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Poaching impact on conservation biodiversity – The case of leatherback turtle's in Caribbean Costa Rica.

Impacto da caça furtiva na conservação da biodiversidade – o caso da tartaruga-de-couro na costa caribenha da Costa Rica.

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Biologia Aplicada, realizada sob a orientação científica do Doutor Mário Verde Jorge Pereira, Professor auxiliar do Departamento de Biologia da Universidade de Aveiro

Dedico este trabalho à minha família, namorado e amigos.

o júri

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agradecimentos

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palavras-chave

Conservation of biodiversity, sea turtles, poaching, overharvesting, sustainability, rural (sea-side) communities, traditional believes and costumes, tourism, ecotourism, costa rica, endangered species atc.

resumo

A caça furtiva de ovos de tartarugas marinhas é uma realidade em todo o mundo. Para garantir a proteção dos ninhos, programas de conservação precisam ser implementados com medidas específicas para cada local de nidificação, levando em consideração o impacto da caça furtiva e o impacto das alterações climáticas. As preferências de nidificação da tartarugas-de-couro em Playa Tres, na Costa Rica Caribenha, foram analisadas, bem como a distribuição de nidificação entre áreas e setores. O impacto da lua também foi estudado, uma vez que o perfil da praia está diretamente relacionado a ele. Ambos os fatores analisados pelo perfil da praia (comprimento e declive da praia) parecem ter influência na emergência e decisão de nidificação. A distribuição dos ninhos de acordo com o perfil da praia foi analisada mostrando alguns ninhos perdidos devido à subida da água. A distribuição da nidificação mostrou que as tartarugas-de-couro preferem as áreas ao norte da praia e encostas suaves, que evitam à subida do nível da água. Os ninhos de tartarugas-de-couro sofreram um declínio severo. Estimamos que 45% dos ninhos postos durante a época de nidificação desapareceram, devido à caça furtiva ou à proximidade da linha de água. Este estudo enfatiza a importância da proteção de Playa Três, e pode ajudar na criação de melhores medidas de proteção levando em consideração as particularidades da praia.

keywords

Conservation of biodiversity, sea turtles, poaching, overharvesting, sustainability, rural (sea-side) communities, traditional believes and costumes, tourism, ecotourism, costa rica, endangered species atc.

abstract

Illegal harvesting of sea turtle eggs is a reality worldwide. To ensure nest protection, conservation programs need to be implemented with specific measures for each nesting site location, taking in account poaching impact and climate impact. Nesting preferences of leatherback turtles in Playa Tres, Caribbean Costa Rica, were analysed, as well as nesting distribution among areas and sectors. The moon impact was also studied, since beach profile is directly related to it. Both factors analysed by beach profile (beach length and beach slope) appeared to have influence on the emergence and nesting decision. Distribution of nests accordingly to the beach profile was analysed showing some nests lost due to the rising water. The nesting distribution showed that leatherback turtles prefer the northern areas of the beach, and gentle slopes that prevent water rising. Leatherback nests suffered a severe decline. We estimate that 45% of nests laid during nesting season disappeared, due to poaching or due to the proximity to the water line. This study emphasizes the importance of Playa Tres protection, and may help in creating better protective measures taking in account the particularities of the beach.

Contents

1. GENERAL INTRODUCTION

Worldwide, oceans have been facing several threats along the years. Nowadays, the main threats are related to climate change (Hawkes et al., 2009), loss in biodiversity (Pimiento et al., 2020) resulting, most of the time, from anthropogenic impacts (Anastácio et al., 2012; Boyce et al., 2010) resulting in loss and degradation of ecosystems (Posa et al., 2008), their functionality and services (Díaz et al., 2006; Pimiento et al., 2020).

Sea turtles are reptiles from the Testudines order, evolving separately from the other members, approximately 110 million years ago, being considered as an example of living fossils (Hirayama, 1998). These organisms are also an example of adaptation from terrestrial to marine environment (Hirayama, 1998). However, sea turtles are still dependent on the terrestrial environment, females do their nests in sandy beaches, to complete the reproductivity process.

Nowadays there are 7 species of sea turtles, all listed in the Red List of Threatened Species from International Union for Conservation of Nature and Natural Resources (IUCN, 2019). The main causes for the vulnerable (*Carreta carreta*, *Dermochelys coriacea* and *Lepidochelys olivacea*), endangered (*Chelonia mydas*) and critically endangered (*Eretmochelys imbricata* and *Lepidochelys kempii*) state are the illegal capture of females on nesting beaches, the poaching of eggs, bycatch and pollution (IUCN, 2019). The remain specie, *Natator depressus* has not enough data available.

In Costa Rica occur 5 of the 7 species of sea turtles (*Chelonia mydas*, *Dermochelys coriacea, Lepidochelys olivacea*, *Eretmochelys imbricata* and *Carreta carreta*). The Caribbean coast of Costa Rica is home of 4 species of marine turtles: *Chelonia mydas, Dermochelys coriacea, Eretmochelys imbricata* and occasionally *Caretta caretta* (Cortés, 2016; Velez-Espino et al., 2018). This coastline is home of one of the most important green turtle rockeries in the world, protected by the Tortuguero Nacional Park (TNP). TNP covers 30 km of coastline, making it a large colony, the largest nesting population of *Chelonia mydas* in the Atlantic Ocean (Cortés, 2016; Velez-Espino et al., 2018). Tortuguero is also thought to be one of the four largest remaining leatherback rookeries in the world (Velez-Espino et al., 2018). Despite the majority of the population nests inside the park, the adjacent beaches are also used as nesting grounds, even if in smaller numbers (Velez-Espino et al., 2018).

As sea turtles still depend on the terrestrial environment, they become easy preys and have been used as a resource since millennia, for food and products (Eckert et al., 1999) inducing great declines in their populations (Eckert et al., 1999; Mazaris et al., 2009). But, as a highly migratory species, facing threats in all life stages, declines in population are harder to reverse (Eckert et al., 1999). These declines are mostly motivated by bycatch and the harvest of eggs and adult individuals (Mazaris et al., 2009). Protection is been assured trough intergovernmental agreements, national and local conservation programs (Mazaris et al., 2009). However, and despite the urge need of conservation of sea turtles thanks to their value as a natural resource, they have also as immeasurable value in some cultures, playing a key role in their costumes and beliefs (Eckert et al., 1999). Are the case of some sea-side rural and indigenous communities in Guyana, Kenya, Mexico, Nicaragua, Tahiti and Madagascar, that traditionally hunt and exploit sea turtles (Eckert et al., 1999).

Costa Rica rural sea-side communities, in both Caribbean and Pacific shores, harvest and has always been harvesting sea turtles' eggs and adult individuals, with their primary threat being the high market value for eggs and shell by-products (Hunt & Vargas, 2018). Conservation strategies started in the country in the 1960s. In 1988 was created the National System of Conservation Areas (SINAC) that regulates the protected areas, public and government activities with conservation strategies and sustainable development of natural resources (Valverde Sanchez, 2018). Conservation programs have been created for an appropriated wildlife management and biological conservation (Eckert et al., 1999). Besides the protected areas, all Costa Rica coastline is protected by national legislation (Hunt & Vargas, 2018).

1.1. Sea Turtles Natural History

Sea turtles are long living, late maturity and slow-grown species with a wide range of migrations across the oceans (Bjorndal et al., 2010; Bräutigam & Eckert, 2006). They have a long and complex life cycle, and are highly migratory, travelling thousands of miles, becoming hard to study and protect (Luschi, 2018; Stubbs et al., 2019; Yalçın-Özdilek & Sönmez, 2006), which increases their importance as an environmental status indicator from both marine and coastal areas. Their life cycle starts with an incubation period that varies from 45-70 days, depending on the species (Godfrey & Mrosovsky, 2001). However, this also hangs from other features, such as the temperature which eggs are incubated (Robinson & Paladino, 2013). Temperature is also responsible for the sex determination on sea turtles. The interval between 28-30°C is the range where females and males are produced in the same ratio (Ackerman, 1997). Higher temperatures are responsible for an increase of females proportion, while lower are responsible for the increase of males (Robinson & Paladino, 2013). The incubation period is followed by an emergence journey, when the hatchlings crawl to the water oriented towards the light of the moon and stars at the horizon and the sound of the waves (Wyneken & Salmon, 1992). As they reach the ocean, the swimming frenzy begging's, as the hatchlings try to go out of the reef and find the relative safety of the neritic and pelagic areas (Robinson & Paladino, 2013). As they reach these areas, it becomes very difficult to monitor immature turtles, males, and non-breading females, which creates a bias in sea turtle's studies, leading to limited knowledge of their life cycle.

