
Chu The Cuong, Bui Thi Thu Hien
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Cover photo: A sea turtle heading to the ocean after laying the eggs © IUCN Viet Nam.

Back cover: A newly born sea turtle in Con Dao National Park © IUCN Viet Nam.

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INTRODUCTION

Vietnam is a country located to the West of the Eastern Sea/Pacific Ocean, with a coastline of over 3,450 km (including coastal inner and outer boundaries, islands, and archipelagos). It has an exclusive economic zone (EEZ) of around one million km² (according to the United Nations Convention on the Law of the Sea - UNLOS, 1982). There are 3,200 islands of various size scattered across the country, many of which are unnamed (including emerged, sub-emerged and temporarily emerged islands) and therefore hard to spot on a map and less impacted by human activities, making them potential unknown habitats and nesting grounds for sea turtles. The land area of Vietnam is 310,060 km². The total population is 97.5 million people, making Vietnam one of the countries with the highest population density in the world (315 people/km²) (statistic dated August, 2019) with the coastal regions being the most densely populated (nearly 55% of the total population). The locations, geography, and climates together making Vietnam's waterbody a high biodiversity compared to other countries in the region and in the world in term of structure and composition of species, ecosystem diversity, and genetic resources. Vietnam sea is quite unique. It is affected by diurnal tides and semidiurnal tides and consists of more than 20 types of ecosystems capable of regeneration with high biological productivity, such as: mangroves, coral reefs, tidal bottom flats, sandy beaches, seagrass and seaweed beds, and complex lagoon systems. These ecosystems are essential habitats for sea turtles as well as other aquatic species such as reptiles, birds, and marine mammals. According to the Prime Minister's Decision No. 45/QD-TTg dated January 8, 2014 on Approving the Comprehensive Planning on National Biodiversity Conservation to 2020, with a vision to 2030, there are 219 protected areas in Vietnam (including land and marine areas), among which are 12 established marine protected areas (MPA) (or MPAs that have received an establishment decision), including: Cô Tô, Trần Island, Cát Bà (part of Cát Bà National Park), Bạch Long Vĩ, Côn Cỏ, Cù Lao Chàm, Lý Sơn, Nha Trang Bay, Núi Chúa (part of Núi Chúa National Park), Hòn Cau, Côn Đảo, Phú Quốc and 04 marine protected areas that have completed their detailed planning and are in the process of completing the application for planning approval: Hòn Mê, Hải Vân - Son Chà, Phú Quý, Nam Yết.
Initial reports on sea turtles in Vietnam have been published by Bouret. According to this report, there are 05 marine turtle species in the Vietnam’s coastal zone and four found on the Paracel islands. From 1999 to 2008, international organizations: IUCN, World Wildlife Fund (WWF), and TRAFFIC - the Wildlife Trade Monitoring Network, with support from the Danish International Development Agency (DANIDA), collaborated with the Ministry of Fisheries (now the Ministry of Agriculture and Rural Development (MARD)) and research institutions to conduct research on the status of marine turtles, protect marine turtles on their nesting grounds, and develop Marine Turtles Protection Plan in Vietnam to 2010. On March 14, 2016, the Ministry of Agriculture and Rural Development issued Decision No. 811/QD-BNN-TCTS on “Approving the Action plan for Vietnamese Sea Turtle Conservation for the period 2016-2025” with a series of programs and activities aimed at the protection of marine turtles. Sea turtle protection was raised to a higher level in the Prime Minister's Decision No. 1176/QD-Ttg dated September 12, 2019 on “Approving Conservation Program for Vietnam's Endangered Turtle Species to 2025, with vision to 2030”. These are the evidence of the special attention that the Government, specialized management agencies, and the community have given to the issue of Marine Turtles and their conservation in Vietnam. However, because of many factors, both subjective and objective, including historical (war), natural (long coastline, complex topographic structure, etc.), human (economic development needs, customs, social resources for conservation, etc.), the study and conservation of many marine turtle species in Vietnam is still facing several limitations. During the last few decades, marine turtles have been severely impacted by the harvesting of turtles for food and handicraft products, overfishing, marine environment pollution, loss of habitats, and decreasing food sources. Furthermore, the existence of humans on the islands, the impacts of artificial light, waste, and noise generated by ships, etc. are responsible for the devastating decline in marine turtle populations. Objective causes include coastal erosion and landslides at nesting sites caused by natural disasters like storms and floods, as well as runoff and urbanization.
1. DISTRIBUTION PATTERNS OF MARINE TURTLE POPULATIONS

1.1. Nesting marine turtle populations

Marine turtles are among the oldest creatures in the world. They first appeared 100 to 150 million years ago, during the age of dinosaurs. After a series of events that changed the natural environment of the Earth, most reptiles including dinosaurs went extinct. Meanwhile, sea turtles are still existing today. Currently there are seven marine turtle species which belong to two families. They are the Cheloniidae family, consisting of Green turtle (Chelonia mydas and its subdivision Galápagos green turtle Chelonia mydas Agassiz), Hawksbill turtle (Eretmochelys imbricata), Olive Ridly turtle (Lepidochelys olivacea), Kemp's Ridley turtle (Lepidochelys kempii), Loggerhead turtle (Caretta caretta), and Flatback turtle (Natator depressus) and the Dermochelyidae family, consisting of only one species, Leatherback turtle (Dermochelys coriacea). All of the marine turtle species are dispersed in tropical and subtropical regions, in warm and hot waters in most oceans. The exception to this is the Flatback turtle, which is only found in the North and North East regions of Australia, and the Kemp's Ridley turtle, which only appears in the Gulf of Mexico. An exact estimation of the total population of sea turtles in the world is not feasible yet. This is because the counting of marine turtles usually relies on the observation and monitoring of the number of female turtles emerging from the sea to lay eggs. Meanwhile, male turtles and juvenile turtles do not crawl up the beaches, making it difficult to determine their actual number in the wild. However, after several years of observing marine turtles at nesting sites, scientists have realized a declining trend in wild turtle populations at most of the studied sites. Compared to the early years of the 20th century when research on marine turtles first started, there has been at least a 43% decrease in the Green turtle population (Seminoff, 2004), 50% to 60% decrease in Olive Ridley turtle and Kemp's Ridley turtle, and a nearly 80% decrease in Leatherback and Hawksbill turtle (Mortimer & Donnelly, 2008; Spotila et al., 1996). This is the reason why all marine turtle species are listed in IUCN's Red List, which is a list of wild species at risk of extinction (Group, 1996).

According to existing research, there are four marine turtle species that have nesting grounds in Vietnam, which are the Green turtle (Chelonia mydas), the Hawksbill turtle (Eretmochelys imbricata), the Olive Ridley turtle (Lepidochelys olivacea) and the
Leatherback turtle (*Dermochelys coriacea*) (Hamann, Cuong, Hong, Thuoc, & Thu Hien, 2006). The results of the observation and monitoring of marine turtles nesting in coastal provinces show that there is a critical decline in the number of nesting marine turtles and nesting grounds in Vietnam’s coastal region. In many areas where a large number of nesting turtles used to be found like the Central coastal provinces such as Quảng Trị, Quảng Ngãi, and Phú Yên, there are rarely any sightings of turtles nesting nowadays. Currently the only regularly found nesting turtles are the Green turtles. Nesting Leatherback turtles have also been found, but very irregularly. Nesting Hawksbill turtles and Olive Ridley turtles have disappeared from all surveyed locations for the last 10 years. Therefore, all of marine turtle species are listed in the Red List, which is a list of wild species at risk of extinction in Vietnam *(Error! Reference source not found.*) and are prioritized for protection according to Decree No. 160/2013/ND-CP November 12, 2013 on Criteria to Determine Species and the Mechanism for Managing Species Under the List of Endangered, Precious and Rare Species That Required Prioritized Protection.

### Table 1. The list of marine turtles in Vietnam and in the world

<table>
<thead>
<tr>
<th>Species</th>
<th>English name</th>
<th>Vietnamese name</th>
<th>IUCN Red List</th>
<th>Vietnam Redlist</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHELONIIDAE FAMILY (Vích)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caretta caretta</td>
<td>Loggerhead turtle</td>
<td>Quản đồng</td>
<td>EN</td>
<td>CR</td>
</tr>
<tr>
<td>Chelonia mydas</td>
<td>Green turtle</td>
<td>Vích</td>
<td>EN</td>
<td>EN</td>
</tr>
<tr>
<td>Eretmochelys imbricata</td>
<td>Hawksbill turtle</td>
<td>Đồi mồi</td>
<td>CR</td>
<td>EN</td>
</tr>
<tr>
<td>Lepidochelys olivacea</td>
<td>Olive Ridley</td>
<td>Đồi mồi dứa</td>
<td>VU</td>
<td>EN</td>
</tr>
<tr>
<td>Lepidochelys kempii</td>
<td>Kemp's Ridley</td>
<td>Rùa Kempri</td>
<td>CR</td>
<td>N/A</td>
</tr>
<tr>
<td>Natator depressus</td>
<td>Flattback turtle</td>
<td>Rùa lưng phẳng</td>
<td>DD</td>
<td>N/A</td>
</tr>
<tr>
<td>Dermochelyidae Family (Rùa da)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dermochelys coriacea</td>
<td>Leatherback turtle</td>
<td>Rùa da</td>
<td>CR</td>
<td>CR</td>
</tr>
</tbody>
</table>

(Notes: CR: Critically endangered, EN: Endangered, VU: Vulnerable, DD: Data deficient)

Areas where there are regular sightings of nesting turtles include Côn Đảo (averagely from 420 to 820 turtles/year), Núi Chúa (5 turtles/year), Hòn Cau (3 turtles/year). According to interviews conducted with the local people, Central provinces such as Quảng Trị, Đà Nẵng, Quảng Ngãi, and Bình Định used to be home to huge nesting grounds, with hundreds of turtles nesting in a night. Currently there has been a
There has been a significant decline in nesting marine turtles, especially in areas with a large population or tourism development such as Sơn Trà Peninsula (Đà Nẵng), Bãi Dài (Cam Lâm, Khánh Hòa), Tam Quan Bắc (Phú Yên), etc. There has been little to no nesting marine turtles found since 2005 in those areas. There are still a small number of marine turtles nesting per year in other areas, bringing the total number of nesting marine turtles in the region up to 20 turtles per nesting season. Green turtles make up the majority of that (with an average of 10 turtles across a 70 km-long beach in Quảng Trị, about 10 turtles in Hải Giang and Hòn Khô Beach in Bình Định, and 2 to 4 turtles in Khánh Hòa). In addition, a number of past nesting grounds are now void of any nesting marine turtles, such as Bạch Long Vĩ (Hải Phòng), Phú Yên, Bình Định and Phú Quốc Island (Kiên Giang).

