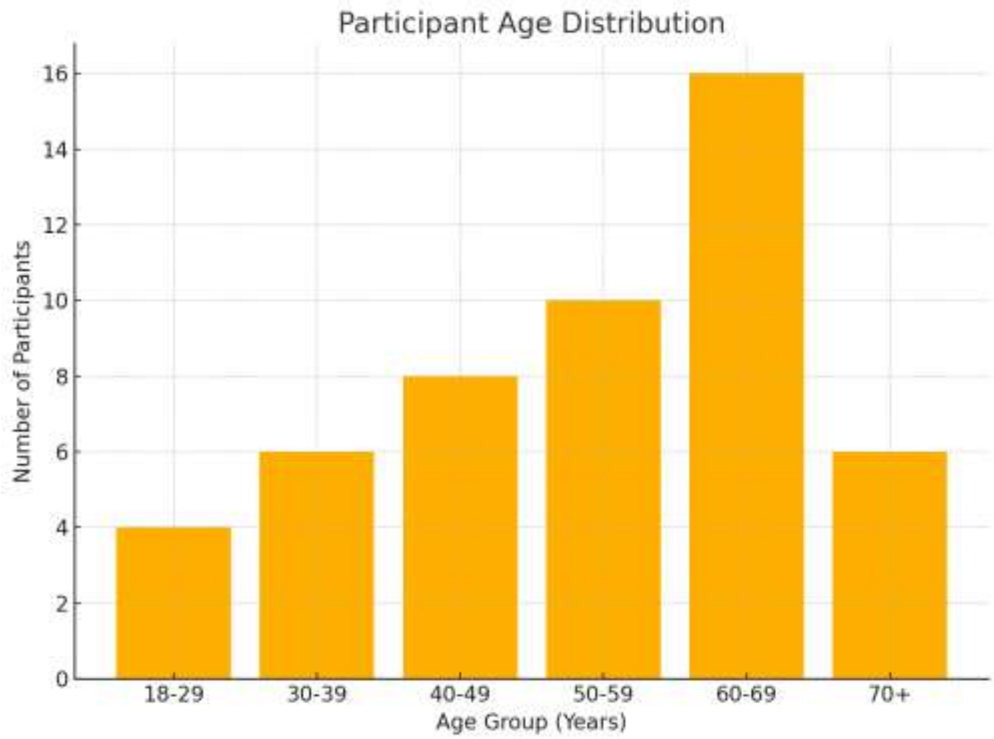

Figure 3: Age groups in years of participants interviewed

Figure 4 demonstrates a nearly balanced gender participation in the study, with 55% male and 45% female respondents. While the gap is minimal, it reflects a slight male dominance, likely due to the greater involvement of men in field-based roles such as fishing, turtle monitoring, and coastal patrols. Nonetheless, the significant female participation is noteworthy, as it ensures that diverse community perspectives, including those of women involved in tourism, education, and local governance, are captured. This balanced input strengthens the credibility and inclusivity of the study's social findings and helps ensure that future conservation strategies are informed by the experiences and knowledge of both genders.

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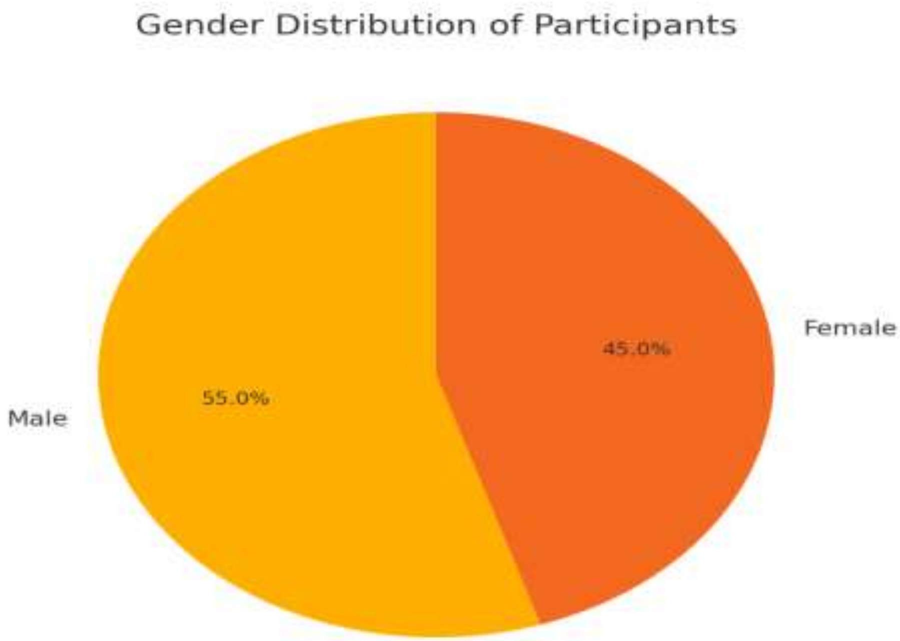