After the lost years, juveniles move from the open ocean to coastal and shallow feeding grounds (with an exception for the leatherback), where they stay until they reach maturity. As mature adults, the reproductive migrations start and they return to the nesting areas (Robinson & Paladino, 2013). The males stay in the coastal areas, where they will mate with the females. Each female can mate with several males and have the ability to storage sperm and randomly fertilize the eggs. Only females return to land, where they are able to make 1-14 postures, with a clutch size 50-150 eggs, depending on the species (Robinson & Paladino, 2013). It is defended that in a healthy population, at least 70% of the laid eggs should be incubated in order to ensure the population sustainability (Chan, 2006).

1.2. Leatherback Turtle

Leatherback turtles (*Dermochelys coriacea*) are the largest of the seven extant marine turtles and the only living species of its family (*Dermochelyidae*) (Rivas et al., 2016). Unlike the other hard-shell sea turtle species, leatherbacks have a soft “like leather” skin and are the most distinctive of the sea turtles (Bräutigam & Eckert, 2006). Leatherbacks can reach 2.4 meters, can have a range weight from 250 kg to 1000 kg (Paladino et al., 1990) and reach maturity around 9-15 years (Jones et al., 2011) but it is not a matter of consent between researchers (Eckert et al., 2012). Some studies estimate the age of maturity between 5 to 30 years, with remigration intervals of 2-3 years (Rivas et al., 2016). However, their lifespan is unknown, and the oldest female had an estimated age of 43 years, using skeletochronology (Eckert et al., 2012).

The species has circumglobally distribution and are highly migratory, being the most widely distributed extant living species in the planet (Horrocks et al., 2016; Wallace et al., 2015). They often travel vast distances between tropical nesting beaches to temperate and boreal foraging areas (Horrocks et al., 2016) where they follow a diet based on jellyfish and medusae (Bräutigam & Eckert, 2006; Hawkes et al., 2009; James et al., 2005). Although their wide range, leatherback turtles are not distributed uniformly around the globe, and the formation of nesting colonies is rare (Eckert et al., 2012). In the Atlantic, the northwest Atlantic subpopulation, nests in the Caribbean beaches, between late February and mid of July (Ordoñez et al., 2007; Troëng et al., 2004) , and then migrate to their foraging grounds that extend from Gulf of Venezuela to northwest Africa, and reaching the cold North Atlantic (Horrocks et al., 2016; Wallace et al., 2015).

As a sexual mature adult, leatherback turtles nest primarily on tropical latitudes (Eckert et al., 2012). One of the largest nesting colonies in the world is located in the Caribbean region (Horrocks et al., 2016), and is though that the Caribbean coast of Costa Rica, is part of one of the four largest remaining leatherback rookeries in the world (Chacón-Chaverri & Eckert, 2007; Rivas et al., 2016; Troëng et al., 2004; Velez-Espino et al., 2018). Unlike the other turtle species, leatherback females may not return to the exact same beach where they were born, but is though that they nest in only one rockery, where movements between nesting sites can be as far as more than 100 kilometres (Horrocks et al., 2016) as documented in Panama and Costa Rica (Chacón-Chaverri & Eckert, 2007) and between the Caribbean islands (Bräutigam & Eckert, 2006; Georges et al., 2007). The size of a mature adult depends on the subpopulation and the mean is 140-160 centimetres of curved carapace length (CCL) weighting 250-500kg. The Atlantic subpopulation has an average of 150 to 160 cm of curved carapace length (Eckert et al., 2012).

Leatherback turtles nesting grounds share some characteristics: debris clean, sandy beaches, strong currents and waves, that may help turtles when they crawl up to the beach to nest (Bräutigam & Eckert, 2006; Eckert et al., 2012). It is though that the moon, the tides and the beach profile influence their behaviour, since the three parameters are related (Eckert et al., 2012). After they crawl and reach the dry sand, the female starts doing her “body pit”, where she clean and sweeps the dry sand and debris with the front flippers from the sand surface. After the body pit is complete, leatherback start the nest excavation using their back flippers, alternately and gently, like a spoon, to take the sand out of the forming nest chamber. Nests chambers are usually in a boot shape or pear shape with a mean depth of 70cm (Eckert et al., 2012). When the nest chamber is ready, oviposition starts, with one of the back flippers covering the entrance of the egg chamber. Eggs are laid in pulses, expelling 1 to 4 eggs in each pulse. During this time, the turtles enter in a trance phase and are mostly indifferent to external stimulation and disturbance, from predators or from human activities, such as research. Usually, a female leatherback turtle crawls up to the beach 5 to 7 times, with clutches with an average of 80 to 90 eggs, for the Atlantic subpopulation (Horrocks et al., 2016; Rivas et al., 2016). Once all the eggs are laid, the turtle refills the egg chamber, gently compacting the sand until the chamber is full and the sand is at the same level as the body pit or sand surface. Then the turtle starts to disguise the nest location using the same technique used for the body pit, resulting in a much larger disturbed area than initially, making it hard to be encountered by predators. After that, the turtle returns to the sea. Leatherback egg incubation last approximately 60 days (Eckert et al., 2012).

Leatherback turtle is declining worldwide due to cumulative effects from the main threats, such as bycatch, overharvesting of eggs and individuals, coastal development and pollution (Tomillo et al., 2008; Troëng et al., 2007). Although, the Northwest Atlantic population is classified as least concern.

1.3. Sea Turtle Conservation in Caribbean Costa Rica

Costa Rica is a tropical central America country, located between Panama (south border) and Nicaragua (north border), with a landmass of 51 100 km^2, and 589 000 km^2 of marine surface (Alvarado et al., 2012; Cortés & Wehrtmann, 2009). Although is small area of land surface (0.03%) Costa Rica has 5% of the world's biodiversity due to its geographical position (Valverde Sanchez, 2018) and its topography, that originates a vast amount of microclimates (Alvarado et al., 2012). Costa Rica is known worldwide for its vast protected areas and as an ecotourism destination, with more than 25% of its territory with a protection status (Valverde Sanchez, 2018).

Costa Rica has 50% of its coastlines preserved in association with 166 protected areas, that were visited by 2.4 million tourist in 2013 (Alvarado et al., 2012). Protected areas in Costa Rica are regulated by the *National System of Conservation Areas* (SINAC), created in 1988, on coordination with the government, universities, NGOs, tours and local communities, to regulate the protected areas, public and government activities with conservation strategies and sustainable development of natural resources (Valverde Sanchez, 2018). Marine Protected Areas (MPAs) are defined in Costa Rica as "*any area of intertidal or subtidal terrain, together with its overlying water and associated flora and fauna, and historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment*" according to Kelleher (1999) (Alvarado et al., 2012). The primary objective of MPAs is to protect the marine biodiversity, from the genes to the ecosystem functions (Alvarado et al., 2012). Within the Marine Protected Areas, ecotourism is promoted by the *National Sustainable Tourism Plan for Costa Rica,* in order to reduce the anthropogenic impacts on the marine resources (Hunt & Vargas, 2018). Off the 166 protected areas, there are 20 MPAs, 3 of which are located in the Caribbean coast (Cortés & Wehrtmann, 2009).

The Caribbean coast of Costa Rica is a shoreline of 212 kilometres of mostly sandy beaches, with some coastal lagoon areas located north, and rocky subtract areas in the south (Cortés, 2016). This coast has a typical tropical climate, hot and humid, with rainy periods during the year (Cortés, 2016; Cortés & Wehrtmann, 2009). The Caribbean coast is a high-energy coast with rip-currents directed normally from north to south, influencing the tides in the area. Tides can be mixed or semidiurnal according to the moon phase observed and have a very narrow range, between 40 to 50 centimetres (Cortés, 2016; Cortés & Wehrtmann, 2009). Waves, wind direction and strength also influence the tides range.

