Trend analysis of green turtle (*Chelonia mydas*) and hawksbill turtle (*Eretmochelys imbricata*) landings in Paloh District, West Kalimantan

Mohamad Jakaria[1] , *Mirza* Dikari Kusrini[2] , and *Mohammad* Mukhlis Kamal[3]

[1]Department of Natural Resources and Environmental Management, Graduate School, IPB University, Jl. Pajajaran Raya, Baranangsiang, Bogor City, West Jawa, Indonesia
[2]Department of Forest Resource Conservation and Ecotourism, Faculty of Forestry and Environment, IPB University, Jl. Raya Dramaga, Babakan, Bogor Regency, West Jawa, Indonesia
[3]Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, IPB University, Jl. Raya Dramaga, Babakan, Bogor Regency, West Jawa, Indonesia

Abstract. Kalimantan sea turtles are considered conservation icons due to their crucial role in maintaining marine ecosystem balance and serving as indicators of global water conditions. However, their population in Paloh District, West Kalimantan, is increasingly threatened by habitat destruction, human activities, and the illegal trade of turtle eggs. This study aims to provide data on the region's landing population trends of different sea turtle species. Data collection on nesting turtles was conducted by direct survey and information from the West Kalimantan Natural Resources Conservation Center and the Wahana Bahari Community Monitoring Group. The monitoring focused on the Tanjung Belimbing Nature Park coastlines, Sungai Belacan, and Tanjung Api Beach from 2008 to 2023. The findings reveal significant variations in the number of landing turtles, with a declining trend in the populations of Green Turtles and Hawksbill Turtles at the monitored sites.

1 Introduction

Sea turtles are commonly found in Kalimantan waters [1, 2, 3, 4] and are considered conservation icons, given their vital role in maintaining the balance of marine ecosystems and serving as indicators of healthy global waters [5, 6]. Several species of sea turtles inhabit Kalimantan, including the Green Turtle (Chelonia mydas), Hawksbill Turtle (Eretmochelys imbricata), Leatherback Turtle (Dermochelys coriacea), and Olive Ridley Turtle (Lepidochelys olivacea) [1].

These sea turtles occupy various aquatic habitats in Kalimantan, such as coastal waters, estuaries, and coral reefs. They frequently venture into shallow waters to feed and return to beaches for nesting. Key nesting beaches for sea turtles in Kalimantan include Derawan Island in Berau, East Kalimantan; Sungai Perlu Resort in Tanjung Puting National Park;

* Corresponding author: jakariamohamad47@gmail.com

Denawan Island in South Kalimantan; and Sungai Belacan and Tanjung Api Beach in West Kalimantan [3, 4, 7, 6].

Paloh District, a coastal region of 1,148.28 km², lies on the border between Indonesia and Malaysia. Located in the northern part of Sambas Regency, Paloh District is home to four species of sea turtles: the Green Turtle (*Chelonia mydas*), Hawksbill Turtle (*Eretmochelys imbricata*), Olive Ridley Turtle (*Lepidochelys olivacea*), and Leatherback Turtle (*Dermochelys coriacea*) [8]. Major hatcheries for Green and Hawksbill turtles are situated within the Tanjung Belimbing Nature Park and the Paloh Regional Marine Protected Area, particularly along Sungai Belacan and Tanjung Api Beach. However, Olive Ridley and Leatherback turtles rarely nest in this region [6].

Initial assessments of sea turtles in Paloh District began between 2009 and 2010 [6], identifying four sea turtle species and noting nesting activity along the district's coastline [9]. Despite establishing several turtle conservation areas in Paloh District, early surveys raised concerns about anthropogenic threats to turtle populations, including the loss of nesting habitats, beach erosion, and the illegal harvesting of turtle eggs [1, 10, 11].

In response, sea turtle conservation efforts were strengthened in 2011 by creating community watchdog groups along Paloh's coast, supported by various government agencies. Notable groups include Kambau Borneo, established in 2011, and Wahana Bahari, formed in 2016 by residents. These groups aim to protect nesting female turtles in the Turtle Conservation Area of Paloh District [6]. Volunteers conduct nightly monitoring, patrols, and turtle landing records, improving data accuracy over time. Additionally, these groups are involved in turtle egg-hatching programs, ecotourism, community education, beach habitat conservation, and the development of *Kelulut* honey [6].

Although systematic monitoring of sea turtle nests has been conducted for 15 years, there has been no comprehensive evaluation of population trends for the four turtle species. This study aims to present data on the population trends of Green and Hawksbill turtles, focusing on their landings and nesting activity within the Turtle Conservation Area of Paloh District over the past 15 years.

2 Methods

2.1 Location and time of research

This research was conducted at a sea turtle nesting beach in Paloh District, Sambas Regency. The observation point was focused on Tanjung Belimbing Nature Park Beach along ± 10 km and Sungai Belacan and Tanjung Api Beach (2.9 km). The research was conducted for three months, from April to June 2023.

Paloh District is in the north of Sambas Regency, between 1° 35' North latitude and 2° 05' North latitude, and 109° 38' West longitude and 109° 38' East longitude. Paloh District covers an area of 1,148.84 km² (114,884 hectares), accounting for 17.96% of the total area of Sambas Regency. As a coastal region, it has the longest coastline in Sambas Regency and is home to Indonesia's longest sea turtle nesting beach. Out of the 102.56 km of coastline, which extends from Kalimantan Village to Temajuk Village, 63 km serve as vital nesting grounds for sea turtles [8].

Paloh District primarily comprises coastal or sandy terrain, with most villages directly along the shoreline. The land has a gentle slope of 0-8% (ranging from flat to slightly undulating) and is between 0 and 500 m above sea level. The highest point in the district, at 500 m above sea level, lies in the northern part near Telok Melano Village (Malaysia). The lowest points are found in coastal areas like Temajuk, Kalimantan, Tanah Hitam, and Sebubus villages, which are adjacent to the sea. The district's topography is shaped by the

flow of the sea, forming a headland that connects two major bodies of water: the South China Sea to the north and the Natuna Sea to the west. The soil structure typically slopes toward the coastal edge [12].

Tanjung Belimbing Nature Park was established by the Decree of the Minister of Forestry and Plantation of the Republic of Indonesia No. 259/Kpts-II/2000. This coastal park features a forest predominantly covered by Sea Spruce (*Casuarina equisetifolia*). According to the West Kalimantan KSDA Center [13], the area boasts a gently sloping beach with brownish-white sand and uninterrupted waves. It serves as a vital turtle nesting and breeding ground while providing coastal protection against ocean waves and a habitat for various marine biota.

