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Causes of Stranding of Sea Turtles on the North Coast of São Paulo State, Southeastern Brazil

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***Abstract*.—We quantified and analyzed the distribution and causes of strandings of five species of sea turtles: Green Turtle (*Chelonia mydas*), Loggerhead (*Caretta caretta*), Hawksbill (*Eretmochelys imbricata*), Olive Ridley (*Lepidochelys olivacea*), and Leatherback (*Dermochelys coriacea*) found on the north coast of the state of São Paulo in southeastern Brazil. This area is considered a crucial feeding area for Green Turtles and a potential nesting site for Loggerheads. Between August 2015 and May 2019, we recorded 5,453 strandings of sea turtles, 91% of which were attributed to Green Turtles, predominantly females and juveniles. Approximately 79% of the records involved dead animals with poor physical integrity. The São Sebastião channel and the municipality of Ubatuba had the highest number of incidents. Strandings were more prevalent in the winter and spring months, coinciding with the increase in anthropomorphic interactions. About 80% of the animals analyzed during necropsies were classified as thin or emaciated. Harm from solid waste was the most evident anthropomorphic impact in the analysis of gastrointestinal contents, due to the presence of derivatives from human activities (trash) in 88 animals. The necroscopic diagnoses showed a possible association of the cause of death with bacterial and parasitic infections, mainly parasites from the family Spirorquiidae. Our study generated crucial data that will contribute to the conservation of sea turtles and future research into population analysis, survival, diseases, and habitat use.**

Key Words.—animal-human interactions; conservation; diseases; sea turtles; strandings

Introduction

For centuries, humans hunted sea turtles for meat, eggs, shells, and oil, bringing them to the brink of extinction as commercial interests increased and sea turtle populations declined (Márquez M. 1990). Sea turtles face endangerment according to the International Union for Conservation of Nature (2024) due to numerous anthropic impacts threatening their survival. Presently, urbanization poses one of the main threats. Pollution by pesticides, chemicals, industrial sewage, and large amounts of organic matter dumped into the oceans without prior treatment compromises the ecological balance of marine environments. The lack of knowledge about the effects of these pollutants on species makes it difficult to assess the severity of their impacts. A few studies have correlated marine pollution with the emergence of infectious diseases in turtles (Rossi 2014; Silva et al. 2016).

Coastal regions, especially areas close to urban centers and places with high human population density, are most susceptible to the impacts of land-based pollution on the marine environment. Solid wastes, especially various types of plastics when improperly discarded, are easily transported over long distances by ocean currents due to their light weight, buoyancy, and continuous accumulation in the oceans. Solid wastes can threaten the survival of turtles and other marine animals when ingested, causing weakness and even death of the animals (Macedo et al. 2011). Microplastics, which originate from plastic products and the weathering of plastic material, have been widely studied due to their accumulation in the food chain and their impacts on the ecosystem (Andrady 2011; Ferreira 2015). The ability of plastic to absorb heavy metals and other contaminants makes it particularly dangerous for the ecosystem and its inhabitants (Ashton et al. 2010). In addition to their toxicity, when plastics are transported by ocean currents, they carry with them invasive species that can negatively impact distant habitats and ecosystems (Ferreira 2015).

Solid waste is not the only risk to animals when ingested. Fishing gear, such as lines and nylon ropes, especially when improperly discarded or lost in the area, is termed ghost fishing because this material can drift and then entangle animals (Macedo et al.

2011). This entanglement can limit the movement of animals, damage their limbs, and even lead to death. Interaction with discarded fishing gear, both in coastal and oceanic regions, has been identified as one of the main human-caused factors responsible for the high mortality of sea turtles in Brazil (Kotas et al. 2004; Lewinson et al. 2004; Amaral and Jablonski 2005; Marcovaldi et al. 2011; Alvarenga et al. 2018).

Beyond pollution and fishing gear discards, additional causes of mortality of sea turtles can be attributed to two other distinct causes: human actions (such as hunting or mutilation), or natural causes, such as disease, presumed old age, or predation (Coelho 2009). Many types of diseases affect sea turtles and may have different etiologies. Viral diseases, such as fibropapillomatosis (Baptistotte 2007; Santos et al. 2008; Prioste 2016), have been well recognized in previous studies in Brazil, and diseases such as coccidiosis and spirorchiidiosis have been recorded in animals from different regions of the world (Stacy et al. 2010; Goldberg et al. 2013; Chapman et al. 2017). When sick, sea turtles may become stranded due to physical weakness or other symptoms that may compromise locomotion, feeding, and other vital functions. Ectoparasites and endoparasites, another potential source of illness, are commonly found in sea turtles.

The most common ectoparasites are barnacles (Crustacea: Cirripedia) and leeches (Annelida: Hirudinea), which, respectively, can hinder locomotion and cause anemia and skin lesions on animals (Coelho 2009). Trematodes (Platyhelminthes: Trematoda) and nematodes (Nemathelminthes: Nematoda) are endoparasites reported in several studies of sea turtles in Brazil, found mainly in the circulatory system and digestive tract (Werneck 2007 and references therein). Klingenberg (1993) reported different ways in which parasites can affect the health of reptiles, but there are few studies on the effects of ectoparasites on marine chelonians. Werneck (2007) pointed out a frequent appearance of epibionts and ectoparasites in weakened animals; however, the existing data do not allow confirmation whether the animals acquired the parasites because they were weakened or if the parasites were the primary cause of the weakness.

Five of the seven recognized species of sea turtles are found along the Brazilian coast: Green Turtles (*Chelonia mydas*), Loggerheads (*Caretta caretta*), Hawksbills (*Eretmochelys imbricata*), Olive Ridleys (*Lepidochelys olivacea*), and Leatherbacks (*Dermochelys coriacea*; Marcovaldi and Laurent 1996; Marcovaldi and Marcovaldi 1999). All sea turtles are included in the Brazilian Red List of Endangered Species (Instituto Chico Mendes de Conservação da Biodiversidade 2016), with the Green Turtle listed as Vulnerable, Loggerhead and Olive Ridley considered Endangered, and the Leatherback and Hawksbill as Critically Endangered. Data on strandings of sea turtles may shed light as to the causes of mortality using collections of both biological data and carcasses (e.g., Marcovaldi and Marcovaldi 1999; Chaloupka et al. 2008; Hamann et al. 2010; Vélez-Rubio et al. 2013; Monteiro et al. 2016). We quantified and analyzed the distribution and causes of stranding of the five species of sea turtles that inhabit the northern coast of São Paulo state in southeastern Brazil.

