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Hopper Dredging Impacts on Sea Turtles on the Northern Coast of Rio de Janeiro State, Brazil

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The northern coast of the state of Rio de Janeiro, eastern Brazil, is an important nesting ground for loggerhead turtles (*Caretta caretta*), with about 1500 nests laid annually (Lima *et al*. 2012). It also hosts foraging grounds for juvenile green turtles (*Chelonia mydas*) and serves as a migration corridor (and possibly provides foraging habitat) for olive ridley turtles (*Lepidochelys olivacea*) (Reis *et al*. 2010; TAMAR - Brazilian Sea Turtle Conservation Program database, unpublished data) and leatherback (*Dermochelys coriacea*) turtles (López-Mendilaharsu *et al*. 2009).

Despite the high importance of the area for sea turtles, construction began in 2008 for a large, private mixed-use port complex, named Açu Superport. This enterprise, which is the largest port-industry facility in South America, is located at 21.8157°S, 41.0060°W (Fig. 1), just south of the city of São João da Barra and about 260 km (geodesic distance) from the city of Rio de Janeiro (Barreto & Quinto Junior 2012). The port complex, now in operation, is equipped with two sets of terminals, one offshore and the other onshore, which together have 17 km of wharves accommodating up to 47 vessels

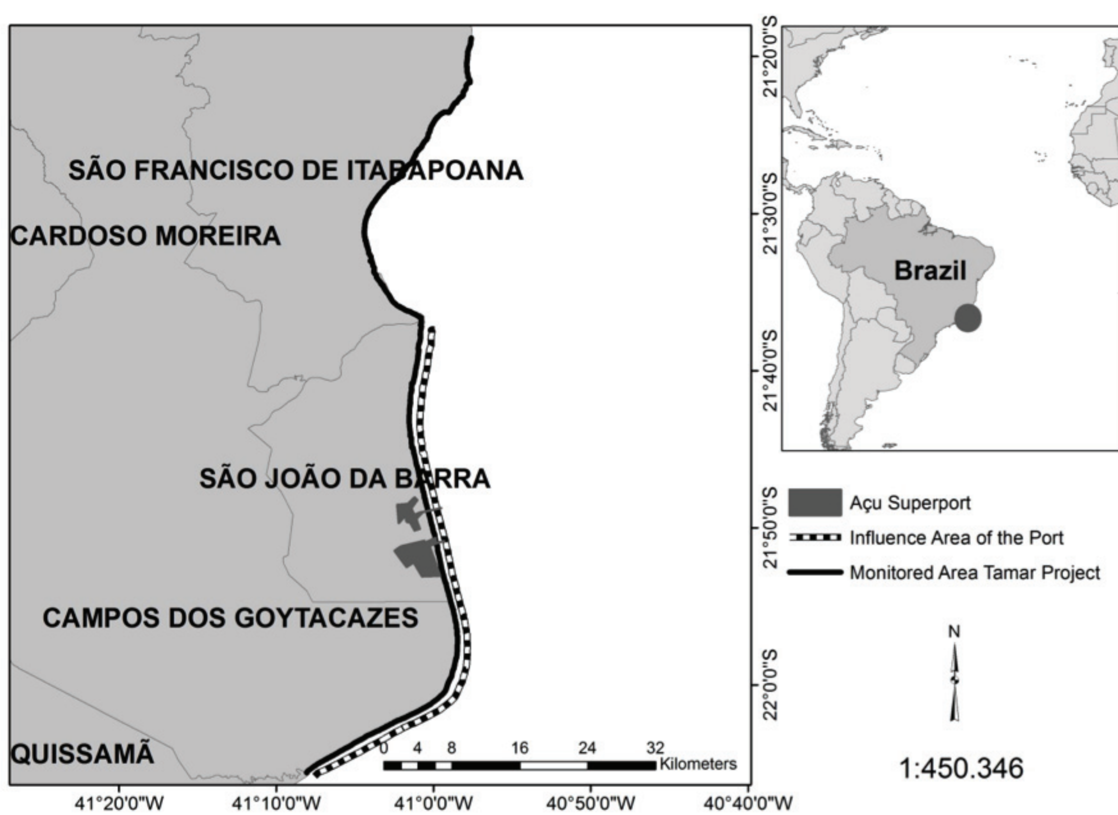

Figure 1. Map showing the location of Açu Superport and shipyard (in dark gray); the area of influence near the Açu Superport monitored by the port operator under TAMAR supervision (dotted line) and the overall area monitored by TAMAR (black line), which is an important nesting ground for loggerheads.

Figure 2. Dead adult loggerhead cut in half by a hopper dredge on the northern coast of Rio de Janeiro state, Brazil.

Figure 3. Dead adult leatherback cut in half by a hopper dredge on the northern coast of Rio de Janeiro state, Brazil.