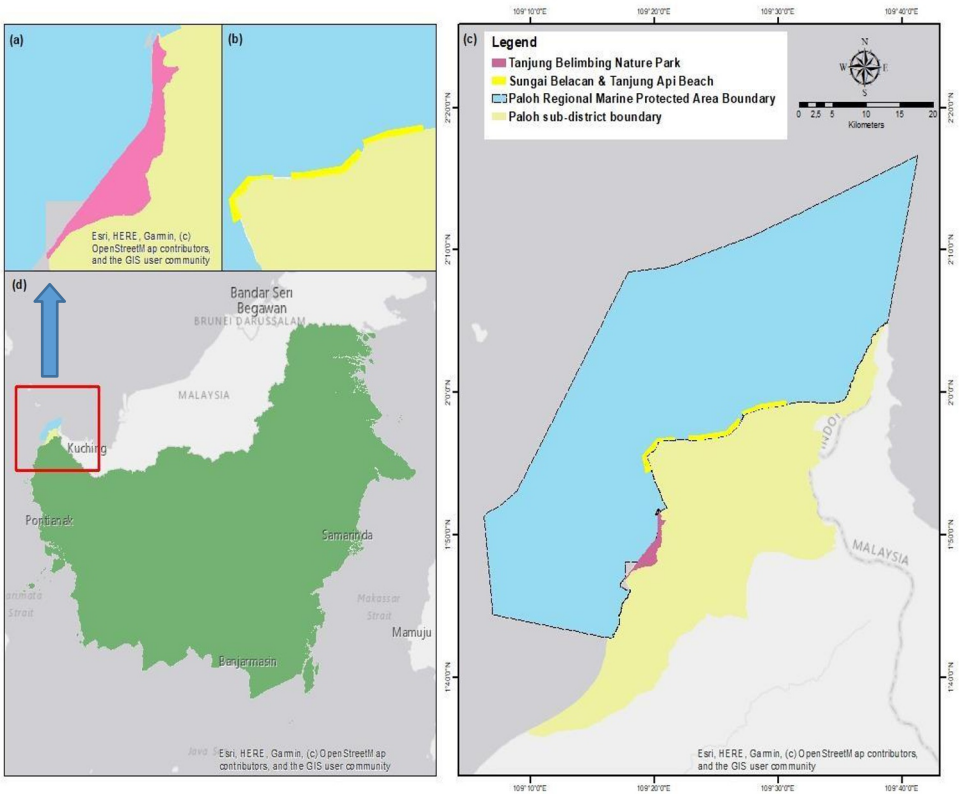

Fig. 1. Map of the research location. (a) Tanjung Belimbing Nature Park on the coast of Paloh District, (b) Sungai Belacan and Tanjung Api Beach on the coast of Paloh District. (c) Details of the Paloh Regional Marine Protected Area (area boundaries indicated by dotted lines), and (d) Paloh District on Kalimantan Island.

A gentle slope also characterizes Sungai Belacan and Tanjung Api Beach and features white sand and calm waves. This location is part of the Paloh Regional Marine Protected Area, designated under the Decree of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia Number 93/KEPMEN-KP/2020. The coastal forest around Sungai Belacan and Tanjung Api Beach is home to at least ten plant species, including Sea Fir (Casuarina equisetifolia), Sea hibiscus (Hibiscus tiliaceus), Beach naupaka (Scaevola taccada), Screwpine (Pandanus tectorius), Bitter ginger (Zingiber aromaticum), Indian almond (Terminalia catappa), Wahong Laut (Premna nauseosa), Beach morning glory (Ipomoea pes-caprae), Elephant apple (Dillenia indica), and Simpleleaf chastetree (Vitex

trifolia). Pandanus tectorius, Scaevola taccada, and Hibiscus tiliaceus are the most frequently found species [14].

2.2 Data collection

Data collection on nesting turtles was conducted through the activities of the West Kalimantan Natural Resources Conservation Center and the Pengawas Wahana Bahari Community Monitoring Group, as well as direct observations made with permission from the relevant area management agencies. Tanjung Belimbing Nature Park data was collected from 2009 to 2023, excluding the years 2015, 2016, and 2019 due to lost records. Data for Sungai Belacan and Tanjung Api Beach was recorded only for the period of 2019 to 2023.

Monitoring efforts began in 2009 with West Kalimantan BKSDA staff, consisting of 4 to 6 personnel who conducted nightly observations every day for 12 months. Community monitoring groups, comprising 27 members, also participated in these efforts, rotating 4 to 6 members each night for the same duration. The monitoring focused on approximately 10 kilometers of beach in Tanjung Belimbing Nature Park and about 2.9 kilometers along Sungai Belacan and Tanjung Api Beach. The monitoring team walked the beach from 19:00 to 24:00 each night.

Before monitoring began, observers underwent community empowerment and capacity-building activities related to turtle nesting beach monitoring. Conservation staff received training in sea turtle observation from the WWF Indonesia Foundation team [6]. To minimize disturbance to newly emerged or nesting female turtles, observers moved slowly and quietly, avoiding using flashlights and maintaining a respectful distance. Female turtles emerging from the sea were monitored from afar until their nesting process was complete. Once the turtle finished laying eggs, the length and width of its shell were measured along the centerline, from the anterior to the posterior.

Observers recorded the date, time, nesting location, and number of eggs laid. When necessary, they also relocated eggs by carefully digging up nests and transferring them to a clean bucket with moist sand, preventing them from rolling during handling. To facilitate the reconstruction of a semi-natural nest, observers measured the depth of the original nest, from the surface of the sand to its deepest point. The number of relocated eggs was documented, and each semi-natural nest was fenced and labeled with the turtle species, nest number, number of eggs, and laying date.

Additionally, secondary data was gathered for overlay analysis, which included the boundary map of Tanjung Belimbing Nature Park obtained from the West Kalimantan BKSDA, the Paloh Marine Protected Area Boundary Map from the local Marine and Fisheries office, and DEM (Digital Elevation Model) raster data sourced from the USGS (United States Geological Survey).

2.3 Data analysis

Nesting turtle population data were analyzed descriptively using statistical software to identify population trends and determine nesting seasons. The analysis focused on the two most frequently landed turtle species: Green and Hawksbill turtles. The community regularly relocates eggs from these species to calculate hatching success, which is determined by dividing the number of eggs hatched by the total number of eggs laid.

An ANOVA test was conducted to assess the significance of landing numbers for Green and Hawksbill turtles at two locations: Tanjung Belimbing, Sungai Belacan, and Tanjung Api Beach. This test also utilized the landing success rate as the dependent variable to compare trends for the two turtle species at each observation point over the years.

Additionally, correlation analysis was performed to examine relationships between the number of turtle landings and the number of turtle eggs, as well as average rainfall and average turtle landings. Rainfall data were sourced from the Central Bureau of Statistics reports for Sambas Regency, covering the period from 2008 to 2023.