Materials and Methods

Database.—The Aquatic Biota Monitoring Information System (SIMBA) consists of compiled data on marine turtle strandings, sourced from the monitoring activities carried out by institutions involved in the Beach Monitoring Project-Santos Basin (PMP-BS). The following information about PMP-BS actions is based on the Projeto de Monitoramento de Praias da Bacia de Santos (https://comunicabaciadesantos.petrobras.com.br/projeto-de-monitoramento-de-praias-pmp-). When live turtles strand, they are provided with veterinary care either directly on the beach or at rehabilitation and stabilization centers. This process aims to treat and subsequently release the turtles back into the marine environment. Necroscopic analyses are carried out on many dead marine species, including marine mammals, oceanic and marine birds, and marine turtles to determine a likely cause of death. These analyses are crucial to understand potential causes of mortality and disruptions in their life cycle at sea, particularly during events that affect numerous animals, such as in the case of an oil spill, or particular but frequently occurring events such as drowning due to fishing or aggression against animals.

Aggression against sea turtles refers to any action that causes physical damage, such as mutilations and wounds, stress or death to these animals (Santos 2011). The SIMBA data system not only includes the results of laboratory analyses and necropsies of sea turtles but also records cases of nesting of sea turtles and information on the presence of oil, large-scale waste disposed at beaches or in water, and other waste linked to human activities, to evaluate their impacts on the coastal ecosystem. This is a monitoring

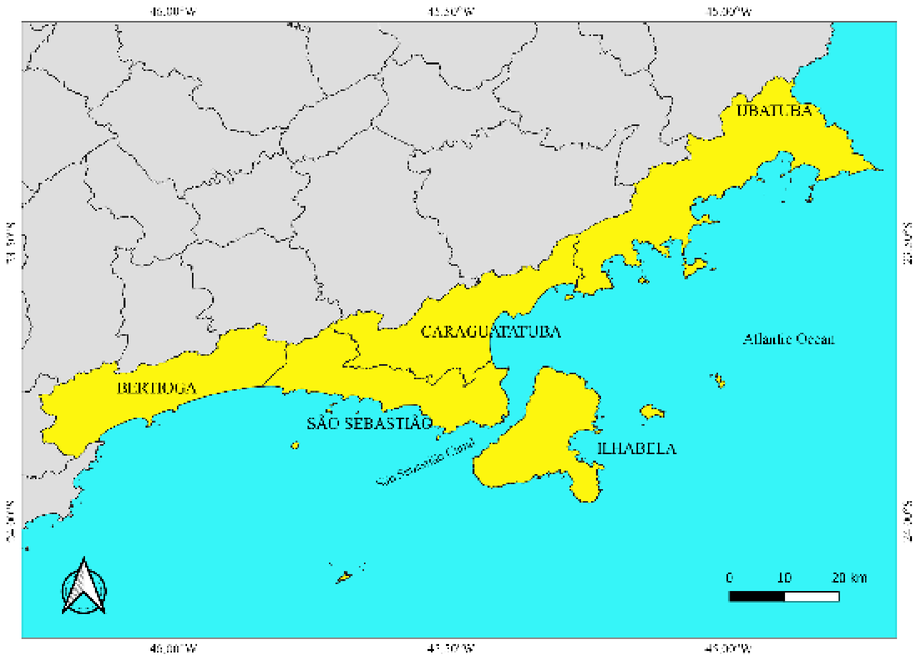

Figure 1. Map of the municipalities that comprise the north coast of São Paulo state, southeastern Brazil.

program to comply with federal environmental licensing requirements.

Study site.—We focused on the north coast of the state of São Paulo, Brazil, covering the municipalities of Bertioga, São Sebastião, Ilhabela, Caraguatatuba, and Ubatuba (Fig. 1). These municipalities are known for their picturesque beaches with clear waters, attracting numerous tourists during the high season. Historically, according to Panizza (2004), fishing and tourism were the predominant economic activities; however, urban development in the region has evolved along with the exploitation of natural resources, mainly gas and oil. In the last century, the expansion of the port of São Sebastião and the modernization of access routes to the coast, which intensified tourism, further accelerated the process of territorial occupation (Panizza 2004) with the construction of holiday homes and the expansion of tourist activities. The north coast of the state of São Paulo is one of the regions with the highest population growth in the state over the last five decades (Vieira et al. 2023). According to the 2022 census by the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística, IBGE), Bertioga covers a territorial area of 491.5 km², housing an estimated population of 64,188 people; São Sebastião has 402.4 km² and a population of approximately 81,595 people; Ilhabela, the smallest municipality in the region, covers 346.4 km² and has an estimated population of 34,934; Caraguatatuba, with a population of 134,873 people, has the highest population density in a territory of 484.9 km²; finally, Ubatuba, with the largest territorial extension of 708.1 km², is home to an estimated population of 92,981 people.

Data analysis.—From individual sea turtle stranding records, we quantified the total number of occurrences per turtle species throughout the study area, taking into account temporal and spatial variation. Each record contained the following information: (1) location; (2) date and time of stranding; (3) environmental conditions; (4) photographs; (5) individual condition (dead or alive); (6) external assessment; (7) body condition (to assess the physical and nutritional state of the individual); (8) presence of petroleum oil; (9) basic biological parameters (including developmental stage and taxonomy); and (10) signs of anthropogenic interactions. The physical integrity of the animal was assessed by a veterinarian, documenting evidence of natural marks, anthropic interactions, the presence of ectoparasites or epibionts, decapitation, fractures, amputations, or the presence of pathologies. Spreadsheets containing the data from the necroscopic analysis included information on the dates of death and necropsy of each individual, carcass condition, weight at the time of necropsy, body score, clinical suspicion, external examination, history, signs of anthropomorphic interaction, collection of organ samples, diagnosis of any lesions found, and confirmation of the stage of development and taxonomy of the animal.