Later researches on marine turtles mostly focus on bycatch and experimental turtle release gears (conducted by WWF and the Research Institute for Marine Fisheries), raising community’s awareness on marine turtles conservation (conducted IUCN in collaboration with the Management Boards of national parks and marine protected areas), and comprehensive surveys at marine turtles’ nesting sites (conducted by IUCN and the Institute of Marine Environment and Resources)(Cuong, 2009, 2010; Cường, 2011; Thế & Cường, 2011)

<table>
<thead>
<tr>
<th>Species</th>
<th>Vietnamese name</th>
<th>2010 (in comparison to 2000)</th>
<th>2020 (in comparison to 2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cheloniidae Family</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Caretta caretta</em></td>
<td>Loggerhead turtle</td>
<td>Declining</td>
<td>Declining</td>
</tr>
<tr>
<td><em>Chelonia mydas</em></td>
<td>Green turtle</td>
<td>75% decline</td>
<td>Increasing in a number of protected areas</td>
</tr>
<tr>
<td><em>Eretmochelys imbricata</em></td>
<td>Hawksbill turtle</td>
<td>90% decline</td>
<td>Declining, no sighting</td>
</tr>
<tr>
<td><em>Lepidochelys olivacea</em></td>
<td>Olive Ridley turtle</td>
<td>90% decline</td>
<td>Declining, no sighting</td>
</tr>
<tr>
<td><strong>Dermochelyidae Family</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Dermochelys coriacea</em></td>
<td>Leatherback turtle</td>
<td>99% decline</td>
<td>Declining, only 02 turtles sighted</td>
</tr>
</tbody>
</table>
Table 3. The number of nesting turtles in Vietnam

<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
<th>Before 2002</th>
<th>2001-2010</th>
<th>2011-2015</th>
<th>2016-2020*</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bái Tử Long (Quảng Ninh)</td>
<td>15</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cô Tô (Quảng Ninh)</td>
<td>-</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Trần Island (Quảng Ninh)</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Quảng Trị coastline</td>
<td>10</td>
<td>10</td>
<td>2*</td>
<td>0</td>
<td>1 leatherback turtle</td>
</tr>
<tr>
<td>5</td>
<td>Sơn Trà Peninsula (Đà Nẵng)</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>The main nesting ground of Olive Ridley turtles. Currently no nesting turtles have been recorded.</td>
</tr>
<tr>
<td>6</td>
<td>Cù Lao Chàm (Quảng Nam)</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0*</td>
<td>Relocating Green turtles’ eggs from Côn Đảo to Bãi Bắc</td>
</tr>
<tr>
<td>7</td>
<td>Hòn Khô – Hải Giang* (Bình Định)</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>-</td>
<td>This area has been handed over to the business sector to carry out tourism services, hence the lack of information</td>
</tr>
<tr>
<td>8</td>
<td>Nha Trang Bay (Khánh Hòa)</td>
<td>10</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Cam Lắm (Khánh Hòa)</td>
<td>-</td>
<td>2</td>
<td>2*</td>
<td>0</td>
<td>1 Leatherback turtle</td>
</tr>
<tr>
<td>10</td>
<td>Núi Chúa (Ninh Thuận)*</td>
<td>5</td>
<td>8</td>
<td>8</td>
<td>5 (2-8)</td>
<td>Estimation was based on the number of nests</td>
</tr>
<tr>
<td>11</td>
<td>Hòn Cau (Bình Thuận)*</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>3 (0-5)</td>
<td>Estimation was based on the number of nests</td>
</tr>
<tr>
<td>12</td>
<td>Phú Quý (Bình Thuận)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>Recently discovered a nest in 2020</td>
</tr>
<tr>
<td>13</td>
<td>Côn Đảo (BR-VT)</td>
<td>217</td>
<td>282</td>
<td>523</td>
<td>616</td>
<td>* by September, 2020</td>
</tr>
<tr>
<td>14</td>
<td>Thọ Chu (Kiên Giang)</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>Sighting at Cao Cát Island’s beach, Green turtle</td>
</tr>
<tr>
<td>15</td>
<td>Phú Quốc (Kiên Giang)</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>295</td>
<td>328</td>
<td>551</td>
<td>626</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1. The distribution of main marine turtle nesting grounds in Vietnam (red: Green turtle rookeries, blue: Leatherback turtle rookeries; Gray: historical rookeries)
1.1.1. **Green turtle (Chelonia mydas)**

This is the most commonly found species of marine turtles in Vietnam’s waters, including both feeding and nesting populations. According to interviews and field surveys, all surveyed provinces used to have Green turtles nesting and feeding in their coastal waters. Currently (from 2016 to 2020), the number of Green turtles nesting on the beaches of all coastal areas is 620 turtles/year (varying from 420 to 820 turtles/year), accounting for 99% of the total number of nesting turtles in Vietnam (Figure 2).

![Figure 2. Estimated number of nesting Green turtles in Côn Đảo annually](image)

According to the estimation by Hamann (2006), the number of Green turtles spawning in Vietnam during the 1960s was approximately 1000 individuals per year. By 2002, this number decreased to about 270 individuals per year, and was mostly found in the nesting grounds in Côn Đảo, several islands in the Gulf of Tonkin, the central provinces from Đà Nẵng to Ninh Thuận and some islands in the Gulf of Thailand (Hamann et al., 2006). By 2010, the number of mother turtles spawning on the beaches in Con Dao alone was about 400 individuals and tended to continue to increase to more than 600 individuals. Thus, the number of spawning Green turtles in Vietnam has increased by more than 50% compared to that of 2002.
However, the number of nesting grounds has significantly decreased compared to the past. Before the end of 1960s, Green turtles were found to nest in almost all beaches and islands. By 2015, the number of nesting grounds dropped to only 9 sites. At the moment, Green turtles only nested in 7 sites, including (1) Cô Tô Island, (2) Trần Island – Quảng Ninh; (3) Núi Chúa – Ninh Thuận, (4) Hòn Cau, (5) Phú Quỹ* - Bình Thuận; (6) Côn Đảo - Bà Rịa - Vũng Tàu, (7) Thổ Chu Island - Kiên Giang (Figure 1), among which Phú Quỹ Island, after many years of zero nesting turtle sighting, has recently reported 01 new nesting Green turtle. This is a very encouraging sign, as it shows the possibility of marine turtles returning to historical nesting grounds if they are protected for a substantial period of time.

Among the current nesting grounds, Côn Đảo (Bà Rịa - Vũng Tàu Province) has the most nesting Green turtles, with an annual number of nesting turtles of 623.8 ± 159.7 per year (varying from 390 to 818) across 14 sites. Among these 14 sites in Côn Đảo, five are monitored nightly during nesting season (Hòn Tài, Bãi Dương, Cát Lớn, Hòn Cau and Hòn Tre). These five sites account for 80% of the total nesting population during the nesting season. Cát Lớn Beach (of Bảy Cạnh Island) has the highest number of female turtles and nests with an average of 671.7 ±113 nests/season (accounting for 59%), followed by Hòn Tre with 153±23.4 nests/season (13%), Bãi Dương with 138.7±26.6 (9%), and finally Hòn Tài with 82.7±41.3 (8%).

Núi Chúa National Park (Ninh Thuận Province) has the second highest number of nesting Green turtles. However, it is a relatively low number - an average of 16 nests/season (from 9 to 24 nests/season) in three main beaches (Bãi Thịt, Bãi Dài, and Móng Tay Beach). Hòn Cau (Bình Thuận) has the third highest number of nesting Green turtles, with an average of 10 nests/season (from 6 to 15 nests per season, except for 2019 when there was no nest). In the North, Green turtles are still found to nest in Cô Tô (Thanh Lân Island) and Trần Nhạn Island at an irregular rate, ranging from 2 to 5 turtles per nesting season, which is significantly lower compared to the past (100 turtles/season) (Hamann et al., 2006).
Figure 3. Average percentage of Green turtle nests on nesting grounds in Côn Đảo
Figure 4. The number of Green turtle nests, eggs & hatchlings on nesting grounds under monitoring & protection in Côn Đảo, Núi Chúa & Hòn Cau.
1.1.2. **Hawksbill turtle (Eretmochelys imbricata)**

Hawksbill turtles are among the most common turtle species in Vietnam. Before 2000, they nested on sandy beaches of coastal and offshore islands such as Cát Bà (Hải Phòng), Quan Lạn, Nứt Đất (Quảng Ninh), Côn Đảo (Bà Rịa – Vũng Tàu)... On Ông Đụng Beach of Côn Đảo, around 03 female turtles and 10 nests are found annually. Similarly, nesting Hawksbill turtle are found to nest in some sandy beaches of small islands in Cát Bà. Hawksbill hatchings are even raised in small bays as supply for shell export. However, due to various reasons including overexploitation, there has been a significant decline in Hawksbill turtle population in Vietnam - a decline so devastating that it pushes the species to a near-extinction status (Hamann et al. 2006). In the monitoring period from 2016 to 2020, we did not record a single nesting turtle on the beaches. According to the interviews conducted, areas like Côn Đảo and Cát Bà have been completely void of nesting turtles since 2000s (Table 2). Despite sightings in Hòn Cau (01 nest in 2015) and Núi Chúa (01 nest in 2019), the lack of Figures of the hatchings and information on the sizes of the female turtles as well the sizes and number of the eggs means that there was no sufficient evidence to confirm that the reported turtles were Hawksbill turtles.

1.1.3. **Leatherback turtle (Dermochelys coriacea)**

In Vietnamese culture, or more specifically Vietnamese fishermen's culture, the Leatherback turtle is a sacred animal. It is associated with the sea gods and is believed to bring good luck to fishermen at sea. Therefore, fishing communities completely eschew the practice of catching, killing or eating sea turtles. However, in reality, the Hawksbill turtle population has significantly declined and is now close to extinction in Vietnam. According to Hamann's report (2006), in the 1960s, the total number of leatherback turtles nesting across all of Vietnam's waters is 500 turtles per year. By 2002, this number had decreased to 10 turtles per year. From 2008 to 2013, we recorded only one leatherback turtle nesting in Cát Dài Beach in Cam Lâm District (Khánh Hòa Province) in 2013 and one in Triệu Lằng (Quảng Trị) in 2010. In other provinces that used to have Leatherback turtles nesting on their beaches like Quảng Ngãi, Bình Định, Phú Yên, ect., there has not been any evidence that indicates the presence of nesting Leatherback turtles. (Table 2)
1.1.4. Olive Ridley turtle (*Lepidochelys olivacea*)

Olive Ridley turtle used to be very commonly found on Vietnam's beaches a few decades ago. However, this is another species that is overexploited as a food source. By 2002, the number of Olive Ridley turtles decreased to 40 turtles per nesting season. The only areas where nesting Olive Ridley turtles could be found were Quan Lạn Island (Quảng Ninh) and Sơn Trà Peninsula (Đà Nẵng) (Hamann et al. 2006). At the present, there is not a single trace of Olive Ridley turtles in Sơn Trà Peninsula, especially after the construction of the new road that runs along the peninsula and a series of resorts and hotels on the main sandy beaches of the peninsula such as Nam Beach and Tre Beach. Olive Ridley turtles can only be found on beaches with no human presence such as Nứt Đất Island (Quảng Ninh) and the beach of Núi Chúa National Park. However, the number of turtles found there is very small and unverified. (Table 2).

1.2. Feeding marine turtle populations

Vietnam is a maritime country with a variety of marine ecosystems that are ideal feeding grounds and living habitats for marine turtles, such as seagrass, coral reef, rocky reef, and bays. As of now, 05 marine turtle species have been confirmed to live and feed along Vietnam's coastal waters and offshore islands. Marine turtles that are found to have feeding grounds in Vietnam include: Green turtle (*Chelonia mydas*), Hawksbill turtle (*Eretmochelys imbricata*), Olive Ridley turtle (*Lepidochelys olivacea*), Loggerhead turtle (*Caretta caretta*) and Leatherback turtle (*Dermochelys coriacea*). There is yet a quantitative research on the population of each species that live and feed in Vietnam's waters. However, through the interviews conducted with fishermen working in coastal and offshore waters, it can be established that the aforementioned marine turtles are still found in Vietnam, albeit with significantly smaller populations compared to before 2002. Among the five species, Green turtles have the biggest population and are found in all surveyed provinces, followed by Hawksbill turtles and Olive Ridley turtles, with Loggerhead turtles and Leatherback turtles having the smallest populations. As the only herbivorous marine turtle species, Green turtles are found in shallow waters that have seagrass beds of offshore islands such as Phú Quý (Bình Thuận), Phú Quốc Island (Kiên Giang), Côn Đảo (Bà Rịa - Vũng Tàu), Hoàng Sa (Đà Nẵng), Trường Sa (Khánh Hòa), and Bạch Long Vĩ (Hải Phòng). In addition, Green turtles are also found to feed in coastal
areas, specifically coastal lagoons such as Tam Giang – Cầu Hai or Thủy Triều. Surveys conducted by the Institute of Marine Environment and Resources from 2016 to 2019 in the provinces of Quảng Ninh, Hải Phòng, Quảng Bình, Thừa Thiên Huế, Quảng Nam, Kiên Giang and Côn Đảo (Bà Rịa – Vũng Tàu) showed similar results. Once again, Green turtles are still the species with the highest population and are found in all surveyed locations, followed by Hawksbill turtles and Olive Ridley turtles, which are often found in geological and coral reefs in the Gulf of Tokin - from Quảng Ninh to Thanh Hóa, in the Central - from Quảng Trị to Bình Thuận, and in the Gulf of Thailand. Loggerhead turtles have also been found, but only in the coastal areas of Nghệ An and Bình Thuận and in small number and with irregular frequency. Leatherback turtles are very rarely seen in shallow coastal waters. They are mostly found in deep offshore waters and there has been a very small number of them sighted (very infrequently sighted, only a few times per year) (Figure 5).

