AN OVERVIEW OF THE LEATHERBACK SEA TURTLE (DERMOCHELYS CORIACEA), WITH A PERSPECTIVE IN PUERTO RICO

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Abstract - Worldwide population of leatherback sea turtle (*Dermochelys coriacea*) has declined by ~67%. Hunting for the consumption of their eggs, the transformation of the coast used by this species as nesting areas, global warming and fisheries bycatch are some of the main threats affecting these turtles. This literature review evaluated studies and documentation related to this species to highlight and synthesize its importance, population status, causes of decline, and conservation efforts. Search consisted of official reports from government agencies, non-profit organizations, and scientific research of less than 10 years from ScienceDirect, Google, and Google Scholar. In addition, agency reports and news articles were included. Results showed that leatherback turtle populations continue to decline worldwide due to the large number of threats produced by anthropogenic activities. In Puerto Rico, volunteer efforts have been increasing in recent years, managing to enlarge the documentation of nests and mitigating light pollution. Peer review literature for Puerto Rico is limited. Most of the information were from personal communications, news and annual reports from volunteer groups. Efforts should be increased for the development of scientific literature in peer-reviewed journals that evidence the work of voluntary groups.

Keywords: leatherback, sea turtle, population decline, climate change, Dermochelys coriacea, global warming, beach, pollution, exotic species

Resumen - La población mundial de tinglares ha disminuido en aproximadamente un ~67%. La caza para el consumo de sus huevos, la transformación del litoral utilizado por estas como áreas de anidación, el calentamiento global y la pesca son algunas de las principales amenazas que afectan a estas tortugas. La caza para el consumo de sus huevos, la transformación del litoral utilizado por estas como áreas de anidación, el calentamiento global y la pesca son algunas de las principales amenazas que afectan a estas tortugas. Esta revisión de la literatura evaluó artículos científicos bajo las bases de ScienceDirect, Google y Google Scholar y documentos de agencias relacionados con la especie. Los resultados demuestran que las poblaciones de tortugas tinglar continúan disminuyendo a nivel mundial debido a la gran cantidad de amenazas producidas por la actividad antropogénica. En Puerto Rico, los esfuerzos voluntarios han ido en aumento en los últimos años logrando incrementar la documentación de nidos, y mitigación de la contaminación lumínica. Existe una limitación en la literatura científica revisada por pares para Puerto Rico. La mayoría de la información que se tienen son de comunicaciones personales, noticias o informes anuales de los grupos voluntarios. Se deben de aumentar los esfuerzos en el desarrollo de científicas en revistas arbitradas que evidencien la labor de los grupos voluntarios.

Palabras claves: tinglar, tortuga marina, disminución poblacional, cambio climático, Dermochelys coriacea, calentamiento global, contaminación, especies exóticas, playa

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Introducción

Reptiles are a group of animals composed of more than 20,000 species in the world. These are amniotic vertebrates with epidermal keratin scales and the ability to shed their skin (Pough et al., 2016). They are found distributed in various ecosystems on all continents, except for Antarctica. This group of organisms are segregated in four orders; Crocodilia, Rhynchocephalia, Squamata, and Testudines (Vitt & Caldwell, 2013). Within vertebrates, the Testudines (turtles) are considered one of the oldest groups on the planet. These are divided into 14 families with approximately 341 species (Pough et al., 2016).

Despite their diversity and longevity, certain populations of species belonging to these groups are decreasing (Wallace et al., 2010; International Union for Conservation of Natures, 2016; National Oceanic and Atmospheric Administration, 2020). Among the most vulnerable families, the Cheloniidae and Dermochelyidae stand out. They depend on the world's seas and oceans to survive. The ecosystems that these bodies of water have, are constantly exposed to a great extent to anthropogenic activities, affecting the organisms that inhabit them (Markic et al., 2018).

Another thing that puts the Cheloniidae and Dermochelyidae families in a vulnerable position is that they continue to be cryptic organisms (Pfallar at al., 2014). For example, little is known about the development of hatchlings in the seas and oceans (Mansfield et al., 2012). This represents an even greater challenge to be able to generate accurate data on these animals and thus make conservation and management plans for their protection (Mansfield et al., 2012).