(Ditty & Rezende 2014). Here we provide an account of sea turtle mortalities observed in the region that appear to be the result of dredging operations during both port construction and operation.

Since the beginning of construction in 2008, hopper dredges have been used for clearing and maintaining access channels, a turning basin, and a harbor basin, all to facilitate navigation of vessels using the port. In 2012, additional hopper dredges entered into operation for the construction of a new terminal and shipyard. Because the port complex is situated in a high-energy coastal zone, maintenance dredging of constructed channels is regularly required to remove sediments that build up after being transported and deposited by currents.

Hopper dredging was first identified as a source of turtle mortality in 1980, when 71 turtle interactions with hopper dredges were recorded over a period of five months in Canaveral Channel, Florida (NMFS 1991; Dickerson et al. 2004). Subsequently, between 1980 and 2003, 508 turtles have been impacted by dredgers from 38 different locations throughout the southeastern United States (Dickerson et al. 2004). Hopper dredges remove bottom sediments through articulated suction pipes, discharging it into a holding area (hopper) within the vessel. The dredged material is then taken away from the dredged area and subsequently released in a disposal area. During active dredging operations, the hopper dredge dragheads are slow-moving and nearly silent while suctioning bottom sediments, thereby potentially causing injuries or death to sea turtles that are entrained into the draghead (Dickerson et al. 1991; Banks & Alexander 1994; Dickerson et al. 2004; Fitzpatrick et al. 2006). Besides physical harm (*e.g.*, massive injuries, fractures, crushed tissues and hemorrhage) and mortality, indirect impacts such as alteration or destruction of foraging habitat might also occur, especially when dredged material is placed on rocky bottom habitats commonly used by sea turtles as foraging grounds. In addition, dredging may stir up toxic pollutants that have settled and become trapped by bottom sediments. Common measures used to reduce the likelihood of turtle and hopper dredger interactions include: working during times of year when turtles are less likely to occur at the project location; using deflectors and specially designed dragheads; relocating turtles from the project area via net capture prior to dredging operations (Dickerson et al. 2004).

In the case of the Açu Superport complex, only the dredges used in the construction of the shipyard and onshore portion of the complex were equipped with sea turtle deflectors and had observers on board to detect any turtle interactions, for reasons related to the environmental licensing process. Dragheads were checked after every load to ensure that no sea turtles had been entrained and turtle deflectors were also inspected to assure correct alignment. Daily

	0-21 cm	22-41 cm	42-61 cm	62-81 cm	82-101 cm	<101 cm	NM	Total
CC	0	0	0	2	3	3	18	26
CM	0	7	1	0	2	0	58	68
DC	0	0	0	0	0	3	1	4
LO	0	0	1	3	0	0	7	11
NI	0	0	0	0	0	0	3	3
Total	0	7	2	5	5	6	87	112

Table 1. Sea turtles with dredging-related injuries, per species and size class category, found stranded along the area monitored by the port operator under TAMAR supervision, on the northern coast of Rio de Janeiro state, Brazil, from 2008 to 2014 (CC = *Caretta caretta*; CM= *Chelonia mydas*; DC = *Dermochelys coriacea*; LO = *Lepidochelys olivacea*; NI = not identified; NM = not measured).

Figure 4. Dead olive ridley cut in half as a result of a hopper dredge interaction on the northern coast of Rio de Janeiro state, Brazil. Note the presence of the dredge in background.

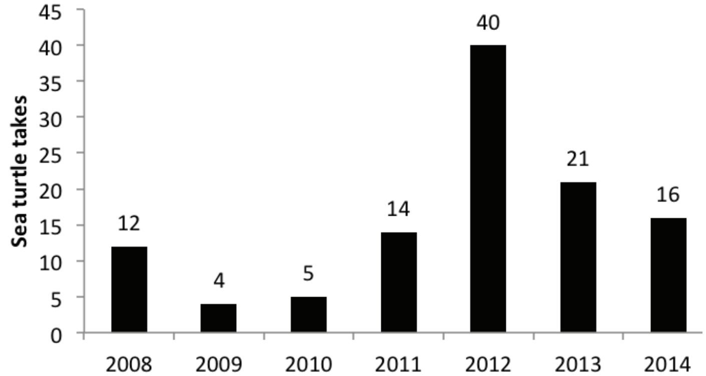

Figure 5. Sea turtle mortalities by hopper dredging, per year, along the northern coast of Rio de Janeiro state, Brazil.

inspection reports were filed by the observers, summarizing the dredging events of the day and documenting cases when a turtle was sighted or a lethal take occurred. Since dredging activities began, two different deflector types have been used: rigid deflectors and flexible chains. Although the rigid deflector is more effective in reducing entrainment than the flexible deflector (Nelson & Shafer 1996), the hopper dredge operator decided to use the latter.