Researches that monitor the migration patterns of Green turtles after their nesting in Côn Đảo, Hongkong, Thailand, and the Philippines affirmed this finding. According to data from Côn Đảo National Park, after nesting, female Green turtles migrate to their feeding grounds in Pahang (Malaysia), Palawan (Philippines), Nautuna (Indonesia), Phú Quý, and Trường Sa (Giang, 2010). In addition, Green turtles that nest in Lamma Island (Hongkong) and Ko Khram Island (Thailand) return to their feeding grounds in Bạch Long Vĩ (Hải Phòng) (Agriculture, 2006) and Côn Đảo (Bà Rịa – Vũng Tàu) (Charuchinda, Sakamoto, Arai, & Monanansup, 2002) (Figure 6).
Figure 5. Feeding grounds of marine turtles in the coastal waters and nearshore islands
(red: green turtles, blue: hawksbill turtle, yellow: Olive Ridley turtle, green: loggerhead turtle)
Figure 6. Green turtle’s migration patterns in Vietnam
(green line: foraging routes, cyan line: nesting routes)
2. BIOLOGICAL CHARACTERISTICS OF MARINE TURTLE POPULATIONS

2.1. Marine turtle foraging populations

In order to calculate the nesting season of marine turtles in Vietnam, there needs to be substantial statistics on the number of nesting female turtles and nests. However, as stated in Section 1.1, currently only the data on the Green turtle population in Côn Đảo is enough sufficient for calculation. Therefore, marine turtle nesting season in Vietnam is entirely based on the data on nesting Green turtles on Côn Đảo’s sand beaches. Green turtles often emerge and crawl to those beaches to lay eggs at the beginning of the rainy season (the end of March), when the sand is moist and firm enough for the turtles to construct their nests. Thereafter, the number of Green turtles nesting and the number of nests gradually increase, and by July they hit their peak (27% of the total nests of the whole season) and then gradually decline until the season ends at the end of November (Figure 7). The peak nesting period of female Green turtles is from June to September, accounting for 83.12% of the total number of nests in a year.

In other areas such as Núi Chúa (Ninh Thuận), Minh Châu, Thanh Lân (Quảng Ninh), Cù Lao Cau (Bình Thuận), etc., Green turtles nest erratically through May to October. Leatherback turtles nesting in Cam Lâm (Khánh Hòa) also start their nesting from late June. Therefore, it can be concluded that the nesting season of marine turtles in Vietnam starts in March and ends in November annually. Peak nesting periods when a high number of marine turtles emerge to nest coincide with months with high rainfall and vice versa.

![Figure 7. Marine turtle nesting season in Vietnam](image-url)
2.2. Female turtle size and nest construction time

The monitoring of female Green turtles emerging to construct nests and lay eggs on the 05 main nesting grounds during the nesting seasons of 2010, 2011, and 2012 showed that the Curved Carapace Lengths (CCL) of female Green turtles did not vary much between nesting seasons. The average CCL of female Green turtles is 97.69±5.19 cm (68-125cm, n=3189). The average CCL range is 97.04±5.18 cm (69-117cm, n = 1340) in 2010, 97.35±5.50 cm (78-120cm, n=792) in 2011 and 98.78±4.77 cm (68-125 cm, n = 1058) in 2012. Female Green turtles that have a CCL in the range from 90 to 100 cm make up 90.5% of the total number of nesting Green turtles in Côn Đảo (Figure 7). In comparison to some other Green turtles populations such as those in Chagar Hutang, Malaysia (100.3 cm, 98.9 - 100.9 cm) (Chan, 2013), Baguan, Philippines (99.5 cm) (Trono, 1991), Ras Baridi, Saudi Arabia (104.7±5.3cm, 89-118 cm), the Persian Gulf (98.2±4.56 cm, 73-114 cm) (Al-Merghani, Miller, Pilcher, & Al-Mansi, 2000), female Green turtles in Côn Đảo have a similar size range.

Female Green turtles crawl up the beaches to start nesting at 18:00 and finish nesting at 6:00 the next morning. The peak nesting period is from 02:00 to 06:00 (39.6%), followed by 18:00 to 22:00 (33.59%), with 22:00 to 02:00 being the least active nesting period (25.8%). Female Green turtles often choose to emerge during the peak of the tidal range and rarely appear during low tides. This helps the female turtle to minimize the trip from the water to the nesting location. The time window that the female turtles choose to nest is also the best for minimizing the risk of being interrupted by other animals. During the nest construction and egg laying process. One nesting attempt of the Green turtle (including constructing the nest and laying and burying the eggs) lasts 117.2 ± 55.5 (minutes) (60 minutes – 185 minutes, n=1822).
2.3. The number and size of eggs

The average number of eggs in one Green turtle nest in Côn Đảo is 98.02 ± 26.65 eggs/nest (40-195 eggs/nest, n = 2765). More specifically, nests with clutch size from 80 to 100 eggs make up the largest percentage (29.67%), followed by clutch size from 100 to 120 eggs (24.65%) and clutch size from 120 to 140 eggs (12%), with clutch size over 180 eggs constituting the smallest percentage (0.7%).

Green turtle nests in Côn Đảo have an average depth (from surface to the bottom of clutch) of 71.57 ± 7.5 cm (40-90 cm, n = 1096) and an average depth (from surface to the top of clutch) of 46.32 ± 8.5 cm (20 – 68 cm, n = 1096).

Green turtle eggs have an average weight of 39.1 ± 4.1 g (27.5 – 49.6 g, n = 999) and an average diameter of 41.5 ± 1.9 mm (21.5 – 50.0 mm, n = 999). In comparison to the egg size and weight of other Green turtle populations such as those in the French Frigate Shoals (46.1±1.6mm, 44.9±0.7g) (Hirth, 1980); in Sabah, Malaysia (45.0±4.8mm, 41.3±3g) (Pilcher, 2000); in Ras Baridi, Arab Saudi (46.3±7.4mm, 42.7±2.6g) (Al-Merghani et al., 2000); or in Rekawa, Southern Sri Lanka (42.8±3.93mm, 42.5±1.74g) (Lalith Ekanayake, Ranawana, Kapurusinghe, Premakumara, & Saman, 2002), the egg size and weight of Côn Đảo Green turtles is on the smaller side. This is possibly due to the food sources and migration distance from feeding to nesting grounds of the female turtles. The diameter and weight of the eggs in Côn Đảo has a linear relationship with
each other (Weight = 0.33 x Diameter + 28.55, R^2 = 0.6). The larger the egg, the heavier it is, and vice versa.

2.4. Incubation time and hatching success rate

The average incubation duration of Green turtles, which is estimated based on three nesting seasons of 2010, 2011, and 2012, is 54.62 ± 5.2 days (shortest at 41 days and longest at 79 days, n = 3049). More specifically, nests with an incubation time from 51 to 55 days make up the highest percentage at 42%, followed by nests with an incubation time from 56 to 60 days (22%) and from 46 to 50 days (21%). Nests with incubation duration shorter than 45 days or longer than 70 days make up a very small percentage at under 1% (Figure 9). 2010 has the longest average incubation time at 55.6 days, while 2012 has the shortest duration at 53.94 days. Comparisons between the years demonstrates that the differences between the yearly average incubation time is of statistical significance (analyzed with ANOVA and verified with Tukey's HSD test). There is also no difference in incubation time between different months of a year (ANOVA: F = 415.0, p < 0.001, df = 2 and verified by Tukey's HSD). Similarly, there are differences between the monthly average incubation times (ANOVA: F = 31.0, p < 0.001, df = 6). Re-testing the data with Tukey's HSD shows that the incubation time of June and July is similar to each other and significantly longer than that of the remaining months (p<0.001 in all cases).
During the peak nesting period of marine turtles (from July to August, accounting for 83.12\% of all nests during a nesting season), the average incubation time is 55.33 ± 5.3 days (n=2181), which is longer than average incubation time from March to May (53.0± 5.6 days, n = 463) and from September to November (53.34 ± 5.18 days, n = 393).

The hatching success rate in Côn Đảo is very high. According to statistics collected during the three nesting seasons of 2010, 2011 and 2012, the hatching success rate is 80.38 ± 9.6\% (0\% - 100\%), in which 54.2\% of the nests have an hatching success rate above 80\%, 43.3\% have an hatching success rate from 60 to 79\%, and only 2.5\% under 60\%. In all three aforementioned nesting seasons, there was only one nest where all eggs were unfertilized. 2010 was the year with the lowest hatching rate, with 77.86 ± 11.2\% of the eggs successfully hatched. This was lower than the rate in 2011 (80.05 ± 10.9\%) and 2012 (84.9 ± 11.21\%) (ANOVA: F = 115,74, p = 0,000, df = 2, n = 3028). Hatching rate is at the lowest from June to August at 80,18 ± 8,6 \%, followed by the rate during the March - May period at 80.8 ± 8.9\%, and the highest hatching rate occurs during the September - November period (81.85 ± 8.3\%) (ANOVA: F= 6,94, p = 0,0001, df = 2, n = 3028). However, comparison using Tukey’s test shows that only the difference between the September - November period and the June - August period is statistically significant (p = 0.002)

![Figure 10. Female sex ratio by incubation days](image)
2.5. Incubation temperature and hatchling sex ratio

During the survey period, the average incubation temperature in Côn Đảo is 30.54 ± 0.86 °C, with the lowest incubation temperature being 28.84 °C and the highest 32.03 °C. The incubation process of marine turtles can be split into three stages. Stage 1 started from the moment eggs are buried in the sand until the first one third of the incubation process (1). Stage 2 is the middle one third of the incubation process. This is a particularly important stage as the sex of a marine turtle hatchling is determined by the temperature of this stage (Georges, Limpus, & Stoutjesdijk, 1994; Miller & Limpus, 1981; Yntema & Mrosovsky, 1982). The nests studied for this research are all similar in that: the temperature during the first one third of the process (1) is lower or similar to the sand temperature, then gradually increases during the middle one third (2) until it is significantly higher than the sand temperature during the last one third (3). When the eggs hatch and the hatchlings are about to emerge, the incubation temperature suddenly drops until it reaches a temperature closed to the sand's temperature (Booth, 2006). The temperature during the middle one third (2) (the sex determination stage) of all studied nests is higher than the temperature of the sand, with an average difference of 0.8 ± 0.3 (0.2 – 1.8°C). Meanwhile, the final one third stage (3) was 1.2 to 2.9°C higher than the sand temperature (averaging at 2.3±0.4 °C) due to the heat generated during the embryo development (Error! Reference source not found.). Therefore, the heat generated by the nest has to be taken into consideration when calculating hatchling sex ratio based on the sand temperature. Clutches that are relocated to a hatchery have an average temperature of 31.35 ± 0.14 °C, which is 1.32°C higher than the temperature of clutches that stay in their naturally selected positions on the beach (30.03 ± 0.145 °C). This is due to the fact that vegetation provides shade in most of the natural sandy beaches of Bảy Cạnh Island (90% of the area is shaded). Meanwhile, the hatcheries are completely exposed to the sun. Incubation temperature has a strong inverse correlation with the hatching time (R² = 0.78) and the incubation time (R² = 0.79). This difference in temperature leads to differences in the incubation duration. Clutches in the natural environment have an average incubation time (from when the eggs are laid to when the hatchlings leave the nest) of 59.44 ± 0.63 days, which is 5.6 days longer than clutches relocated to the hatcheries (53.87 ± 0.70 days) (analyzed with ANOVA: F (1, 39) = 64,544, p = 0.0006). Similarly, natural clutches have an average hatching time of 55.84 ± 0.44 days, which is higher than that of the
clutches relocated to the hatcheries (49.94 ± 0.56 days) (ANOVA: F(1.39) = 67.53; p = 0.001). This means the higher the temperature, the shorter the incubation and hatching time.

After hatching, the hatchlings remain in their nest cavity until all of them are ready to emerge from the nest. This waiting period of hatchlings in Côn Đảo lasts 3.73 ± 0.17 days on average (ranging from 2 to 6 days, with 65% of the nests wait for 3 to 4 days). The waiting period of the hatchlings is highly dependent on rainfall. Nests that hatch during rainy days have a longer waiting period compared to those that don't. This phenomenon happens because after rain, the sand surface will shrink and become firmer and more compact, which makes it harder for the hatchlings to dig out of their nests. Similarly, hot days mean shorter waiting period for the hatchlings as the sand surface becomes easier to dig out of. The waiting period (from when the eggs hatch to when the hatchlings leave their nest) for natural nests is 3.60 ± 0.22 days shorter than that of nests relocated to hatcheries (3.9 ± 0.28 days). However, this is not a statistically significant difference (analyzed by ANOVA: F (1, 39) = 0.85, p = 0.36).