The classification of the stage of an individual turtle (adult, juvenile) depends on the curvilinear measurement of the carapace length (CCL) and the weight of the animal. Green Turtle adults in Brazil have an average CCL of 115 cm (Marcovaldi et al. 2011) and reach a weight of 230 kg (Pritchard and Mortimer 1999). Adult Loggerheads have an average size of 103 cm CLL in Brazil and can weigh between 100 and 180 kg (Pritchard and Mortimer 1999), adult Hawksbills measure about 100 cm CCL and weigh up to 80 kg (Pritchard and Mortimer 1999). Adult Olive Ridleys measure about 70 cm CCL and weigh an average of 50 kg (Pritchard and Mortimer 1999) and are the smallest of the sea turtle species found in Brazilian waters (Marcovaldi et al. 2011). An adult Leatherback can exceed 200 cm CCL and weigh > 900 kg (Reis and Goldberg 2017). We classified turtles equal to or above these measurements (CCL) as adults and those smaller as juvenile. For example, in the case of Green Turtles, we classified individuals with a CCL of 30–50 cm as juveniles (https://comunicabaciadesantos.petrobras.com.br/projeto-de-monitoramento-de-praias-pmp-).

In addition to individual records, we collected data regarding the environment around the recovered turtles, specifically on the presence of garbage, petroleum-based compounds in the environment, as well as noting any nesting records, to help inform on the analysis of human interference at the study site. During the beach monitoring work, the presence of anthropogenic byproducts such as large solid waste and oily waste was recorded to evaluate their impacts on the coastal ecosystem that may interfere with the survival of marine animals. Furthermore, to assess the potential interference of oil and natural gas production and outflow activities in the Santos Basin, the SIMBA database records occurrences and actions related to oil slicks and animals covered with oil, which may be indications of spills or improper disposal in the region. Data on the environmental dynamics at the time of strandings were collected for future studies that may contribute to identifying environmental and geographical factors influencing strandings in the region, particularly in the São Sebastião channel. Finally, we carried out a comprehensive examination of all data available on the SIMBA platform of Petrobras and a temporal analysis of the strandings. We georeferenced the stranding sites using QGIS software, creating a shapefile for the study site based on the São Paulo state shapefile available in the IBGE database (Fig. 1).

Results

Strandings.—Between August 2015 and May 2019, the north coast of the state of São Paulo recorded 5,453 occurrences of strandings and calls for rescue or collection of turtles (Fig. 2). Among these, 4,965 records (91%) were for Green Turtles, 251 (5%) for Loggerheads, 66 (0.6%) for Olive Ridleys, and 47 (0.4%) for Hawksbills, with only five records of stranding for Leatherbacks. In 119 records (2%), the species was not identified. There were 4,329 (79%) strandings of dead animals, of which 92% were Green Turtles. A notable number of females were found (alive and dead) during the study period, totaling 1,956 (36%) occurrences. The number of males found was 516 (9%), and the sex was not determined for 2,981 (55%) individuals. There were 5,154 (95%) turtles categorized as juveniles, 151 (3%) as adults, and eight (0.16%) as hatchlings. There were 2,288 animals classified as in poor body condition. There were 3,737 rescued animals in poor physical condition. A significant proportion of turtles, 62%, were associated with epibionts. Of these, 549 turtles were determined to have ectoparasites during the first clinical analyses; these specimens were not identified to species.

Regarding anthropogenic interactions affecting sea turtle strandings, interactions with fishing gear accounted for 53% of cases. The second-largest threat (29%) was collisions with boats, which were involved in fishing, trade, and/or tourism activities in the region. Aggression/hunting and interactions with plastic were less evident in the first clinical analyses but occurred in 51 and 42 cases, respectively).

Temporal variation.—The turtle records were filtered on the basis of their temporal variation in strandings by development stage, based on estimates from growth models for each species. The analyses revealed a higher number of strandings of both juvenile and adult individuals during the winter and spring periods. Proportional values for juvenile occurrences were 29.4% in the winter months and 31.7% in the spring, whereas lower records occurred in the summer (15.8%) and fall (17.6%). Adult

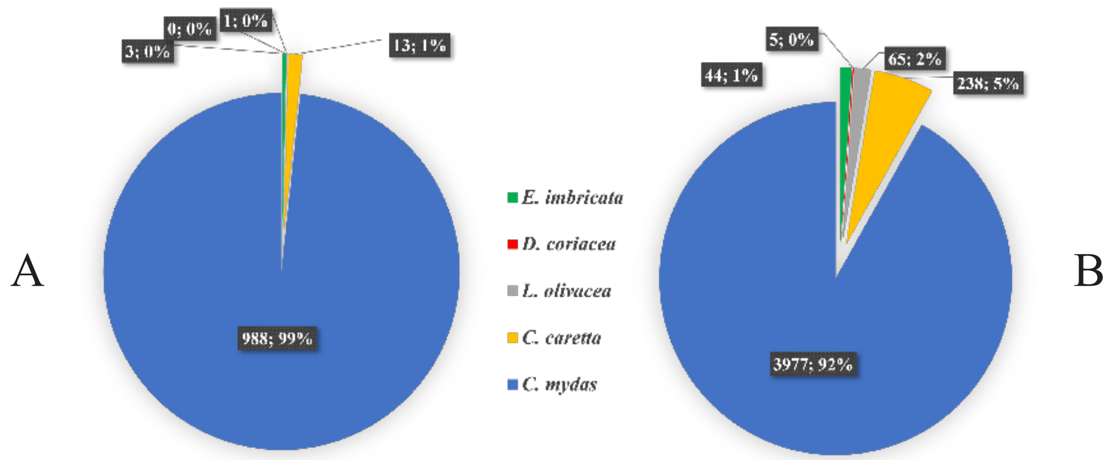

Figure 2. Number of (A) living and (B) dead sea turtles by species observed during the study period along the north coast of São Paulo state, southeastern Brazil. Species listed are Hawksbill (*Eretmochelys imbricata*), Leatherback (*Dermochelys coriacea*), Olive Ridley (*Lepidochelys olivacea*), Loggerhead (*Caretta caretta*) and Green Turtle (*Chelonia mydas*).

individuals were more frequent in winter (1.4%) and spring (0.9%).