Figure 4: Pie graph illustrating the gender of interviewed participants

Figure 5 demonstrates a negative correlation between the level of human activity and hatchling success rates among marine turtles along the Maputaland coastline. In areas with low human activity, hatchling success reaches 72%, reflecting relatively undisturbed and suitable nesting conditions. This success rate drops to 60% in zones with moderate human interference, and further declines to just 42% in high-activity zones. These findings suggest that increased human presence, potentially through beach traffic, pollution, and noise, directly impacts turtle nest viability and the survival of hatchlings. The data strongly indicate that minimizing human disturbance in nesting zones could significantly improve reproductive outcomes for these endangered species.

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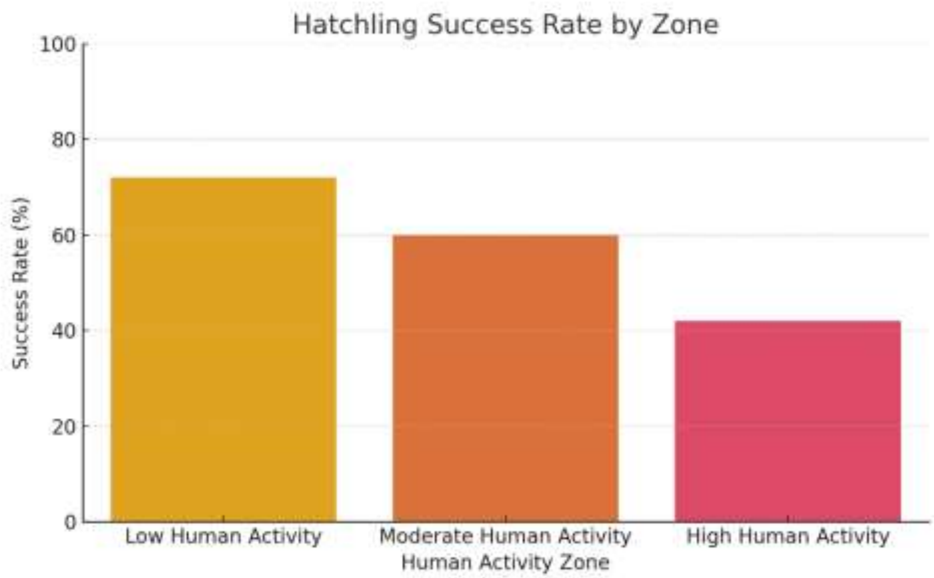

Figure 5: The chart shows a clear decline in hatchling success rates from low to high human activity zones, illustrating the impact of human disturbance on turtle egg viability

Figure 6 illustrates the distribution of the main threats affecting turtle nesting success on the Maputaland coastline. Vehicle activity emerged as the most frequent threat (30%), often resulting in crushed nests and disrupted nesting paths. Beach erosion, linked to climate change and severe weather events, was the second most common threat at 29%, posing risks of nest inundation and habitat loss. Poaching accounted for 23% of nest disturbances, showing ongoing illegal egg harvesting despite protective measures. Lighting disorientation, at 18%, although less frequent, is a critical concern as artificial lighting can misguide hatchlings away from the sea. These results highlight the multifaceted nature of threats and the need for integrated mitigation strategies involving habitat protection, law enforcement, and community engagement.

