Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/20148
DOI URL: http://dx.doi.org/10.21474/IJAR01/20148

RESEARCH ARTICLE

IMPACT OF CLIMATE CHANGE ON REPRODUCTION AND MIGRATION OF CHELONIA MYDAS ALONG THE WEST AFRICAN COAST

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Manuscript Info

Manuscript History
Received: 28 October 2024
Final Accepted: 30 November 2024
Published: December 2024

Key words:-
Bio-Ecology, Green Turtle, Katrack Island, Chelonia Mydas, Republic of Guinea

Abstract

In an ever-changing world, the sustainable protection of marine biodiversity along the Guinean coast is a necessity. This work focuses on the current situation of the green turtle (Chelonia mydas) on Katrack Island in Guinea. The aim of this study is to highlight the current situation of the green turtle (Chelonia mydas) on Katrack Island in Guinea. The methodology adopted includes consultation with officials, managers, and fishermen, patrols over a 90-day period, and processing of the collected data. Consultation with officials confirmed the presence of turtles on Katrack Island. Patrols led to the discovery of 33 green turtle nests containing 3,713 eggs, 31 tracks with nests, 13 strandings, 5 accidental captures, one recovered shell, and two tracks without nests. The discovered eggs were transplanted into a monitored enclosure. 2,695 baby turtles hatched after an incubation period of 45 to 60 days. The sex ratio at hatching was 71% female and 29% male. Regarding maturity stages, 64% were sub-adults, 23% adults, and 11% juveniles. These results demonstrate that the Guinean coast is frequently visited by green turtles. However, sustainable protection is necessary to ensure the conservation of this species in the region.

Introduction:-

The green turtle, scientifically known as the Chelonia mydas, is a species that belongs to the Cheloniidae family, its average size is 99 cm for an average weight of 145 kg. The size and weight records are respectively 139.5 cm and 235 kg. This sea turtle migrates along the coasts from nesting beaches to feeding areas, which are sometimes several thousand kilometers away [1]. Green turtles are legally protected in the Mediterranean as is the case for other species of turtles, this species is globally threatened and is classified as "Endangered" in the IUCN Red List of Threatened Species.[2] and listed in Appendix 1 of the Convention on International Trade in Endangered Species (CITES) since 1981 [3].

Green turtles, like other species of marine turtles, are threatened by human activities that degrade the beaches suitable for their nesting. Their habitats are victims of attacks in their natural integrity and tranquility in all the world's oceans. Continental beaches near villages or in island environments are invaded by domestic or wild species introduced or proliferating due to unmanaged garbage. These invasive animals prove to be important predators for eggs and hatchlings, leading the terrestrial breeding habitat to offer very little chance of success for nests.[4].

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The African coasts in general have suitable areas for the reproduction and feeding of sea turtles, the second area of great interest for the feeding of sea turtles of the Gulf of Guinea assembly, is the bay of Coriso at the mouth of the Rio Muni in Equatorial Guinea and two other areas of ecological importance comparable for green turtles are known in Africa on the Bijagos archipelago in Guinea-Bissau (classified as a biosphere reserve by UNESCO) and the Banc d'Arguin in Mauritania [5].

Opening to the sea over a coastal distance of 300 km from north to south, the Republic of Guinea is full of ecological diversity of great value, sheltering a range of important marine and terrestrial species. Its coastline brings together three very differentiated ecosystems, namely the mangrove swamps, the piedmont and the continental shelf, representing an ecological mosaic as constituting a system with innumerable interfaces. The abundance of these interfaces generates considerable biodiversity and productivity gathered on a relatively small surface area.[6]. The diversity of its habitats means that it has six MPAs covering 220,384 hectares. Three of its six MPAs are considered key habitats (Tristao Islands, Alkatraz and Loos Islands). These island complexes with ecosystem diversity such as coral reefs, sandy beaches and islets, rocky bottoms, Sesuvium plant formation meadows, constitute favorable areas for migration, reproduction, nesting and hibernation for coastal and marine species.[7]in general, but also particularly for sea turtles

[1]. These ecological values offered to Guinea have motivated the ratification of several conventions for the protection of its ecosystemic and genetic biodiversity, including among others: the Bonn Convention on the