At the Caribbean coast of Costa Rica there are 3 Marine Protected Areas (MPAs), that cover both land and sea areas: Gandoca-Manzanillo National Wildlife Refuge, Cahuita National Park and Tortuguero National Park (Cortés & Wehrtmann, 2009). Gandoca-Manzanillo National Wildlife Refuge was created primarily to protect the coral reefs and the seagrass beds, as well as Cahuita National Park. Besides that, the wildlife refuge also protects a mangrove forest in Laguna Gandoca and a relevant leatherback nesting ground. Besides the MPAs there's also a private reserve, the Pacuare Reserve, to protect sea turtle nesting beaches. And at last, Tortuguero National Park, created with the intention of protect turtle nesting beaches and one of the biggest green turtles rookery (Cortés, 2016). Conservation strategies, focused on marine turtle protection, started in the country in the 1960s. In 1988 was created the SINAC, that regulates the protected areas, public and government activities with conservation strategies and sustainable development of natural resources (Valverde Sanchez, 2018). Conservation programs and national legislation have been created for an appropriated wildlife management and biological conservation (Eckert et al., 1999; Hunt & Vargas, 2018).

Nonetheless, marine turtles are highly migratory species, facing threats in all life stages, what makes conservation plans harder to successfully preform in a long term (Eckert et al., 1999). These declines are mostly motivated by bycatch and the harvest off eggs and adult individuals (Mazaris et al., 2009). In fact, wildlife capture as resource for human subsistence is one of the major biodiversity conservation threats, especially in poor countries, which can lead to declines and local extinction of the captured species (Jerozolimski & Peres, 2003). Another problem is that more than 80% of sea turtles nesting grounds are located in developing countries, with only 25% protected in MPAs (Sardeshpande & MacMillan, 2019).

1.4. Sea Turtles Threats

Although protection is been assured trough intergovernmental agreements, national and local conservation programs (Mazaris et al., 2009) marine turtles are still facing threats (Troëng et al., 2004). Sea turtles have a great value has a natural resource and have been part of sea-side societies, since at least 5000 bc, for medicine, cultural traditions and beliefs, and food (Eckert et al., 1999; Mejías-Balsalobre et al., 2021). In Caribbean Costa Rica, in rural sea-side communities, sea turtles are used traditionally for food (Pheasey et al., 2021; Troëng et al., 2007) and the high market value for eggs and shell-by products (Hunt & Vargas, 2018). Leatherback turtles, due to its size and unpleasant meat taste, is the only species with no trade of adult individuals, however its eggs are largely appreciated, and besides the sub-population its considered least concern, the population appear to be declining since 2004 (IUCN, 2013; Pheasey et al., 2021; Troëng et al., 2004)

Tortuguero is a small village on the Caribbean coast of Costa Rica, where turtles have been playing an important role on the community, both in economy and culture (Mejías-Balsalobre et al., 2021). Initially Tortuguero was a village of fishermen, loggers and sea turtle hunters, that exploited the resources without any control or legal regulation (Mejías-Balsalobre et al., 2021; Valverde Sanchez, 2018). However, nowadays, since the implementation of the TNP, and the national legislation, sea turtles are protected and still a source of income, through ecotourism (boat tours, nesting tours, night tours directed to nocturnal species) (Troëng et al., 2007; Valverde Sanchez, 2018). But, even with the conservation projects, the ecotourism and its related activities, that can generate income for the families, poaching and trade of adult individuals are still a threat to marine turtles (Hunt & Vargas, 2018; Mejías-Balsalobre et al., 2021). This occurs because some locals do not have any income related to the turtles protection, and besides the legislation, there are still a high demand of this resource (Mejías-Balsalobre et al., 2021). But not only Tortuguero village, depends from the ecotourism, in fact, a nearby community, Barra de Parismina, shares the same issues as Tortuguero before the establishment of the National park (Hunt & Vargas, 2018).

Besides the unregulated exploitation of marine turtles, sea-side Caribbean communities, are also under the threat of climate change, that can private the communities of this resource in the future, since nesting grounds are dependent of sea level rise and sex ratio are dependent of the temperature (Hawkes et al., 2009). However, the impact that climate change will pose in the Caribbean coast of Costa Rica has not been studied yet, but in fact, changes can already be felt, especially with coastal erosion (Cortés & Wehrtmann, 2009). Coastal erosion and temperature rising have a capacity to change nesting beaches which is a problem for a species that depends on the interface between terrestrial and marine environments (Fish et al., 2008; Hawkes et al., 2009). Erosion of the coastline is a continuous process, motivated by sea-level rise and increasingly stronger storms, and can be seen in more than 70% of the world's coastline (Jongejan et al., 2016). But coastline loss is not a problem just for the marine species, coastal loss has and will have effects also in the economy and ecological services (Fish et al., 2005, 2008). Tourism and ecotourism are the main driving for the Caribbean economics (Fish et al., 2005). Without the sandy beaches and coastal habitats, income will be loss directly, with the loss of tourism driving by nature, and indirectly with the loss of infrastructures (Fish et al., 2005). Beaches also protect the inland environment acting like a natural barrier, protecting nesting grounds for marine turtle species (Fish et al., 2005).

Beaches are the interface between both marine and terrestrial ecosystems. These are coastal areas of high productivity worldwide for marine-terrestrial species and their surroundings hosts the majority of the human population, that live mainly near the ocean (Jongejan et al., 2016; Mahapatra, 2013). Human induced pressures, combined with climate change, are a serious threat for the coastal areas, and so, for sea turtles (Baker et al., 2006; Fish et al., 2008).

1.5. Aims of the study

The motivation to this study is strongly related with the need to incorporate the two major threats to sea turtles' survival and the interlink between them, to refine and understand future conservation measures. There are several studies that analyse sea turtle trends globally and regionally, but there are only a few about climate change impact on nesting habitat for sea turtles, leading to a lack of knowledge, that is essential for the future conservation of sea turtles. This study intends to estimate population trends of leatherback turtles nesting in the Caribbean Costa Rica, taking in account, illegal and unregulated harvesting off eggs and possible climatic pressures. To achieve this purpose, a set of main objectives was defined, namely:

i. to determine turtle nesting density and magnitude of poaching;
ii. to evaluate the dynamics of the nesting beach;
iii. to verify if beach dynamics influence nesting density;
iv. to estimate future population trends.

2. MATERIALS AND METHODS

2.1. Study Area

Data was collected in a tropical black sandy beach (due to its volcanic origin) in *Barra de Parismina*, that was previously, part of the TNP. At that time, the south border of TNP was *Rio Parismina* River mouth. Nowadays, the south border of TNP is the Jalova Lagoon, that opened to the ocean in 1994 (Troëng & Rankin, 2005). This event created a new beach, called *Playa Tres.* As the stretch of beach was part of TNP in the past, it is important to monitor and protect, as it is part of one of the most important rockeries worldwide, for leatherback and green turtles (figure 1).

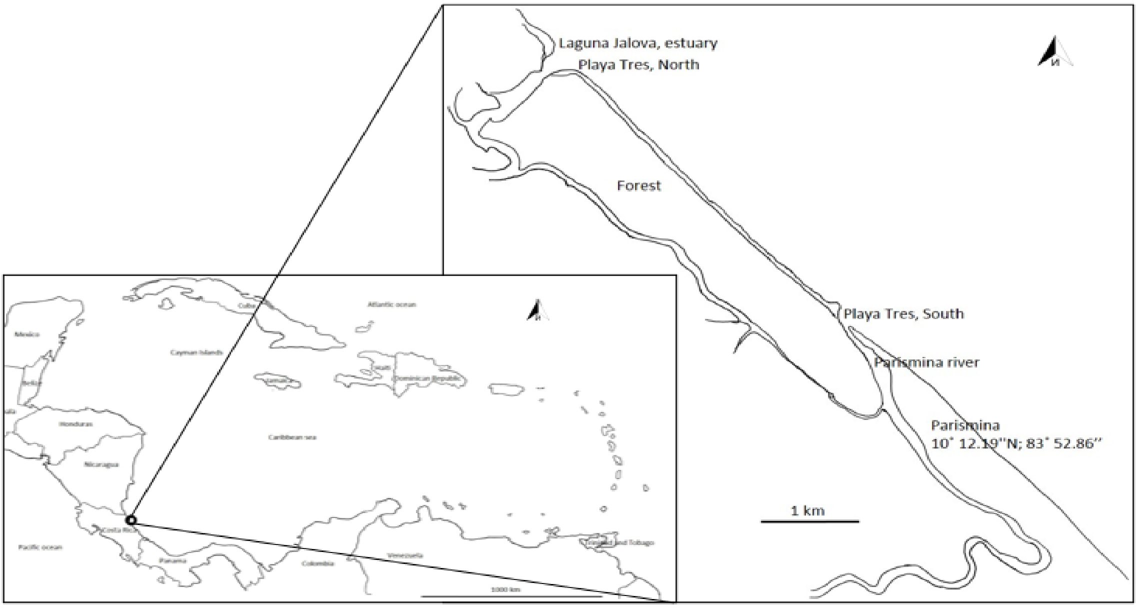

Figure 1-Study site, Playa Tres, location at the Caribbean coast of Costa Rica, in the Caribbean Sea, Central America.