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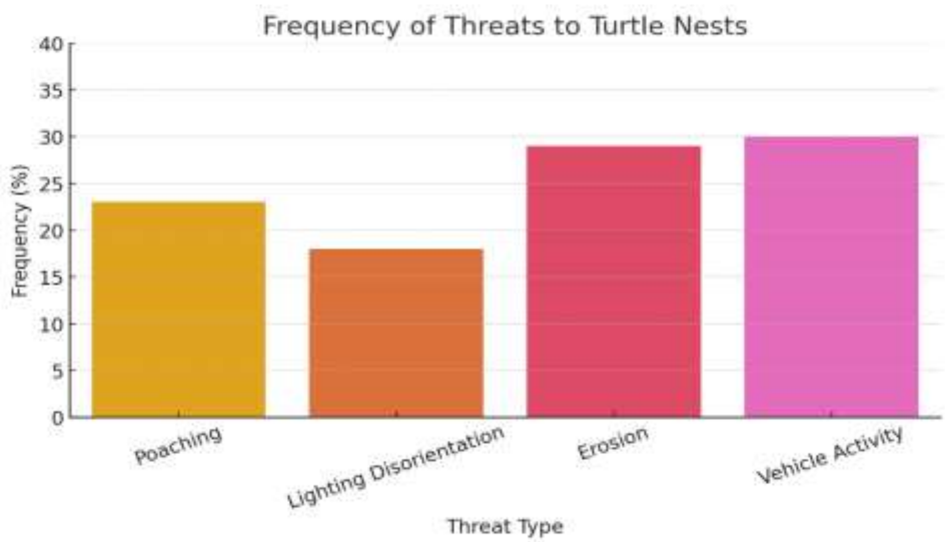

Figure 6: This graph highlights the primary threats, with vehicle activity and beach erosion being the most frequent, followed closely by poaching and lighting disorientation.

Table 4: Coding Framework – Codes and Themes Generated from Qualitative Data

Theme	Category	Codes	Description
Perceived Importance of Turtle Conservation	Conservation value	Cultural importance of turtles; Ecological significance; Heritage protection	Recognition of turtles as culturally and ecologically valuable species
Community Knowledge and Awareness	Awareness levels	Knowledge of nesting seasons; Awareness of conservation laws; Understanding of turtle behaviour	Extent of community understanding regarding turtle ecology and legal protection
Livelihood and Economic Considerations	Economic dependence	Tourism benefits; Employment as monitors; Loss of income from harvesting	Economic trade-offs associated with conservation
Cultural Practices and Traditions	Traditional use	Egg consumption; Historical harvesting; Cultural beliefs	Persistence of traditional practices influencing turtle exploitation
Drivers of Illegal Harvesting	Socio-economic pressures	Poverty; Food insecurity; Market demand	Factors motivating continued poaching
Perceptions of Enforcement and Governance	Institutional capacity	Limited patrols; Weak enforcement; Trust in authorities	Views on conservation governance effectiveness
Community Participation and Co-management	Engagement	Inclusion in decision-making; Training opportunities; Local stewardship	Role of communities in conservation activities
Environmental Threats to Nests	Habitat disturbance	Erosion; Human disturbance; Vehicle tracks	Non-biological threats affecting nest success

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Theme	Category	Codes	Description
Future Conservation Expectations	Aspirations	Education programmes; Youth involvement; Sustainable livelihoods	Desired improvements for conservation outcomes

Qualitative Findings with Illustrative Quotations

Theme 1: Perceived Importance of Turtle Conservation

Participants expressed strong appreciation for the ecological and cultural value of sea turtles.
"These turtles have been here longer than we. If they disappear, something is wrong with our land and sea."
(Community elder, Mabibi)

Theme 2: Community Knowledge and Awareness

Knowledge of turtle nesting and protection laws varied across communities.
"We know the turtles come every year, but many people don't know the rules about protecting the eggs."
(Former turtle monitor, Mpukane)

Theme 3: Livelihood and Economic Considerations

Participants highlighted the tension between conservation and survival needs.
"Tourism brings jobs, but when there is no work, people still think about taking the eggs."
(Local fisherman, Mqobela)

Theme 4: Cultural Practices and Traditions

Traditional practices were described as deeply rooted but changing over time.
"Long ago, eggs were food for families. Now we are learning they must be protected."
(Community elder, Novunya)

Theme 5: Drivers of Illegal Harvesting

Poverty and food insecurity were frequently cited.
"People don't poach because they hate conservation, they poach because they are hungry."
(Community leader, Kwa-Dapha)

Theme 6: Perceptions of Enforcement and Governance

Participants expressed concern about limited enforcement capacity.
"The rangers try, but there are too few of them for such a long beach."
(Former monitor, Mabibi)

Theme 7: Community Participation and Co-management

Strong support was expressed for participatory conservation.
"When we are part of the programme, we protect the turtles ourselves."
(Youth group member, Mpukane)

Theme 8: Environmental Threats to Nests

Non-human disturbances were also highlighted.
"Sometimes the sea washes away the nests before the eggs can hatch."
(Field ranger, iSimangaliso Wetland Park)

Theme 9: Future Conservation Expectations

Participants articulated clear aspirations for improvement.
"Education for the children will help protect turtles better than fines."
(Community leader, Mabibi)

Discussion

The findings from this study provide valuable insights into both ecological patterns and socio-cultural dynamics influencing the conservation of Loggerhead (*Caretta caretta*) and Leatherback (*Dermochelys coriacea*) turtles along the Maputaland coastline.