![Sand temperature and some typical clutch examples](image)

**Figure 11. Sand temperature and some typical clutch examples**

The sex of marine turtles is determined by the incubation temperature during the middle one third stage (Error! Reference source not found.); therefore, we can
calculate the sex ratio of Green turtle hatchlings of the studied nests based on this temperature and formula (1). The percentage of female hatchlings in this study is estimated to be 68.08 ± 25.37 % (ranging from 16.25% to 100%). Among the 41 nests studied in the research, 19 of them had a sex ratio of 80% - 100% female (making up 46.3% of all nests). 12 nests had a sex ratio of 61% - 80% female (29%), while 8 nests had 51% - 80% female (19.5%). In the 41% to 60% range, there was 6 nests (14.7%), and in the under 40% range, there was 8 nests (19.5%). The nests in the hatcheries had a very highly female-skewed sex ratio, with an overall ratio of 83.15 ± 5.63 female (%), while this ratio in natural nests is 58.43 ± 4.50 (%). This is a statistically significant difference (ANOVA: F (1,39)=11.753, p = 0.00145). According to researches on sex ratio of juvenile sea turtles in other populations such as those in Akyaka (Turkey), the Mediterranean Sea, and Suriname, the sex ratio is about 60% female (Broderick, Godley, Reece, & Downie, 2000; Casale, Gerosa, & Yerli, 2000; Godfrey & Mrosovsky, 2006). The female percentage in the wild, including mature and juvenile turtles, is also about 60% (Bolten, Bjorndal, Grumbles, & Owens, 1992; Katselidis, Schofield, Stamou, Dimopoulos, & Pantis, 2012). The incubation temperature in the second stage also inversely correlates with the incubation time, but not as strongly as the correlation between incubation time and overall incubation temperature. However, data taken from incubation time monitoring can be used to estimate the incubation temperature during the second stage and subsequently the overall sex ratio of the entire nesting season.

\[ \text{Stage 2 temperature} = 3,998 - 1,750 \times \text{Incubation time} \]

With this formula and the data on incubation time of the three nesting seasons in Côn Đảo (2010, 2011, and 2012), it can be estimated that the sex ratio is, respectively, 93.3% female (2010), 93.1% female (2010), and 90.4% female (2012). Therefore, the overall sex ratio of hatchlings born in hatcheries is significantly more female-biased than that in natural environment. This is partially due to the fact that a large portion of nests in main nesting grounds like Bây Cạnh, Hòn Cau and Hòn Tre were moved to hatcheries where the temperatures are higher than the natural nesting grounds. If the relocation of nests to hatcheries continues without a system of shading structure in place to reduce heat, hatchlings born in such hatcheries will be female, creating a serious sex imbalance compared to the natural ratio.
2.6. Hatchling characteristics

Basic data on Green turtle hatchlings in Côn Đảo is presented in (Table 4). The average weight of Côn Đảo hatchlings is quite low compared to those of other areas, such as Sabah, Malaysia (21.53 ± 2.1g), Arab Saudi (22.3 ± 2.15 g). Similarly, the carapace length of Green turtle hatchlings here is shorter than those of other areas (46.45 ± 1.84 mm in comparison with 46.61 ± 1.65 mm in Sabah and 47.7 ± 1.78 mm in Ras Baridi, Arab Saudi). This will somewhat affect the survival rate of hatchlings in the first stage of their life cycle, as they have to crawl across the beach and swim across the coral reef in shallow water where there are many of their predators live. During this initial stage, the mortality rate of marine turtle hatchlings is at its lowest at 40% to 60% of the total number of hatchlings, as their predators have the tendency to go for weaker and smaller ones (Gyuris, 1994).

Table 4. Basic data on Green turtle hatchlings (Chelonia mydas)

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Average</th>
<th>SD</th>
<th>Lowest</th>
<th>Highest</th>
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<tr>
<td>Weight (g)</td>
<td>21.01</td>
<td>1.96</td>
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<td>Carapace length (mm)</td>
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<td>1.68</td>
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<tr>
<td>Front leg length (mm)</td>
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<td>0.34</td>
</tr>
</tbody>
</table>

Notes: * indicating area measurement

2.7. Hatchling running speed

The average running speed of Green turtle hatchlings in Côn Đảo is 0.187 ± 0.046 m/s (0.09 – 0.33; n = 840). The linear regression analysis between running speed and weight of hatchlings shows that the two variables have a positive correlation (F = 65.95,
df = 1.807, p = 0.0013, n = 840) albeit weak one (R^2 < 0.1). Green turtle hatchlings in Côn Đảo have a greater running speed than their counterparts in Terengganu (Malaysia)(van der Merwe, Ibrahim, & Whittier, 2006). This is very meaningful to conservation efforts, as the faster hatchlings can run on sand, the higher their chances of evading predators such as crabs and birds will be. However, it must be noted that a hatchling's running speed depends a lot on their retention time. In nature, after emerging from their nests, hatchlings will immediately orient themselves and dash towards the sea. They will swim continuously for 48 to 72 hours (frenzy period), using the energy reserve stored in their bodies. If retained, the hatchlings will be slowed down in both their running and swimming speed and suffer weight loss (due to water loss and spending their energy reserve) (Pilcher & Enderby, 2001; van de Merwe, Ibrahim, & Whittier, 2013). Therefore, it’s important to consider the retention time and the number of retained hatchlings when hatchling retention is done for eco-tourism activities in certain marine turtle nesting grounds.

3. CAUSES OF POPULATION DECLINE AND THREATS TO MARINE TURTLES

Marine turtles have a long lifespan (60 to 100 years) and very complex life cycle, with each stage requiring a different habitat such as sand beach, seagrass bed, coral reef, rocky reef, or deep water. Despite a high number of nests and eggs per nest, the mortality rate during the hatchling stage is very high (up to 60%) (Pilcher, Enderby, Stringell, & Bateman, 2000), meaning only an estimated one in 1000 hatchlings will survive to adulthood (Heppell, Limpus, Crouse, Frazer, & Crowder, 1996). Therefore, if mature turtles go extinct and their eggs are all captured, the marine turtle population will be destroyed within a few decades. In Vietnam, marine turtles were just included in harvesting ban list in the 90s, and currently marine turtle conservation in many areas is still facing several limitations. This has contributed to the decline in Vietnam's marine turtle populations, with loss in both the number of species and the population of each species. The main causes that lead to this situation is listed as follows:

3.1. Marine turtle bycatch

According to the beliefs and customs of most fishermen communities, especially those in the Central and Northern provinces, marine turtles are sacred animals. Before, when coming across marine turtles or finding turtles trapped in fishing nets, fishermen
often released them back to the sea. Marine turtles are not an intended harvesting target, but often the collateral bycatch that gets caught in nets and died. Activities that kill the most marine turtles are (1) dragnet fishing, (2) seine fishing, and (3) offshore tuna fishing (Hamann et al., 2006). Dragnet fishing often happens in shallow coastal waters, especially in seagrass beds, while seine fishing and offshore tuna fishing often occur in offshore deep waters.

Surveys conducted with fishing vessels engaging in dragnet fishing, gillnetting, and offshore tuna fishing in 05 provinces of Quảng Trị, Phú Yên, Bình Thuận, Bà Rịa - Vũng Tàu and Kiên Giang by the Research Institute for Marine Fisheries (2018) showed that marine turtles’ feeding grounds often overlapped with the fishing grounds of these activities. Among the 05 surveyed locations, Phú Yên was the province with the highest rate of turtle bycatch by fishing vessels with 59.0% of the surveyed vessels, followed by Bà Rịa - Vũng Tàu with 48.8%, Quảng Trị with 40.0%, and Bình Thuận with 36.3%. Kiên Giang was the province with the lowest rate as only 16.3% of the fishing vessels incidentally captured marine turtles during their fishing process. Offshore fishing is the activity with the highest rate of turtle bycatch, with 86.0% of all vessels engaging in this activity had incidentally captured marine turtles, most of which were offshore tuna fishing vessels in Phú Yên. Dragnet fishing had the second highest rate of bycatch at 39.3%. Gillnetting had a quite relatively low bycatch rate, with 31% of all surveyed gillnetting vessels responded affirmatively to whether they had experienced bycatch problems. With gillnetting, most of the marine turtle bycatch is pulled along with the net, while a small number of turtles get caught in the net and die from drowning. Currently, fishermen that operate gillnetting offshore in the Central and Southeast regions largely use nylon nets with $2a=100\text{mm}$ mesh size, making it incredibly difficult for caught turtles to escape. The average length of a gillnet is about 40 km, which is casted about 5 to 10 m under the water surface. Therefore, gillnetting has an incredibly extensive fishing range. However, as the main target of gillnetting is Skipjack tuna ($Katsuwonus pelamis$), a gillnet is often vertically operated within the 40-0m water level. This affects marine turtles when they surface for air and occasionally to hunt for food. According to interviews with fishermen and sea inspections conducted by the Research Institute for Marine Fisheries, marine turtles that got caught in trawl nets were of varying sizes. Certain turtles caught in the net died (due to oxygen depletion) while some stayed alive (a small number were released
back to the sea, but most of them were used as food or sold to merchants). Current sensitivity analysis of the effect of gillnetting on marine turtles in Vietnam rates the situation at a medium level. However, marine turtle bycatch often coincides with the mating and nesting season (from February to August), especially during February and March. Killing and eating turtles that are incidentally captured is still quite common, which shows that a low awareness of marine turtle protection among fishermen, many of whom do not even know that killing and harvesting marine turtles is illegal (Thành, Toàn, Thu, & Liêm, 2019). A survey on harvesting and trading turtles in Vietnam by TRAFFIC in 2019 showed a similar result. 100% of the fishing vessels interviewed did not intentionally harvest marine turtles due to the outlawing of marine turtle harvesting and widespread beliefs that marine turtles are sacred animals among fishermen, especially those from Central and Northern provinces. According to interviews with owners of fishing vessels in Kiên Giang, Bà Rịa - Vũng Tàu, Khánh Hòa, and Đà Nẵng, 100% of the interviewees said that in the last 3 years they found/saw marine turtles during their fishing activities, and 90% said that turtle bycatch happened during their fishing activities. In addition, when asked about whether they saw or knew of other fishing vessels capturing marine turtles, 100% respondents answered affirmatively. The marine turtles that are often spotted during harvesting are Green turtles, Hawksbill turtles, and Olive Ridley turtles. Leatherback turtles and Loggerheads have not been spotted during harvesting. The most commonly found in bycatch are Green turtles at 75%, followed by Hawksbill turtles at 41%, with Olive Ridley turtles coming last at 2%. With a total of 95,847 vessels that engage in fishing and logistics service in Vietnam (2018 data), which are capable of turtle bycatch, it can be said that the number of incidentally captured turtles is not insignificant at all.

Offshore tuna fishing is a harvesting activity affecting marine turtles recognized by many researches in the world (WWF, 2004). During the 2006-2008 period, WWF collaborated with the Research Institute for Marine Fisheries to implement Component “Raising awareness and identifying management solutions to reduce marine turtle bycatch during marine harvesting in Vietnam” During 14 field surveys on tuna fishing vessels in Trường Sa area and Tư Chính Beach conducted by the Research Institute, 8 incidentally captured turtles were found, including 04 Olive Ridley turtles, 02 Hawksbill turtles, 01 Green turtle, and 01 Leatherback turtle (sản, 2008). The total number of tuna
fishing vessels in Vietnam is about 5998 (Bộ & Minh, 2013), concentrated mostly in provinces like Đà Nẵng, Quảng Nam, Quảng Ngãi, Bình Định, Phú Yên, Khánh Hòa, Vũng Tàu, Kiên Giang. Every fishing season, each vessel often takes 3 to 4 trips, putting the potential number of incidentally captured marine turtles in the thousands every year (WWF, 2019).