Overlay analysis was conducted using the boundary map of Tanjung Belimbing Nature Park and Digital Elevation Model (DEM) raster data, as well as for the Sungai Belacan and Tanjung Api Beach areas. This analysis aimed to assess changes in the coastline between 2019 and 2023, helping to identify areas affected by coastal erosion

3 Results

3.1 Nesting turtle population

Data on sea turtle landings at the study sites show variations in the number of individuals from year to year. (Table 1) presents the total landings by species at Tanjung Belimbing Nature Park (2008-2023) and Sungai Belacan and Tanjung Api Beach (2019-2023). The most frequently landed turtles were Green Turtles (*Chelonia mydas*) and Hawksbill Turtles (*Eretmochelys imbricata*).

Table 1. Turtle species that landed on the beaches of Paloh District, West Kalimantan, including data from Tanjung Belimbing Nature Park from 2008 to 2023 (Natural Resources Conservation Center, West Kalimantan), while data for Sungai Belacan Beach and Tanjung Api Beach cover the years 2019 to 2023 (Wahana Bahari Community Group).

Location (Year of Observation)	Local name	Latin name	Total N (highest N; year)
Tanjung Belimbing Nature Park	Green Turtle	*Chelonia mydas*	838 (161; 2010)
	Hawksbill turtle	*Eretmochelys imbricata*	671 (99; 2010)
	Olive Ridley Turtle	*Lepidochelys olivacea*	9 (6; 2012)
	Leatherback turtle	*Dermochelys coriacea*	1 (1;2012)
Sungai Belacan and Tanjung Api Beach	Green Turtle	*Chelonia mydas*	16.509 (4594; 2019)
	Hawksbill turtle	*Eretmochelys imbricata*	171 (57; 2019)
	Olive Ridley Turtle	*Lepidochelys olivacea*	23 (9; 2019)
	Leatherback turtle	*Dermochelys coriacea*	1 (1; 2021)

Trends in landings of green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) at the study sites show variation from year to year. Data from TWA Tanjung Belimbing (2008-2023) and Sungai Belacan and Tanjung Api beaches (2019-2023) illustrate changes in the populations of both species over the period. (Figure 2) presents the landing patterns based on the research data.

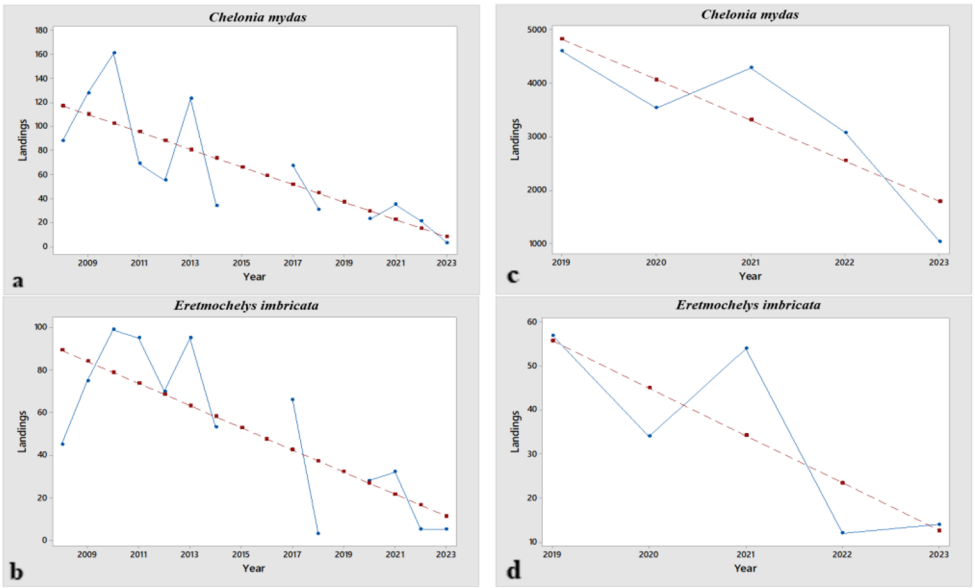

Fig. 2. Landing trend of Green Turtle (*Chelonia mydas*) and Hawksbill Turtle (*Eretmochelys imbricata*) (left): at Tanjung Belimbing Nature Park 2008 - 2023; right: data at Sungai Belacan and Tanjung Api Beach 2019 - 2023

There was a consistent downward trend in sea turtle landings for both green and hawksbill turtles at the two sites (Figure 2). A large decline in the number of green turtle landings at Tanjung Belimbing Nature Park occurred in 2020, 2022, and 2023, with 23, 21 and 3 landings respectively. Meanwhile, a drastic decline in hawksbill turtle landings began in 2014, with no landings recorded in 2015 and 2016. The same thing happened at Sungai Belacan and Tanjung Api Beach. Trends in landings of green and hawksbill turtles in the Belacan River and Tanjung Api Beach show fluctuations influenced by factors such as poaching and trade of turtle eggs and bycatch of turtles (6). The largest decline for green turtles occurred after 2021, and for hawksbill turtles, a clear decline occurred in 2020, although it increased in 2021 and then decreased again (Figure 2c and Figure 2d).

Based on the study results, the beach in Tanjung Belimbing Nature Park has been identified as a landing site for Green and Hawksbill turtles from 2008 to 2023. The results indicated a significant difference in the number of landings between these two species over the study period ($F= 9.951$, $p < 0.005$, $p = 0.000$). Furthermore, the study also found that Green turtles had a higher number of landings compared to Hawksbill turtles. This difference is likely due to differences in habitat and behavior between the two species.

The results of this study are also supported by previous research. [15] found that hawksbill sea turtles have a complex population structure and biogeography in the Caribbean. This study also demonstrated that hawksbill sea turtles have the ability to adapt to different environments, which may explain why they have lower landing numbers compared to green turtles at Tanjung Belimbing.

Furthermore, [16] found that green turtles have an increasing trend in landing numbers at the Great Barrier Reef, Australia. This study also demonstrated that green turtles have the ability to adapt to changes in environmental conditions and beach characteristics. The results of this study also support the finding that green turtles have higher landing numbers compared to hawksbill sea turtles at Tanjung Belimbing.

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demonstrated that green turtles have an increasing trend in landing numbers in the area. The results of this study also support the finding that green turtles have higher landing numbers compared to hawksbill sea turtles at Tanjung Belimbing.

Green turtles are the most frequently landed species in Tanjung Belimbing Nature Park, with a total of 838 landings recorded from 2008 to 2023. A significant difference in landings was observed across the years [$F=0.00$, $p<0.005$, $p=0.00$]. The changes in landings from year to year were notable, with some years displaying a high degree of variability and 1 to 2-year intervals. The population of green turtles landing at Tanjung Belimbing Nature Park declined, dropping from a peak of 161 turtles in 2010 to just 3 turtles in 2023 (Figure 2a).