An increase in the number of anthropogenic interactions was identified over the years, particularly in interactions with fishing gear and collisions with boats (Fig. 3). Aggressions occurred more frequently in the fall and spring, unlike other interactions, which predominated in the spring and winter. The growth of interactions with boats, plastics, and aggression followed the same pattern of growth as interactions with fishing, sharing the same peaks of increase (Fig. 3).

Spatial analysis.—The spatial distribution of strandings revealed that the city of Ubatuba had the highest concentration of sea turtle strandings (2,130 occurrences) followed by the municipality of São Sebastião (982 occurrences). Several beaches in the municipality of Bertioga, namely Itaguaré/Guaratuba, Enseada, and Canto do Indaiá/Riviera, recorded strandings of the Green Turtles, with 233, 255, and 122 occurrences, respectively (Fig. 4). These strandings were the largest on a single beach. In the São Sebastião channel, strandings of Leatherbacks ranged from one to two individuals on the same beach. Olive Ridleys exhibited greater variation in the number of stranded animals, with three of its most significant records in the municipality of Bertioga (Fig. 4).

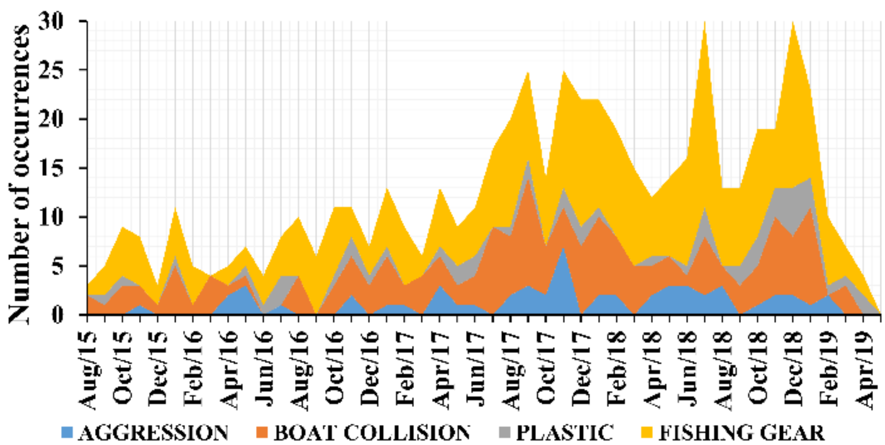

Figure 3. Number of occurrences of anthropic interactions identified in Green Turtles (*Chelonia mydas*), Loggerheads (*Caretta caretta*), Hawksbills (*Eretmochelys imbricata*), Olive Ridleys (*Lepidochelys olivacea*), and Leatherbacks (*Dermochelys coriacea*) between August 2015 and May 2019 along the north coast of São Paulo state, southeastern Brazil. Month abbreviations are Apr = April, Aug = August, Feb = February, Dec = December, Jun = June, and Oct = October.

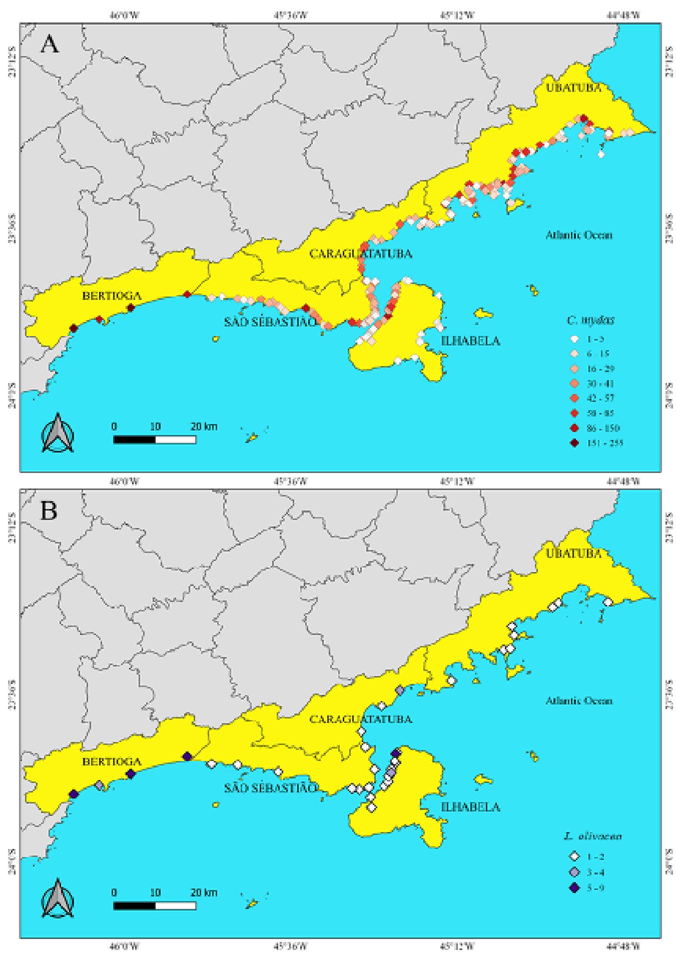

Figure 4. Occurrences of strandings of (A) Green Turtles (*Chelonia mydas*) and (B) Olive Ridleys (*Lepidochelys olivacea*) in the study area by the beach along the north coast of São Paulo state, southeastern Brazil between August 2015 and May 2019.

Higher frequencies of strandings occurred under open and under cloudy skies. According to the Beaufort scale for classification of wind and sea state, in most strandings, the sea was at strength 1, presenting some roughness, less than sea swells. Predominant tides were flood and ebb, with the prevailing wind at the beginning of the collection coming from the east with speeds between 0 and 5 km/h.