3.2. Illegal marine turtle consumption and trade and marine turtle derived products

For a long time, marine turtles were not protected in Vietnam and people living in coastal areas (especially those who are not part of a fishing community) considered marine turtles to be an important food source. According to interviews with local people, in the past, almost 100% of nesting female turtles and their eggs would be captured and killed for meat if spotted. Marine turtle meat would be consumed by the household or the village or sold to the market. Before 2000, marine turtles and marine turtle derived products were openly displayed in tourist destinations such as Phú Quốc, Nha Trang, Hồ Chí Minh City, etc. According to Traffic ASEAN’s report (2008) on fishermen harvesting turtle shells (from September 2001 to February 2002), there were 22,000 Hawksbill turtle products displayed nationwide. The survey also showed that large-scale organized international trade of Hawksbill turtle products was happening during this time. Hawksbill turtle products were transported via sea routes before exported in large quantities to other countries or sold to domestic/international tourists as souvenirs. However, large-scale wholesale trade and export of marine turtle derived products has ceased to exist. The retail market of such products has also considerably shrunk, and more specifically: The number of marine turtles derived products sold from 2002 to 2008 went down from 22,000 to 5,800. During the period from 2008 to 2012, authorities confiscated 1,336 kg of Hawksbill turtle shells, 900 kg of Green turtle shells, and tens of tons of dried marine turtles of various species, which were illegally imported into Vietnam through Hải Phòng Port, Sa Kỳ Port, Sài Gòn Port, Cát Lở Port, etc. In late 2014, the authorities founded three marine turtle processing facilities in Nha Trang (Khánh Hòa) along with 7,000 marine turtles weighting over 10 tons (6 tons of fresh turtles and 4.4 tons dried). These facilities bought turtles from the local fishermen at VND 200,000 to 800,000/turtle, before soaking them in formaldehyde and other chemical solutions to turn them into handicraft
products. The results of the Research Institute for Marine Fisheries’ quick survey in April 2015 showed that the main consumers were coastal tourist sites and souvenir shops in major city. In Hà Nội: Marine turtle products were stealthily sold at the old quarter and main shopping streets, such as Hàng Khay Street, which could be an important area for product distribution in the city. In Hồ Chí Minh City: Marine turtle products were sold in old colonial streets and main shopping areas. District 1 was an area with lots of trading activities, most of which were done with tourists. In addition, souvenir shops in Hạ Long (Quảng Ninh), Lý Sơn (Quảng Nam), Nha Trang (Khánh Hòa), Côn Đảo (Bà Rịa - Vũng Tàu), and Hà Tiên (Kiên Giang) still conducted secret transactions with a limited number of marine turtle products. Most of the Green turtles and Hawksbill turtles that get illegally captured and sold to create jewelries, handicraft products, and taxidermy.

Recently, thanks to campaigns aiming at raising people’s awareness and partly due to the declining marine turtle population, marine turtles are no longer openly captured or consumed. However, in certain provinces, female marine turtles and their eggs are still captured and collected illegally in areas that are not under protection. Even in Côn Đảo, the illegal harvest of marine turtle eggs to sell to tourists is still an ongoing problem. There are no longer any domestic shops or trading activities, as most of marine turtles are sold to foreign markets. It’s very difficult to determine the exact number of marine turtles that are killed each year and the consumption rate of such products as these activities are illegal in Vietnam. Additionally, there are other illegal trading activities, such as: (1) organized wholesale (and retail) trade of marine turtle products, (2) illegal import of turtle shells from foreign black markets, and (3) a considerable of turtle shell products have been sold to foreign traders in international waters.

3.3. Decline in area and quality of marine turtle nesting grounds

Beaches where nesting marine turtles are found often are often secluded beaches that are offshore or located far from areas with tourism development. However, there are already tourism developments in place or in planning for beaches in Sơn Trà Peninsula (Đà Nẵng City) and numerous beaches in Quan Lạn - Minh Châu (Quảng Ninh), Cam Lâm (Khánh Hòa), etc. If these developments are to take place, the nesting grounds of marine turtles will be threatened by various elements such as beach transformation, artificial light, noises, and an increase in visitors to the beaches. The reality is, after the
road that goes along Đà Nẵng Peninsula was completed and resorts popped up on the majority of the beaches there, Hawksbill turtles has nearly disappeared.

In addition to natural phenomena that cause beach erosion such as storm and wave, activities such as sand mining, tourism development, marine wastes, and overdevelopment are the main sources of negative impacts on marine turtles’ nesting grounds. Despite the lack of data on sand mining in Minh Châu Island and Quan Lạn Island (Quảng Ninh) or titanium mining in beaches in Quảng Trị and Bình Định or the nesting process of marine turtles, it is certain that if the sand mining operation is expanded to beaches where marine turtles still come to nest, it will affect the stability of those nesting grounds. Similarly, the currently expanding shrimp farming operation in Central provinces has considerably diminished the size of marine turtles’ nesting grounds for the upcoming season.

According to a quantitative research on the quantity and volume of waste on the beaches of 11 MPAs conducted by IUCN, GreenHub, WWF Việt Nam and the Management Boards of the 11 MPAs in 2019 and 2020, plastic waste is currently a huge problem for the environment in general and for the marine species in particular. The majority of the surveyed beaches has a pollution level ranging from medium to very high, including the beaches inside the MPAs and on offshore islands like Côn Đảo, Bạch Long Vĩ, Cù Lao Chàm, etc. This demonstrated an alarming state of environment quality found in beaches in our country. In addition, during fishing, fishing equipment are sometimes lost or thrown away (also known as “ghost net”). These are gillnets that get tangled on a rocky reef or coral reef and continue to kill marine turtles and other marine species that get caught in them. These nets can cause damages for decades after they were left at the bottom of the sea. While there is no adequate statistic yet, every year the total length of lost gillnets nationwide is potentially in the range of hundreds of kilometers. This can negatively affect turtle populations and other species when they accidentally eat these nets, get tangled in or injured by the nets, have the nets lodged in their digestive system, or have their feeding grounds and habitats diminished by these ghost nets. Waste (including nylon bags, broken nets, and other objects) does not only affect marine turtles but also threatens the health of marine ecosystem and relevant industries such as tourism and fishery. If these issues do not receive the necessary attention soon, valuable coastal
areas and marine ecosystems of Vietnam will be seriously threatened and suffer from irreversible damages.

Figure 12. The CCI (Coastal Clean Index) of surveyed coastal beaches
3.4. The degradation of marine turtle living habitats and feeding grounds

The development of coastal economy has brought about consequences in the form of waste, noise, and light pollution, which is generated by coastal economic activities and has ongoing impacts on the health of marine ecosystems... Coastal economic development has caused direct and indirect impacts on living habitats and feeding grounds of marine turtles in the ecosystems of coral reefs and seagrass beds found along coastline and islands (Figure 13). The majority of these areas are part of marine protected areas that have been designated in Decision 742/QD-Ttg dated 26 May 2010 by the Prime Minister. By the end of 2020, Vietnam had only established and put into operation 11 out of 16 planned marine protected areas, meaning 0.172% of all-natural marine area of Vietnam is under conservation in comparison to the target of 0.24%, of which less than 11% will be strictly protected area. The planning and expansion of marine protected areas is currently a huge challenge due to growing infrastructure projects and coastal economic development. Certain strictly protected zones of marine protected areas were even converted to service and administrative zones in order to 'make space' and 'create opportunity' for development projects of various scales. This has happened in Phú Quốc, Cát Bà, etc. and heavily impacted the ability to achieve the target of expanding marine and coastal protected areas to at least 6% of the natural marine area of the country stated in Resolution No. 36/NQ-TW dated October 22, 2018 of the 12th Party Central Committee on the Strategy of Sustainable Development of Vietnam's Marine Economy to 2030, Vision to 2045. In recent years, governmental bodies and international NGOs have focused serious efforts on preventing the use of destructive fishing methods and proposing appropriate directions for utilizing marine and coastal ecosystems. However, it requires a very extensive period of time for these ecosystems to be restored to their initial states. The degradation of corals and seagrass in Marine turtles' feeding grounds will diminish the quality of nesting as there won’t be enough energy resources for the next nesting cycle: The time between nesting seasons will increase and the number and quality of eggs and hatchlings will decrease.

Coral reefs in Vietnam were destroyed for a long time due to blast and cyanide fishing. Similarly, the seagrass beds and mangroves were overexploited for centuries and suffer from sediment deposition among various other issues. Cồ Tô marine area and Trần
Island (Quảng Ninh Province) is a strong example of the degradation of marine ecosystems. The coral ecosystem in the Cô Tô went from 70 hard coral species of 28 genera and 12 families in 1996 to 23 species in 2017. They are dispersed over a bed of dead corals; and cross-sectional layers that were included in survey showed very low number of species, ranging from 2 to 16 species each. From this data, we can see that this is currently the area with the lowest number of species in the Gulf of Tonkin when compared to similar areas such as Bái Tử Long, Hạ Long, Cát Bà, Long Châu, and Hòn Mê. Since 2010, corals in this area have nearly disappeared, with the seabed covered by long dead corals and a season-dependent algae bed. The live coral coverage (LCC) is under 5%. Areas where coral reef used to form include: The 4km long and nearly 1km wide coral reef of Hồng Vân Beach was considered to be the largest reef of the Gulf of Tonkin with 45% coral cover, but as of now, the entire reef is dead without any sign of recovery. This is also the current state of coral reefs of Nam Ngang beach (or Bưu Điện Beach), along Khe Trâu Island, in the East and North of Lưỡi Cày, along Đặng Văn Châu Island, and at the rocky shore in the Southeast of Cô Tô and Thanh Lân. The cause was determined to be the local fishermen’s long-term use of cyanide fishing. At the moment, Cô Tô islands have very few live corals left, which are sparsely dispersed near islands with rocky bottoms at the depth range of 1 to 8m. The result of coral reef survey shows that the current coral cover percentage in Cô Tô is only ranging from 0% to 10%.

Figure 13. Image of dead coral reef near Hồng Vân Beach, Cô Tô Islands
Figure 14. Dispersion of coral reefs in Cô Tơ Islands

For the Green turtle (*Chelonia mydas*), seagrass bed is a very important ecosystem. 14 seagrass species have been identified along Vietnam’s coastline, of which 8 are found in the Northern coastal waters (from Quảng Ninh to Thừa Thiên Huế) and 12 are found in the South (from Đà Nẵng to Kiên Giang) - two species fewer than before (2010). Seagrass is found over 155,000 ha of coastal waters. The Northern region has seen the most significant decline, with a 62% decline in seagrass area, while the Southeastern and Southwestern regions experience the smallest decline at respectively 13% and 2% (in comparison to 2010 density).
Kiên Lương Bay and Phú Quốc Island have the largest area of seagrass. 2018 survey results revealed that the total area of seagrass of these two locations is 10,000 ha. They remain the sites with the largest area and highest density of seagrass in Vietnam, and yet they still suffer from a 36% decline (compared to 2014). The largest area of seagrass recorded is found near Hòn Đập Island and Bãi Khem with a total area of 4000 ha - 1300 ha less than in 2004. The average seagrass cover is relatively quite high at 55.8%, which is higher than the cover percentage in 2004 (43.48%) (Nguyễn Văn Tiến, 2006). In Rạch Vjem, seagrass is observed to decline over time in term of area - from 900 ha before 2013 to 600 ha in 2018. Cover percentage in studied locations in Phú Quốc does not vary much from data in previous researches, except for Bãi Bổn, where seagrass cover is 75% to 100% and has been assessed as the location with the strongest seagrass growth in Phú Quốc. The average seagrass biomass is 6412.3 ± 1150.6 g of live seagrass/m². Biomass varies by species, with Narrowleaf seagrass *Halodule uninervis* having the lowest biomass at 2625 ± 423.67 g/m² and Tape seagrass *Enhalus acoroides* having the highest at 6261.067 ± 1469.0 g/m². Due to the high species diversity, the bud sizes also vary by species. The smallest bud size is found in *H. pinifolia* while the largest belongs to *E. acoroides* (Figure 15).

