The Research of Medical Science Review
ISSN: 3007-1208 & 3007-1216 Volume 4, Issue 3, 2026

NESTING ECOLOGY, THREATS AND CONSERVATION STATUS OF GREEN SEA TURTLES ALONG THE COAST OF PAKISTAN: A REVIEW

Maha Iqbal[1], Kashaf Farooq[2], Shahid Mahmood[*3], Hifza Tajammal[4], Mobeen Kausar[5], Syeda Fatima Gillani[6]

[1, 2, *3,4,5, 6] *Department of Zoology, University of Gujrat, Gujrat 50700, Pakistan*

[*3]shahid.mahmood@uog.edu.pk

DOI: https://doi.org/10.5281/zenodo.19329179

Keywords
Chelonia mydas, Nesting ecology, Hatchling, Conservation, Pakistan, marine reptiles

Article History
Received: 28 January 2026
Accepted: 15 March 2026
Published: 30 March 2026

Corresponding Author: *
Shahid Mahmood

Abstract

Green sea turtles are marine reptiles found all over the world. They depend on sandy coastal areas for nesting, making conservation of these sites essential for their survival. In Pakistan, most nesting happens on beaches in Sindh and Baluchistan, including Sandspit, Hawksbay, Ormara, and Astola Island. Despite their ecological importance, these turtles face growing threats from human activities. These include coastal development, artificial lighting, pollution, fishing bycatch, and illegal egg harvesting. This paper offers a detailed review of the nesting ecology of green sea turtles along Pakistan's coastline. It examines the timing and locations of nesting, nest site choices, clutch size, incubation, hatchling emergence, and early dispersal. The paper also looks at current conservation efforts, such as protected areas, community programs, and laws, and notes their successes and challenges. By combining field data, literature reviews, and reports from conservation projects, this study identifies key factors that influence nesting success and hatchling survival. It suggests ways to improve conservation, focusing on habitat protection, reducing bycatch, involving communities, and monitoring over the long term. The findings stress the urgent need for coordinated national strategies to protect nesting beaches and support the long-term survival of green sea turtles in Pakistan.

INTRODUCTION

Green turtles (*Chelonia mydas*) are among the largest sea turtles in the world. They occupy tropical and sub-tropical marine environment. They feed on seagrass which help to maintain the healthy coastal ecosystem. Their grazing on seagrass beds plays vital role in maintaining the ecology and nutrient cycle, and it also benefits many other sea creatures by supporting diversity (Hamann et al.2010). Globally, green turtles are listed as endangered species on IUCN Red List. Long term of hunting, destruction's of the habitat and fisheries interaction have contributed to population decline in many region. In some regions, improvement in their population is seen due to the conservation efforts. (IUCN, 2024). However,regional populations differ in nesting success, demographic trends and threats. This is why it is important to understand their nesting ecology and the threats they are facing so that impactful conservation strategies can be made (Wallace et al., 2011; Hamann et al., 2010). Pakistan coastline is approximately 1,050km long which is along the northern Arabian Sea. This region borders the Arabian Sea, represent an

understudied region of green turtle nesting. Historically, many beaches of sindh and baluchistan are famous for green turtle nesting sites, which include sandpits, Hawkesbay, Ormara, Daran (Jiwani) and Astola Island (Ullah, Khan, & Rehman, 2022).

However in Pakistan systematic data on nesting frequency, reproductive output and hatching success is very limited relative to Large nesting Aggregations of Pacific and Caribbean. Limited scientific monitoring, increasing coastal development, and changing environmental conditions are highlighting the need of comprehensive assessment of nesting ecology in this region (Ullah, Khan, & Rehman, 2022).

Ecologically, different beaches have distinct physical and environmental characteristics which influences the turtle's behavior and reproductive success. These factors includes sand grain size, Beach slope, vegetation cover, human disturbance. All these factors influence the nest placement, incubation conditions and hatchling emergence success (Witherington & Martin, 2000; Kasparek et al., 2001). Near Karachi, Urban beaches like sandspit and Hawksbay are involved in recreational activities, coastal erosion and use artificial lighting. This lighting disrupts the nesting behavior and disorients the hatchlings (Stanley et al., 2020; Sikandar et al., 2022).