Conservation of Migratory Species, CITES, the Ramsar Convention, the Convention on Biological Diversity, the Algiers and Abidjan conventions. However, population growth and human activities (urbanization, illegal fishing, poaching, etc.) and climate change today represent an ultimate threat to the sustainable conservation of species and their habitats. Thus, farmers, through their cultivation system, shape the diversity of landscapes, select, move or eliminate species or varieties and their activities are an essential factor in the dynamics of biodiversity.[6].Illegal industrial fishing, as well as uncontrolled artisanal fishing, with the taking of protected species (rays, turtles, etc.) are depleting fish resources. Logging of continental forests and mangroves threatens habitats for the species mentioned above. Rice cultivation and intensive agriculture are also a threat to the diversity of sites. In addition, bauxite mines are also a source of pollution, as are the infrastructures associated with these extractive activities (such as ports). Finally, coastal erosion aggravated by rising sea levels linked to climate change[7].

In the context of the Tristao Islands, the study of the bioecology of green turtles is of capital importance since several study reports have not confirmed its presence on the Guinean coast.[1]. However, these islands, located in a rich and diverse marine environment, remain likely to be visited by the green turtle reported present on the Bijagos Islands, an area neighboring the Tristao Islands. This study is therefore presented as a means of investigation around its presence on the island of Katrack, it envisages patrols to identify nesting areas and analyze threats. For the orientation of this study, the research questions were: do green turtles frequent Katrack Island? what are its nesting areas and what are the threats to which they are exposed? the research hypothesis is that: the Tristao Islands, mainly Katrack Island, have nesting areas for green turtles (Chelonia mydas). The answer to these questions above will allow us to undertake actions for the sustainable conservation and management of the species' breeding grounds.

Material and Methods:-

The Tristao Islands belongto the pBoké Refecture, in northern Guinea, which since 1992 has included a marine protected area (MPA) of 85,000 ha and a RAMSAR site. The MPA, bordering Guinea-Bissau, is made up of four main islands (Katrak, Kapkin, Gnènè Souri and Fori Souri) and a number of smaller islets[8].The name Tristao is rarely used by the islanders and corresponds to the old name given by the settlers. Appearing on all the maps, this name is said to have been given in "memory" of Nino Tristao, a former Portuguese navigator practicing the slave trade between the West African coasts and Cape Verde. Katrack or Kattarak is the usual name given to these islands by all the inhabitants of the region and its surroundings. Previously, the term Ntrak designated a sacred forest in which there was an embankment (in Nalou, Ntrak means rampart) and where all the ancestors met. Over time, the name changed and became Katrack (this place is located near the current village of Katchèmbè, formerly called Ntrak). The Tristao Islands are located in the Kogon River Delta and surrounded to the east by the Kompony River, to the south and west by the Atlantic Ocean, to the north by the Cacine River on the border with Guinea-Bissau. Katrack Island is about 24 km long. It is located between Kabaféér Camp to the northwest and the Kakrity Estuary to the southeast. Very strong water retreating at low tide and presence of numerous skeletons, sponges and gorgonians in the low tide mark.

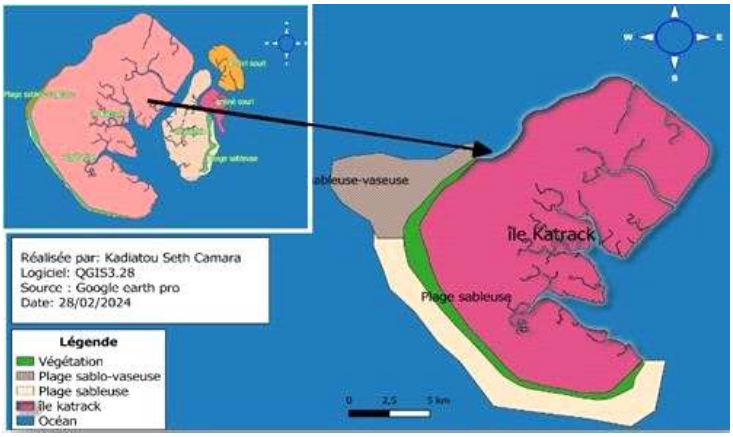

Figure 1:- Map of Katrack Island.