Figure 15. Figure of seagrass bed in Rạch Vjem (aerial view and underwater view)
Figure 16. Seagrass dispersion map in Phú Quốc
3.5. Temperature rises due to Climate change

Climate change (including global warming, rising sea level, and extreme weather conditions) is a huge issue in the management of ecosystems and wild species worldwide (Fuentes, Fish, & Maynard, 2012). The impacts of this phenomenon have been recorded in various ecosystems, fauna and flora species, and ecological processes, and are expected to escalate in the future. (Walther et al., 2002). In order to prepare effective management solutions for wild ecosystems and species in the face of climate change, it is important to predict future climate scenarios. This is especially important to species whose behaviors and biological characteristics are strongly influenced by the environmental conditions of their surroundings, especially temperature.

At the moment, the highest sand temperature is recorded in Bãi Thịt (Núi Chúa) (30.8°C) and the lowest in Bảy Cạnh (Côn Đảo) (27.8°C). Other beaches in Côn Đảo record a similar sand temperature of 28.3°C. According to climate change scenarios, by 2030 the sand temperatures of Côn Đảo beaches increase by 0.67 to 0.93 °C, with Bảy Cạnh beach having the biggest increase of 0.93 °C. Bãi Thịt in Núi Chúa has a smaller increase, ranging from 0.54 to 0.69 °C. By 2050, the sand temperature increase in Côn Đảo is projected to range from 1.16 to 1.57 °C, which is similar to Núi Chúa. The current sand temperatures of all beaches are higher than the pivotal temperatures (Figure 17). By 2010, all beaches recorded high increases in sand temperatures, ranging from 1.14 to 3.12 °C, with Bảy Cạnh Island recorded the highest increase.

Actual measurements and Micro-climate model both show that the sand temperature in Núi Chúa is much higher than that of other beaches in Côn Đảo. During the main nesting period from June to October in 2012, Côn Đảo beaches recorded an average temperature of 28.2 ± 0.2 °C, which was 2.6 °C lower than the temperature of Bãi Thịt in Núi Chúa (30.8 ± 0.3°C). Therefore, all climate change scenarios project that by 2100, the sand temperature on Bãi Thịt (Núi Chúa) reaches the fatality limit for marine turtle embryos (Figure 17).
Figure 17. Average sand temperatures (from June to November) of marine turtle main nesting grounds in Vietnam according to climate change scenarios

Based on the sand temperatures stated in climate change scenarios, female sex ratio in Núi Chúa at the moment would be 82.6%, which is much higher than the average ratio in Côn Đảo (average sex ratio is 38.2±4.73% female). In Côn Đảo, the female sex ratios of hatchlings of different nesting grounds are dependent on incubation temperatures. Bảy Cạnh Beach, the ground with the highest number of clutches (Error! Reference source not found.), has lowest number of female hatchlings at 26%, while the remaining beaches have a female sex ratio ranging from 40% to 44%. By 2030, the female sex ratio increases to 93-96% in Núi Chúa (Ninh Thuận), and to 64-67% in Côn Đảo. By 2050, most hatchlings in Núi Chúa are female, while 79 to 86% of the hatchlings in Côn Đảo are female. By 2100, all hatchlings born in Núi Chúa and Côn Đảo are projected to be female, except in a B1 (low emission) scenario for Côn Đảo (89%).

Global warming due to climate change will potentially have serious impacts on all turtle populations in Vietnam. In most scenarios, by 2100 all nesting grounds suffer from a serious sex imbalance, as nearly 100% of hatchlings are female. In Núi Chúa (Ninh Thuận), the situation is even worse as all climate change scenarios predict a completely
female-skewed sex ratio by 2050. Sex imbalance is already happening, as the majority of clutches are relocated from their natural nesting grounds to the hatcheries, where temperatures are substantially higher. Furthermore, historical nesting grounds of marine turtles in the coastline where there is a variation of incubation temperatures are disappearing due to the human impacts. All of these issues will increase the future risk of marine turtle extinction in Vietnam.

3.6. Sea level rises due to Climate change

In the sea level rise model, factors such as the height, width and slope of a beach are the most important when it comes to determining flood-vulnerable areas. In all three climate change scenarios (B1, B2, and A1F1), the three nesting grounds with the largest number of nests, which are Cát Lớn, Bãi Dương and Hòn Tre (the total number of nests from the three make up 84% of the total number of nests in the region, with Cát Lớn accounting for the largest percentage at 59%) (Error! Reference source not found.) are the most vulnerable ones. By 2100, all climate change scenarios estimate the probability of these grounds getting flooded at 85%. These beaches have small areas and widths, and only 4% to 10% of the total beach area is nesting grounds for marine turtles. This is a very low percentage when compared to other beaches (38% in Hòn Tải, 13% in Hòn Cau, 60% in Núi Chúa). Bãi Thịt in Núi Chúa has an area that is ideal for nesting turtles and the largest ground width. However, since the number of nests here is very low (an average of 8 nests/season), this beach has the smallest area potentially affected by rising sea level.

Clutches that are laid from June to August (the peak nesting period of marine turtles) will be the most impacted due to the combination of rising sea level and high tides from August to October. The differences in flooded area percentages between the months in the A1F1 scenario is the lowest among the three scenarios Figure 19). The average nesting area loss from 2020 to 2100 is estimated to be 6 to 29% in climate change scenario B1, 7 to 34% in B2 and 7% to 45% in A1F1 (Figure 18). By 2040, the loss of nesting area and nests is under 11%, however, in the following years, this figure exponentially increases. By 2100, the number of nests lost to flooding due to rising sea level accounts for 37% (B1), 43% (B2), and 59% (A1F1) of the total number of nests per season.
Figure 18. Nesting area loss in Côn Đảo due to rising sea level according to climate change scenarios from 2020 to 2100

Figure 19. Estimated nesting area loss by month in Côn Đảo by 2100
4. THE CONSERVATION OF MARINE TURTLES

4.1. Management and conservation mechanisms for marine turtles

All marine turtle species in Vietnam including Green turtle (*Chelonia mydas*), Loggerhead turtle (*Caretta caretta*), Olive Ridley turtle (*Lepidochelys olivacea*), Hawksbill turtle (*Eretmochelys imbricata*), and Leatherback turtle (*Dermochelys coriacea*) are protected at the highest level in accordance to the provisions of Vietnamese law as well as international conventions to which Vietnam is a party, specifically:

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) which oversees the trade of wild fauna and flora to prevent overexploitation and consequently extinction. All five marine turtle species in Vietnam are included in Appendix I which lists species that are the most endangered and at risk of extinction. Trade in specimen of species listed in this Appendix requires both an Export Permit and an Import Permit granted by CITES management agencies in the export and import countries. Vietnam joined CITES in 1994 as its 121st member.

In order to implement CITES, the Government of Vietnam issued Decree No. 82/2006/ND-CP on Management of Export, Import, Re-Export, Introduction From the Sea, Transit, Breeding, Rearing, Artificial Propagation of Endangered Wild Fauna and Flora Species, which has been replaced by Decree No.06/2019/ND-CP on Management of Endangered, Precious, and Rare Species of Forest Fauna and Flora and Observation of Convention on International Trade in Endangered Species of Wild Fauna and Flora. According to this decree, all five marine turtle species are included in Appendix 1, which lists wild fauna and flora species threatened with extinction, of which export, import, re-export, introduction from the sea, and transit for commercial purposes is prohibited.

All of these five species are also included in Group I - Endangered, Precious, and Rare Wild Species, of which Exploitation and Usage for Business Investment Purpose is Strictly Prohibited under Appendix 3 - List of Endangered, Precious, and Rare Wild Species of the 2014 Investment Law.

Marine turtles are also listed in Appendix I - List of Endangered, Precious, and Rare Species Prioritized for Protection, which is promulgated in accordance to Decree 160/2013 of the Government on Criteria to Determine and Management Mechanism for
Endangered Precious and Rare Species Prioritized for Protection. This list has been updated in accordance to Decree 64/2019/ND-CP, but Marine turtles still remain in the list.

Export of marine turtles is prohibited according to Appendix IX - List of aquatic species of which export is prohibited according to Decree 26/2019/ND-CP on guidelines for implementation of the Law on Fisheries. It should be noted that marine turtles are not included in the List of Endangered, Precious, and Rare Aquatic Species under Appendix I and Appendix II of Decree 26 as they are already included in Prioritized Protection List in accordance to Decree 160 and 64 as stated above.

Regarding biodiversity conservation, interdisciplinary collaboration and delegation of duties between state specialized management agencies is still ineffective and overlapping. The 2008 Law on Biodiversity states that “The Ministry of Natural Resources and Environment shall be accountable to the Government for taking responsibilities for performing the state management of biodiversity” (Article 6, Clause 2), which ensure the legality and appropriate authority in line with the provisions of the Law on Government Organization 2001 and Law on Environmental Protection 2005. This is also in line with regulations on functions, tasks, authorities and organizational structure of the Ministry of Natural Resources and Environment stated in Decree No. 25/2008/ND-CP dated March 4, 2008. However, the current conservation of marine turtles in Vietnam is mostly carried out by Management Boards of National Parks, Marine Protected Areas, and Aquatic Resources Protection Departments in coastal provinces (under the Ministry of Agriculture and Rural Development). The Ministry of Agriculture and Rural Development (MARD) has developed a marine turtles conservation plan with specific plans and solutions. Marine turtles are also included in the Endangered Turtle Conservation Program promulgated by the Prime Minister in order to increase resources for conservation and protection efforts. These two policies have certain contents in common, such as developing and completing the legal system, capacity building for implementation staff, raising awareness of relevant parties, the socialization of resources, and strengthening international cooperation. However, the managing authorities are two different agencies (the Directorate of Fisheries (MARD) and Vietnam Environment Administration (Ministry of Natural Resources and Environment - MONRE) and the two policies adhere to two different laws.
(Law on Fisheries and Law on Biodiversity). This illustrates the overlap of management authorities between agencies involved in the conservation and protection of marine turtles.

Additionally, the mechanism for multidisciplinary and interdisciplinary collaboration is clearly defined in the provisions in the Law on Biodiversity 2008, and yet in reality the delegation of state management responsibilities is still not clear, specific, and feasible. In Clause 3, Article 6 of the Law on Biodiversity, it is stated that “Ministries and ministerial-level agencies shall, within the ambit of their tasks and powers, perform the state management of biodiversity as assigned by the Government”. Therefore, even though other ministries and departments are still “waiting to be assigned” with their responsibilities, they are still responsible for implementing activities relevant to biodiversity conservation in accordance with their respective functions and powers. Therefore, as the Government assigns tasks to ministries and departments based on the types of ecosystems, these ecosystems will be managed and protected by different agencies, inevitably leading to an overlap in functions and tasks among ministries and departments. In addition, a number of protected areas and national parks are within the administrative boundaries of multiple provinces. This has caused many issues when it comes to coordinating management efforts with the authorities of these provinces.
Figure 20. Biodiversity management hierarchy chart
The resources for biodiversity conservation implementation are still scarce and not well-allocated, especially at local level. The state management system for biodiversity conservation mostly focuses on departments of natural resources and environment, and agriculture and rural development. At local level, most of biodiversity conservation tasks are assigned on a concurrent basis (one person/office in charge of more than one task), and some are not even assigned to any specialized personnel. As the staff members are in charge of multiple tasks, they often don't have the suitable qualifications for the tasks assigned to them. Furthermore, the overlap in functions and duties is both a drain on resources and an obstacle in coordinating implementation activities. In protected areas, the forest rangers play an important role in forest protection efforts. However, the forest ranger force is not fully utilized in the protection of marine and wetland protected areas. There is no consistency in the current management systems of protected areas. Most protected areas are under the direct management of different provincial authorities or the Ministry of Agriculture and Rural Development, therefore the mechanisms for allocating human and financial resources as well as general management regulations for protected areas are still overlapping and not well-defined. The funding for biodiversity efforts is still very limited. In recent times, many Strategies, Plans, and Programs on biodiversity conservation have been approved, but they are not effectively invested in yet. The implementation of these policies is still lacking in term of strategy, coordination, and integration, making it quite inefficient.