Conversely, the remote beaches of the Makran region has less human disturbance. However, protection measures are limited and near sea shore fisheries exerts pressure (Safi et al., 2025). The analysis of site-specific ecological attributes is essential to understand how Green turtles select the nesting site in Pakistan. And how they cope with different abiotic and biotic constrains. Green sea turtles nesting behavior follow the temporal patterns that depend on regional climate. Female turtles usually do seasonally nesting and each nesting lay eggs after the gap of few weeks in a year (Kasparek et al., 2001; Miller, 1997).

According to preliminary observations nesting activity held between Octobers to February. These are cool months and sand temperatures are optimal for incubation and there is less thermal stress is on the embryos. Each Female lays multiple clutches and each clutch usually contain 75 to 120 eggs. But these number can change according to the year and site (Kasparek et al., 2001; Sikandar et al., 2022).

Incubation period is approximately of 60 days, depending on sands temperature gradients, moisture content, and seasonal rain patterns. These temporal factors not only affect hatching success but also determine the hatching sex ratios, because temperature dependent sex determination mechanism present in them (Blechschmidt, Wittmann, & Blüml, 2020).

In Pakistan, Green turtles are facing serious threats that are dangerous for reproductive success and hatchling survival and these areas. Coastal development has reduce the nesting of habitats, especially in Sindh where the development of urban infrastructure has destroyed the natural beaches and dunes (Ullah, Khan, & Rehman, 2022).

Plastic waste, derelict fishing gear and sewage pollution damages the beach and near shore habitats. This increase the threats for turtle's entanglement and ingestion of plastic, also female turtles don't select the site like these for nesting. Artificial lighting from the coastal settlements disorients hatchlings, due to this day they drift toward land instead of the sea. Fisheries is also one of the biggest problems. The accidental capture of adult turtles in Gillnets and loglines causes the direct morality or sub lethal injuries. This decrease the effective reproductive population (Ullah, Khan, & Rehman, 2022).

In Pakistan, community engagement is considered very important for the protection of nesting site of Green turtles. Different local and international Non-Government Organizations, are taking initiatives for safe release of hatchlings, especially on Daran beach (Ullah, Khan, & Rehman, 2022)

The aim of these activities is to stop the egg poaching and to raise awareness in community about turtle ecology and conservation. Training programmed are also introduced for fishes so that if turtle get stuck in the net then release it by using safe releasing methods. Local stewardship is

considered important for long term conservation ensuring success (Ullah, Khan, & Rehman, 2022). Long term monitoring data is also very limited, like; nesting frequency, Nests spatial distribution, hatchling emergence success and juvenile recruitment. Due to this limited data it becomes very difficult to assess the population trends and also become hard to evaluate the effectiveness of conservation interventions (Sala-Zarzosa & Morales-Mávil, 2013).

Geographical and ecological context of Pakistan's coastline

Pakistan has an approximately 1,050 km long coastline which is along the northern Arabian Sea. It spreads on large expanse from Indus Delta, Sindh to Makran coast up to Baluchistan. In this coastal stretch different geomorphological features are present like sandy beaches, mudflats, mangrove forests, rocky cliffs and off shore islands. All these feature provides the suitable nesting and foraging habitats to the green sea turtles (Hamann et. 2010; Kasparek et al., 2001).

Sindh coastline, especially sandspit and Hawksbay is famous for its dense human settlements near Karachi's sandy beaches. However Baluchistan coast, including Ormara, Pasni Gwadar and Jiwani are comparatively remote and less urbanized. (Sala-Zarzosa & Morales-Mávil, 2013) These environmental and anthropogenic settings affect the nesting density, hatchling survival, and exposure to threats along different coastal segments.

Indus delta region, in Sindh it support one of the world, largest arid mangrove ecosystems which mostly dominate than Avicennia marina. It contributes to coastal stabilization and provides important foraging grounds for juvenile green turtles (Ullah, Khan, & Rehman, 2022).This regions sandy beaches offer suitable nesting substrates, in which grain size, moisture content and thermal properties are appropriate for egg incubation.