Additionally, the Hawksbill turtle population also landed in Tanjung Belimbing Nature Park from 2008 to 2023, with a total of 671 landings recorded. A significant difference in the number of landings was noted across the years [$F = 0.00$, $p < 0.005$, $p = 0.00$]. The changes between years were significant, with substantial variability in landing numbers. The Hawksbill turtle population in Tanjung Belimbing Nature Park was declining, decreasing from a peak of 99 turtles in 2010 to just 5 turtles in 2022 (Figure 2b).

Green and hawksbill turtles were two turtle species commonly recorded landing at Sungai Belacan and Tanjung Api Beach from 2019 to 2023. There was no significant difference in the number of landings between these two species in those years [$F = 0.165$, $p>0.005$, $p = 0.947$]. Green turtles were the most common species landing at Sungai Belacan and Tanjung Api Beach, with 16,509 landings recorded from 2019 to 2023. Significant changes in the number of landings were observed during these years [$F = 0.00$, $p < 0.005$, $p = 0.00$]. Year-to-year variations were evident, with some years exhibiting considerable variability, with intervals ranging from 1 to 5 years. Green turtle landings at Sungai Belacan and Tanjung Api Beach demonstrated a declining trend, dropping from a peak of 4,594 landings in 2019 to 1,034 landings in 2023 (Figure 2c).

The Hawksbill turtle population was the only other species recorded landing at Sungai Belacan and Tanjung Api Beach over the past five years, with a total of 171 landings. Significant changes in the number of landings were observed each year [$F = 0.00$, $p < 0.005$, $p = 0.00$]. The Hawksbill turtle population decreased from a high of 57 landings in 2019 to just 14 landings in 2023 (Figure 2d).

Correlation analysis revealed a strong positive relationship between the number of turtle landings and the number of turtle eggs in Tanjung Belimbing Nature Park ($r = 0.892$, $p = 0.000$). In contrast, while there was a positive correlation between the number of landings and eggs at Sungai Belacan and Tanjung Api Beach, the results were not statistically significant ($r = 0.558$, $p = 0.329$).

3. 2 Temporal nesting patterns of green and Hawksbill Turtles

Green turtles land almost all year round in Paloh, with a peak landing season between June and September. The lowest landings occur between December and March, and at Tanjung Belimbing Nature Park, there are no landings in December (Figure 3).

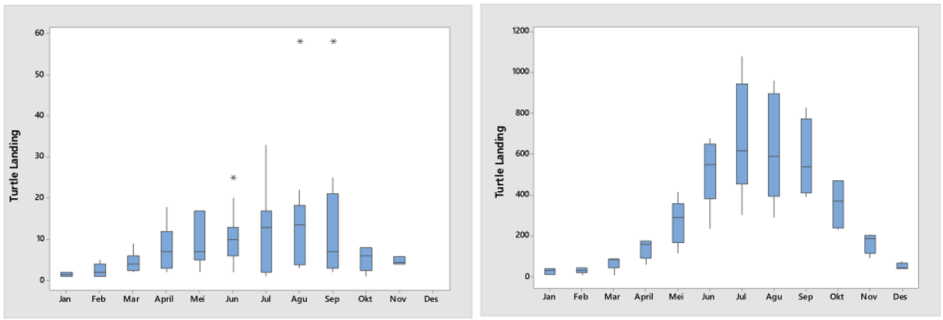

Fig. 3. Green turtle (*Chelonia mydas*) landings by month, left: at Tanjung Belimbing Nature Park 2008 - 2023; right: data at Sungai Belacan and Tanjung Api Beach 2019 - 2023.

The number of Hawksbill turtle landings is fewer than that of green turtles, with a peak landing season between February and May. The lowest landings occur between October and December (Figure.4).

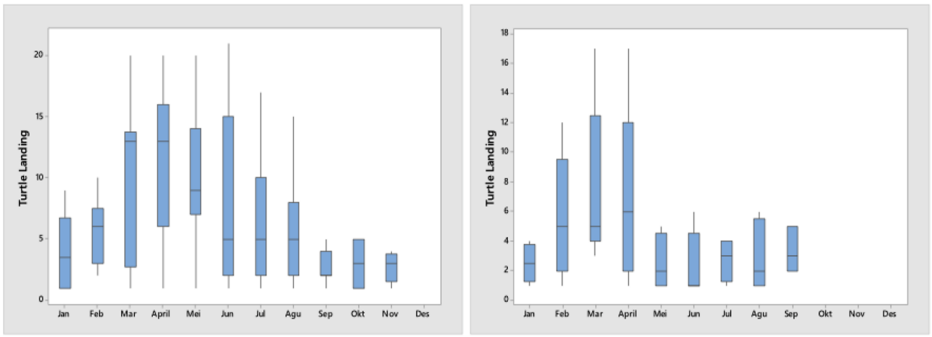

Fig. 4. Hawksbill Turtle (*Eretmochelys imbricata*) Landings by Month, left: at Tanjung Belimbing Nature Park 2008 - 2023; right: data at Sungai Belacan and Tanjung Api Beach 2019 - 2023.

There is a correlation between average rainfall and average landings of green turtles ($r = -0.711$, $p = 0.010$) and hawksbill turtles ($r = -0.754$, $p = 0.005$) in Tanjung Belimbing Nature Park. However, this correlation was insignificant for green turtles in Sungai Belacan and Tanjung Api Beach ($r = -0.384$, $p=0.218$). Conversely, there is a correlation between average rainfall and hawksbill turtle landings at Sungai Belacan and Tanjung Api Beach ($r = -0.781$, $p = 0.003$). The correlation between rainfall and turtle landings can be explained by several factors. First, rainfall can affect the availability of food for turtles. Green turtles and hawksbill turtles are herbivores and carnivores, respectively, and therefore require different food sources. High rainfall can increase the availability of food for turtles, leading to more frequent landings.

Rainfall can also affect beach conditions. High rainfall can cause beach erosion, making the beach more steep and hazardous for turtles. This may explain why green turtles do not have a significant correlation with rainfall in Sungai Belacan and Tanjung Api Beach. Other studies also support these findings. For example, [18] found that hawksbill turtles have a negative correlation with rainfall in Costa Rica. Additionally, [19] found that green turtles have a positive correlation with sea surface temperature in Barbados

3. 3 Egg hatching success in Tanjung Belimbing Nature Park, Sungai Belacan and Tanjung Api Beach

In general, relocated nests in Tanjung Belimbing Nature Park had lower hatching success than those in Sungai Belacan and Tanjung Api Beach. In the first 10 years, hatching success in Tanjung Belimbing Nature Park was less than 50%, while in Sungai Belacan and Tanjung Api Beach, it was always more than 75% (Table 2)

Table 2. Nest Relocation and Hatching Success of Sea Turtle Eggs at Tanjung Belimbing Nature Park and Belacan River and Tanjung Api (2008-2023).