Necropsies.—By May 2019, the partner institutes of the Santos Basin Beach Monitoring Project, which is responsible for monitoring the north coast of São Paulo, had carried out 396 necropsies (9% of all strandings recorded as dead animals). Among these, 284 (72%) were carried out on carcasses in good condition, 82 (21%) on carcasses in moderate decomposition, and 30 (8%) on carcasses in advanced decomposition. Of the total necropsies, 119 animals (30%) showed signs of anthropogenic interactions, with the highest occurrences associated with solid waste and fishing interactions. Gastrointestinal contents contained pieces of solid waste of unknown origin, with varying sizes and colors in 88 animals (22%). The primary lesions were in the circulatory, respiratory, and digestive systems. Impact to the circulatory system, accounting for 30% of the reports, was predominantly affected by bacterial infectious agents, with 79 cases, and parasites in 20 cases. In the respiratory system, representing 20% of the reports, drowning/asphyxia was the predominant cause of death in 66 cases. The digestive system, covered in 21% of the reports, showed effects from bacterial infectious agents, indeterminate infectious agents, and parasites. The results of the necropsy analysis emphasized the significant capacity of infectious agents, mainly bacterial, to affect various systems of the animal's body. Among the contributory diagnoses of the 396 necropsies performed, 194 cases of spirorchiidiasis were diagnosed, presenting in severe, moderate, and mild generalized forms. Spirorchiidiasis is a parasitic disease caused by trematodes of the genus *Spirorchis*, which lodge in the blood vessels and internal organs of sea turtles, potentially causing inflammation, tissue necrosis, and even death of the host.

Solid wastes and oils.—Between May 2015 and August 2019, 36 incidences of solid waste were found on the stretch of beach between the municipalities of Bertioga and Ubatuba. Among the waste found, 14 were buoys and floats for signaling and mooring, made of polyurethane foam and nine records included oil drums of different capacities, both full and empty. Fishing nets were found on three occasions. Of the various waste items found, the majority were on the beaches of Bertioga, including refrigerators, sofas, and two cars. The municipality of Bertioga recorded 20 of the 36 waste items improperly discarded in the marine and coastal environment.

During the study period, 77 occurrences of oil and its derivatives, such as tar, were reported. The municipality of Ubatuba contributed the most records, with 47 occurrences of tar stains ranging from small to large fragments. The residues were found embedded in rocks or in the sand at the tide line.

Nesting.—Although the northern coast of São Paulo is not considered a sea turtle nesting region, the beach monitoring efforts outlined in the program resulted in the discovery of six nesting events in the municipality of Ubatuba, one nesting event in São Sebastião, and one nesting event in Ilhabela. The only species previously known to nest in the region is the Loggerhead in the municipality of Ubatuba (Marcovaldi et al. 2011). Although nesting was recorded in 2015 and 2016, no reports or traces of sea turtle nesting were observed in the following years.

Discussion

Juvenile Green Turtles comprised the largest number of records of stranded sea turtles, which we expected because they are common throughout the Brazilian coast, including the coast of São Paulo state. This area is an important feeding and resting area for Green Turtles (Marcovaldi et al. 2011). The second-highest number was juvenile Loggerheads, which are occasionally recorded in the region during interactions with fishing activities or strandings. however, constant attention to these beaches must be maintained (Marcovaldi et al. 2011). Hawksbills and Olive Ridleys were sparsely recorded on the southern coast of São Paulo state, perhaps due to the preference for the northeastern coast for laying eggs (Marcovaldi et al. 2011). Finally, the Leatherback is essentially oceanic, with only one regular breeding area in Brazil located in the north of Espírito Santo state, which likely explains the very few records of this turtle in the region (Marcovaldi et al. 2011).

In Bertioga, the spatial distribution of stranded sea turtles was unique, diverging from the other municipalities because of its very scattered distribution of strandings, concentrating on only four separate beaches. Like Caraguatatuba and Ilhabela, Bertioga does not have a rehabilitation facility for sea turtles, so the stranded animals are transported to neighboring municipalities where they receive veterinary care and/or undergo necroscopic analysis. It is possible that the methods that institutions use to record the strandings, the difficulty of transportation, as well as the lack of knowledge of the human population about the work done by the institutions (and/or lack of contribution to the actions), may be the cause of the low number of beaches with strandings recorded in the city. The geographical location of the city, the water quality, and the oceanographic phenomena may also be related to the low number of occurrences recorded.

In the municipality of Ilhabela, strandings were concentrated on the side of the island closest to the São Sebastião channel, rather than the less urbanized part of the island, which faces the ocean. The concentration of the strandings near this channel may be related to the amount of food available, the ease of access to beaches, and the presence of humans, or even the physical characteristics of shallower waters. The channel has temperatures that vary depending on ocean currents. In spring, the channel receives the Central South Atlantic Water in the deepest region (up to 40 m) with temperatures between 9° and 18° C, whereas in the other seasons of the year, the exclusive presence of Coastal Water is characterized by temperatures above 20° C (Vanin et al. 1997).

Sea turtles have a long life span and late sexual maturity (Avens and Snover 2013). The number of juvenile and female deaths in this region highlights the conservation status of the species and its natural habitats, especially the feeding area of Green Turtles on the coast. The high mortality numbers put the survival of populations at risk, although the lack of data on the population growth of the species makes it difficult to accurately assess and quantify this threat (Marcovaldi et al. 2011).

The large number of turtles that were classified in poor body condition and low physical integrity demonstrates the frequent occurrence of weakened animals in the region. Factors such as stress, predator attacks, and diseases can lead to variation in the composition of encrusting species and epibionts that can contribute to low mobility and weakness of the animal. In addition to the presence of encrusting and epibiont species, it is important to analyze the marks on the body of turtles, which may be the natural result of interactions with other animals or with the environment itself or are clearly marks of anthropogenic interactions that may be directly or indirectly related to the cause of death.

There were 574 marks clearly caused by human actions that were counted in the anthropomorphic interactions category. Here, interactions with fishing gear based on the presence of fishing lines or hooks tangled in the body of turtles and collisions with boat propellers based on the presence of wounds on turtles of a characteristic shape were the highest occurring human-caused impacts. The large number of sea turtles in the winter and spring months may have been a result of oceanic processes such as ocean fronts and currents that carry carcasses and weakened animals to the coastal region, as well as the increase in anthropogenic interactions that accounted for increases of 134% in spring, 180% in summer, 163% in autumn, and 133% in winter in 2018 compared to the values of 2016. This suggests that the frequency of these interactions, especially those related to fishing, have increased in the region over the years. The incidental capture of sea turtles by fishing activities has been reported as one of the main threats to these animals by the U.S. National Research Council Agency (Committee of Sea Turtles Conservation 1990), from the 1990s to the present. Coastal fishing, especially gillnetting, has been identified as the main threat to juvenile Green Turtles along the Brazilian coast (Pádua Almeida et al. 2011).