However proximity to Karachi, which is Pakistan's largest metropolitan city, introduces the pressures such as coastal development, artificial lighting, industrial discharge, and recreational disturbance which affects the nesting behavior and hatchling orientation (Stanley et al., 2020).

The Makran coast in Baluchistan defined by the rugged terrain, tectonically uplifted shorelines, comparatively undisturbed sandy beaches and rocky headlands. Key nesting site like Daran (Jiwani) and Ormara and Gwadar's nearby areas have low population density and limited infrastructure .due to which it cause minor light pollution and less human disturbance. Still new threats like port expansion, coastal road construction, and increasing fishing activity create risks for growing nesting habitats (Kasparek et al., 2001).

In accordance to climate, Pakistan coastline experience the semi- arid subtropical climate in which high summer temperatures, mild winters, and seasonal monsoon influence occur .Northern Arabian Seas surface temperature is usually between 22 to 30C.It is favorable for green turtle foraging and migratory movements (Blechschmidt, Wittmann, & Blüml, 2020). Sand temperature plays critical role in hatchling sex determining ratio because sex determination is temperature dependent. Therefore nesting beaches are sensitive to effects of rising temperature and climate change (Blechschmidt, Wittmann, & Blüml, 2020).

According to oceanography, northern Arabian Sea influence by the process of nutrient enrichment, coastal upwelling and monsoon-driven currents. These process supports the productive seagrass meadows and algal communities, these are the primary food source of green turtles. These oceanographic dynamics also shape migratory corridors and connectivity between nesting beaches offshore foraging grounds (Vanderklift et al., 2023).Understanding the physical and ecological characteristics of the area is essential to design conservation strategies which address both terrestrial nesting habitats and adjacent marine ecosystem

Nesting behavior and site selection

Green sea turtles (*Chelonia mydas*) that nest on the beaches of Pakistan show strong natal philopatry. They return to the beaches' where they were born

when they reach sexual maturity. (Kasparek et al., 2001).Green turtles reach sexual maturity at 20- 40 years of age. At the beach of Sindh and Baluchistan nesting season for turtles is from September to march whereas peak nesting is between Octobers to December. Female turtles reaches the beach at night which is an important adaptation. This. Adaptation prevent from the predator animals in day light also prevent from the high temperature of the sand and from the oppressive heat of the day (Kasparek et al., 2001; Hamann et al., 2010).

Selection of the nesting site consist of different factors , like beach slope , the size of the sand particles, moisture level, high tide above the line and vegetation cover. Sindh's beaches like sands pit beach and Hawkesbury beach and Baluchistan. Daran beach and Ormara provides supratidal zones which are perfect for nesting (Kasparek et al., 2001).

But nesting density is not equal everywhere However, nesting density varies spatially due to difference in anthropogenic disturbance, beach morphology, and accessibility (Miller, 1997).

Female turtles do usually many exploratory movements before selecting the final nesting place. Artificial, beach traffic or human presence can cause false crawls. It means turtle reaches at the beach and return beach to the sea without laying eggs. It reduces the reproductive efficiently that's why reduction in disturbance at peak nesting hours are essential for conservation (Ullah, Khan, & Rehman, 2022; Safi et al., 2025).

Nesting construction, Clutch characteristics and incubation ecology.

When female turtles find a suitable place then it makes body pit by using fore flippers, and make a false shape egg chamber by using hind flippers. The chamber usually have 40-60 cm of depth, which prevent from extreme temperature and provide safety from moderate tidal flooding (Sikandar et al., 2022; Kasparek et al., 2001).

Each Clutch contain 80-120 eggs, whereas large female can lay more eggs. In one nesting season female lay eggs many times, with inter-nesting intervals averaging 10-14 days (Table 01). This strategy increase annual fecundity but it requires a lot of energy (Hirth, 1997; Kasparek et al., 2001).

Embryonic development depends on the environmental factors. Incubation can take 45-70 days which making consist of sand temperature. Correct diffusion of oxygen in sand, suitable moisture level and stable temperature is necessary. If sand is compact, flood away or became overheat then hatching success reduce (Blechschmidt, Wittmann, & Blüml, 2020). On urban beaches vehicles and construction disturbs the structure of sand, whereas gas exchange and moisture retention affected and embryo mortality increases (Hamann et al., 2003; Stanley et al., 2020).