Playa Tres (10º21'09" N 83º23'13" W / 10º19'09" N 83º21'36" W) is 5.4 km long, divided in 5km. Each kilometre is divided in sectors of 100 metres, that allows a better documentation of spatial distribution. The sectors start 200 metres away from each one of the river mouths. The sector marks start in sector 0, located north, in Jalova lagoon; and end in sector 5, located in the south limit, Rio Parismina River mouth.

2.2. Surveys and Nest Monitoring

Turtle data was collected during beach surveys: night patrols and occasionally morning census. Night patrols recorded reproductive events and turtle morphology. Morning census recorded reproductive events, nesting activity and nest fate. During leatherback season, census occurred when the first hatchlings started to emerge and adjusted to the nest incubation timing. Surveys started on 10th March with the objective to assess occurrence and distribution of reproductive events. Patrol surveys and census surveys lasted all leatherback season, until 28th June.

Beach monitoring started at 22 pm, between 10th March and 28th of June, in a total of 113 surveys. During night surveys, every new nest location was recorded, both in GPS and in the field book. All emergence of females were identified using the present metal tags, or adding new ones (AP_ _ _ _) to the turtles without tags. In every turtle encounter tag number was recorded as well the morphological parameters. When a turtle was found during nesting and/or the egg chamber location was possible to encounter, the nest was relocated to maximize the hatch probabilities. Nests were classified separately as wild nests (TLW) or as relocated nests (TL).

During morning surveys, nests were exhumated and their fate classified. Hatched nests were classified as Exhumated, Poached or Predated. Tracks were marked to avoid bias in nesting counting during surveys.

2.3. Beach Dynamics

To assess the coastal dynamics of Playa Tres, beach width, coastal slope and sand steps were measured following a beach profile technique. The model was applied to every 500 meters of the beach, evaluating 11 sectors. Measurements started in sector 0.2 instead of 0.0 due to a bad function of the GPS. For the measurements were used two vertical poles of bamboo, with known height (148cm) and a transect line with 10 meters and a level. The transect line of 10 meters is marked in the middle, and attached to one of the poles, the same with the level (pole 1). Data will be read in the opposite pole (pole 2), marked with an upside-down scale. The upside-down scale allows us to get (h2-h1) directly, the y measure (figure 2).

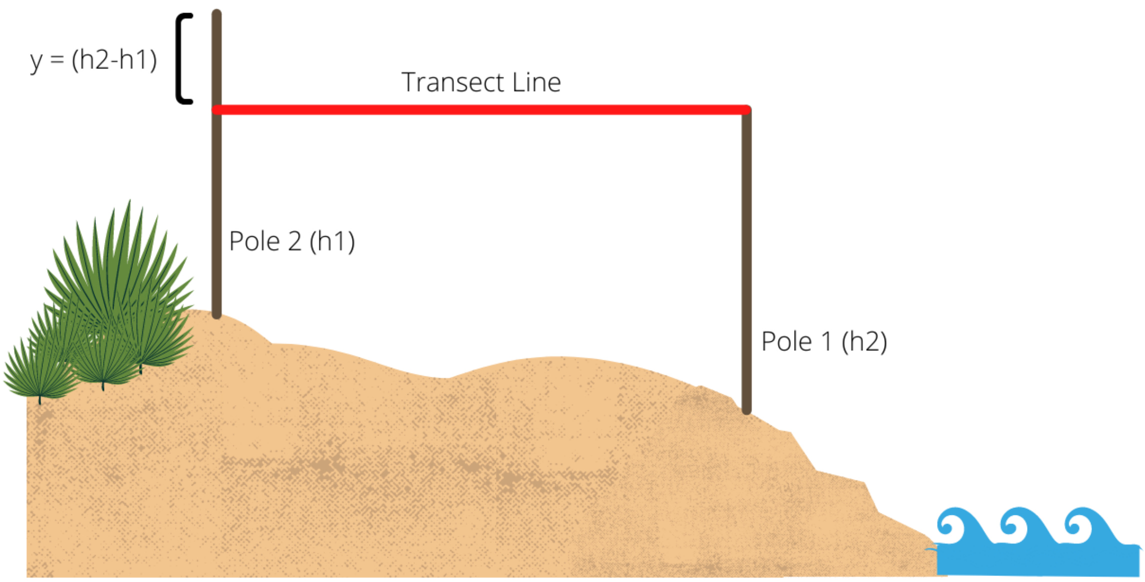

Figure 2-Method for the measurements of beach length and coastal slope.

Measurements started in the vegetation line until the water line. Beach width was obtained directly with the transect line, using the horizontal distance of each section of the sector.

Coastal Slope was calculated using the following formulas:

$$Coastal\ Slope° = \frac{h2 - h1}{d} \times 100$$

$$Coastal\ Slope° = arctan$$

Beach dynamics was a weekly survey that started in the 6th of April and ended in the 11th of June. Every survey was coordinated with the peak lunar phase, being performed in the early morning of the next day.

2.3.1 Lunar phase

To test if tides or lunar phases had any influence on reproductive events, the tide during each survey was recorded, as low or high. Moon phases were divided into lunar quarters: plus three/four days before the peak phase, and plus three/four days after the peak phase (number of days before and after peak phases, dependent of the moon light). Lunar phases were categorized as: new moon; first and last quarter (quarters) and full moon.

2.4 Statistical Analysis

To access the significance of the studies, a one sample t-test was performed to the majority of treatments. A Kruskal-Wallis One Way Analysis of Variance on Ranks was performed to check the differences between beach length.

Statistic analysis were performed with SigmaPlot 14.0. Ink (Systat Software, Inc. SigmaPlot for Windows).

3. RESULTS

3.1. Reproductive events and nesting density

During leatherback nesting season of 2021, in the 85 surveys, were registered 83 leatherback emergences: 65 successful nesting events (78%) and 18 false crawls (22%), with an average of 1 emergence per patrol survey (SD = 1,15; range: 0 – 4).

Nesting distribution between the 5 areas varied markedly. Most of the nests were found in the 3 middle areas of the beach. Area 0 (that goes from sector 0.0 to 0.9) had 10 nesting events, which represents 15%. Area 1 (that goes from sector 1.0 to 1.9) had 22 nesting events, which represents 33%. Area 2 (that goes from sector 2.0 to 2.9) had 19 nesting events, which represents 29%. Area 3 (that goes from sector 3.0 to 3.9) had 13 nesting events, which represents 20%. Area 4 (that goes from 4.0 to 5.0) had 1 nesting event, which represents 2% (Figure 3). The nesting was significantly different between areas with P=0.024.

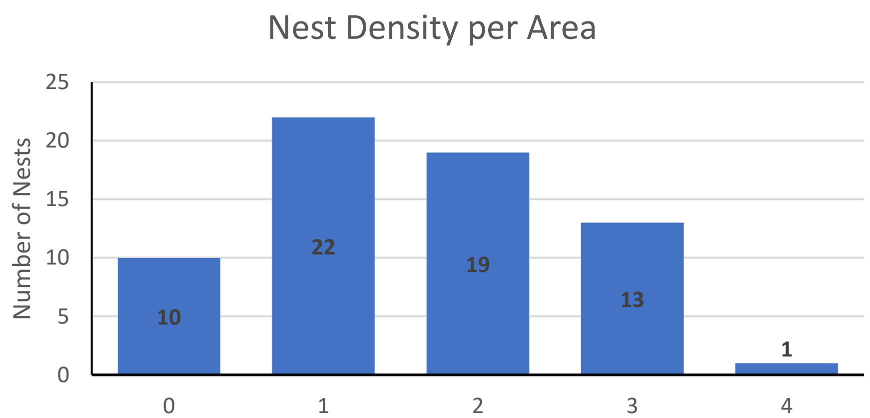

Figure 3-Nesting distribution along the 5 km of Playa Tres.