It should be noted that the family Dermochelyidae has several extinct genera and only one alive. The leatherback (*Dermochelys coriacea*) sea turtle (Figure 1 & 2) is the only living species within this family and it is also the only one in the genus *Dermochelys* (Pough et al., 2016). In 1973, it was classified as an endangered species under the Endangered Species Act (National Marine Fisheries Service & US Fish and Wildlife Service, 2020). Currently, the world populations of this species keep decreasing and it is estimated that this pattern will continue in the future (International Union for Conservation of Natures, 2016; National Oceanic and Atmospheric Administration, 2020). The main objectives of this literature review were to evaluate studies and documents related to this species to highlight and synthesize its importance, population status, causes of decline, and conservation efforts. In addition, I evaluate documents and studies that focus on this species in relation to Puerto Rico.

Figure 1. Leatherback (*Dermochelys coriácea)* nesting in Yabucoa, Puerto Rico © Adolfo Rodríguez Velázquez

Figure 2. Leatherback (*Dermochelys coriácea)* hatchlings in Arecibo, Puerto Rico. ©Julio Salgado

This search for this review consisted of official reports from government agencies (federal and state), non-profit organizations, and scientific research of less than 10 years, to obtain the most up-to-date information on the biology and ecology of the species and regulations at national and local level. Additionally, it included a review of newspaper articles due to the limitation of scientific articles dedicated to this species in Puerto Rico. The search for the works was carried out from February 2020 to May 2021 using the following tools: ScienceDirect, Google, and Google Scholar. Near 15 combinations of the following words or key phrases, both in Spanish and English, were used for the search: *Leatherback, Leatherback Sea turtle, tinglar, tortuga laud, tinglar* en Puerto Rico, Dermochelys coriacea, neonatos de tinglar. The approximate result of publications obtained were 10,000 publications for Google, 1,000 Google Scholar and 100 for ScienceDirect. The first 200 articles were reviewed to verify the suggested keywords.

Species description and ecologic importance's

It is believed that the first sea turtles existed on Earth more than 230 million years ago, according to fossil records these were part of the Late Triassic (Li et al., 2018). Historical records indicate that when Columbus sailed to the new world, the sea turtles were so abundant that ships that had lost their way in the Caribbean could follow the sound of their shells colliding with each other to reach the Cayman Islands (King et al., 1982). For millions of years turtles have played vital roles in maintaining the health of the world's oceans and seas. They fulfill the function of keeping healthy seagrass beds, coral reefs and coast, providing key habitat for other marine life, helping to balance food webs and facilitating nutrient cycling from water to land (Bjorndal, 1980).

Sea turtles are divided into two families, *Cheloniidae and Dermochelyidae*, formed by seven species; *Caretta caretta, Chelonia mydas, Dermochelys coriacea,*

Eretmochelys imbricata, Lepidochelys kempii, Lepidochelys olivacea and Natator depressus (de Carvalho et al., 2016). The leatherback sea turtle (*Dermochelys coriacea*) stands out by having the largest body size reaching 7 feet long and weighing up to 2, 000 lbs. (Baker et al., 2015). All sea turtles have a rigid bone shell except for the leatherbacks, which have a soft plastron with a hydrodynamic shape which allows them to reach great depths and maintain an elevated body temperature. This species can dive impressive depths of 4, 200 feet and remain submerged for 85 minutes (Wyneken, 2004).

Leatherbacks are considered the most widely distributed vertebrate in the world, ranging from tropical to subarctic waters with varied migration patterns around the globe (Eckert et al., 2012). Like most reptiles, leatherbacks are ectotherms but have several adaptations that allow them to maintain a stable body temperature; for example, they have large stores of oxygen in their blood and muscle, and special features like collapsible lungs, a pulmonary sphincter and slowed heart rate (Doyle et al., 2008).

In terms of reproduction, females can mate with more than one male at sea and opt for the coast of sandy beaches with high waves, located in tropical and subtropical regions (Rivas et al., 2016). This species nests every year between 4 to 7 times per season and lay an average of ~80 fertilized eggs and ~30 unfertilized eggs (Eckert et al., 2012). When preparing their nests, sea turtles move large amounts of sand, transforming the coast lines and forming sand dunes. It also promotes a transfer of ocean minerals to the surface and vice versa, maintaining a healthy exchange for both ecosystems. Each nest provides nutrients such as nitrogen, phosphorus and potassium from the eggshells and embryonic fluid, vital for vegetation growth and food for coastal species. Much of the coastal areas would remain infertile if the leatherbacks do not perform a cyclical supply of nutrients (Bouchard et al., 2000).