Location	Year	Total Nests Relocated	Total Eggs Relocated	Number of Eggs Hatching	Hatching Success
Tanjung Belimbing Natural Park	2008	63	8.716	444	5%
	2009	97	11.062	969	9%
	2010	153	16.948	4.847	29%
	2011	127	15.542	5.906	38%
	2012	100	12.467	5.151	41%
	2013	61	7.426	3.114	42%
	2014	42	5.262	2.132	41%
	2015				
	2016				
	2017	133	7.017	1.186	17%
	2018	34	1.757	656	37%
	2019				
	2020	51	5.770	3.831	66%
	2021	67	7.024	4.873	69%
	2022	26	2.246	1.176	52%
	2023	6	831	300	36%
Sungai Belacan and Tanjung Api Beach	2019	2.254	37.892	31.166	82%
	2020	1.916	38.713	33.580	87%
	2021	2.487	25.277	21.076	83%
	2022	1.507	20.360	16.394	81%
	2023	489	22.280	16.658	75%

3.4 Characteristics and changes in nesting habitat

Vegetation along the shoreline is crucial in sea turtles' landing site preferences. In Tanjung Belimbing Nature Park, turtles tend to land in quieter, sloping areas near the tip of the cape, close to vegetation. In contrast, Sungai Belacan and Tanjung Api Beach feature longer shorelines with denser, more evenly distributed vegetation, offering turtles a wider selection of suitable nesting sites (Figure 5).

Based on the comparison of the 2019 and 2023 images of Tanjung Belimbing Nature Park, there are changes in the coastal area, especially near the river mouth. In the 2019 image, the coastline appears stable with a clear shape, and the delta or sediment around the estuary shows a balanced condition between river and sea flow. However, in the 2023 image, the shoreline is more retreated in this area, indicating that abrasion has eroded the land and removed some of the delta area (Figure 6)

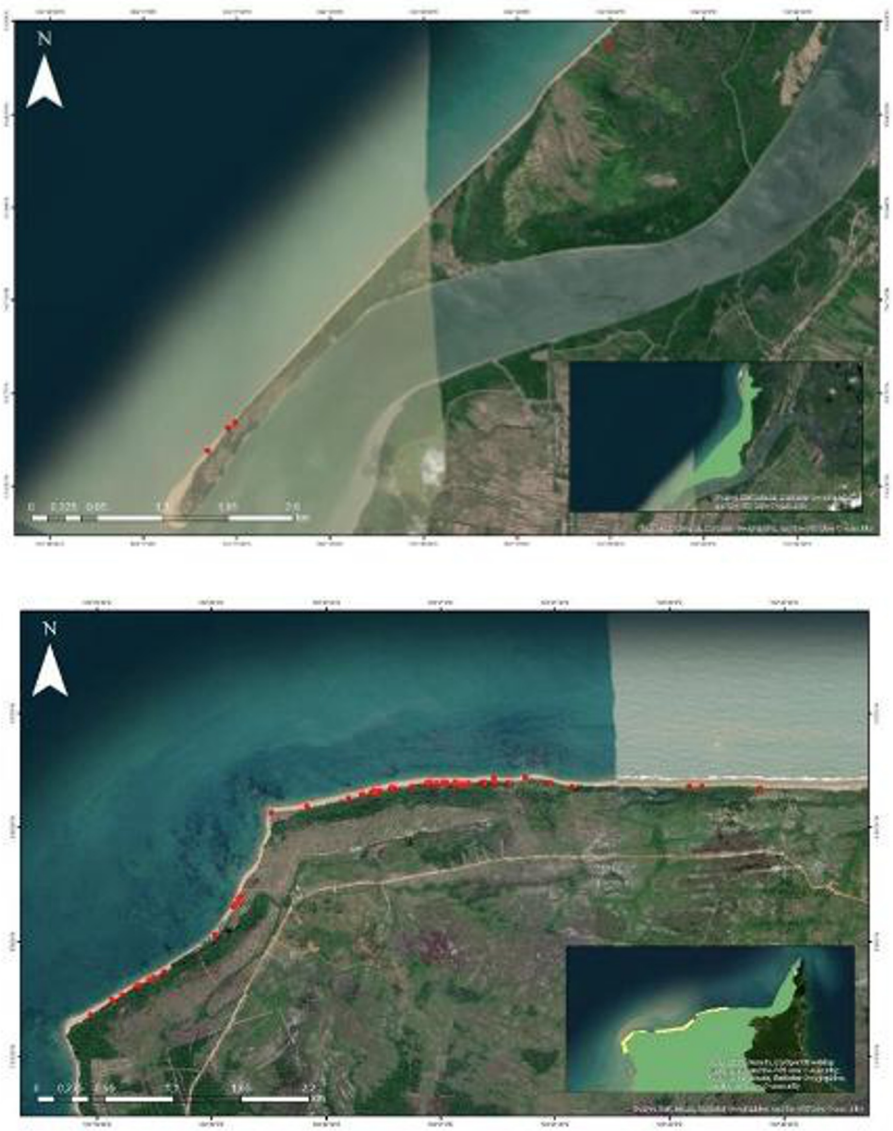

Fig. 5. Distribution Map of Sea Turtle Nesting Sites Along the Shoreline of Tanjung Belimbing Nature Park (top) and Sungai Belacan and Tanjung Api Beach (bottom) During the Study.

Meanwhile, the coastal areas of Sungai Belacan and Tanjung Api Beach appear to be larger. The 2019 image shows a more defined land boundary and no visible impact of abrasion. Then, the 2023 image shows no significant change, with the coastline remaining

parallel to the area boundary, indicating that this area is not experiencing significant abrasion impacts (Figure 6).