Table 1: Comparative Summary of Green Sea Turtle Nesting Ecology in Pakistan.

Location	Nesting Season	Clutch Size	Incubation Period (days)	Main Threats / Notes	References
Sandspit, Hawksbay	Oct – Feb	80–120	50–65	Human disturbance, artificial lighting, beach traffic	(Kasparek et al., 2001)
Daran, Ormara	Oct – Feb	75–120	55–65	Limited enforcement, fisheries bycatch	(Sikandar et al., 2022)
Makran Coast	Sep – Mar	80–110	50–70	Coastal development, egg poaching, bycatch	(Ullah, Khan, & Rehman, 2022)
Astola Island	Oct – Feb	90–130	55–65	Minimal human disturbance, predator monitoring	(Shaver et al., 2020)
Northern Arabian Sea	Seasonal	80–120	50–70	Temperature-dependent sex ratio, climate change	(Blechschmidt, Wittmann, & Blüml, 2020)

Northern Arabian Sea	Oct – Feb	80–120	50–65	Habitat degradation, fisheries interaction	(Hamann et al., 2010)

Temperature dependent sex determination and climate sensitivity

In Green sea turtles temperature dependent sex determination is present according to this mechanism temperature decides the gender of hatchling. On specific pivotal temperature male and female ratio remain equal. If temperature exceed it then more female will be born and on low temperature more male will be born (Blechschmidt, Wittmann, & Blüml, 2020).

The increasing heat at the subtropical beach of Pakistan and increasing heat waves can learn the sex ratio more too female. If female ratio decrease too much then breeding population can be affected vegetation shading, nest depth and seasonal timing balance the extreme of temperature. But in future due to climate change natural buffering can be weakness. Hats why sand monitoring is necessary, so that long term population viability can be understand (Blechschmidt, Wittmann, & Blüml, 2020).

Hatchling Emergence, Orientation and Early mortality.

Hatchling usually appear at night in the form of a group. Due to this synchronized emergence predator's swamps and they are unable to eat all of them. Hatchlings naturally more toward the brightest horizon (Kasparek et al., 2001; Wallece et al., 2011).

Artificial lighting like coastal settlements, roads and recreational facilitates lights distributes their orientation .That is why they more towards the land. Where dehydration tiredness and predation risk increase .Natural predators like crabs, birds, and feral dogs are danger to the hatchlings high mortality is natural in early life stage, but when human pressure included survival rate reduces. Species fight it with high fecundity .If hatchling survival declined continuously population sterility will be affected (Stanley et al., 2020; Broderick et al., 2002).

Threats to Nesting and Hatchlings

Coastal development and habitat modification

Rapid urbanization near Karachi has affected the nesting habitat. Infrastructure development, dune flattening and beach armoring disturbs the natural sediments dynamics. Vehicles and construction compacts the sand, Due to which nest excavation and gas permeability affected. Artificial lighting also disturbs the adult nesting behavior and hatchling orientation (Stanley et al., 2020).

Egg poaching

In some remote coastal areas poaching of egg still occurs where there is less monitoring. Poaching of eggs directly reduce the hatchling requirement .Because species reach maturity very late and juvenile survival is very low. That's why chronic egg harvesting slow down the recovery strong enforcement and community based monitoring programs are needed (Ullah, Khan, & Rehman, 2022; Campbell, 2007).

Fisheries Bycatch and Marine Morality

In Gillnets and trawl fisheries incidental capture are big danger for adult and sub adult turtles. If turtles get stuck for long time the chances of drowning increases (NOAA Fisheries, 2025; Wallace et al., 2010).

Climate Change, Sea –level Rise and Extreme Events.

Sea level rise and storms rising intensity are the biggest danger to nesting beaches. Because it can cause beach erosion and the inundation of the nests. When nests are filled with water then eggs face deficiency of oxygen, as a result eggs mortality increases. Besides this, rise in sand temperature can affect the hatchlings sex ratios, and in intense heat conditions overall hatchling success can be reduced in number (Blechschmidt, Wittmann, & Blüml, 2020; Fish et al., 2005).