Leatherbacks make large migrations between nesting and feeding grounds; they travel an average of 3, 700 miles each way (James et al., 2005). Their diet is based on jellyfish, scalps and siphonophores, consuming up to 440 pounds of jellyfish each day (Houghton et al., 2006). Controlling jellyfish populations is vital to marine ecosystems because they have few predators, high reproductive capacity, endurance, and wide distribution, therefore an increase in abundance may bring detrimental consequences to marine organism's stocks and humans in ecological, economical and health terms (Purcell et al., 2001; 2007).

Status of the Leatherback (populations and subpopulations)

Leatherback sea turtle populations consist of seven subpopulations, according to their migration patterns (Wallace et al., 2010), genetics characteristics, nesting sites, among others (Northwest Atlantic Ocean, Southeast Atlantic Ocean, Southwest Atlantic Ocean, Northeast Indian Ocean, Southwest Indian Ocean, East Pacific Ocean, and West Pacific Ocean) These division are characterized by their size, geographic range, and population trends. Little is known about the males, because only females come to approach the coast for nesting. Subpopulation's categorization considers the number of females nesting, nests and number of eggs by geographical sections, hatching success, among other factors.

The East Pacific Ocean subpopulation has declined 97.4% during the past three generations and are classified as Critically Endangered (Wallace et al., 2013). There's not much data from the Northeast Indian Ocean and Southeast Atlantic Ocean subpopulation because they were the latest established division. Due to the great efforts of conservation programs such as Sea Turtle Conservancy, the subpopulation of Northwest Atlantic is classified as *least concern*. The Southwest Atlantic Ocean subpopulation has only 35 mature members and the Southwest Indian Ocean subpopulation has an estimated of 148 adult males and females in total (Wallace et al., 2013). The evidence of a small but continuing decline of -5.6% in population during the past three generations for the Southwest Atlantic and a slow increase makes this subpopulation critically endangered (Tiwari et al., 2013). The West Pacific Leatherback subpopulation has declined 83.0% during the past three generations; also, the nesting abundance has declined at the two Indonesian index beaches Jamursba-Medi and Wermonby 78.3% over 27 years at and 62.8% over the past nine years respectively, considered *critically endangered* (Tapilatu et al., 2013).

The overall population has decreased by an estimated -40.1% over the past three generations, placing them in the category of Vulnerable (Wallace et al., 2013). During the Red List Assessments made by the IUCN in 1982, 1986, 1988, 1990, 1994, and 1996, the leatherback was declared as Endangered. However, in 2000 was placed as critically endangered (Wallace et al., 2013). It is believed that for the next ten years this species is going to be positioned as Endangered or Critically Endangered according to the IUCN Red List Criteria (IUCN, 2016).

Factors contributing to the decline of the leatherbacks

When nesting, the *D. coriacea* face various obstacles due to various factors such as climate change, predation, hunting, and urban development. Currently global warming and climate change have influenced changes in oceanic currents and

consequently migration patterns (Luschi et al., 2003). Likewise, the frequency of stochastic atmospheric phenomena, and increases in ocean levels by the melting of polar ice cap has caused loss of shores, reducing visits for nesting as shown in Figure 3 (Rivas et al. 2016). Islands are highly susceptible to atmospheric disturbances and their consequences. Barreto-Orta et al. (2019) evaluated the coasts of Puerto Rico after Hurricane María in 2017. Their research indicated that most of the beaches on the Island suffered loss of elevation, changes in width, and a considerable increase in erosion (Figure 4). Some of these changes were in towns of importance for leatherback nesting such as Yabucoa, Humacao, Arecibo, Añasco, among others. It should be noted that in these reptiles, the sex of the hatchlings is determined by incubation days and temperatures (Chevalier et al., 1999). With the global warming and climate change, this feature has played an extremely important role because long periods of rain with lower temperatures increased production of males. By contrast, long periods of drought and higher temperatures, increased production of females (Laloë et al., 2016). Puerto Rico has had seven episodes of droughts between 2000 and 2016, being one of the most critical the period between 2014 and 2016 with 33 weeks of extreme drought conditions (Álvarez-Berríos et al., 2018).