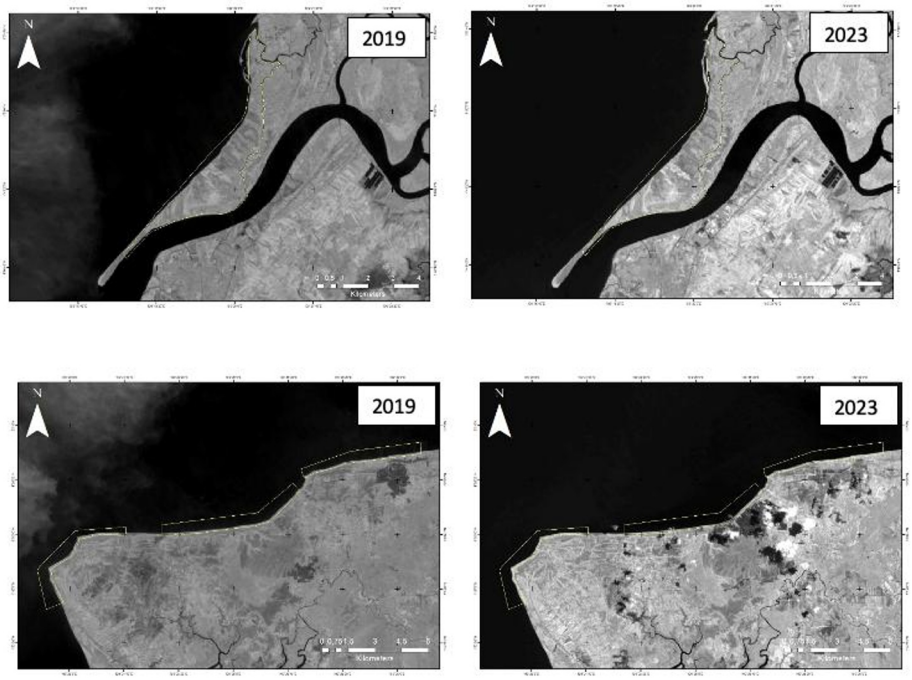

Fig. 6. Shoreline changes in Tanjung Belimbing Nature Park (top) and Sungai Belacan and Tanjung Api Beach (bottom) due to coastal abrasion in 2019 and 2023.

4 Discussion

The findings of this study confirm that Tanjung Belimbing Nature Park and Sungai Belacan, along with Tanjung Api Beach, remain key habitats for green and hawksbill turtles in Paloh District, serving as vital sites for nesting, feeding, and mating. This aligns with previous research [2, 6, 10]. However, from 2008 to 2023, the temporal patterns of nesting populations for these two turtle species show a concerning decline in the number of landings. This decrease is particularly alarming, considering these areas' critical role as primary nesting sites for green and hawksbill turtles.

The decline in sea turtle landings is not just a local issue but mirrors a global trend. Similar reductions have been reported at various sites worldwide, such as Moskito Beach in Puerto Rico and Nicaragua [20], Costa Rica [21], and Yalimapo Beach in French Guiana. In Indonesia, declining landings have been observed at Taman Kili-Kili Beach in Trenggalek [22] and Pangumbahan Beach in Sukabumi [23].

The decline in nesting turtle populations at Tanjung Belimbing Nature Park, Sungai Belacan, and Tanjung Api Beach warrants serious attention, as numerous threats have emerged in recent years [6]. The primary cause of this decline is believed to stem from human activities rather than natural factors like coastal abrasion, although the erosion at Tanjung Belimbing Nature Park is more severe than at Sungai Belacan and Tanjung Api Beach. Other threats include artificial lighting along the beaches, which disrupts the natural nesting behavior of female turtles, as they tend to avoid brightly lit areas [24]. However, tourism-related infrastructure development remains limited in these areas.

The nesting patterns of green and hawksbill turtles at Tanjung Belimbing Nature Park, Sungai Belacan, and Tanjung Api Beach are influenced by various spatial and temporal factors, reflecting the species' adaptation to changing environmental conditions. Spatially, green and hawksbill turtles exhibit different preferences for nesting sites. Green turtles nest more frequently at Sungai Belacan and Tanjung Api Beach than at Tanjung Belimbing Nature Park, while hawksbill turtle numbers are relatively consistent across both locations. This disparity may be due to differences in the suitability of beach areas for turtle landings.

Green turtles select wide, open beaches with soft, stable quartz sand away from the high tide line to reduce the risk of seawater flooding and disturbance from predators [25, 26]. Hawksbill turtles, less common than green turtles, tend to choose narrow beach sites with brighter sand likely formed from the accumulation of coral and shell residues [25, 27]. Hawksbill turtles also select nesting sites closer to beach vegetation, such as shrubs or tree roots, which provide additional protection from predators and help maintain stable nest temperature and humidity [25].

Temporally, these two turtle species also have different nesting seasons at Tanjung Belimbing Nature Park Beach and Sungai Belacan and Tanjung Api Beach. This temporal difference allows both species to reduce competition for space and utilize different times to increase the chances of egg and hatchling survival [28]. These events also occur elsewhere, such as in Alas Purwo National Park, where green turtles perform three different modes of reproduction. The first mode is known as "arribada" which involves the simultaneous nesting behavior and large numbers of hundreds to thousands of individuals in various locations worldwide, lasting for several days. The second mode, referred to as "dispersed nesting," is characterized by isolated nesting behavior. The third is a combination of reproductive modes, where arribada and dispersed nests occur in certain areas [10]. Hawksbill turtles have nesting traits that are highly dispersed along the coast [29].

There are distinct differences in the reproductive strategies of green and hawksbill turtles. Green turtles typically lay 3-4 clutches of eggs per season, with intervals of around 14 days between each nesting event [27]. This strategy helps distribute the risk of predation and environmental threats, increasing the likelihood that at least some nests will hatch successfully [25]. In contrast, hawksbill turtles tend to nest less frequently, laying 4-6 clutches per season, but with slightly longer intervals of around 12 to 14 days [30]. During this period, hawksbill turtles usually remain close to shore, particularly near coral reef areas, which provide feeding grounds that support their nesting process [31]. The proximity to coral reefs reduces the energy expended by hawksbills between nesting intervals and minimizes their exposure to predation and environmental changes [30, 32].

The study observed the presence of water monitor lizards (*Varanus salvator*), suspected egg predators, and turtle eggshells that appeared to have been consumed by these lizards. This highlights the importance of protecting nests from natural threats. Egg relocation to semi-natural hatcheries has become a critical conservation practice in Tanjung Belimbing Nature Park, Sungai Belacan, and Tanjung Api Beach. Hatchery facilities allow for more effective management of turtle hatching, reducing risks from predators and human disturbances, as turtle eggs are often hunted for consumption or commercial purposes. These facilities also enable intensive monitoring of hatching eggs and provide opportunities for education and conservation research [6, 33]. This approach aligns with the middle-ground conservation methods described by [34], where global efforts, including those in these West Kalimantan areas, emphasize both in-situ and ex-situ strategies to safeguard sea turtles.

In the first decade of monitoring (2008-2018), the hatching success rate in Tanjung Belimbing Nature Park remained below 50%. In contrast, from 2018 to 2023, the success rate at Sungai Belacan and Tanjung Api Beach consistently exceeded 75%. This discrepancy highlights the need for improvements in the hatchery practices at Tanjung Belimbing Nature Park. One suggested enhancement is rotating the semi-natural nests every two years to

mitigate bacterial contamination in the sand. Research by [35] identified that bacteria such as *Escherichia coli*, *Salmonella* sp., and *Shigella* sp. could negatively impact turtle egg-hatching success. Rotating nest sites periodically would allow the sand in the older nesting areas to recover naturally, reducing the accumulation of harmful pathogens like bacteria and fungi that can infect eggs or embryos. This method could significantly improve hatching success rates and support long-term sea turtle population health. As noted in [36], clean, pollution-free sand with the appropriate grain size provides optimal conditions for turtle embryos to thrive.