Nesting density between sectors also varied markedly within each area, showing a significant difference with P=<0,001 (Figure 4).

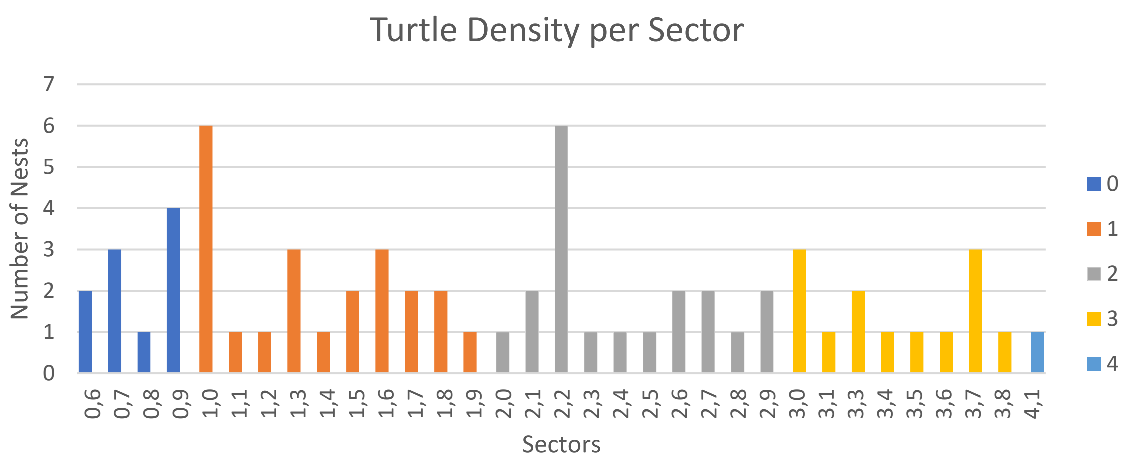

Figure 4-Nesting distribution between sector in Playa Tres.

As an extra, false tracks were analysed. False tracks also varied markedly between areas. Area 0 had no false tracks. Area 1 had 7 false tracks which represents 39%. Area 2 had 3 false tracks, which represents 17%. Area 3 had 5 false tracks, which represents 28%. Area 4 had 3 false tracks, which represents 17%. False tracks were found to be significantly different with P=0,036 (figure 5).

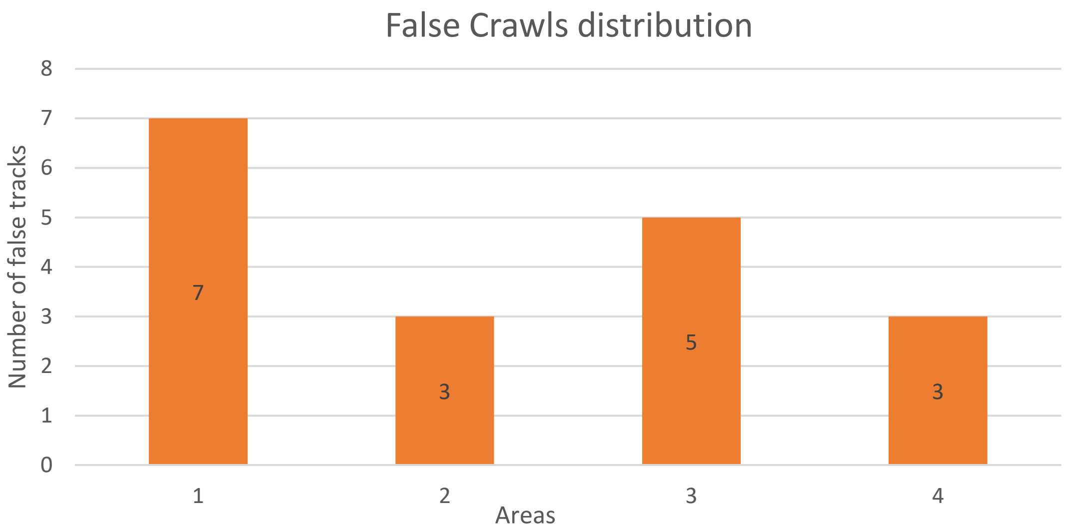

Figure 5-False Crawls distribution along the areas of Playa Tres.

3.1.2. Effect of the lunar phase

The surveys started on the new moon phase and ended on the full moon phase. Data used on the analysis evaluates all leatherback nesting season of 2021. The study corresponds to 15 complete lunar phases and analyses nesting density and number of false crawls. Reproductive events during moon phases are summarized in Table 1.

Table 1-Leatherback turtle nesting activity during 2021 season.

Moon phase	Number of Nests	Number of False Crawls
New moon	15	4
First and last quarter	33	9
Full moon	17	6

False tracks were found to be significantly different between moon phases with P=0,049, however, no significance was found for nesting (figure 6).

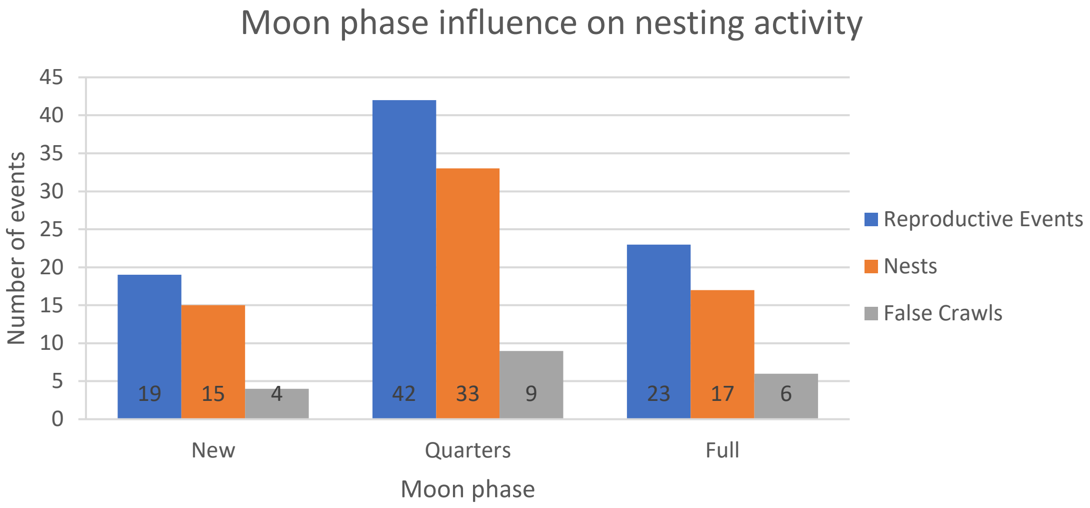

Figure 6-Moon influence in the frequency of the reproductive events of leatherback turtle, in Playa Tres.

3.2. Beach Dynamics

To better understand the nesting habitat and its dynamics, beach profile surveys started at 6th of April 2021 and ended at 11th of June. We evaluated the beach length weakly, according to the moon peak phase. Beach length of each sector during the 10 weeks study can be seen in Table 2 (figure 7).

Table 2-Summary of the beach length by sector, in each week of the study.