Equipment used

To carry out this study, we used three (3) types of equipment: field equipment, biological equipment and technical equipment, mentioned in Table 1.

Table 1:- Inventory of field equipment and biological material for the study of green turtles.

Field equipment	Quantity
Latex gloves	1 pack
Investigation sheets	50
Markers (waterproof)	1
Decameter	1
Samsung brand camera	1
Garmin brand GPS 64p	1
Headlamps	2
Snell twin	1
Patrol flotilla	1
Bicycles	5
Tricycle	1
Buckets	2
Alcohol 98	500ml
Backpack	1
Life jacket	1
Biological material	
Green turtles (Chelonia mydas)	12
Technical equipment	
Identification key	2
Patrol sheet	50

Consultation of exécutives

Officials from the artisanal fisheries department and coastal management authorities were consulted regarding the presence of green turtles, breeding areas, nesting periods and alternatives considered for the conservation of the species on the Guinean coast. The documentary analysis concerned general and specific works (theses, dissertations, scientific journals and articles, bulletins) in the libraries of the National Centre for Fisheries Sciences in Boussoura (CNSHB).

Survey of fishermen

Fishermen were interviewed according to their affiliation to landing stages or their origin (villages), the meetings were often by appointment according to their availability. The questions asked were on the species of sea turtles encountered during fishing activities, the targeted fishing areas, whether the fisherman had ever caught a green turtle or encountered a turtle. The name of the areas of presence, the nesting sites, the state of maturity of the turtles

encountered, the frequentation of the beaches, the periods of presence on the beaches, the cultural links with the turtles. In addition to individual meetings, the other method was focus groups formed in the villages or in the landing stages under the permission of the authorities of the different villages and the port chief. The interviews also made it possible to obtain additional information such as stories related to the islands. All this was done based on a survey form developed in Sphinx V5.0 software. The sampling targeted all fishermen, particularly those who had already seen at least one sea turtle. 5 semi-structured groups were formed and 50 fishermen were interviewed individually.

Daytime observations

Information collected from fishermen was supplemented by direct observations and beach surveys. This diverse information gathered provided a better understanding of the threats to which green turtles are exposed. A Snell binocular was used to observe the movements of the turtles from a distance.

Patrols, tracking and identification

In the field, we conducted permanent night and morning patrols to identify nests, traces of nesting, strandings or accidental captures over a distance of 25 km. The monitored strip was located northwest of the Kabafèr camp and the Kakrity estuary to the southeast. This method is identical to that applied by Delcroix et al., 2008[9]in Martinique. A team of 9 people, composed of researchers, volunteers and eco-guards, carried out the patrol over a period of 60 days. To proceed, the study area was subdivided into 9 prospecting sites including: Katakssan, Kasseguel, Kakompass, Maboya, Kissassi, Kamboff, Kamtcholène, Kakrity, Katimiri. The different areas were traveled and carefully inspected like that of Liebart et al., 2021[10] along the Caribbean coast in Martinique. These patrols were carried out with ecoguards in the morning, day and night by rotation. The means of transport of the patrol team were: 5 bicycles, 1 tricycle or on foot. The patrol flotilla was equipped with a headlight with infrared. The patrol crossed the entire beach and the back beach in search of nests or nesting females. The description of the vegetation present on the beaches, the back beach as well as the local or French vernacular name of the species of turtles encountered were noted on a turtle tracking or patrol sheet and the geographic coordinates were taken through the Garmin GPS.

Transplantation of vulnerable eggs

During patrols, the eggs found are carefully and directly collected using a bucket with a gloved hand and then transplanted into a previously designed enclosure, without changing the positions of the eggs. The eggs were placed in the enclosure less than two hours after laying. It is worth noting that during patrols, if a female is observed laying, the team withdraws and takes shelter nearby, without making any noise. They observe the female without being disturbed until the scanning processes are completed. After laying eggs, the female makes her descent and returns to the sea.