Although there has been a decline in sea turtle nesting populations, this does not indicate that the conservation efforts undertaken by the community over the past 15 years have been ineffective. The current reduction in green and hawksbill turtle populations may be linked to past human activities. Turtles typically take around 20 years to reach sexual maturity [27], so the eggs laid and turtles landing in the 1960s would have contributed to the increase in nesting populations observed in Paloh District from 1992 onward [6]. However, turtle eggs were commonly harvested for consumption during that period [24], and there was even a local tradition of "turtle egg wars" [36].

Before 2005, the local government of Sambas Regency granted concession permits to private companies for the commercial extraction of sea turtle eggs, a practice that likely contributed to the population declines observed today [6]. However, the situation has since improved. The community no longer consumes sea turtle eggs freely, likely due to a ban imposed by stakeholders in Tanjung Belimbing Nature Park and the Paloh Marine Protected Area (MPA) and increased awareness within the local community. Educational campaigns about prohibiting sea turtle egg hunting have been widely successful, leading to a greater public understanding of the importance of sea turtle conservation.

Today, the communities in Paloh District are actively involved in conservation efforts alongside the government and various environmental organizations. They now play a significant role in monitoring beach areas to protect sea turtle nests and ensure no illegal hunting occurs. Since 2020, ecotourism development in Tanjung Belimbing Nature Park, Sungai Belacan, and Tanjung Api Beach has provided alternative livelihoods for many local villagers, reducing reliance on harmful activities like egg poaching [6]. Law enforcement has also been strengthened, curbing poaching and increasing the survival rates of adult turtles [38].

Furthermore, establishing the Paloh Regional Marine Protected Area and stronger national and international policies have enhanced the protection of green and hawksbill turtles and their habitats. These measures may contribute to an increase in sea turtle survival rates, offering hope for the long-term recovery of these endangered species.

5 Conclusions

Over the past 15 years, there has been a declining trend in the populations of green and hawksbill turtles landing at Tanjung Belimbing Nature Park, Sungai Belacan, and Tanjung Api Beach. Green turtles typically land year-round in these areas, with peak landings occurring between June and September and the lowest numbers between December and March. In contrast, hawksbill turtles have their peak landing season between February and May, with the lowest landings between October and December.

Despite ongoing conservation efforts, this decline in sea turtle landings indicates that these measures have not yet been sufficient to reverse the population decreases. However, there is still hope for improvement through more effective management strategies, which could help restore these endangered species and ensure the long-term survival of green and hawksbill turtles.

Furthermore, the hatching success of sea turtle eggs in Tanjung Belimbing Nature Park is much lower than in Sungai Belacan and Tanjung Api Beach. During the first decade of monitoring (2008-2018), the hatching rate at Tanjung Belimbing was less than 50%, while the other two sites have consistently reached more than 75% since 2019. This discrepancy suggests the need for improvements in nest management, particularly in relation to relocation and maintenance of sand conditions

References

1. W. Adnyana, Bio-ekologi penyu laut di Indonesia, in Proc. Seminar Nasional dan Workshop Sea Turtle Conservation, Jun. (2016) pp. 1–21.
2. M. Anshary, T.R. Setyawati, A.H. Yanti, Karakteristik pendaratan Penyu Hijau (Chelonia mydas Linnaeus 1758) di pesisir Pantai Tanjung Kemuning, Tanjung Api dan Pantai Belacan, Kecamatan Paloh, Kabupaten Sambas, J. Protobiont **3**, 232–239 (2014).
3. D. Dharmadi, N.N. Wiadnyana, Kondisi habitat dan kaitannya dengan jumlah Penyu Hijau (Chelonia mydas) yang bersarang di Pulau Derawan, Berau–Kalimantan Timur, J. Penelit. Perikan. Indones. **14**, 195–204 (2008).
4. E. Novitasari, H. Prayogo, S. Anwari, Karakteristik tempat peneluran Penyu Sisik (Eretmochelys imbricata) di Resort Sungai Perlu, Taman Nasional Tanjung Puting, J. Hutan Lestari **6**, (2018).
5. M. Roem, Kajian kemampuan padang lamun Pulau Derawan dalam penyediaan makanan Penyu Hijau (Chelonia mydas Linnaeus, 1758), Doctoral dissertation, Universitas Hasanuddin, Indonesia (2012).
6. A. Yusra, A. Fisesa, A. Fachrizal, H. Susanto, Penyu dan Paloh: Perjalanan konservasi di Ekor Borneo, Yayasan WWF Indonesia, Sambas (2022).
7. A.M. Ghalib, D. Salim, N. Nursalam, Karakteristik habitat peneluran penyu di Pulau Denawan dan Pulau Kalambau, Kecamatan Pulau Sembilan, Kabupaten Kotabaru, Kalimantan Selatan, Mar. Coast. Small Isl. J. **3**, 1–10 (2024).
8. [KKP RPZ], Kawasan Konservasi Perairan Rencana Pengelolaan Zonasi Kabupaten Sambas, PT. Media Karsa Pratama, Pontianak (2019).
9. Safitri, A. Yuliono, H. Susanto, Monitoring penyu sebagai upaya dalam pengelolaan KKP3K Paloh Kalimantan Barat, J. Pengabdi. Masy. Nusantara 5, 119–125 (2024).
10. N. Kurniawan, A. Gitayana, Why did the population of the Olive Ridley Turtle *Lepidochelys olivacea* (Eschscholtz, 1829) increase in Alas Purwo National Park's beach, East Java, Indonesia, Russ. J. Mar. Biol. **46**, 338–345 (2020).
11. B. Manurung, S. Rifanjani, Karakteristik Habitat Tempat Bertelur Penyu di Kawasan Taman Wisata Alam Tanjung Belimbing Kecamatan Paloh Kabupaten Sambas, J. Hutan Lestari **4**, (2015).
12. Sabahan, Perencanaan Lanskap Kawasan Ekowisata Berbasis Masyarakat (Community-Based Ecotourism) Di Wilayah Pesisir Paloh Kalimantan Barat, Sekolah Pascasarjana, Institut Pertanian Bogor (2012).
13. [Balai Konservasi Sumber Daya Alam Kalimantan Barat], Buku Potensi Kawasan Taman Wisata Alam Tanjung Belimbing, Pontianak (ID), (Balai KSDA Kalimantan Barat 2011).
14. D. Darwati, M. Rosmiyati, D. Destiana, Deskripsi Vegetasi Zona Inti Pantai Peneluran Penyu, Desa Sebubus, Kabupaten Sambas, J. Hutan Lestari **10**, 220 (2022).
15. K.A. Bjorndal, A.B. Bolten, Hawksbill Sea Turtles in the Caribbean: Population Structure and Biogeography, Mar. Biol. **157**, 2421-2433 (2010).
16. M.Y. Chaloupka, C.J. Limpus, Trends in the Abundance of Sea Turtles Resident in the Southern Great Barrier Reef, Biol. Conserv. **102**, 235-249 (2001).