Although occurring in smaller numbers, the ingestion of anthropogenic waste by sea turtles threatens the survival of these animals, because it causes obstruction of the digestive tract that can result in the death of the animal even if ingested in small amounts (Bugoni et al. 2001). These plastics, when large enough, lodge in the intestines of the turtles and decrease the absorption of necessary nutrients, generating serious health consequences, such as malnutrition, infections, and death (Gramentz 1988). In our study, plastic waste was found mixed with plant food such as red algae, a typical food item of juvenile Green Turtles (Pádua Almeida et al. 2011). The explanation for the ingestion of anthropogenic waste by these animals is not clear. Gramentz (1988) suggested that part of the ingestion might occur because of the similarity of plastic waste to natural foods. Several other studies reported the accidental ingestion of solid waste because of the similarity with their food (Bjorndal et al. 1994; Santos et al. 2020; Gomes 2021). Reis et al. (2010) found that the feeding areas of Green Turtles are considerably polluted, which facilitates the adhesion of algae to litter that is then ingested by the animals. It is unknown whether the turtles gradually pass to a state of weakness from the ingestion of solid waste or if the ingestion of solid waste occurs is a consequence of the debilitated state of the animal, hindering its ability to search for food (Gramentz 1988). It is critical to determine the number of animals that have died from anthropogenic waste in feeding areas. These data are a priority for population management and survival of sea turtle species (Macedo et al. 2011; Área de Proteção Ambiental Marinha Litoral Centro. 2018. Diagnóstico Técnico Produto 2 - Meio Biótico, Herpetofauna Marinha. Available from https://sigam.ambiente.sp.gov.br/sigam3/Repositorio/511/Documentos/APAM_LC/APAMLC_HerpetofaunaMarinha.pdf. [Accessed 17 May 2024]).

Plastic and anthropogenic interactions, organ impairment by parasitic infections, and bacterial, fungal, and viral infections reinforce the need for attention to the conservation of natural habitats. The contribution of marine biota to microbiological imbalance and the emergence of new pathogens caused by changes in the environment due to climate change and anthropogenic factors, such as the dumping of urban, agricultural, and industrial waste, must be considered (Reis et al. 2010). The identification of pathologies requires the collection of data that can be used in further research to better the understanding of consequences of pathogens in animals. Like the improving knowledge of fibropapillomatosis, it is necessary to study spirorchiidiosis because it is common in debilitated sea turtles. Studies in Florida (Stacy et al. 2010) considered spirorchioidiosis to be the cause of strandings and mortality of sea turtles worldwide, but knowledge about this group of trematodes affecting sea turtles, including species identification, is scarce in Brazil and worldwide.

To reduce sea turtle mortality under current conditions, it is crucial to identify trematode species during necropsies. Understanding the ecology of these parasites, as well as their impact on turtle health, is equally important. In addition, it is necessary to investigate the prevalence of pathogens in turtles stranded in different regions of the world, which will allow for a global comparative analysis. Examining the association between the lesions observed and the weakness of the animals, as well as determining the specific cause of death, are essential steps in developing effective conservation and management strategies. This integrated approach will not only facilitate the identification of risk factors but will also provide valuable data on the health conditions of populations, which will contribute to the formulation of more precise and appropriate preventive measures for the preservation of sea turtles. By quantifying and locating strandings, as well as nesting records, it is possible to better identify critical feeding and nesting areas that will allow the impact of human activities to be assessed and mitigation strategies to be developed. Beach monitoring can reveal nesting patterns that will help protect essential areas during the nesting season, while stranding studies can identify common causes of mortality such as bycatch, pollution, and disease. These insights allow for the creation of more effective regulations, such as fishing restrictions in sensitive areas, beach cleaning programs, and environmental education initiatives. This information is fundamental for the development of action plans and conservation policies that involve cooperation between governments, non-governmental agencies, and local communities.

Although we did not analyze the direct impacts of oily waste on sea turtles, improper discards of these substances in the marine environment were noted and likely come from boats or leaks during the oil extraction process. The Sea Turtle Licensing Guide (Sforza et al. 2017) shows several impacts that oil can cause when ingested, inhaled, or touched by an animal. The characteristics of the oil may vary depending on the source and length of time it remains in the environment, thus affecting its toxic potential to sea turtles (Silva 2021). The analysis of turtle strandings that we made are important data regarding population mortality, which contributes to obtaining demographic and biological parameters essential for population analysis of sea turtles such as growth rates, survival, and habitat use. Further studies of the marine environment will provide a better understanding of the causes of death and the impacts of human actions on the survival of populations of sea turtles, as well as a deeper knowledge of diseases in these animals.

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Literature Cited

Alvarenga, F.S., B.B. Giffoni, A.S. Antonio, V.A. Oliveira, B.M.G. Silvia, and J.H. Becker. 2018. Monitoramento de capturas incidentais de *Chelonia mydas* em redes de emalhe costeira em Ubatuba. Projeto Tamar, São Paulo, Brasil. 6 p.

Amaral, A.C.Z., and S. Jablonski. 2005. Conservação da biodiversidade marinha e costeira no Brasil. Megadiversidade 1:43–51.

Andrady, A.L. 2011. Microplastics in the marine environment. Marine Pollution Bulletin 62:1596–1605.

Ashton, K., L. Holmes, and A. Turner. 2010. Association of metals with plastic production pellets in the marine environment. Marine Pollution Bulletin 60:2050–2055.

Avens, L. and M.L. Snover. 2013. Age and age estimation in sea turtles. Pp. 97–134 *In* The Biology of Sea Turtles. Volume III. Wyneken, J., Lohmann, K.J., and Musick, J.A. (Eds.). CRC Press, Boca Raton, Florida, USA.