Nest monitoring

After the egg transplantation, our enclosure was monitored regularly. Plants that sometimes sprouted on the substrate were removed to prevent the roots from penetrating the eggs. All nests are in a wire enclosure covered with old netting so that predators cannot enter, such as crows or lizards.

Hatching and emergence of twists

After nest monitoring, the eggs hatched, the live baby turtles were protected from predators until they returned to the sea. Before that, the eggs were counted, the number hatched and unhatched as well as the factors of nonhatching were analyzed.

O Release of newborns

Before release, the health (injury) information of the baby turtles is checked. Then, they are placed in the buckets to be carried to the sea. After low tide, they are placed at a distance of 50 m from the sea edge, in order to allow them to have the appearance by developing the plastron and balance to move forward.

Assessment of turtle strandings

The assessment of stranded individuals allows to collect information on the causes of turtle mortality, which contributes to the conservation of the species. For this assessment, the accidental catch rate was analyzed. The operation consisted of crisscrossing the beach on a tricycle to locate stranded turtles, once spotted, the first thing we

chose was to protect the hand and nose with a latex glove and a bib. Then, use a key to identify the species, after systematically observing the species to identify the cause of its mortality.

Data processing

After data collection, the information was processed using Excel software. This step allowed us to analyze the frequency of accidental catches, the number of landings, but also to evaluate the fishing areas and seasons using the statistical tests used. The different nesting sites were relocated using a Garmin 64p GPS in order to be presented on a map.

Results:-

Consultation of executives

From the consultation of the authorities in charge of coastal management, it follows that green turtles visit the Tristao Islands in July, August, September, October and November, they come to lay their eggs on the beaches and that raising awareness among fishermen and the community is one of the means used by the authorities to combat poaching but also surveillance by teams of eco-guards.

Accidental capture gear for green turtles

The survey made it possible to identify the devices used by fishermen to accidentally capture green turtles. Figure 2 shows the types encountered.

Figure 2: Green turtle accidental capture gear.

There are no specific gears for capturing green turtles, however, four (4) types of fishing gear have been inventoried for the accidental capture of green turtles, namely otolith encircling gillnets (EOG), Ethmalose drifting gillnets, small mesh set gillnets (PMGF) and longlines, which are used depending on the season. The regular 90-day patrol on 25 km of beach, back beach in search of signs of presence gave the results recorded in Table 1.

Table 1:- Types of indicators encountered during patrols.

No.	Study area		Type of presence during patrol				
		Nests	Shells	Eggs	Strandings	Traces	accidental rises
1	Kakompass	1	0	108	3	1	1
2	Kamboff	9	0	940	2	8	0
3	Kantcholene	5	0	650	1	5	1
4	Kissassi	1	1	0	2	1	0
5	Katonkeyette	1	0	0	1	0	1
6	Katacssan	1	0	140	0	1	1
7	Maboya	5	0	483	1	5	0
8	Nafaya	1	0	0	1	1	0
9	Dougoufouloun	5	0	706	0	5	1
10	Kakrity	1	0	140	1	1	0
11	Kasseguel	2	0	408	1	2	0
12	Katimôiri	1	0	138	0	1	0
13	Total	33	1	3713	13	31	5

From this table it appears that the patrol allowed to discover: 33 nests; a total of 3713 eggs, 13 strandings, 31 tracks, 5 accidental captures and a green turtle shell. In addition, two tracks were discovered without nests and nests without eggs

Status of strandings

The figure 3 shows the stages of development or maturity of green turtles stranded during research.
Figure 3: Classification of stranded or accidentally caught individuals according to maturity stages.

This figure shows that the sub-adult phase represents the majority, i.e. 11 out of 17, 4 adults and two juveniles.

Overall sex ratio of stranded individuals
Females
Males

Figure 4: Sex ratio of stranded green turtles.

Analysis of this figure shows that there is a higher percentage of women than males, respectively: 71% versus 29%.

Egg Tranplatation and follow-up

Figure 7: release of newborn turtles.