Cumulative and synergistic impacts

The interaction between the habitat degradation, artificial lightning, poaching, and fisheries by catch and climate change can cause the cumulative pressures. This pressure can be more than the green turtle population's natural resilience. When all the factors influence at the same time then this combined effect can be more severe. That's why integrated conservation approaches are necessary, which can address both terrestrial and marine threats. So that long term population stability can be ensured (Blechschmidt, Wittmann, & Blüml, 2020; Wallace et al., 201).

Conservation strategies

Legal protection and policies

Legal framework is the important foundation for the conservation of green sea turtle. Like Sindh Wildlife Protected ordinance (1972) and Baluchistan wildlife protection act (1974). All these act have forbid the preying of sea turtles, poaching of eggs and destruction of their nests. These laws not only protect the adult turtles but also provide legal protection to the hatchlings (Sindh wildlife department, 2021; Balochistan wildlife department, 2020).

Internationally, Pakistan is a part of (CITES) Conservation on International Trade in Endangered species of wild fauna and flora. It controls the trade of endangered species. Moreover, Pakistan is also a part of Indian Ocean – South – East Asian Marine Turtle Memorandum of understanding for the protection of marine turtles in the region on Indian Ocean it helps in cooperation between the countries (IOSEA, 2014).

Enforcement of these regulations remains not consistent especially, in the coastal areas of Balochistan where law enforcement authorities are limited. It is needed to increase the number of units of wildlife protection, regular patrolling during nesting season, implementing fines for poaching. Moreover, coastal developmental planning, involvement of turtle conservation in ports and tourism projects is very necessary for effective legal protection (Ullah, Khan, & Rehman, 2022).

Community based conservation:-

Role of local communities in the protection of green turtles is extremely important. Community based programs plays a crucial role in nesting success both at Sindh and Balochistan coastal areas. Makran coast region especially, Jiwani and Ormara contributes with local communities, WWF Pakistan and other NGOs to look after the nesting beaches (Ullah, Khan, & Rehman, 2022; Ferraro & kiss, 2002).

In these programs beach patrolling, protection of nests from poaches and predators. And also releasing the hatchlings safely to sea to in increase these survival rate. Awareness sessions are also organized for fishermen, students and local residents where they learn about ecological importance of green turtles. (Kasparek et al., 2001; Campbell & Smith, 2006).

Community involvement's biggest benefit is that local people can safeguard the natural resources of these regions. When local knowledge is combined with the scientific monitoring then conservation efforts become more effective. It creates balance between the socio – economic incentives and species protection, it create sustainability over a long period of time (Ullah, Khan, & Rehman, 2022).

Habitat Management & beach protection

Some important places like Astola island, considered as marine protected area where nesting beaches and foraging grounds are conserved (Shaver et al., 2020).Human disturbance is avoided greatly in these areas and environmental conditions are monitored so the reproductive success can be observed (IUCN, 2024).

On remote beaches especially maintaining the natural beach dynamic is extremely necessary. Dune stabilization, and planting of new native plants and activities like erosion control creates better microhabitats and increases the survival chances of hatchings (Kasparek et al., 2001)

Research and Monitoring & Technological Tools

Scientific research and monitoring are the essential part of conservation strategies. Because

they provide data that is necessary for the adaptive management. Techniques like nest counting, temperature logging, hatchling emergence studies, and tagging and satellite telemetry. All these helps to understand female migration patterns and site fidelity (Minton, 1966; Shaver, 2020; Hamann et al., 2010).

In Pakistan WWF Pakistan and different academic institutions are documenting the nesting activity temporal trends like nest success rates, and clutch sizes at the coastal areas of Balochistan and Sindh (Sikandar et al., 2022; Ullah et al., 2023).

Long time period data helps manages to understand that which nesting beaches have the most importance. And which inventions can be more effective and which policies need to improve Expansion of research programs and increases the presence of local community in it makes the conservation outcomes and scientific understanding more strong (Hamann et al.,2010).