The sanctions, inspection, examination, and handling of biodiversity legal violations are still facing many shortcomings. Biodiversity conservation violations in different areas have been handled in accordance to laws and legal documents. Many administrative responsibilities related to the planning of biodiversity conservation, species conservation, genetic resources conservation, genetic resources access and benefit sharing, etc. are not clearly defined in current legal documents, whose administrative penalties are not serious enough to deter violations, especially the exploitation and trade of wild flora and fauna species of high economic values. Regarding criminal liability, Law No. 37/2009/QH 12 Amending and Supplementing a Number of Articles of the Penal Code has provisions on crimes related to biodiversity conservation in Article 182 to Article
191. However, due to the late promulgation of the guiding regulation, a number of crimes are “on standby” while waiting for sufficient grounds for prosecution. The inspection and handling of biodiversity violations have made some remarkable achievements in the area of forest protection and development. In other areas of biodiversity, there have been no clear development steps. There is still a large number of biodiversity violations and the penalties are not serious enough to deter violations, meaning the probability of recidivism remains very high.

4.2. **Media activities to promote the conservation and protection of marine turtles**

Vietnam is one of the most biodiversity countries in the world. However, socio-economic development has led to a significant decline in biodiversity in our country at all three levels of ecosystem, species, and genetic resources. In the last several years, the Government of Vietnam has taken the initiatives to join and implement international conventions on biodiversity conservation, with a particular focus on the conservation of endangered, precious, and rare flora and fauna species, including marine turtles. In recent years, the conservation of marine turtles in Vietnam has achieved a number of positive results, especially since the promulgation of the “Action Plan for the Conservation of Marine Turtles in Vietnam, period 2016 - 2025” by the Ministry of Agriculture and Rural Development. Marine turtle protection activities in Vietnam in recent years have effectively “realized” the 4th task of the action plan for the conservation of marine turtles with quite diverse media activities carried out by numerous agencies, including both state bodies and NGOs.

For state management agencies, media activities on marine turtle protection have been carried out at both central and local levels. At central level, the Directorate of Fisheries, represented by the Department of Aquatic Resources Conservation and Development - the agency responsible for undertaking tasks related to marine turtles conservation, has implemented many media activities, such as: creating and placing billboards promoting marine turtles conservation in some major fishing ports of the country; designing and printing posters on marine turtles conservation, organizing national and international seminars on marine turtle protection. A particularly noteworthy activity is helping Côn Đảo National Park to apply for and get recognized as a member of
the IOSEA International Network for Marine Turtles Conservation. Training programs aimed at enhancing awareness of local-level management staff regarding marine turtles conservation is conducted annually by state management agencies (the Department of Aquatic Resources Conservation and Development). The contents of these programs focus on marine turtle identifying skill and regulations on marine turtle conservation. Results of surveys conducted in coastal areas show that the awareness of marine turtle conservation management staff has been substantially improved. That helps to establish the foundation from which the localities can disseminate information on marine turtles such as marine turtles that are included in prohibited species list to the local people in various forms. Most people who used to engage in marine turtle trading and harvesting activities are now aware that such activities are illegal.

In addition to teaching and training activities, state management agencies also design and print leaflets and billboards to aid the local levels in disseminating information to the local people. Surveys conducted in the provinces show that Bà Rịa - Vũng Tàu has effectively carried out their media campaigns. For example, in Cát Lở fishing port, the Port Management Board put up billboards with the message “Join in to conserve and protect marine turtles and their habitats” in the most visible locations. Another example is the Department of Fisheries of Bà Rịa - Vũng Tàu handing out leaflets to fishing vessels. Kiên Giang Province is a marine turtle consumption hotspot. In 2017, the Provincial Department of Fisheries took the initiative to design leaflets specifically for the area to promote “Things to know about sea turtles” to the local people, which is a dissemination of regulations on the protection of aquatic species. However, regulatory citations on sanctions are no longer in effect. The classification of sea turtles is also not in line with the current guidelines of authorities on marine turtle species in Vietnam.

Along with the promotion and conservation of marine turtles by state management agencies, organizations such as the International Union for Conservation of Nature (IUCN), the Wildlife Fund (WWF), and TRAFFIC International Office in Vietnam have collaborated with the management agencies of the Ministry of Agriculture and Rural Development, National Park Management Boards, marine protected areas, etc. to organize a number of activities focusing on training and instructing the technical processes and management solutions for marine turtles conservation.
One of the most successful outreach and communication programs is the Marine Turtles Conservation Volunteer Program which implemented by IUCN in collaboration with the Management Boards of Côn Đảo National Park, Hòn Cau MPA, Núi Chúa National Park. The program was started in 2014 and is still ongoing. The Marine Turtles Conservation Volunteer Program organized by IUCN over the past 7 years (2014-2020) received about 10,000 applications, only 5% of which were accepted under strict conditions. The majority of volunteers came from two major cities, Hà Nội and Hồ Chí Minh City. The volunteers were between the ages of 22 to 30 and came from a variety of occupation backgrounds. The gender ratio of the volunteers leans more towards female than male. All of these factors helped to facilitate diverse activities at the research stations in addition to marine turtle rescue. In Côn Đảo, the volunteers spent a total of 259 days at the stations and relocated 2316 nests, which contained a total of 307,938 eggs, to hatcheries. Although Hòn Cau and Núi Chúa have a smaller number of nesting turtles, meaning fewer chances for the volunteers to catch sight of marine turtles, other activities such as painting and decorating ranger stations were no less exciting. Most importantly, marine turtle conservation volunteers produced thousands of articles, pictures, videos, projects, and campaigns related to marine conservation and marine turtle protection using the experience and knowledge they had gained from the volunteering program. Volunteers also joined hands to build two conservation houses in Bãi Thịt (Núi Chúa National Park) and Hòn Cau (Hòn Cau MPA).

In addition to the regular activities mentioned above, a number of other communication activities were also organized. For example, in 2019, an creative media campaign promoting the conservation of endangered sea turtles co-operated by Change and WildAid named "To not create suffering is to salvage" was launched at Vĩnh Nghiêm Pagoda, Hồ Chí Minh City. It attracted the participation of a large number of the community members. Or in December 2019, in Hà Nội, Education for Nature Vietnam (ENV) released a short film promoting the prevention of marine turtles related crimes. The film shows the belated remorse of an individual when they have to pay the price for engaging in illegal marine turtle trade. The harshest punishment is the penalty of conscience when one having to sit behind bars and losing out on precious moments with their family. The film attracted the attention of the community.
Overall, communication activities on marine turtle conservation in Vietnam have been relatively well implemented. Communication, education and dissemination of knowledge on marine turtle conservation and protection have also been carried out through mass media. Information on the sanctions for violations in trading and transporting marine turtles has been widely reported by the media. However, according to interviews with owners/captains of fishing vessels, the handling of captured marine turtles depends on the awareness of fishermen in each region and fishing occupation, varying from releasing the turtles back to the sea to killing for food, and sometimes both. Although the number of respondents that still eat sea turtles is still very low, it is clear that this phenomenon still exists.

4.3. Solution proposals for marine turtle management and conservation

4.3.1. On-site (natural nesting grounds) marine turtle management (in-situ conservation)

The sex of a baby turtle depends entirely on the incubation temperature of its nest, so global warming in the future will cause a sex imbalance among wild marine turtles, as more and more female turtles will be born. This can severely impact marine turtle populations by reducing their fertility. Marine turtle nesting grounds at Núi Chúa are currently suffering from a very skewed sex ratio with more than 90% of hatchlings being female - a figure that is projected to be 100% by 2050 in all climate change scenarios. A sex ratio of more than 50% female would be normal if there is a large number of nesting grounds in Vietnam with a wide variation of temperature ranges among the nesting grounds. However, as the number of nesting grounds is decreasing, it is essential to take artificial measures to help balance the marine turtle sex ratio born at Vietnam's nesting grounds.

One of the measures currently being employed in marine turtle sanctuaries around the world is constructing a hatchery system with a shade structure to reduce incubation temperature. Clutches on nesting grounds such as Bãi Dương, Cát Lớn and Hòn Tre have been relocated to hatcheries due to the large number of female turtles nesting on those beaches and the flood risk the low-lying nesting grounds during high tides. These hatcheries, however, do not have any shade structures and therefore their temperatures are higher than those of natural nesting grounds by an average of 1.2°C. This results in
a sex ratio of 80-90% female among hatchlings born in the hatcheries, significantly higher than the 30-40% female among hatchlings born in their natural locations. Therefore, shade systems for hatcheries should be urgently constructed to reduce the incubation temperature to the temperature of natural nesting grounds. This is particularly important as rising sea level will contribute further to the decline in nesting area and most nests will have to be relocated to artificial hatcheries.

In nesting grounds that have not yet been included in a protected area such as Hải Giang and Hòn Kho (Bình Định), Cam Lâm (Khánh Hòa), Cô Tô - Thanh Lân (Quảng Ninh), the protection of marine turtles is still facing many difficulties due to the illegal exploitation of female turtles and turtle eggs by the people. The solution to this problem is to raise people’s awareness through training programs and establish volunteer groups consisting of local officials and local people to patrol and protect marine turtles during the nesting season.

4.3.2. Relocate marine turtles to ideal locations (ex-situ conservation)

Ex-situ conservation is the relocation of marine turtles from their natural surroundings for the purpose of propagation, conservation, cloning or rescue in the event of habitat degradation or habitats becoming no longer suitable. Ex-situ conservation of marine turtle has been practiced in several parts of the world. Cayman Turtle Centre was established in 1968 with the relocation of turtle eggs from Suriname, Ascension Island and Costa Rica. The original goal of the Centre was to restore the turtle population in a semi-natural habitat, but then it switched to catching adult marine turtles and raising them in captivity. By 1973, a number of turtles started to be successfully bred in captivity. Conrail Turtle Centre in Reunion Island begun farming Green turtles with juvenile turtles captured from the wild as their breeding stock. The turtle farming center of Torres Strait was established in 1970 with the breeding stock made up of Green turtle eggs from adjacent islands. However, all of these centers had difficulty in maintaining their operations due to the considerable funding needed, high morbidity and mortality rates, long nurturing and development times, and difficulty in finding mate and breeding in captivity. In addition, living in captivity changes the natural behavior of marine turtles, making them unable to adapt to the natural environment when released. Therefore, all of the aforementioned centers ceased to operate after a short period of time. This means if
Vietnam wants to implement captive breeding programs, it is necessary to have long-term, adequate research and funding.

Ex-situ marine turtle conservation was implemented by Cù Lao Chàm MPA in 2017. 450 40-day-old turtle eggs were transported over more than 1000km from Côn Đảo National Park to Cù Lao Chàm Island before they were buried in the hatchery in Bãi Bấc, which is a historical nesting ground of marine turtles. After nearly 20 days all the eggs successfully hatched and the hatchlings were released back to sea. This was the first success of the ex-situ conservation efforts, which is potentially applicable in other areas. The aim of ex-situ conservation is to relocate the nests from areas impacted by rising temperature or sea level to somewhere more suitable for their incubation (Bãi Bấc is an example of a suitable nesting ground that has no longer seen any nesting turtle). Hatchlings born at the new nesting ground will return there to nest in the future, which will gradually restore the marine turtle population of that location. This is possible due to a nesting behavior of marine turtles - they return to the same beach where they hatched to lay eggs.

4.3.3. Protect historical nesting grounds of marine turtles

Historical nesting sites of marine turtles are beaches where marine turtles used to be found, but for many reasons, are now completely void of nesting marine turtles or see very few of them. Important beaches for marine turtles before the 1980s such as Quan Lạn, Minh Châu, Ngọc Vừng (Quảng Ninh), a number of islands in Cát Bà – Hạ Long (Hải Phòng – Quảng Ninh), the beaches of Quảng Trị Province, the beaches of Sơn Trà Peninsula (Đà Nẵng), Tam Quan Bạc (Bình Định), Bãi Dài beach in Cẩm Lệ (Nha Trang), etc. are areas that need to be protected despite their lack of nesting marine turtles. One of the adaptive behaviors marine turtles display in response to rising sea level is changing their nesting ground. Dethmers et al. (2006) pointed out that about 6% of female turtles switched nesting grounds between nesting seasons and marine turtles were capable of change nesting grounds if the old sites were no longer suitable for them. This is a very important finding, as in the future, when familiar nesting grounds are lost to rising sea level, marine turtles can switch to other nesting grounds that are not flooded.