Ecological Trends in Nesting Success and Population Recovery

Figure 5 on *hatchling success rates by human activity zone* showed a clear decline in nesting success with increasing human interference, where high-activity zones had only 42% success compared to 72% in low-activity zones. This is consistent with studies by Hawkes et al. (2008) and Mazaris et al. (2009), which confirm that anthropogenic disturbances, particularly beach development, vehicle

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traffic, and artificial lighting, negatively affect sea turtle reproductive success. The data reinforce the importance of maintaining undisturbed nesting beaches for optimal hatchling survival. Figure 6 outlined the *frequency of nesting threats*, with vehicle activity (30%) and coastal erosion (29%) topping the list, followed by poaching (23%) and light disorientation (18%). This aligns with findings by Bachoo (2018) and Foley et al. (2006), who documented how vehicular compaction, sand disturbance, and habitat modification disrupt both adult nesting behaviours and hatchling emergence. Notably, poaching, still prevalent in the region, is rooted in longstanding cultural practices and economic hardship, also observed by Frazier (1980) in other developing coastal regions.

The seasonal data presented in Table 3 (not shown in a graph but discussed in context) highlight a rebound in Loggerhead activity, with 7088 emergences and 4551 nests in the 2021–2022 season, almost double the figures of the previous year. Nesting success surpassed 60%, higher than the global average of 55% (Spotila, 2004). This recovery corresponds to improved monitoring and management. Similar population rebounds have been noted in other long-term studies, such as Chaloupka et al. (2008) in Australia and Bachoo (2018) in Brazil, affirming that long-term conservation programmes can lead to measurable success when consistently implemented. Leatherback nesting patterns (Table 4) showed high inter-annual variability, which is common across their global range due to migratory behaviours and environmental variability (Wallace et al., 2011). The increase from 394 to 531 emergencies between 2020/21 and 2021/22 further illustrates the benefits of continuous protection and regional cooperation. However, high variability underscores the need for long-term data to differentiate between natural fluctuation and anthropogenic impact.

Community Perceptions and Knowledge Systems

Figure 2, examining beliefs about turtle egg use, reveals that over 50% of respondents still believe in the myth that turtle eggs enhance livestock reproduction. Similar myths were documented by Bachoo (2018) in Caribbean communities, where turtle eggs are consumed due to spiritual and medicinal beliefs. The belief in turtle eggs as aphrodisiacs (19%) or as food (22%) mirrors findings by Bachoo (2018) in Southeast Asia. These misconceptions underscore the urgent need for culturally sensitive education and awareness initiatives. Figure 3, detailing age distribution, shows that older generations (60–69 years) were key informants. This reflects their rich oral knowledge and long-term observation of environmental changes, a value emphasized in traditional ecological knowledge (TEK) literature, such as Bachoo (2018) and Johannes (1981). Integrating elder perspectives into conservation planning offers context-specific insights that may not be captured through scientific monitoring alone. Figure 4, which presents a near-equal gender participation (55% male, 45% female), contrasts with earlier studies where men often dominate conservation discourse (e.g., Tisdell & Wilson, 2001). The strong representation of women in this study points to an evolving gender balance in environmental stewardship roles, echoing findings by Arora-Jonsson (2011), who emphasized the growing role of women in grassroots conservation and natural resource management.

Synthesis and Implications

The integration of biological monitoring data and community perceptions offers a holistic view of conservation challenges and progress in Maputaland. The ecological results confirm that consistent protection, effective monitoring, and reduced human disturbance led to population recovery for sea turtles, particularly Loggerheads. Simultaneously, the community responses indicate lingering cultural beliefs and knowledge gaps that may hinder conservation if left unaddressed. The comparative analysis with global literature validates the ecological trends observed and reinforces the Maputaland programme's relevance in the broader context of marine turtle conservation. However, the fluctuating Leatherback data and cultural use of eggs reveal that biological success alone is insufficient; socio-cultural transformation is equally critical.