Baptistotte, C. 2007. Caracterização espacial e temporal da fibropapilomatose em tartarugas marinhas da costa brasileira. Ph.D. Dissertation, Universidade de São Paulo, Piracicaba, São Paulo, Brazil. 66 p.

Bjorndal, K.A, A.B. Bolten, and C.J. Lagueux. 1994. Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. Marine Pollution Bulletin 28:154–158.

Bugoni, L., L. Krause, and M.V. Petry. 2001. Marine debris and human impacts on sea turtles in southern Brazil. Marine Pollution Bulletin 42:1330–1334.

Chaloupka, M., T.M. Work, G.H. Balazs, S.K.K. Murakawa, and R. Morris. 2008. Cause-specific temporal and spatial trends in Green Sea Turtle strandings in the Hawaiian Archipelago (1982–2003). Marine Biology 154:887–898.

Chapman, P.A., H. Owen, M. Flint, R.J.S. Magalhaes, R.J. Traub, T.H. Cribb, M.T. Kyaw-Tanner, and P.C. Mills. 2017. Molecular epidemiology and pathology of spirorchiid infection in Green Sea Turtles (*Chelonia mydas*). International Journal for Parasitology: Parasites and Wildlife 6:39–47.

Coelho, B.B. 2009. Análise dos encalhes de tartarugas-marinhas (Reptilia: Testudines) ocorridos no litoral sul da Bahia, Brasil. M.Sc. Thesis, Universidade Estadual de Santa Cruz, Ilhéus, Bahia, Brazil. 72 p.

Committee of Sea Turtles Conservation. 1990. Decline of sea turtles: causes and prevention. National Research Council, National Academic Press, Washington D.C., USA. 259 p.

Ferreira, J.S. 2015. Impacto ambiental e ingestão de lixo pelas Tartarugas Verdes (*Chelonia mydas*) na praia de Regência, norte do Espírito Santo. Bachelor Monograph, Universidade Federal do Espírito Santo, Vitória, Espírito Santo, Brazil. 46 p.

Goldberg, D.W., G.D. Stahelin, C.T. Cegoni, J. Wanderlinde, E.P. Lima, R.M. Medina, and E.C.Q. Carvalho. 2013. Case report: lung Spirorchidiasis in a Green Turtle (*Chelonia mydas*) in southern Brazil. Marine Turtle Newsletter 139:14–15.

Gomes, B. G. 2021. Avaliação da ingestão de resíduos sólidos por Tartarugas-verdes, *Chelonia mydas* (Linnaeus,1758), no litoral centro-sul do estado do Rio de Janeiro, Brasil. Master's Thesis, Instituto de Biologia, Universidade Federal Fluminense, Niterói, Rio de Janeiro, Brazil. 45 p.

Gramentz, D. 1988. Involvement of Loggerhead Turtle with the plastic, metal, and hydrocarbon pollution in the central Mediterranean. Marine Pollution Bulletin 19:11–13.

Hamann, M., M.H. Godfrey, J.A. Seminoff, P.C.R. Barata, K.A. Bjorndal, A.B. Bolten, A.C. Broderick, L.M. Campbell, C. Carreras, P. Casale, et al. 2010. Global research priorities for sea turtles: informing management and conservation in the 21st Century. Endangered Species Research 11:245–269.

Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio). 2018. Livro Vermelho da Fauna Brasileira Ameaçada de Extinção. ICMBio, Ministério do Meio Ambiente. Brasília, Distrito Federal, Brazil.

International Union for Conservation of Nature (IUCN). 2024. The IUCN Red List of Threatened Species. Version 2023-1. https://www.iucnredlist.org.

Klingenberg, R.J. 1993. Understanding Reptile Parasites: A Basic Manual for Herpetoculturists & Veterinarians. 2nd Edition. The Herpetocultural Library, Special Edition. Advanced Vivarium Systems, Lakeside, California, USA.

Kotas, J.E., S. Santos, V.G. Azevedo, B.M.G. Gallo, and P.C.R. Barata. 2004. Incidental capture of Loggerhead (*Caretta caretta*) and Leatherback (*Dermochelys coriacea*) sea turtles by the pelagic longline fishery off southern Brazil. Fishery Bulletin 102:393–399.

Lewinson, R.L., L.B. Crowder, A.J. Read, and S.A Freeman. 2004. Understanding impacts of fisheries bycatch on marine megafauna. Trends in Ecology and Evolution 19:598–604.

Macedo, G.R., T.T. Pires, G. Rostán, D.W. Goldberg, D.C. Leal, A.F. Garcez Neto, and C.R. Franke. 2011. Ingestão de resíduos antropogênicos por tartarugas marinhas no litoral norte do estado da Bahia, Brazil. Ciência Rural 41:1938–1941.

Marcovaldi, M.A., and A. Laurent. 1996. A six season study of marine turtle nesting at Praia do Forte, Bahia, Brazil, with implications for conservation and management. Chelonian Conservation and Biology 2:55–59.

Marcovaldi, M.A., and G.G. Marcovaldi. 1999. Marine turtles of Brazil: the history and structure of Projeto Tamar-Ibama. Biological Conservation 91:35–41.

Marcovaldi, M.A., A.S. Santos, and G. Sales. 2011 (Orgs.). Plano de Ação Nacional para conservação das tartarugas marinhas. Série Espécies Ameaçadas n. 25. ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade), Brasília, Brazil.

Márquez M., R. 1990. Sea Turtles of the World. An Annotated and Illustrated Catalogue of Sea Turtle Species Known to Date. Fisheries Synopsis No. 125, Volume 11. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy.

Monteiro, D.S., S.C. Estima, T.B.R. Gandra, A.P. Silva, L. Bugoni, Y. Swimmer, J.A. Seminoff, and E.R. Secchi. 2016. Long-term spatial and temporal patterns of sea turtle strandings in southern Brazil**.** Marine Biology 163:247. https://doi.org/10.1007/s00227-016-3018-4.

National Research Council. 1990. Decline of Sea Turtles: Causes and Prevention. National Academy Press, Washington, D.C., USA.