	Beach length (m)									
Sector	**week 1**	**week 2**	**week 3**	**week 4**	**week 5**	**week 6**	**week 7**	**week 8**	**week 9**	**week 10**
0,2	51,89	54,16	55,23	52,59	51,46	47,98	51,56	51,73	50,00	48,78
0,5	46,71	61,66	60,35	47,68	52,36	50,00	47,31	42,79	44,81	46,69
1	40,00	48,05	47,68	42,00	39,08	47,00	43,21	40,00	42,84	40,00
1,5	37,64	38,14	36,56	41,82	36,90	40,00	38,60	38,56	38,79	40,00
2	26,50	28,29	37,07	31,39	33,26	34,52	35,20	30,00	35,69	40,00
2,5	25,59	26,54	38,05	29,35	27,35	30,00	30,00	30,00	29,07	40,00
3	30,00	33,51	34,57	35,44	39,70	37,17	41,58	30,00	36,41	40,00
3,5	34,69	35,38	39,00	37,55	39,06	40,00	45,79	40,10	42,56	40,00
4	21,64	29,02	27,89	34,14	30,00	32,00	40,00	33,72	40,00	50,00
4,5	20,00	20,00	19,57	17,60	19,36	16,75	20,00	15,00	15,10	20,00
5	17,35	8,98	0	0	0	0	0	0	0	0

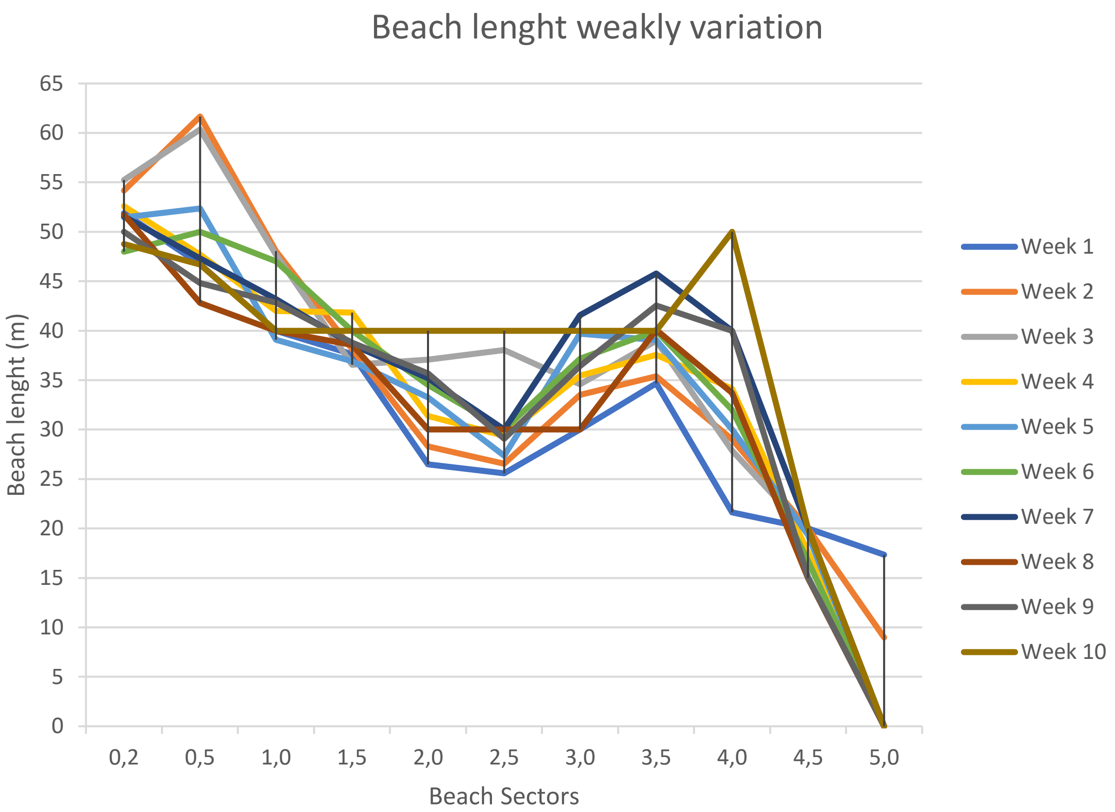

Figure 7-Variation of the beach length during the beach profile study.

Playa Tres beach length did not vary significantly during the 10-week study. However, a significant variance of the weekly beach length was found for 7 of the 10 weeks (table 3).

Table 3-Differences in the beach length for each week of study. One way t-test was used to see significant differences between weeks.

	Mean	SD	df	test	P
Week 1	32,00	11,21	10	9,47	P<0,001
Week 2	34,89	15,21	10	7,61	P<0,001
Week 3	36,00	16,58	10	7,20	P<0,001
Week 4	33,60	14,58	10	7,65	P<0,001
Week 5	33,50	14,70	10	7,56	P<0,001
Week 6	34,13	14,75	10	7,67	P<0,001
Week 8	32,00	14,16	10	7,49	P<0,001

Beach slope was also measured during surveys. Beach slope of each sector during the 10 weeks study can be seen in Table 4 and figure 8.

Table 4 - Summary of the beach slope by sector, in each week of the beach profile study.

	Beach slope									
Sector	**week 1**	**week 2**	**week 3**	**week 4**	**week 5**	**week 6**	**week 7**	**week 8**	**week 9**	**week 10**
0,2	1,35	3,54	5,53	3,75	4,99	4,94	3,47	4,02	3,73	3,77
0,5	1,13	3,58	3,89	2,77	2,22	4,17	2,21	2,38	4,17	2,71
1,0	0,85	9,70	7,96	6,94	7,67	7,90	8,24	6,65	7,10	5,34
1,5	0,68	9,27	8,63	3,01	8,63	12,04	9,54	10,47	8,91	7,97
2,0	0,71	7,35	6,36	4,19	13,35	11,51	7,89	1,37	10,26	5,39
2,5	0,58	0,50	0,46	1,19	0,52	0,50	0,70	1,50	0,50	4,68
3,0	2,01	14,86	15,15	13,79	9,54	9,74	7,35	2,51	9,90	7,98
3,5	3,57	5,14	3,00	4,06	6,03	8,42	3,23	3,52	6,14	6,73
4,0	1,99	11,40	0,63	4,08	0,66	13,00	4,80	6,93	6,20	5,70
4,5	1,68	0,34	0,36	0,69	0,40	0,26	0,68	0,99	0,28	0,42
5,0	3,16	1,03	0,21	0,00	0,00	0,00	0,00	0,00	0,00	0,00

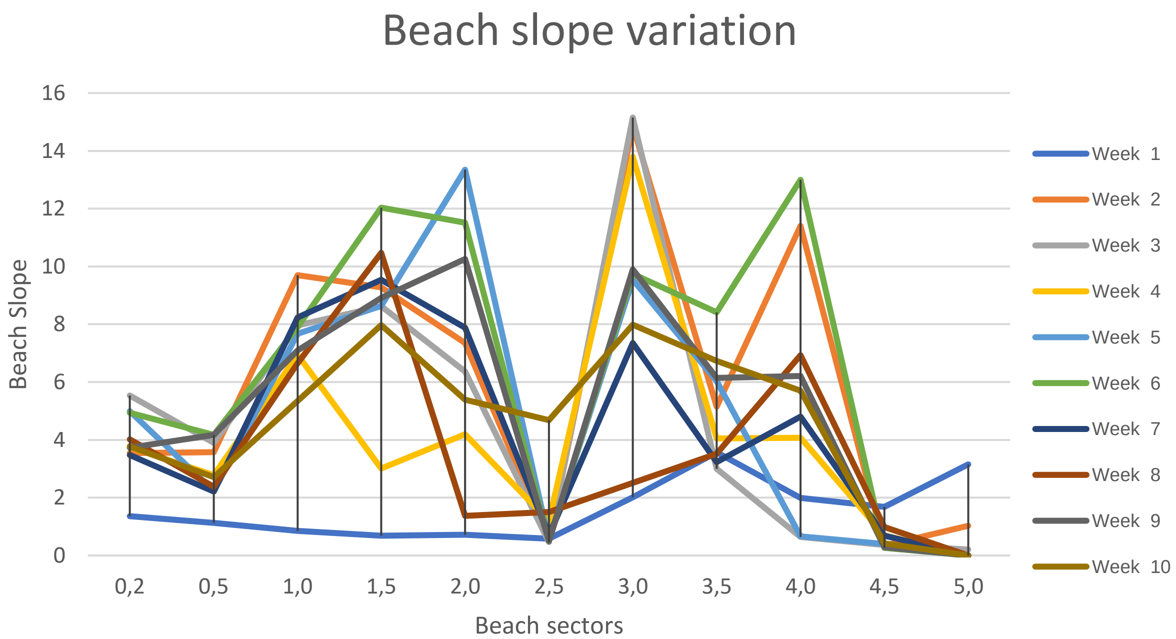

Figure 8-Variation of the beach slope during the beach profile study.

Beach slope of Playa Tres varied significantly during 9 of the 10-week study. Only week 4 did not show any significant changes (table 5).