17. M. Hamann, C.J. Limpus, M.A. Read, Nesting Green Turtles (Chelonia mydas) in the Southern Great Barrier Reef: A Review of the Past 25 Years, J. Sea Res. **64**, 251-262 (2010).
18. C. Carreras, C. Castillo, J.J. Calvo, J. Tomás, Hawksbill Sea Turtle Nesting Activity in Costa Rica: A 10-Year Study, Mar. Turtle Newsl. **157**, 12-18 (2018).
19. J.A. Horrocks, N.M. Scott, Nest Site Selection and Nesting Success in the Green Turtle (Chelonia mydas) in Barbados, West Indies, Mar. Ecol. Prog. Ser. **74**, 43-53 (1991).
20. L. McClenachan, J.B. Jackson, M.J. Newman, Conservation Implications of Historic Sea Turtle Nesting Beach Loss, Front. Ecol. Environ. **4**, 290-296 (2006).
21. P. Tomillo Santidrián, L.G. Fonseca, M. Ward, N. Tankersley, N.J. Robinson, C.M. Orrego, V.S. Saba, The Impacts of Extreme El Niño Events on Sea Turtle Nesting Populations, Clim. Change **159**, 163-176 (2020).
22. V.D. Pratama, S. Sukandar, M. Marjono, A. Kurniawan, Suitability Analysis of Habitat and Ecotourism of Olive Ridley Sea Turtle (Lepidochelys olivacea) in Development of Turtle Conservation Strategy at Taman Kili-Kili Beach, ECSOFiM **9**, 86-100 (2021).
23. R. Haryanti, Status Populasi Penyu Hijau (Chelonia mydas, Linnaeus 1758) di Taman Pesisir Pantai Penyu Pangumbahan, Kabupaten Sukabumi, Jawa Barat, (2014).
24. T.Z.A.E. Hamino, I.N.Y. Parawangsa, L.A. Sari, S. Arsad, Efektifitas Pengelolaan Konservasi Penyu di Education Center Serangan, Denpasar Bali, J. Mar. Coast. Sci. **10**, 18-34 (2021).
25. I.N.S. Nuitja, Nesting Site Requirements for Green Turtle (Chelonia mydas L.) in Indonesia, Treubia **30**, 203-212 (1992).
26. K.L. Eckert, K.A. Bjorndal, F.A. Abreu-Grobois, M.D., Research and Management Techniques for the Conservation of Sea Turtles, Prepared by IUCN/SSC Marine Turtle Specialist Group-Reducing Threats to Eggs and Hatchlings: In Situ Protection, **4**, 179 (1999).
27. A. Dermawan, N.S. Nuitja, D. Soedharma, M.H. Halim, M.D. Kusrini, S.B. Lubis, R. Alhanif, M. Khazali, M. Murdiah, P.L. Wahjuhardini, S. Setiabudiningsih, A. Mashar, Pedoman Teknis Pengelolaan Konservasi Penyu, Direktorat Konservasi dan Taman Nasional Laut, Direktorat Jenderal Kelautan, Pesisir dan Pulau-Pulau Kecil, (Departemen Kelautan dan Perikanan RI, Indonesia 2009).
28. M.C. López-Castro, E. Cuevas, V. Guzmán Hernández, Á. Raymundo Sánchez, R.C. Martínez-Portugal, D.J.L. Reyes, J.Á.B. Chio, Trends in Reproductive Indicators of Green and Hawksbill Sea Turtles Over a 30-Year Monitoring Period in the Southern Gulf of Mexico and Their Conservation Implications, Animals **12**, 3280 (2022).
29. M.J. Liles, M.V. Jandres, W.A. López, G.I. Mariona, C.R. Hasbún, J.A. Seminoff, Hawksbill Turtles Eretmochelys imbricata in El Salvador: Nesting Distribution and Mortality at the Largest Remaining Nesting Aggregation in the Eastern Pacific Ocean, Endang. Species Res. **14**, 23-30 (2011).
30. P. Kasenda et al., Lokasi Bertelur Penyu Di Pantai Timur Kabupaten Minahasa Provinsi Sulawesi Utara, J. Pesisir Laut Tropis **2**, 1 (2013).
31. M.A. Marcovaldi, G.G. Lopez, L.S. Soares, M. López-Mendilaharsu, Satellite Tracking of Hawksbill Turtles Eretmochelys imbricata Nesting in Northern Bahia, Brazil: Turtle Movements and Foraging Destinations, Endang. Species Res. **17**, 123-132 (2012).
32. J. Walcott, S. Eckert, J.A. Horrocks, Tracking Hawksbill Sea Turtles (Eretmochelys imbricata) During Inter-nesting Intervals Around Barbados, Mar. Biol. **159**, 927-938 (2012).
33. M. Iqbal, N. Nurfathurrahmah, N. Azmin, Keberhasilan Ekowisata Berbasis Penangkaran Penyu Hijau (Chelonia mydas) Dengan Sarang Semi Alami Pada Lokasi Hatchery Yang Berbeda Di Taman Nasional Moyo Satonda, Oryza, J. Pendidik. Biol. **12**, 219-228 (2023).

34. N.B. Frazer, Sea Turtle Conservation and Halfway Technology, Conserv. Biol. **6**, 179-184 (1992).
35. D. Elfidasari, T. Gifari, I. Sugoro, Deteksi Cemaran Mikroorganisme pada Kawasan Konservasi Penyu di Pangumbahan Sukabumi, J. Al-Azhar Indones. Seri Sains Teknol. **4**, 28-35 (2017).
36. D. Margaritoulis, Nesting Activity and Reproductive Output of Loggerhead Sea Turtles, Caretta caretta, over 19 Seasons (1984–2002) at Laganas Bay, Zakynthos, Greece: The Largest Rookery in the Mediterranean, Chelonian Conserv. Biol. **4**, 916-929 (2005).
37. R.D.A. Akbarinissa, N. Taufiq-Spj, R. Hartati, Pengaruh Kedalaman Dan Lokasi Sarang Semi Alami Terhadap Masa Inkubasi Dan Daya Tetas Telur Penyu Hijau (Chelonia mydas) Di Pantai Paloh, Kabupaten Sambas, Provinsi Kalimantan Barat, J. Mar. Res. **7**, 59-68 (2018).
38. A.P. Tarigan, L. Syarifuddin, A. Wati, Penegakan Hukum Terhadap Perdagangan Telur Penyu, Risalah Hukum, 83-94 (2020).