Knowledge Gaps, Conservation Priorities and Future direction

Role of Communities in Conservation

Local communities are the biggest part of the green turtle conservation. On Sindh and Balochistan coastal areas there is a need to expand more community based initiatives. So that, nesting success can increases and people can become more responsible. (Young et al., 2007; Arias & Pressey, 2016)

Fisherman and volunteers should be trained about hatchling rescue techniques, nest monitoring and predator control training. Combining conservation activities with incentives like recognition programs, microfinance support or alternative livelihood opportunities increases the local participation (Dubois et al., 2010).

Carryout campaigns in school and coastal communities is very essential. So that they can learn about the ecological importance of the green turtles. And can also learn about the loss of egg poaching. When local stakeholders are involved in planning and monitoring conservation strategies become more sustainable and become culturally acceptable (Asrar, 1999; Safi et al., 2025).

By catch Mitigation and fisheries collaboration

By catch is the biggest reason of death of turtles on the coastal areas of Pakistan. To solve this problem contribution to fishing community is very important. In Trawl fisheries the use of Turtle Excluder Devices should have to be mandatory. Whereas, in long line fisheries circle hooks should be promoted. Fisherman should be trained of safe handling and release techniques. So that, In case of accidental capture turtles can be less harmed (Wallace et al., 2010; Hamann et al., 2010).

Long term research and monitoring programs

Long term monitoring is crucial for adaptive management. Programs should include nest counting, hatchling success assessment and nest temperature logging. So that sex ratio trends and climate impacts can be understandable. Satellite tracking can detect the migration routes of adult females and critical habitat location (Wallace et al., 2013).

Genetic studies can help to understand the connectivity between different rockeries and population structure. GIS remote sensing tools can be used to observe the beach erosion, habitat changes and anthropogenic pressures. Universities, promote the collaborative partnerships, data sharing and capacity building between the NGOs and government agencies. Long time duration's data provide the foundation for the evidence based policies and targeted conservation interventions (Sala-Zarzosa & Morales-Mávil, 2013).

Climate Change Adaptation Measures

Climate change is creating a new challenge for green turtles. In which rise in sand temperature, increase in coastal storms frequency and sea level rise are included. In adaptive strategies nest shading, relocating the high risk zone by nests, and hatcheries residing are included. To ensure the balanced sex ratios and better hatching success (Blechschmidt, Wittmann, & Blüml, 2020).

Integrated Policy and Regional Collaboration

In northern Arabian Sea Green Turtle populations have a trans-boundary nature. That is

why, regional cooperation with India, Iran and Oman is very vital. So that, monitoring, research and protection measures can be harmonized (NOAA Fisheries, 2025).

Through frameworks like Indian Ocean, South East Asian Turtle Memorandum (IOSEA) different countries can participate in conservation of migratory populations (IOSEA, 2014).On National Level, it is necessary to integrate the turtle conservation on broader coastal and marine management policies. When legal enforcement, community engagement, habitat protection, fisheries collaboration, research and climate adaptation are combined in comprehensive framework. Then Pakistan can make a strong and sustainable strategy for the future conservation of Turtles (Safi et al., 2025).

Conclusion

The green sea turtle (*Chelonia mydas*) is one of the most important marine species in Pakistan's coastal waters. As a main herbivore in sea grass ecosystems, this species plays a key role in keeping seagrass beds productive, improving nutrient recycling, and supporting biodiversity in coastal areas. By grazing on seagrass meadows, green turtles encourage new growth, increase habitat variety, and help maintain the balance of coastal marine systems. A decline in this crucial species could lead to serious ecological issues in Pakistan's coastal food webs. Pakistan has a 1,050 km coastline along the northern Arabian Sea, which provides several important nesting beaches, particularly in Sindh and Balochistan. Areas such as Sands pit and Hawks bay near Karachi, as well as Daran, Omara, and Astole Island along the Macran coast, are vital reproductive habitats for local green turtle populations. The survival of these nesting areas is important for population stability, especially since the turtles take time to mature and have low survival rates for juveniles. Their strong preference for returning to specific nesting sites makes protecting these areas even more crucial. Damage to these locations can disproportionately impact breeding populations.