Table 5-Differences in the beach length for each week of study. One way t-test was used to see significant differences in each week.

	Mean	SD	df	test	P
Week 1	1,61	1,01	10	5,30	P<0,001
Week 2	6,07	4,83	10	4,16	P=0,002
Week 3	4,74	4,65	10	3,39	P=0,007
Week 5	4,91	4,52	10	3,60	P=0,005
Week 6	6,59	4,89	10	4,47	P=0,001
Week 7	4,37	3,40	10	4,26	P=0,002
Week 8	3,67	3,16	10	3,86	P=0,003
Week 9	4,20	3,79	10	4,56	P=0,001
Week 10	4,61	2,69	10	5,67	P=<0,001

3.2.1. Natural Risk Nests

To better understand the habitat preferences of leatherbacks in relation to a water level rising and beach slope, nest location on the beach was analysed (figure 9). However, beach profile only started in April. For that reason, from the total 65 nests, only 49 nests, encountered during the beach profile timing interval, were analysed. Mean distance from the nest to the water line was 16,73 meters (SD=7,14; range -0.69 meters to 31,10 meters). Beach slope mean was 5,88 degrees (SD=4; range 0,46 to 15,15). From the total 49 nets, 9 were found to be in a dangerous beach zone (figure 9).

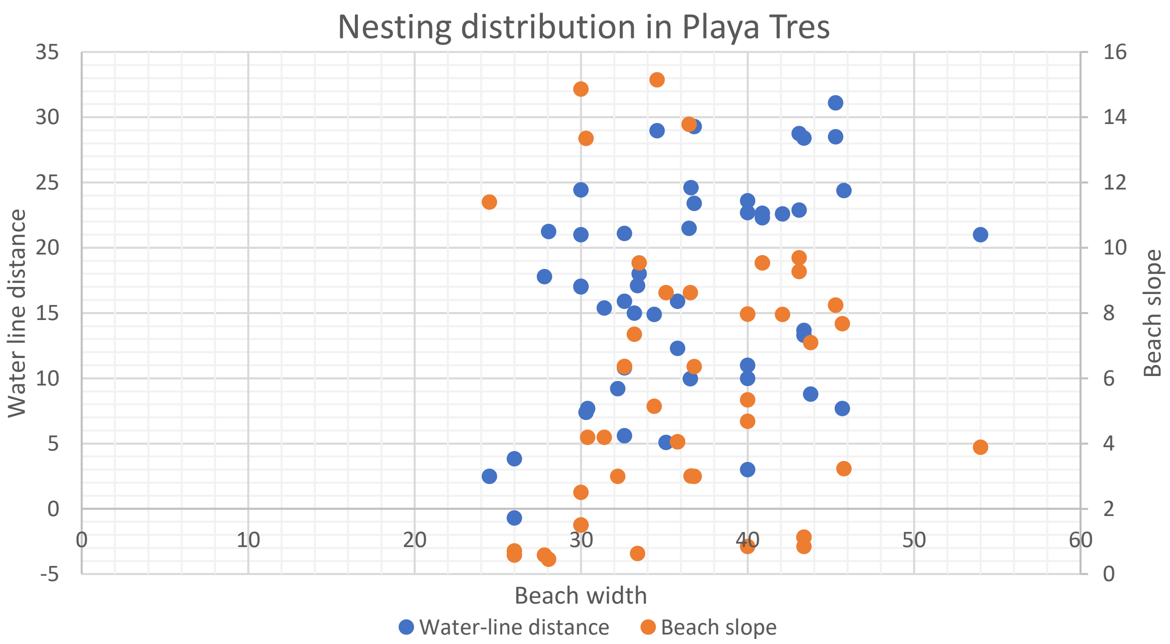

Figure 9-Nesting distribution during beach profile study.

3.3. Future Population Trends

3.3.1. Nests Fate

During surveys, 65 successful nesting events were recorded. However, nesting events were separated in nests (the nests that we managed to relocate) and wild (the nests were the egg chamber could not be found). We registered 22 relocated nests (34%) and 43 wild nests (66%).

For the relocated nests (N), practically all were exhumated (18 of the total 22), 13 were successfully exhumated (60%), 3 were poached (13%) and 2 were predated (9%). No significance was found between relocated nests fate (figure 10).

For the wild nests (W), 25 of the recorded nests were not found (58%). However, 18 wild nests were found and categorized. Of the total wild nests, 8 were exhumated (19%), 10 were poached (23%). There was no record of predation for the wild nests. No significance was found between wild nests fate (figure 10).

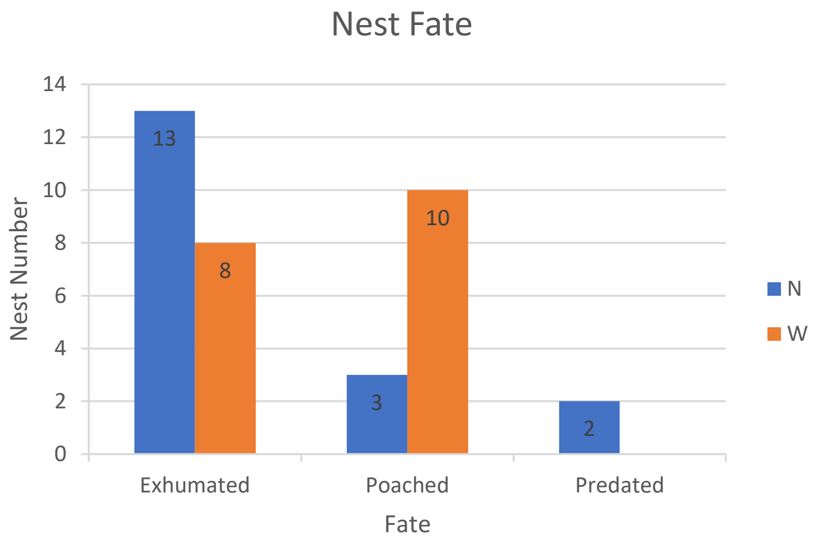

Figure 10-Distribution of the nest fate. Blue bars correspond to the nest fate of relocated nests, orange bars correspond to the nest fate of wild nests.

In total, at least, 13 nests were poached (20%), 21 nests were exhumated (32%), 2 were predated (3%) and 29 nests were never found (45%).

3.3.2. Future Trends

During leatherback season 2021, 20 different nesting females were encountered at the beach. From the CCL data collected, the nesting population has an average of 153,21 centimetres of CCL (SD=6,75 and range 140,43 – 165,25). CCL was found to be significantly different between the 20 nesting female individuals with P<0,001 (figure 11).

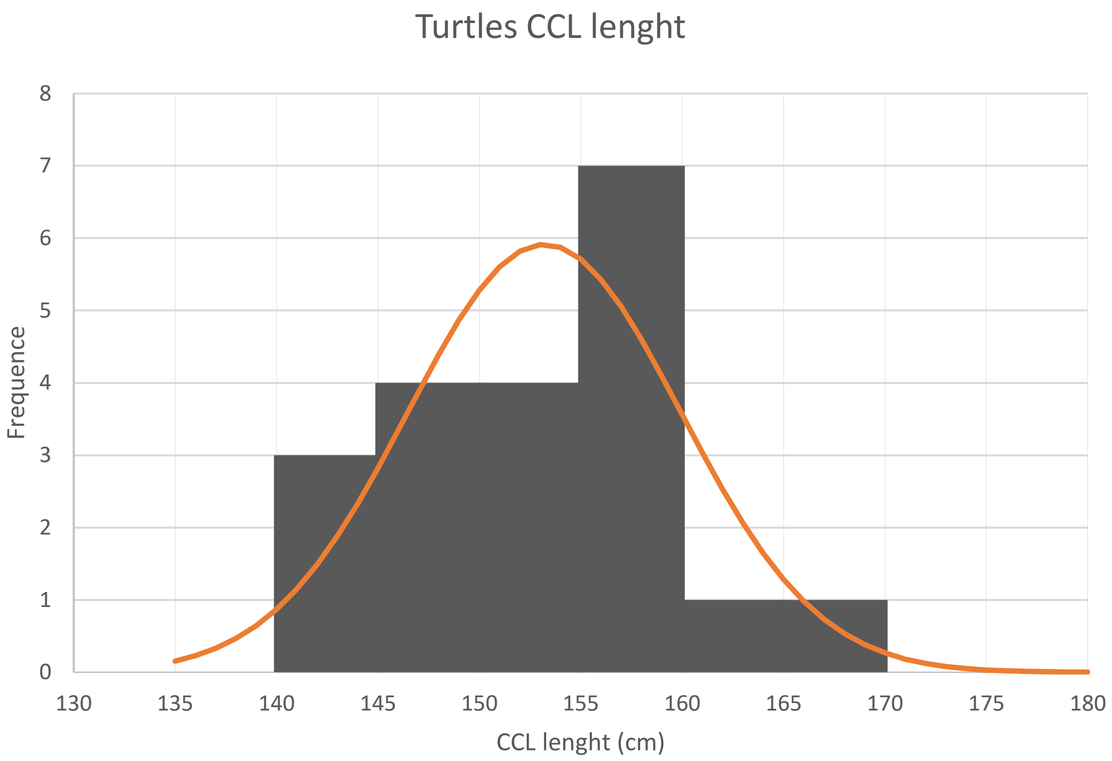

Figure 11-CCL length distribution of Playa Tres nesting females.