Generalizability

While the study's findings are highly relevant to the conservation context of the Maputaland coastline, their generalizability to other regions may be limited by ecological, cultural, and governance differences. The nesting success rates, community beliefs, and conservation outcomes observed here are specific to the iSimangaliso Wetland Park and its surrounding communities, where long-standing conservation programs and partnerships exist. In regions lacking such institutional support or community engagement, similar interventions may not yield comparable results. Nonetheless, the observed trends and challenges, such as human disturbances, poaching, and cultural beliefs,

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are shared across many coastal areas globally, suggesting that the insights from this study could inform broader conservation models when adapted to local conditions.

Conclusion

This study set out to identify, assess, and document the key anthropogenic and environmental threats affecting the nesting success, egg survival, and conservation outcomes of Loggerhead (*Caretta caretta*) and Leatherback (*Dermochelys coriacea*) sea turtles along the Maputaland coastline. The findings demonstrate that, despite more than six decades of structured conservation efforts, marine turtle reproductive success in this region remains compromised by a combination of human-induced pressures and natural stressors. Anthropogenic threats, particularly illegal egg harvesting, off-road vehicle activity, coastal development pressures, and limited enforcement capacity, emerged as the most significant factors undermining nest survival and hatchling success. These pressures are compounded by environmental stressors such as coastal erosion, storm surges, and habitat alteration, which further reduce the suitability of nesting beaches. The study also revealed that socio-economic hardship, cultural practices, and limited awareness of conservation legislation continue to influence community interactions with turtle nesting sites. At the same time, the findings highlight the critical role of long-term monitoring, protected area designation, and community involvement in sustaining turtle populations. Areas with consistent patrols and stronger community engagement exhibited relatively lower levels of nest disturbance, underscoring the importance of inclusive, locally grounded conservation approaches. Qualitative insights further suggest that when communities are meaningfully involved and derive socio-economic benefits from conservation, compliance and stewardship improve.

Limitations

One of the key limitations of this study lies in the variability of field monitoring quality, particularly during the 2020–2021 nesting season, which resulted in gaps and possible underreporting in the ecological data. Inconsistencies in tagging, patrol frequency, and observer training may have affected the reliability of some findings. Additionally, the community survey component relied on self-reported responses, which may be influenced by recall bias or the desire to provide socially acceptable answers. The questionnaire design, while translated for accessibility, may have also introduced interpretation challenges for some participants. Finally, logistical and time constraints limited the number of communities and individuals surveyed, potentially omitting valuable perspectives from less accessible or more marginalized populations.

Recommendations

To strengthen future conservation outcomes, it is recommended that monitoring protocols be standardized across all camps, with clear guidelines, increased oversight, and regular performance assessments of turtle monitors. Continued investment in training and community-based hiring can improve data consistency and foster long-term stewardship. Educational outreach should be intensified, particularly to dispel persistent cultural myths surrounding turtle eggs and to promote the ecological importance of sea turtles. These programs should be delivered in local languages and tailored to different age and gender groups for greater impact. Additionally, transboundary collaboration, especially with Mozambique, should be enhanced to address poaching and migratory pressures outside South African borders. Future research should also incorporate geospatial tracking, environmental modelling, and broader community sampling to deepen our understanding of turtle migration, nesting behaviour, and human-wildlife interactions in the Western Indian Ocean region.

Table 5: The table below contains the list of abbreviations within the thesis document

Abbreviation	Explanation
MPA	Marine Protected Area
WHS	World Heritage Site
EKZNW	Ezemvelo KZN Wildlife
IUCN	International Union for Conservation of Nature
EEZ	Exclusive Economic Zone
CL	Carapace Length

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CW	Carapace Width
PIT	Passive Internal Transponder
GPS	Graphic Positioning System
NPB	Natal Parks Board
DDT	Dichlorodiphenyltrichloroethane

Biography

Dr. Sibonelo Thanda Mbanjwa is a dedicated lecturer in the Department of Nature Conservation at Mangosuthu University of Technology (MUT), South Africa. He holds a Ph.D. in Environmental Science and specializes in biodiversity conservation, sustainable development, and environmental education. Dr. Mbanjwa is deeply committed to community engagement, student mentorship, and the integration of indigenous knowledge systems into conservation practices. His work bridges academia and practical application, empowering students and communities through innovative teaching, research, and outreach initiatives.

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Competing Interests

The author has no relevant financial or non-financial interests to disclose.

Author Contributions

The author contributed to the study conception and design. Material preparation, data collection, and research were performed by Mbanjwa S.T.

Data Availability

The data supporting the findings of this study are available upon reasonable request from the corresponding author. Due to ethical considerations and confidentiality agreements, individual participant data cannot be publicly shared. However, anonymized and aggregated data may be provided for academic or research purposes upon institutional approval.

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