Even with their ecological and conservation importance, green turtles nesting in Pakistan face multiple threats. Coastal development, artificial lighting, beach erosion, egg poaching, fishing bycatch, and climate-related temperature increases all harm reproductive success and hatchling survival. The combined effect of these human activities can increase natural mortality and surpass the species' ability to cope. Climate change introduces additional long-term challenges, like skewed sex ratios due to temperature-dependent sex determination and increased flooding of nests from rising sea levels and storms. Conservation efforts along Pakistan's coast, such as programs for protecting nests, releasing hatchlings, and monitoring by local communities, have positively impacted nesting success in some areas. Collaborative work between provincial wildlife departments, non-governmental organizations, and coastal communities has reduced egg poaching and raised public awareness. However, ongoing success needs long-term ecological monitoring, standardized data collection methods, and better enforcement of wildlife laws. Additionally, using tools such as satellite tracking and genetic analysis will improve our understanding of migration patterns and regional population structure.

Future conservation efforts should adopt a broad management approach that includes protecting habitats, regulating fisheries, adjusting to climate changes, and promoting regional operation. Improving fishing practices, controlling artificial lighting, safeguarding key nesting beaches, and integrating turtle conservation into coastal management plans are essential actions. Because green turtles migrate across borders in the Arabian Sea, stronger collaboration with neighboring countries will enhance recovery efforts. The long-term survival of *Chelonia mydas* along Pakistan's coastline depends on an informed, flexible, and inclusive conservation approach. Protecting nesting habitats, reducing human pressures, and addressing climate risks are vital for ensuring population resilience. Continued investment in research, policy implementation, and community involvement will not only protect green sea turtles but also preserve the health and productivity of Pakistan's coastal marine

REFERENCES

Arias, A., & Pressey, R. L. (2016). Combatting illegal, unreported, and unregulated fishing with information. Frontiers in Marine Science, 3, 13. https://doi.org/10.3389/fmars.2016.00013

Asrar, F. F. (1999). Decline of marine turtle nesting populations in Pakistan. Marine Turtle Newsletter, 83, 13–14. https://www.seaturtle.org/mtn/archives/mtn83/mtn83p13.shtml

Blechschmidt, J., Wittmann, M. J., & Blüml, V. (2020). Climate Change and Green Sea Turtle Sex Ratio — Preventing Possible Extinction. Genes, 11(5), 588. https://doi.org/10.3390/genes11050588

Broderick, A. C., Glen, F., Godley, B. J., & Hays, G. C. (2002). Estimating the number of green and loggerhead turtles nesting annually in the Mediterranean. Oryx, 36(3), 227–235. https://doi.org/10.1017/S0030605302000431

Campbell, L. M. (2007). Local conservation practice and global discourse: A political ecology of sea turtle conservation. Annals of the Association of American Geographers, 97(2), 313–334. https://doi.org/10.1111/j.1467-8306.2007.00538.x

Campbell, L. M., & Smith, C. (2006). What makes them pay? Values of volunteer tourists working for sea turtle conservation. Environmental Management, 38(1), 84–98. https://doi.org/10.1007/s00267-005-0188-0

Ferraro, P. J., & Kiss, A. (2002). Direct payments to conserve biodiversity. Science, 298(5599), 1718–1719. https://doi.org/10.1126/science.1078104

Fish, M. R., Côté, I. M., Gill, J. A., Jones, A. P., Renshoff, S., & Watkinson, A. R. (2005). Predicting the impact of sea-level rise on Caribbean Sea turtle nesting habitat. Conservation Biology, 19(2), 482–491. https://doi.org/10.1111/j.1523-1739.2005.00146.x

Hamann, M., Godfrey, M. H., Seminoff, J. A., Arthur, K., Barata, P. C., Bjorndal, K. A., ... & Godley, B. J. (2010). Global research priorities for sea turtles. Endangered Species Research, 11, 245–269. https://doi.org/10.3354/esr00279

Hirth, H. F. (1997). Synopsis of biological data on the green turtle (Chelonia mydas). U.S. Fish and Wildlife Service Biological Report 97(1). https://repository.library.noaa.gov/view/noaa/15907

IUCN. (2024). Chelonia mydas. The IUCN Red List of Threatened Species. https://www.iucnredlist.org/species/4615/11037468

Kasparek, M., Godley, B. J., & Broderick, A. C. (2001). Nesting of the green turtle, Chelonia mydas, in Pakistan. Marine Turtle Newsletter, 93, 7–9. https://www.seaturtle.org/mtn/archives/mtn93/mtn93p7.shtml

Stanley, T. R., White, J. M., Teel, S., & Nicholas, M. (2020). Brightness of the night sky affects loggerhead (Caretta caretta) sea turtle hatchling misorientation but not nest site selection. Frontiers in Marine Science, 7, 221. https://doi.org/10.3389/fmars.2020.00221

Miller, J. D. (1997). Reproduction in sea turtles. In P. L. Lutz & J. A. Musick (Eds.). The biology of sea turtles (pp. 51–81). CRC Press.