Figure 3. Sea level rising in Naguabo, Puerto Rico © Adolfo Rodríguez Velázquez

Figure 4. Costal erosion in Toa Baja, Puerto Rico © Adolfo Rodríguez Velázquez

In many countries, the collection and sale of the eggs was a normal phenomenon because these are considered aphrodisiac and some cultures believe that eating sea turtle eggs leads to a long life (Seeturtles.org, 2016). When sea turtles are nesting, they become vulnerable and sometimes are killed for oil for caulking boats, for use in lamps, and for medicinal use (Wilson et al., 2010). In some parts of Asia, Africa, Central America, and the Caribbean leatherback turtles are hunted for their meat and for performing religious rituals. In Puerto Rico exists several records of dead leatherback sea turtles that have been found with what appear to be fin and

head cuts. According to the local press, in June 2011 a dismembered leatherback was found (Rivera-Arguinzoni, 2011) and in May 2014 another dead with a contusion on the head was identified (Rosario, 2014). In 2015, another individual was found dismembered on a beach in Isabela (Caro-González, 2015).

Urban development adjacent to the coast like the construction of breakwaters, boardwalks, jetties, hotels, etc., serve as physical barriers for nesting sea turtles. Coastal urban development accelerates coastal erosion, reduces the amount of available habitat for nesting, and degrades the quality of the remaining habitat by introducing new harms (Ordoñez et al., 2013). Reports presented by non-profit organizations that works with leatherback turtles in Puerto Rico mentioned the concern of coastal development on the island, specifically on beaches of importance for this species such as playa El Paraíso in Dorado (Crespo & Diez, 2016; Flores & Diez, 2016). It is even emphasized that many of these developments occur in maritime land areas. It should be noted that Puerto Rico has 44 coastal municipalities, with a total of 2,140,579 inhabitants (H), 65% of the total population of the country (Censo Puerto Rico, 2020). Some of these, such as San Juan (355,181 H), Carolina (161,684 H), Barceloneta (24,583 H) and Mayagüez (79,615 H) have beaches of great importance for the nesting of leatherback (National Marine Fisheries Service & US Fish and Wildlife Service, 2020) and in the same way make up the municipalities with the highest number of persons per square mile (Censo Puerto Rico, 2020). Coastal constructions like the ones shown in Figure 5 are common on the Island because of coastal developments.

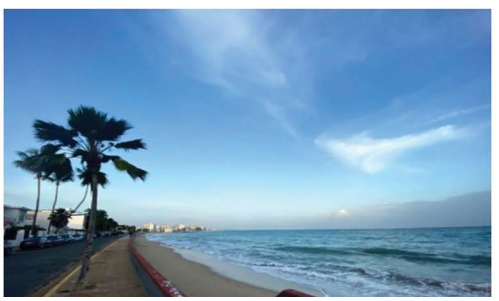
On the other hand, costal developments can bring the problem of light pollution. The phenomenon of light pollution near nesting sites can disorient females and hatchlings when leaving their nests. These associate the brightness of the lights with the moon and the ocean, heading toward them (Witherington et al., 2003). There have been reported cases of leatherback turtles in roads, parking lots, houses, among other places which can make them easy prey, or they die of dehydration. In 2018, volunteers from *Vida Marina* of the University of Puerto Rico in Aguadilla reported the death of 33 neonates of leatherback turtle that fell into a sewer due to light pollution (Rodríguez, 2018). According to an article presented by the newspaper *El Nuevo Día,* annually, in Puerto Rico there are between 50 to 60 complaints due to light pollution, most of which are presented by groups that work with sea turtles (Agencia EFE, 2018). On the other hand, according to statistics from the United States Department of Energy, for 2019 Puerto Rico was in position number 76 in net energy consumption (17 billion kilowatt hours)

and number 90 in oil consumption (79 thousand barrels per day), mostly used for lighting production (US Energy Information Administration, 2021).

Human proximity increases predation of neonate and nest by exotic animals, such as cats, dogs, mongooses, crabs, raccoons, birds, coyotes, boars, pigs, and rats (Engeman et al., 2016). Currently in Puerto Rico, Regulation 6765 of the Department of Natural and Environmental Resources that lists the invasive species present on the Island has not been updated since 2004 (Departamento de Recursos Naturales y Ambientales, 2004). To mention a few examples, in this regulation cats are only considered invasive in nature reserves, wildlife refuges and state forests. Other species such as dogs and red tail boas are not listed but their populations continue to increase around the Island (Personal data). Currently, few organisms in Puerto Rico have a management plan for their control and / or eradication. Unfortunately, leatherback turtles are vulnerable to these. In 2012 at California Beach in Maunabo, the predation of 30 hatchlings by dogs was reported (Crespo & Diez, 2016). This type of situation could increase, and other species could be added if the proper actions are not taken.