After a minimum incubation period of 48 to a maximum of 88 days in an enclosure, the eggs hatch and the baby turtles are grouped in colonies, hugging each other. The turtles sleep and, if one of them moves, a kind of transmission spreads from turtle to turtle and they all become agitated. It should be noted that not all eggs are fertile and not all hatchlings reach the surface. 2,695 wriggles were released at low tide. After an interval of 40 to 60 days of incubation. They are directed at low tide or at the beginning high tide, placed approximately 50 m from the sea, which allowed them to find their rhythm, develop their plastron and balance their progress.

Hatching Succes Rate
In order to determine the success rate after emergence, an analysis of the different nests was carried out. The results obtained are presented in Figure 8.

Figure 8: Hatching success rate.

Analysis of this figure shows that out of 3,713 eggs monitored, there were 2,695 hatchlings released after emergence, 36 stillborn, 265 rotten eggs, 654 eggs with no development and 63 eggs with unhatched embryos. The presentation of success rates by site is shown in Figure 9.

Figure 9: Success rate by spawning site.

These results show that the success rates on all nesting sites were higher than 50%. The highest rate is observed at Kakompasse at 90%, followed by Katakcssan (89%) and 86%, 86%, 76%, 71%, 67%, 66%, 62% are noted respectively at Kakrity, Katimiri, Kamboff, Kantcholène, Maboya, Dougoufoulou and Kasseguel.

Mapping of nesting sites
Figure 10 shows that the southwest beach of Katrack Island is a nesting area for green turtles, and therefore constitutes a sensitive ecological habitat to be protected. Among the ten (10) areas studied, the areas of Kasseguel, Maboya, Kissassi, Kamtcholène Kamboff Katimiri and Kakrity are favorable for the nesting of green turtles because they are uninhabited, calm and more or less far from dwellings, rich in plant cover.

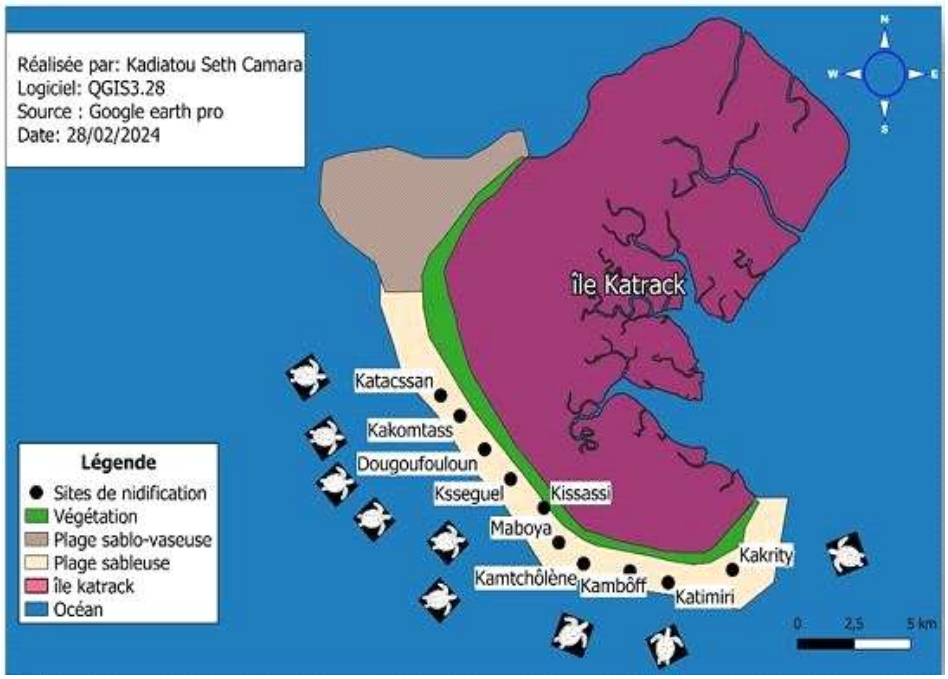

Figure 10:- Nesting map of Chelonia mydas on Katrack Island (Tristao Island, Guinea).