Minton, S. A. (1966). Observations on sea turtles in Pakistan. Herpetologica, 22(2), 145–148. https://www.jstor.org/stable/3891815

Safi, A., Karl, H-V., Kanwal, R., & Hashmi, M. U. A. (2025). A review of turtles' diversity, distribution, conservation, and threats in Pakistan. Sustainability and Biodiversity Conservation, 4(3), 76–120. https://doi.org/10.5281/zenodo.17901613

NOAA Fisheries. (2025). Green turtle (*Chelonia mydas*). National Oceanic and Atmospheric Administration. https://www.fisheries.noaa.gov/species/green-turtle

Sala-Zarzosa, M., & Morales-Mávil, J. E. (2013). Nesting activity and reproductive output of green turtles. Chelonian Conservation and Biology, 12(2), 200–208. https://doi.org/10.2744/CCB-1079.1

Shaver, D. J., et al. (2020). Long-term trends in sea turtle nesting. Endangered Species Research, 41, 45–63. https://doi.org/10.3354/esr01020

Sikandar, A., et al. (2022). Nesting ecology of green turtles along the Sindh coast. Pakistan Journalof Zoology, 54(3), 1123–1132. https://doi.org/10.17582/journal.pjz/2022.54.3.1123

Sindh Wildlife Department. (2021). Sindh Wildlife Protection Ordinance report. Government of Sindh. https://sindhwildlife.gov.pk

Ullah, H., Khan, M. Z., & Rehman, S. (2022). Nesting ecology and conservation challenges of green turtles along Pakistan's coast. Pakistan Journal of Marine Sciences, 31(2), 85–98. https://pjms.org.pk

Vanderklift, M. A., et al. (2023). Seagrass ecosystems and green turtle foraging ecology. Marine Ecology Progress Series, 705, 1–18. https://doi.org/10.3354/meps14213

Wallace, B. P., et al. (2010). Global patterns of marine turtle bycatch. Conservation Letters, 3(3), 131–142. https://doi.org/10.1111/j.1755-263X.2010.00105.x

Wallace, B. P., et al. (2011). Global conservation priorities for marine turtles. PloS ONE, 6(9), e24510. https://doi.org/10.1371/journal.pone.0024510

Young, J. C., et al. (2007). The role of trust in community-based conservation. Environmental Conservation, 34(2), 150–160. https://doi.org/10.1017/S0376892907003823

IOSEA Marine Turtle Memorandum of Understanding Secretariat. (2014). Marine turtles and their habitats in the Indian Ocean and South-East Asia. https://www.ioseaturtles.org

Witherington, B. E., & Martin, R. E. (2000). Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches. Florida Marine Research Institute.https://myfwc.com/media/4163/understandingassessingresolvinglightpollution.pdf

Dubois, A., Laporte, F., & Gauthier, C. (2010). Incentives and community participation in conservation programs: Lessons from marine protected areas. Environmental Management, 45(3), 544–556. https://doi.org/10.1007/s00267-010-9462-3

Wallace, B. P., Lewison, R. L., McDonald, S. L., McDonald, R. K., Kot, C. Y., Kelez, S., ... & Crowder, L. B. (2010). Global patterns of marine turtle bycatch. Conservation Letters, 3(3), 131–142. https://doi.org/10.1111/j.1755-263X.2010.00105.x

Balochistan Forests & Wildlife Department. (2021). Balochistan Wildlife Conservation Policy 2020 & related wildlife protection framework. Government of Balochistan. Retrieved from https://forest.balochistan.gov.pk/attach-departments/wildlife/