As well, the presence of exotic vegetation in the beach has repercussions on the turtle species. An example of this is the introduction of *Casuarina equisetifolia* (Australian pine), producing excess shade on the coasts, altering the natural hatchling sex ratio (Schmelz & Mezich, 1988) and hindering access to sandy beaches with its roots (Reardon & Mansfield, 1997). In Puerto Rico, *Casuarina* is very common in coastal areas. There are several plantations around the island and some of these, such as Guánica, Luquillo and Toa Baja, are close to leatherback nesting areas (Francis et al., 2000). Individuals of this species (Seven Seas, Ocean Park, Isla Verde, etc.) can be found due to the shade they provide (Personal data). Some of these are nesting places for the leatherback turtle.

In addition, coastal development increases runoff of pollutants and waste by sewage systems. Certain pollutants, such as fertilizers, pesticides, nutrients, and



untreated waste, may cause immediate harm to sea turtles through direct contact or can build up in tissues over time and lead to immunosuppression resulting in disease and or death. For example, polychlorinated biphenyls (PCB's), an organic chlorine compound that can cause cancer, mutations and weakness in the immune system, have been found in turtle's eggs (Landry et al., 1992). Polybrominated diphenyl ethers (PBDEs) and pesticidal components have been documented in adults and leatherback eggs (Stewart et al., 2011). These may have alterations in the immune, reproductive, and endocrine systems of adults, in addition to affecting the development of neonates (Stewart et al., 2011).

As in other species, some pathogens affect the leatherbacks. The fungi *Fusarium falciforme* and *Fusarium keratoplasticum* are globally distributed in major turtle nesting areas and are implicated in low hatch success (Sarmiento et al., 2015). Rosado-Rodríguez and Maldonado-Ramírez (2016) carried out a study between 2008 and 2009, off the coasts of Mayagüez to Añasco, to evaluate the presence of fungi in leatherback sea turtle nesting areas. The results demonstrated three types of fungi present: *Penicillium, Fusarium, Aspergillus and Cladosporium*. According to the publication, these genera have been associated with the direct loss of eggs in nests of the leatherback turtle.

Turtles are often experiencing the *Fibropapilloma virus.* Despite this disease being more common in species of hard-shelled sea turtles, in leatherback there is one report. In 1997 a female was found nesting on the beaches of Mexico with the presence of fibropapilloma (Huerta et al., 2002). In general, the species that experience this disease present massive tumors that affect their ability to swim and eat, leading to a slow and lingering death. This virus is linked to pollutants in the ocean that are associated with anthropogenic causes (Work et al., 2013). In the future, the increase in these activities could represent a threat in these species, possibly making tumors more common.

According to the Food and Agriculture Organization of the United Nations (FAO), between 1990 and 2018, the total consumption of fish as food had an increase of 122%. In the same period, world fishing increased by 14% (FAO, 2020). This has implications for leatherback populations around the world. The Endangered Species Act Status Review of the Leatherback Turtle (*Dermochelys coriacea*) 2020, indicated that incidental catches from fishing activities represent the main threat to sea turtle populations in the world. Techniques such as pot / trap fisheries, trawl fisheries, dillnet fisheries, and long line fisheries have been highlighted as having the greatest impact (National Marine Fisheries Service & US Fish and Wildlife Service, 2020). Technological advances and great fish demand for consumption

have recently established longlining, which is composed of fishing vessels that lay out a 40-60-mile-long line of vertically hanging baited hooks where leatherback can get caught up, causing them to drown (Roach, 2003). Lewison et al. (2004) estimated that approximately 250,000 sea turtles are caught each year by commercial longline fishing. Of this number, 50,000 are considered leatherback turtles. The 90% of longline fishing conducted in international waters originates from international fleets, primarily from Japan, Taiwan, Korea, and China (Lewison et al., 2004).

The increase in maritime activities with boats, vessels, cruise ships, etc., in areas where leatherback frequent, increase the risk of incidents of contact with the turtles. At least 72 leatherbacks are known to be stranded in Massachusetts with vessels strikes between 2006 and 2018 (Dourdeville et al., 2018). In Florida, necropsy was made on 194 stranded turtles, identifying vessels impacts as the death reason of the 92% of the stranded specimens. The same study estimated that between 2000-2014, mean annual number of leatherbacks that died because of vessels impacts was 4-6 turtle (Foley et al., 2019). Despite not having so many current records of this type of accident, it is a threat that can increase with anthropogenic activities.