Additional monitoring was conducted daily along 66 km of adjacent coastline, by the port operator, under Projeto TAMAR supervision. Each stranded turtle found (dead or alive) was identified, photographed and measured with a flexible tape. Curved carapace length (CCL) was measured from the anterior point at midline (nuchal scute) to the posterior tip of the supracaudal scutes. Curved carapace width (CCW) was measured across the widest part of the carapace, perpendicularly to the longitudinal body axis (Marcovaldi & Laurent 1996).

Fresh dead turtle carcasses found on the beach were taken to a laboratory for necropsy and decomposing carcasses were examined in the field by veterinarians. Both the necropsies and the field examinations were performed to determine whether the observed injuries were the result of dredge interactions and also to differentiate dredging lesions from propeller injuries, which are typically multiple linear-parallel lacerations and/or fractures that may penetrate the skin, coelomic cavity or the skull. The correct identification of dredging injuries was based on comparisons with lesions recorded in our 20-year stranding database, and the review of publications related to dredging, and technical reports provided by a pathologist from the local university (Universidade Estadual do Norte Fluminense), who has extensive experience in sea turtle injuries caused by hopper dredges. Injuries to sea turtles from hopper dredges are caused by blunt force trauma and are generally characterized by serious crushing wounds (*e.g.*, extensive fractures, lacerations and amputations). Only individuals with these types of injuries were considered in this evaluation.

Between 2008 and 2014, 1725 stranded sea turtles were found along the 66 km coastline monitored by the port operator under Projeto TAMAR supervision. This monitoring was part of a mitigation environmental measure required by the licensing authority. Of all stranded sea turtles observed, 112 individuals were found with injuries indicative of dredging interaction, including two that were found entrained in the hopper dredge draghead by observers. Of these, 68 were green turtles, 26 were loggerheads, 11 were olive ridleys, four were leatherbacks and three could not be assigned a species identification.

Considering that hopper dredges have huge dragheads and strong suction power, interactions with sea turtles frequently result in fatal injuries. The 112 turtles with dredging-related injuries often were cut in half and/or had parts of their carapace and/or flippers missing (Figs. 2, 3 and 4). Because most of the 112 turtles had parts of their carapace missing (Figs. 2, 3 and 4), only 25 of them could be accurately measured (Table 1).

In addition to the analysis of stranded turtles, we also evaluated dredging operations, by reviewing technical reports or by direct field observation of the dredging events. The technical reports included information regarding the number of hopper dredges operating within a defined period of time. Whenever these reports were unavailable, dredging activities were documented through direct observation and information available in the environmental license of the port. Although dredging operations started in 2008, we had access to data on hopper dredge activities only at the shipyard, which started in the end of 2011. Therefore, we lack precise information on the total number of dredges (port + shipyard) operating from 2008 onwards, and on the exact number of days/month that the dredges from the port were operating between 2008 and 2014.

The available information on dredging activities from 2011 onwards was cross-referenced with sea turtle takes and stranding location data, to search for a potential correlation between dredge events and sea turtle mortality. For this analysis, we considered two situations: periods with dredging activity and periods without dredging activity. We found that strandings with injuries directly attributable to hopper dredging operations occurred more frequently while dredging was active (Figure 6). Only 11 stranded turtles occurred in periods without dredging operations. However, even these occurrences may be related to hopper dredging, as we do not know exactly when the dredges from the port were operating. Additionally, months with <10 days of dredging activities were considered as months without dredging operations.

Individuals were classified as juveniles or adults based on CCL measurements, considering the minimum values for nesting females in Brazil (see Kotas et al. 2004; Silva *et al*. 2007; Thomé et al. 2007; Sales et al. 2008; Grossman et al. 2007; Marcovaldi and Chaloupka,