Discussion:-

This study on the impact of climate change on the reproduction of green turtles (Chelonia mydas) along the Guinean coastline has shed light on several important aspects of the nesting, threats, and reproductive success of this species in the region. Our results show that three types of fishing gear are responsible for incidental captures of green turtles on Katrack Island (Figure 2). These observations corroborate those of Rosales et al. (2010)[11],who reported that all sea turtle bycatch in their study was due to gillnets of various sizes. This concordance highlights the importance of targeting these gear types in conservation and awareness efforts among local fishermen.

The discovery of 33 C. mydas nests along 25 km of coastline of Katrack Island (Table 1) contrasts with observations made by Segniagbeto et al. (2012)[12]in Togo and Benin, where no C. mydas nests were identified despite the presence of nests of other marine turtle species. Similarly, Hyacinthe et al. (2012)[13]did not observe nests or adults of C. mydas in the coastal region of Campo Ma'an Park in Cameroon, considering this area as a feeding area. These differences suggest that the Tristao Islands in Guinea, which include Katrack, are an important nesting area for green turtles in the West African region.

Our data reveal a worrying number of strandings (13) and accidental captures (4) of green turtles (Figure 3), with a predominance of sub-adult individuals (11). This life stage is particularly critical, as these individuals have not yet reached reproductive maturity and their survival is essential for the maintenance of the population. The vulnerability of stranded turtles, especially in the absence of regular patrols, underlines the urgency of implementing more effective protection measures. This situation is consistent with the concerns raised by Fretey and Triplet [1]regarding the need to strengthen the conservation of marine turtles in West Africa.

The high proportion of females observed (Figure 4) is likely explained by the period of the study, which coincides with the nesting season. This observation highlights the particular vulnerability of females to accidental captures and poaching during the breeding season. Analysis of hatching success by spawning site (Figure 9) reveals significant variations, with the highest rate at Kakompasse and the lowest at Kasseguel. These differences can be attributed to several factors, including the quality of egg transplantation protocols, the presence of vertebrate and invertebrate predators, site-specific edaphic conditions, and temperature and humidity variations. These results highlight the importance of site-specific management to maximize the reproductive success of C. mydas on Katrack Island, as also suggested by Fretey and Triplet[4]in their study on Ramsar sites and sea turtles.
This study highlights the crucial role of Katrack Island as a nesting site for C. mydas in West Africa. The threats identified, including bycatch and strandings, call for urgent conservation measures, in line with COP19

recommendations.[3]on the protection of endangered species. There is a need to develop alternative fishing techniques to reduce bycatch, strengthen patrols and surveillance of nesting beaches, implement awareness programs for local communities, and improve nest management protocols to increase hatching success rates. These actions are in line with the conservation efforts described by Merceron et al. [7] for West African marine protected areas.

Further studies on factors influencing hatching success and long-term population dynamics are needed to refine conservation strategies for C. mydas in this region. Such research could include detailed analysis of environmental parameters affecting hatching success, long-term monitoring of population trends, assessment of the impact of climate change on nesting, and sex ratio, and a study of the migratory movements of green turtles frequenting Katrack Island. Such studies would align with the biodiversity conservation approaches discussed by Leciak et al. (2006) [6] in the context of maritime Guinea.

Conclusion:-

The study of the bioecology ofChelonia mydason Katrack Island in Guinea, shows that the Guinean coast is visited by sea turtles and that Katrack Island is a nesting area for green turtles. Thirty-three nests and 3,713 eggs including 2,695 wriggles released in the space of 60 days of monitoring over a distance of 25 km sufficiently demonstrate the interest that must be given to this area for the survival of this endangered species. However, these species are exposed to several threats including the abandonment of old fishing gear (nets) at sea and on the beaches. Nest monitoring is a solution to save turtle eggs and patrols to rescue those that strand. The main threats to green turtles on Katrack Island are: abandonment of old fishing gear (ghost nets), fishing itself (accidental catches), poaching of eggs, human transformation of the beach that creates obstacles on the turtles' bridge path. Finally, we conclude that the initial hypothesis has been confirmed by the research results.

We recommend further studies on the same species on these migrations on all the islands of Guinea and research for the identification of feeding areas. But it is necessary that international and local organizations mobilize to guarantee the future of this species by the preservation of its nesting areas.

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