Puerto Rico has 13 yacht clubs, 16 marinas, and 11 maritime ports (Suárez-Gómez, & Ayala-Cruz 2016; Diaz & Hevia, 2017). These areas have a constant movement 24 hours throughout the year due to the import and export of products. Puerto Rico is a popular destination for cruise ship tourism. In 2018, the Island received the arrival of 517 cruises (Garcia-Pelatti, 2019). The ships arrival peaks coincide with the peak (April to July) of the nesting season (National Marine Fisheries Service & US Fish and Wildlife Service, 2020). Many of these cruises enter the island's shores during the early morning hours, this could be representing a risk for the turtles that return to the sea in those hours after laying their eggs.

The production of waste also affects sea turtles. Plastic has had a negative effect on different species, but leatherback is even more susceptible to it. These turtles feed exclusively on gelatinous zooplankton and jellyfish, being able to mistake plastic material such as bags, balloons, etc., as potential prey (Mrosovsky 1981; Schuyler et al., 2013). According to Schuyler et al. (2016), approximately 52% of all sea turtle known to have ingested marine debris, mostly plastic. In the Western Mediterranean, 79.6% of dead turtles revealed presence of plastic, 60.5% of turtles in Southern Brazil and 56% of turtles in Florida (Tomás et al., 2002). Moskovy et al. (2009) found that 38% of 408 leatherback necropsied contained plastic in their gastrointestinal tract. Being party balloons, fishing lines and plastic bags the most common (Morosovsky et al., 2009). The presence of microplastic has been documented in leatherback nests and in their gastrointestinal tract (Duncan et

al., 2019). This can affect the health of the turtle at the cellular or subcellular level, being able to introduce viruses, bacteria, fungi, etc. (Ducan et al., 2019).

Puerto Rico nesting beaches evidenced the presence of plastic debris (Figure 6). In 2019, Ocean Conservancy's International Costal Cleanup reported that - 440.4 km of the Puerto Rican coast, with plastic being the material with the greatest presence (Ocean Conservancy, 2019). Furthermore, a study in which sand was sampled from 6 beaches in the northern part of Puerto Rico found the presence of microplastics in all sampled areas (Pérez-Alvelo et al., 2021). It should be noted that the collection areas are close to leatherback nesting places (Puerto Las Vacas in Barceloneta, La Esperanza Peninsula in Cataño, Isla Verde in Carolina, La Pocita in Loíza, Herrera in Loíza, and Costa Azul in Luquillo).

Conservation (Legislation and efforts)

Annex II of the Specially Protected Areas and Wildlife (SPAW) Protocol to the Cartagena Convention; Appendix I of Convention on International Trade in Endangered Species (CITES); and Appendices I and II Convention on Migratory Species (CMS); the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC), the Memorandum of the Indian Ocean and South-East Asia Marine Turtles (IOSEA), among others, are some examples of international and national legislations and or movements looking for the protection of leatherbacks. All these designations intend to make illegal the harming, harassing, or killing of any sea turtles, hatchlings or their eggs. Also, it is illegal to import, sell, or transport turtles or their products. Each country is supposed to have conservation laws and regulations that protect marine turtles. For example, in the United States they have legal protection under the Endangered Species Act (ESA), in Costa Rica the Law 8325, Guatemala Law 223-2005, Spain Law 42/2007, among other.

In terms of laws and regulations, leatherback in Puerto Rico is protected by the Endangered Species Act (1973) because of the territories status and protected at the state level by the New Wildlife Law known as Law number 241 of 1999 (Departamento de Recursos Naturales y Ambientales de Puerto Rico, 2016). In addition, there are specific laws for protected areas where these species nest, such as the Law of the Natural Reserve of the Northeast Ecological Corridor know as Law number 126 of 2012 (Endangered Species Act Status Review of the Leatherback Turtle, 2020). These regulations prohibit the capture, possession, sale, transport, export, disturbance, habitat destruction, among other aspects related to adult leatherback turtles, hatchlings and eggs (Departamento de Recursos Naturales y Ambientales de Puerto Rico, 2016; National Marine Fisheries Service & US Fish and Wildlife Service, 2020). On the other hand, if a person mutilated, injured or harmed an individual of a sea turtle, the Law for the protection and welfare of

animals known as Law number 154 of 2018 could apply (Departamento de Recursos Naturales y Ambientales de Puerto Rico, 2016).