Pádua Almeida, A., A.J.B. Santos, J.C.A. Thomé, C. Belini, C. Baptistotte, M.Â. Marcovaldi, and M. Lopez. 2011. Avaliação do estado de conservação da tartaruga marinha *Chelonia mydas* (Linnaeus, 1758) no Brasil. Biodiversidade Brasileira 1:12–19.

Panizza, A.C. 2004. Imagens orbitais, cartas e coremas: uma proposta metodológica para o estudo da organização e dinâmica espacial, aplicação ao Município de Ubatuba, Litoral Norte do Estado de São Paulo, Brasil. Ph.D. Dissertation, Universidade de São Paulo, São Paulo, Brazil. 302 p.

Prioste, F.E.S. 2016. Detecção e quantificação de alguns elementos químicos inorgânicos em sangue e tecidos de tartarugas-verdes, *Chelonia mydas* (Linnaeus, 1758), da costa brasileira: possível correlação com a fibropapilomatose. Ph.D. Dissertation, Universidade de São Paulo, São Paulo, Brazil. 115 p.

Pritchard, P.C.H., and J.A. Mortimer. 1999. Taxonomy, external morphology, and species identification. Pp. 1–18 *In* Research and Management Techniques for the Conservation of Sea Turtles. Eckert, K.L., K.A. Bjorndal, F.A. Abreu-Grobois, and M. Donnelly (Eds.). International Union for Conservation of Nature/Species Survival Commission, Washington, D.C. USA.

Reis, E.C., and D.W. Goldberg. 2017. Biologia, ecologia e conservação de tartarugas marinhas. Pp. 63–89 *In* Mamíferos, Quelônios e Aves: Caracterização Ambiental Regional da Bacia de Campos, Atlântico Sudoeste. Reis, E.C., and M.P. Curbelo-Fernandez (Eds.). Elsevier, Rio de Janeiro, Brazil.

Reis, E.C., C.S. Pereira, D. Prazeres Rodrigues, H.K.C. Secco, L.M. Lima, B. Rennó, and S. Siciliano. 2010. Condição de saúde das tartarugas marinhas do litoral centro-norte do estado do Rio de Janeiro, Brasil: avaliação sobre a presença de agentes bacterianos, fibropapilomatose e interação com resíduos antropogênicos. Oecologia Australis 14:756–765.

Rossi, S. 2014. Análise da atividade de leucócitos e de bifenilas policloradas aplicada ao estudo da fibropapilomatose em *Chelonia mydas* (Testudines, Cheloniidae) (Linnaeus 1758). Ph.D. Dissertation, Universidade de São Paulo, Piracicaba, São Paulo, Brazil. 165 p.

Santos, A.S., L. Soares, M.Â. Marcovaldi, D. Silveira Monteiro, B. Giffoni, A. Pádua Almeida. 2011. Avaliação do estado de conservação da tartaruga marinha *Caretta caretta* Linnaeus, 1758 no Brasil. Biodiversidade Brasileira 1:3–11.

Santos, G., M. Herrera, and R. Pereira. 2008. Fibropapilomatose em tartarugas marinhas (*Chelonia mydas*) - revisão de literatura. Revista Científica Eletrônica de Medicina Veterinária 11:1–5.

Santos, R.G., R. Andrades, G.R. Demetrio, G.M. Kuwai, M.F. Sobral, J.S. Vieira, and G.E. Machovsky-Capuska. 2020. Exploring plastic-induced satiety in foraging Green Turtles. Environmental Pollution 2020 Oct;265(Pt B):114918. https://doi.org/10.1016/j.envpol.2020.114918.

Sforza, R., A.C.J. Marcondes, and G.T. Pizetta. 2017. Guia de Licenciamento Tartarugas Marinhas - Diretrizes para avaliação e mitigação de impactos de empreendimentos costeiros e marinhos. ICMBio (Instituto Chico Mendes de Conservação da Biodiversidade), Brasília, Brazil. 130 p.

Silva, C.C., R.D. Klein, I.F. Barcarolli, and A. Bianchini. 2016. Metal contamination as a possible etiology of fibropapillomatosis in juvenile female Green Sea Turtles *Chelonia mydas* from the southern Atlantic Ocean. Aquatic Toxicology 170:42–51.

Silva, M.F.S.D. 2021. Tartarugas marinhas, macroalgas e derramamento de óleo: áreas de alimentação e contaminação (Ipojuca, Pernambuco). M.Sc. Thesis, Universidade Federal de Pernambuco, Recife, Brazil. 121 p.

Stacy, B.A., A.M. Foley, E. Greiner, L.H. Herbst, A. Bolten, P. Klein, C.A. Manire, and E.R. Jacobson. 2010. Spirorchiidiasis in stranded Loggerhead *Caretta caretta* and Green Turtles *Chelonia mydas* in Florida (USA): host pathology and significance. Diseases of Aquatic Organisms 89:237–259.

Vanin, A.M.S.P., T.N. Corbisier, E. Arasaki, and A.M. Moellmann. 1997. Composição e distribuição espaço-temporal da fauna bêntica no Canal de São Sebastião. Relatório Técnico do Instituto Oceanográfico da Universidade de São Paulo 41:26–46.

Vélez-Rubio, G.M., A. Estrades, A. Fallabrino, and J. Tomás. 2013. Marine turtle threats in Uruguayan waters: insights from 12 years of strandings data. Marine Biology 160:2797–2811.

Vieira, E.T., M.C. R. Lemes, R.C. Silva, G. Fisch, and M.J. Santos. 2023. Desenvolvimento regional e a intensificação das catástrofes socionaturais: o caso do município de São Sebastião/SP. Revista Brasileira de Gestão e Desenvolvimento Regional 19:467– 492.

Werneck, M.R. 2007. Helmintofauna de *Chelonia mydas* necropsiadas na base do projeto Tamar-Ibama em Ubatuba, Estado de São Paulo, Brasil. M.Sc. Thesis, Universidade Estadual Paulista Júlio de Mesquita Filho, Botucatu, São Paulo, Brazil. 46 p.

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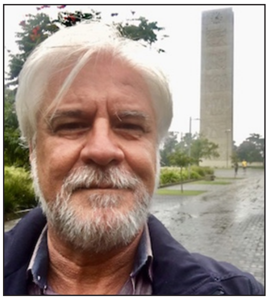

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