Future sea level rise will be the biggest threat to nesting beaches in Côn Đảo, especially for Cát Lớn, Bãi Dương and Hòn Tre - the three beaches with the largest
number of nesting turtles that make up 84% of the total nests in the area. Rising temperatures in the future may also cause marine turtles to nest earlier or later (JF, DA, LM, & AC, 2010), which would coincide with high tide periods in Côn Đảo. The seawater can then affect nests during the incubation period and limit suitable nesting areas. Therefore, historical nesting grounds can be the alternative options for marine turtles in the future when Côn Đảo run out of suitable nesting grounds for them. The protection of these beaches will increase the resilience of marine turtles against climate change in the future.

4.3.4. Establish marine turtle rescue centers

Establishing Marine Turtle Rescue Centers is a very crucial measure for Vietnam. In the context of an increasing number of fishing vessels active at sea, the number of accidents or incidental captures of turtles by fishing vessels will continue to increase. Therefore, it is very important to treat or restore the health of marine turtles before releasing them back to the wild. Besides, with a large number of marine turtles kept in captivity for a long time by local households, it is also necessary to have a process in place to restore these turtles of their natural behaviors such as finding food, mating, migrating, etc. in order to help them adapt to living in the natural environment. Rescue centers need to be situated in areas with a large number of marine turtles such as Côn Đảo (Bà Rịa - Vũng Tàu), or areas with a large number of fishing vessels like Nha Trang (Khánh Hòa). These centers rescue not only marine turtles but also other marine animals such as dugongs, whales, or dolphins. Marine turtle rescue centers also serve as storages of genetic resources, aiding scientific research and raising awareness of the local people.

4.3.5. Solutions for on-site management of marine turtles

In 2010, the Government approved a system of 16 marine protected areas, 6 of which are currently in operation: Nha Trang Bay, Cù Lao Chàm, Núi Chúa, Phú Quốc, Côn Cờ, Hòn Cau. Among these MPAs, many are areas where a high concentration of marine turtles lives and feed such as Bạch Long Vĩ, Côn Đảo, Phú Quốc, Phú Quý, and Nam Yết. However, due to the characteristically vast feeding grounds and extensive migration distance of marine turtles, the area of current MPAs has yet to meet the conservation requirements for long-distance migratory species. In addition, the feeding
grounds of marine turtle species such as Olive Ridley and Leatherback turtle are overlapping areas with the main fisheries zone including Trường Sa, Hoàng Sa, Bạch Long Vĩ, Tư Chính Beach, etc. Therefore, in order to obtain the goal of minimizing human impact on marine turtles due to intentional or random fishing, the following solutions are to be considered:

- Quickly put the system of marine protected areas into operation.
- Quickly expand strictly protected areas in protected areas where marine turtle populations are found such as Côn Đảo, Phú Quý, Nam Yết, Bạch Long Vĩ, Phú Quốc.
- Implement fishing ban or time-based fishing restriction in certain fisheries to restore resources and reduce marine turtle mortality due to incidental fishing.
- Make turtle escape device (TED) and loop hook mandatory for gillnetting and tuna fishing.

### 4.3.6. Solutions for law enforcement and resource management capacity building

The reality is at the moment, Vietnam has a quite substantial number of legal documents and agencies responsible for the management and protection of marine turtles. However, the enforcement of such laws and decrees is still limited. In many places, despite knowing that marine turtle fishing is illegal, the sanctions against marine turtle fishers and traders only stop at administrative penalties. Compared to other countries in the region such as the Philippines and Malaysia, Vietnam's penalties are still quite light and therefore unable to deter violations. Furthermore, the general capabilities of local staff in charge of aquatic resource protection and biodiversity conservation are still lacking, with most of them serving concurrent positions and some positions not even assigned to anyone. Therefore, capacity building for local staff is very crucial. In addition to capacity building, strengthening specialized knowledge, and providing patrol equipment, it is necessary to maintain adequate, sustainable, and long-term financial resources for marine turtle conservation efforts as their results can only become visible after 10 to 30 years.
CONCLUSION

1. Nesting marine turtle populations in Vietnam are declining at a significant rate along with their nesting grounds. Currently (2016-2020), only Green turtle (*Chelonia mydas*) have been found to nest at 7 areas, while Olive Ridley turtles (*Lepidochelys olivacea*), Hawksbill turtles (*Eretmochelys imbricata*) and Leatherback turtles (*Dermochelys coriacea*) are no longer found, or at least there is no evidence that indicates otherwise. Green turtle population has the highest number of nesting turtles per year (600 turtles/year on average, accounting for 99% of the total number of nesting turtles). A recent significant discovery is the reappearance of Green turtles emerging to nest at the small beach of Phú Quý Island (Bình Thuận) after 30 years of no sighting. This is a very positive sign that supports the continuation of long-term marine turtle conservation programs in Vietnam.

2. Côn Đảo is the area with the highest concentration of nesting Green turtles in Vietnam. Each year, an average of 1145 clutches are laid in 5 main nesting sites, which are Cát Lớn, Bãi Dương, Hòn Cau, Hòn Tre Lớn, and Hòn Tài. Among these five nesting grounds, Cát Lớn has the highest number of clutches at 59% of Côn Đảo’s total clutches per nesting season, followed by Hòn Cau and Bãi Dương (12-13%), with Hòn Tài in the last place at 8%. Bãi Thịt in Núi Chúa National Park (Ninh Thuận) is the onshore site with the highest number of clutches with 8 to 20 clutches per nesting season.

3. The nesting season of Vietnam’s marine turtles begins in March and ends in November every year, of which June, July, and August are the peak nesting period. Nesting season often begins when there is an increase in temperature and rainfall at the nesting beaches. The size of a nesting female turtle in Côn Đảo is 97.67±5.19 (cm) Nesting female turtles tend to lay eggs at night, especially from 22h to 02h. The total duration of the egg laying process is 117.2±55.5 (minutes). The number of eggs per nest is 98.02±26.65 (eggs) and the average depth of one nest is 71.57±7.5 (cm). Green turtle eggs have an average weight of 39.1±4.1 (g) and an average diameter of 41.5±1.9 (mm). The average incubation time is 54.62±5.2 days, with the majority of nests undergo incubation for 51 to 54 days. Hatching success rate is 80.39±9.6%. Green turtle hatchlings have an average weight of 21.01±1.96 (g), body condition index (BCI) of 26.5±1.79 (cm²). Their average running speed is 0.19±0.05 (m/s).
4. The causes of the decline in marine turtle populations of Vietnam are intentional and incidental fishing, illegal trade of marine turtles and derived products, socioeconomic and infrastructure development at areas where marine turtles are dispersed, the degradation of the environment and marine ecosystems, and climate changes. Additionally, the large amount of waste, especially plastic waste, can have quite an impact on marine turtle populations that have nesting and feeding grounds in Vietnam.

5. Many marine turtle species in Vietnam are at risk of complete disappearance from historical nesting beaches and even from coastal waters and islands. Therefore, it is necessary to employ measures to conserve and manage marine turtle populations and their nesting and feeding grounds, such as: Managing nesting grounds, relocating nests, establishing rescue centers, minimizing incidental harvesting, and strengthening law enforcement. All of these measures need to be promoted and implemented in the near future.
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APPENDIX: NATURAL CHARACTERISTICS OF SOME IMPORTANT NESTING GROUNDS OF MARINE TURTLES

In Côn Đảo, there are 14 marine turtle nesting grounds, the largest of which are Cát Lớn, Bãi Dương, Hòn Tre, Hòn Cau, and Hòn Tài beaches. In Núi Chúa, two nesting sites are adjacent to each other (Bãi Thịt and Móng Tay).

Table 5. Topographic characteristics of marine turtle nesting grounds

<table>
<thead>
<tr>
<th>Name</th>
<th>Length (m)</th>
<th>Area in low tides (ha)</th>
<th>Area in high tides (ha)</th>
<th>Area of nesting</th>
<th>Attitude to 0mHD (m)</th>
<th>Slope (cm/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cát Lớn</td>
<td>649</td>
<td>31.37</td>
<td>1.365</td>
<td>0.137</td>
<td>4.6 ± 0.4</td>
<td>11,5</td>
</tr>
<tr>
<td>Bãi Dương</td>
<td>354</td>
<td>45.29</td>
<td>0.739</td>
<td>0.060</td>
<td>4.3 ± 0.4</td>
<td>16,4</td>
</tr>
<tr>
<td>Hòn Tre</td>
<td>196</td>
<td>1.61</td>
<td>0.335</td>
<td>0.015</td>
<td>5.4 ± 0.4</td>
<td>9,5</td>
</tr>
<tr>
<td>Hòn Cau</td>
<td>544</td>
<td>6.15</td>
<td>1.768</td>
<td>0.233</td>
<td>4.2 ± 0.3</td>
<td>4,2</td>
</tr>
<tr>
<td>Hòn Tài</td>
<td>119</td>
<td>0.34</td>
<td>0.149</td>
<td>0.057</td>
<td>6.4 ± 0.9</td>
<td>33,6</td>
</tr>
<tr>
<td>Núi Chúa</td>
<td>785</td>
<td>43.16</td>
<td>1.793</td>
<td>1.037</td>
<td>5.1 ± 0.7</td>
<td>4,1</td>
</tr>
</tbody>
</table>

These nesting grounds are in different locations and face different directions. The nesting grounds of Côn Đảo are offshore, with a small area and are completely separated from human activities. Cát Lớn faces the South - Southeast direction, with a nesting ground that takes up 10% of non-flooded area. The distance from the water to the turtle nesting area is only 2.6m. Bãi Dương consists of 2 small beaches with a total nesting area that takes up 8.2% of the total beach area. The distance from the highest water level to the nesting area is only 2.4m. Hòn Tre and Hòn Tài are both facing North, however, Hòn Tre’s nesting ground only takes up 4.5% of the total beach area, while Hòn Tài’s takes up 50% (Topographic 3, Topographic 5). Hòn Tài’s nesting ground also has the steepest slope and also the farthest distance from the water level to the nesting ground. Bãi Thịt, which is part of Núi Chúa National Park, has the largest area but the lowest number of nesting turtles (Error! Reference source not found.).
The nesting beaches of Côn Đảo and Núi Chúa all have large sand grain with a dark yellow color. This color increases the beach’s heat absorption. Except for Cát Lớn beach, which has quite a shady landscape due to its vegetation, all other beaches have little shade as most of their vegetation is small shrubs. Except for Bãi Thịt, Núi Chúa has little to zero vegetations aside from small grass plants.

<table>
<thead>
<tr>
<th>Name</th>
<th>Md</th>
<th>S₀</th>
<th>Sₖ</th>
<th>Sediment type</th>
<th>Color</th>
<th>Humidity (%H₂O)</th>
<th>Vegetation cover (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cát Lớn</td>
<td>0.241</td>
<td>1.358</td>
<td>0.923</td>
<td>Small sand grain</td>
<td>Dark yellow</td>
<td>6.11</td>
<td>90</td>
</tr>
<tr>
<td>Bãi Dương</td>
<td>0.559</td>
<td>1.381</td>
<td></td>
<td>Large sand grain</td>
<td>Dark yellow</td>
<td>6.57</td>
<td>10</td>
</tr>
<tr>
<td>Hòn Tre</td>
<td>0.6</td>
<td>1.36</td>
<td>1</td>
<td>Large sand grain</td>
<td>Dark yellow</td>
<td>4.84</td>
<td>40</td>
</tr>
<tr>
<td>Hòn Cau</td>
<td>0.478</td>
<td>1.552</td>
<td>0.990</td>
<td>Medium sand grain</td>
<td>Dark yellow</td>
<td>4.22</td>
<td>50</td>
</tr>
<tr>
<td>Hòn Tài</td>
<td>0.713</td>
<td>1.359</td>
<td>1</td>
<td>Large sand grain</td>
<td>Dark yellow</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Núi Chúa</td>
<td>0.942</td>
<td>1.602</td>
<td>1.076</td>
<td>Large sand grain</td>
<td>Dark yellow</td>
<td></td>
<td>5%</td>
</tr>
</tbody>
</table>
Topographic 1. Cát Lớn Beach on Bảy Cạnh Island, Côn Đảo

Topographic 2. Bãi Dương on Bảy Cạnh Island, Côn Đảo
Topographic 3. Nesting ground on Hòn Tre Island, Côn Đảo

Topographic 4. Nesting ground on Hòn Cau Island, Côn Đảo
Topographic 5. Nesting ground on Hòn Tài Island, Côn Đảo

Topographic 6. Nesting ground of Bãi Thịt, Núi Chúa National Park
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