Figure 7 & 8. Community efforts in monitoring and patrolling nests, in San Juan, Puerto Rico
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Some international established entities, like Seaturtles.org, are dedicated to the study, conservation, and ecological tourism. They organize activities like conferences, turtles watching, egg counts, release of hatchlings, monitoring at sea, etc. These provide certain services which generate a fund for the purchase of materials research, expansion of centers, research facilities, amongst others. For example, during 2015, at least 120 travelers visited sea turtle conservation projects in Costa Rica, Cuba, Nicaragua, and Mexico. These tours generated more than $100,000 for sea turtle conservation and local communities. Of those travelers, 95 volunteered during their trips, completing more than 300 work shifts. A greater number of projects like these should be integrated into other countries that have sea turtles in addition of education for the conservation of the species. In Puerto Rico there are about 9 non-profit organizations focused on the conservation and protection of sea turtles (Personal data). Some of these specialized in leatherback turtles. It should be noted that the number of organizations and volunteers has been increasing in recent years, thus allowing greater action in conservation efforts: coastal patrolling, nest census, light pollution mitigation (Personal data). In Puerto Rico, 70 km of beach have been identified where leatherback turtles' nest. These are found distributed in 23 municipalities: Río Grande, Luquillo, Fajardo, Humacao, Maunabo, Yabucoa, Dorado, Añasco, Arecibo, Isabela, Loíza, Rincón, Mayagüez, Cabo Rojo, Barceloneta, Guánica, Manatí, Hatillo, San Juan, Carolina, Culebra, Vieques (National Marine Fisheries Service & US Fish and Wildlife Service,

2020). In the last 10 years the number of nests registered exceeded 1,000, with 2016 being the year with the highest number with 2,167 reported nests in total (National Marine Fisheries Service & US Fish and Wildlife Service, 2020). The identification of these areas has been thanks to the efforts of volunteer groups and government entities (Figure 7 & 8).

Conclusion

The loss of biodiversity worldwide has accelerated affecting more and more organisms by the Anthropocene. The most recent edition of the *Living Planet Report*, published by the *World Wildlife Fund for Nature* revealed a 68% decrease in the size of vertebrate populations (fish, birds, mammals, amphibians and reptiles), since 1970 to 2016 (WWF, 2020). The impact on the oceans is evident with pollution, warming of the waters, increases in level, acidification, among others. Leatherbacks are constantly affected by these factors.

The world leatherback populations will continue to decrease according the increase in anthropogenic activities. The ecological, economic, and cultural importance of this species are diverse, and an extinction would be detrimental to ecosystems, affecting humans directly. Despite the existence of legislation, conservation programs, and international cooperative efforts, it is necessary to continue increasing conservation efforts to achieve at least stabilization in leatherback losses and eventually increase the number of individuals. Environmental education is necessary and should not be restricted to coastal areas as occurs in various countries. This must cover all sectors because people must internalize that something that happens in a remote area in the mountains, such as the generation of plastic, can directly affect leatherback populations.

On the other hand, conservation measures in the countries where they nest must directly include coastal areas. Annually, the spaces they must reach the coasts are reduced due to human disturbances and many of those that remain are not safe (invasive species, light pollution, etc.). It should be noted that both Global Warming and Climate Change bring with them even greater challenges for the conservation of the species. An example of this are the major hurricanes altering the coastal profiles, having implications for the development of nests. Even though every year scientific research is carried out with this species, the support and development of studies to answer questions that serve to add to natural history, biology and even help in conservation efforts continue to be necessary and should be supported even more by the citizen and governmental effort.

In Puerto Rico, there has been an increase in the number of voluntary groups dedicated to the conservation of this species. However, in the same way, there is a

growing number of coastal developments that these same groups have documented. Within the efforts of these organizations, they have managed to remedy various situations linked to anthropogenic activities, but there are others threats, such as the management of invasive species, in which the government must act. It should be noted that voluntary work done is documented by informal reports presented to government authorities. As well, it is reported to general public by the local press, but not in peer-reviewed journals to demonstrate the efforts of these groups. Learning by example, other community groups can adopt similar measures for conservation in their respective countries. These and other field measures should be taken to assure data compilation of the species ecology and biology.

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