4. DISCUSSION AND CONCLUSION

Reproductive events and nesting density

Playa Tres study suggests that the choice of nesting site location may not be due to a random process, and that leatherback turtles may actually choose beach characteristics. However, it is not clear what those characteristics can be and how they work together to become an eligible nesting site (Eckert et al., 2012). Area 1, in the north of Playa Tres, is the area with higher number of false crawls and higher number of successful nesting events. This can indicate that turtles may actually do an exploratory emergence before nesting. In fact, differences found in the emergence densities, that increases as we move from south to north, shows a preference from the leatherbacks to nest closer to the TNP. Area 3, 2 and 1 had, in this order, the major number of nests, and nests in all or almost all sectors. These areas present a major protection than the border areas (0 and 4) of the beach. Also, middle areas are a lot cleaner from debris than border areas. Both border areas are influenced by the river system. South, is influenced by Rio Parismina River mouth, and north by Jalova lagoon (Troëng & Rankin, 2005). Coastal areas next to hydrographic systems usually carry all the anthropogenic impacts and debris, from inland to the sea. Actually, sector 5,0 until around sector 4,5, has so much debris and mainly wood debris, that it was hard for humans to walk through, even next to the water line. This factor, even if decreasing in impact as you move north, could be felt until around sector 4,0, what explains the avoidance of area 4 by nesting turtles, since they prefer debris clean beaches (Bräutigam & Eckert, 2006; Eckert et al., 2012). Area 0, although its proximity with Jalova lagoon, had almost the same number of nests as area 3, but only after sector 0,6. This can be explained by the river system. Jalova was a lagoon before the connection to the ocean. What means that the river current flows mainly and strongly, through Playa Tres south border, making it more dynamic and unstable. Area 0 is in fact the area with the wider beach length, reaching, in some weeks, more than 60 metres. As the current is probably less intense than in the south border, there are also, less wood debris in the sand.

Although, not only physical characteristics affect or may affect leatherback emergences. Night visibility and so, lunar phase, may affect sea turtles' vision on the beach. Too bright nights will expose sea turtles' presence and location to predators, and too dark nights will probably make it harder for them to actively analyse the safety of the nesting beach at the emergence time. False crawls were found to be significantly different between moon phases, with the lower record of events for the new moon phase. Nesting events records were found to be higher during quarters, and showed very similar distribution for full and new moon, what can support the previous theory. However, differences observed between moon phases are unlikely to play any important biological role. Longer study times were necessary, together with the evaluation of other related parameters, such as in-situ night visibility, tides and tide range.

Beach Dynamics

Playa Tres is a very dynamic, high-energy beach. For that reason, a beach profile study was designed, to comprehend the impact of site location characteristics in nesting site selection. Beach slope and length are physical characteristics that have already been proven to affect nesting site location for sea turtles (Wood & Bjorndal, 2000). Beach length was very dynamic, with the major changes seen in sector 5. Sector 5 is probably the most dynamic area of the beach due to its proximity to Rio Parismina River mouth. In fact, during the study period, sector 5 completely disappeared, due to coastal erosion. At the end of the study, sea water was already compromising the vegetation, and in the interface sea-river, several trees had already fallen in the water. In the rest of the beach area, beach length decreases from sector 0 to sector 2,5, increases again until sector 4,0 and then decreases until sector 5. Beach slope followed the tendency of beach length, showing a down-peak in sector 2,5. This down-peak in sector 2.5 could be probably explained with tide and currents data.

Leatherback turtles does their nests in the open sand, the location of the beach that receives 100%-day light during day time. So, leatherbacks will choose beaches, or beach areas, that, at the nesting time, show characteristics that will protect the nesting site location (Eckert et al., 2012). A bigger areal extension will prevent the overlap of body pits (that actually happened in sector 1,0), and together with a gentle slope will prevent the water level to enter the beach habitat. However, sand steps or a very sharp slope will make it to energetic dispendious for leatherbacks to crawl up (Wood & Bjorndal, 2000).

But as a very dynamic beach, Playa Tres suffered significant changes in areal extension and in beach slope during the 10 weeks, altering the conditions evaluated by turtles during nesting site selection. Some nests, around 4%, were probably lost, impacting the population future trends.

Population Trends

According to the nesting population that laid nests in Playa Tres, average CCL (153,21cm) for nesting females corresponds to the average range of CCL (150 to 160 cm) for the Atlantic subpopulation (Eckert et al., 2012). Looking for the normal distribution of the CCL of the nesting females there are a higher frequency of CCL smaller individuals than CCL bigger individuals. According to the graphic, we can assume that there has been a recruitment of younger (smaller CCL) individuals. However, 20 individuals are a too small proportion of the Atlantic subpopulation to predict any trends, and a really small nesting population when compared to the 1000 estimated breading females in the nearby Matina (Eckert et al., 2012). Only one season of study is not enough to study such a long-lived species and try to predict or estimate population trends.

This study shows that poaching, even if as a much lower pressure, is still present in Playa Tres. We found that only 3 of the 22 relocated nests were poached, against 10 of the 18 wild nests. Poaching rate on relocated nests (13%) and wild nests (23%) shows us the importance of conservation and beach monitoring and protection. In total counts we are sure that at least 13 nests (20%) were poached and 45% of the nests were never found. If we include the natural risk nests in the lost nests, 20% was lost to poaching, 14% was lost to climate impacts and 13% were never found. It is defended that, for a healthy turtle population, at least 70% of the eggs should be successfully incubated (Chan, 2006). For the leatherback turtle nesting population, 47% of the laid nests disappeared.

Poaching was mainly practiced during the day in Playa Tres. Although the quasi-island location of the beach offers some protection to several species, poachers are included, as they can do their activity without being caught. The only way to get to Playa Tres is by boat, Playa Tres needs a major conservation effort with more monitoring surveys and probably morning census even during leatherback season, to prevent poaching.

Conclusions

With this study, we conclude that Playa Tres is an important Caribbean beach for leatherback turtles' conservation. Despite the legislation and the conservation strategies in Costa Rica, illegal harvesting of eggs is still a threat (Eckert et al., 1999; Hunt & Vargas, 2018; Valverde Sanchez, 2018). Playa Tres is been protected for the last 3 years. Before the conservation program for Playa Tres, almost 100% of all nests laid in the beach were collected. This year, poaching impact was reduced in 80%. However, if we actually look for the nests that disappear, we lost 47% of the nests during the season. Playa Tres has not an easy access, what makes the beach more appealing to poachers. Even with the monitoring surveys and the existence of the projects, poaching still occurs. Also, there is a farm on the first area of the beach, known to support poachers' activity and hiding poached green turtle individuals during green turtle season.

To solve Playa Tres conservation problem, the lack of knowledge on the breading population and on climate change impacts, is fundamental that the NGO is able to monitor the beach during the night, and start doing beach profile surveys. If beach monitoring covers a more extensive temporal scale, the knowledge on nesting population will be higher and more accurate. Also, during leatherback season, morning census should be carried out to protect nests against poachers, that maybe has been sifting hunting habits in the particular beach due to the human presence during the night. Incorporated in the morning census, beach profile surveys should also be conducted to understand the climate impact on nesting areas.

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