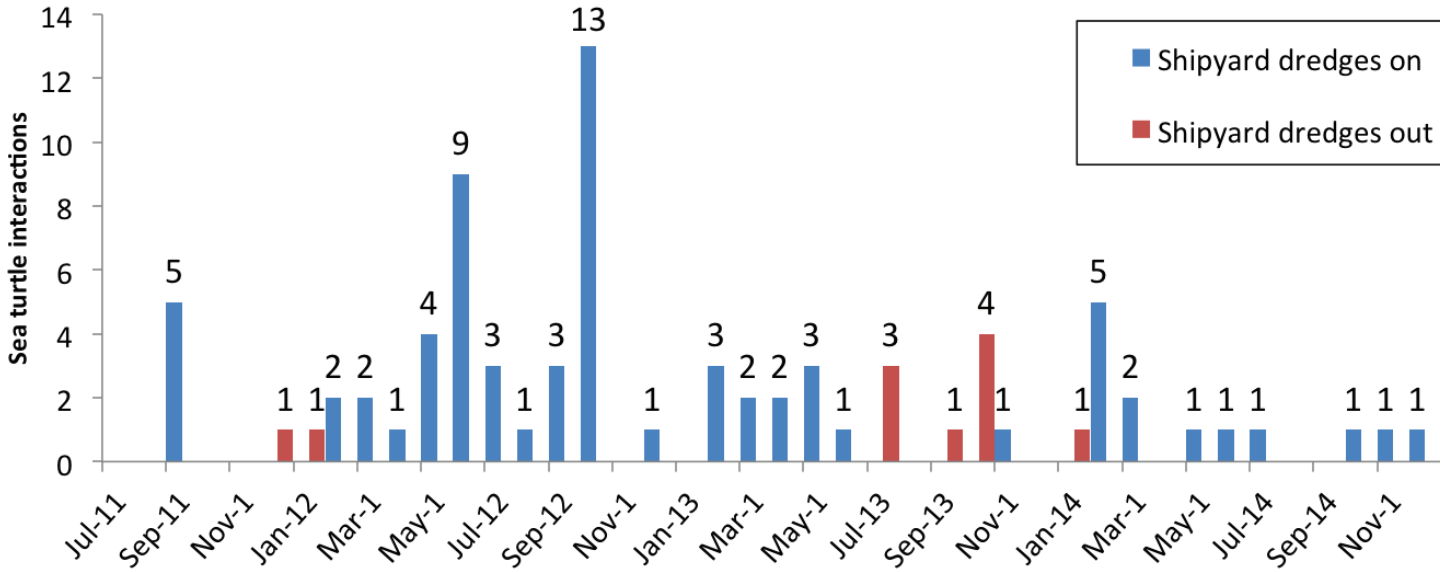

Figure 6. Sea turtle interactions (y axis) by dredging operation situation per month (x axis) along the area of influence of the Açu Superport, from September 2011 to December 2014. Red columns mean no dredging operations in those months. Blue columns indicate active dredging operations in those months. From October 2011 to January 2012 and from July 2013 to September 2013, the shipyard dredges were not operating; however, we do not have information on the port dredges.

2007; Santos et al. 2010 for reference values). All except two of the loggerheads were adult-sized (Table 1), reflecting the fact that the northern coast of Rio de Janeiro is a nesting area for loggerheads. Sixty-three green turtles were juveniles (Table 1), reflecting the importance of the area as foraging ground for juvenile *C. mydas*. Almost all leatherbacks and olive ridleys taken by the hopper dredge were adults and subadults (Table 1). The northern coast of Rio is considered a high use area for adult leatherbacks (López-Mendilaharsu et al. 2009) and an important migration corridor for adult olive ridleys (TAMAR, unpublished data).

In 2012, the number of turtles with these injuries increased considerably (Fig. 5), probably because additional hopper dredges started operating in the region during the construction of the new terminal and shipyard. In 2013 and 2014, we noted a gradual decrease in dredged-related strandings. The cause(s) for this decreasing trend are not clear, but may be related to the partial adoption of mitigation measures, or a shift to dredging closer to the shore.

In order to minimize dredging impacts on sea turtle populations, Projeto TAMAR has provided technical support to the environment agencies in charge of the port operation, for the development of a detailed plan to prevent additional incidental takes. Mitigation measures such as alternative dragheads, deflector equipment, as well as environmental time windows and using dredges other than hopper dredges, have been proposed, following Dickerson et al. (2004), with an understanding that the effectiveness of each measure is dependent on local environmental conditions. However, the Açu Superport authority chose not follow all of the proposed mitigation measures. For instance, a no-dredge environmental time window during the entire nesting season, which extends from October to March, was proposed but not implemented. Since November 2012, dredging has been restricted only to nighttime hours from November to January. However, subsequent numbers of observed stranded turtles linked to dredging operations in November-January remain similar to levels prior to November 2012 (Fig. 6). Had all the proposed mitigation measures been adopted and properly carried out, at both the port and the shipyard, it is possible that the dredging impacts on sea turtles in the area would have been much reduced.

According to Koch et al. (2013), the probability that turtles which are injured or killed in the water and subsequently are found on the beach as a stranded animal varies widely and usually does not exceed 10-20% of total mortality. Therefore, it is likely that the number of incidental captures by hopper dredges in this area based on stranded animals is an underestimate. Additionally, given the powerful draw of water into the hopper dredge during active dredging, a turtle entrapped on the underside of the draghead would never free itself while the pumps are on. While on the bottom, the massive draghead could pulverize a turtle beyond recognition (Dickerson & Nelson 1990).

Hopper dredging poses a serious threat to sea turtles, and on the northern coast of Rio de Janeiro, dredges have been killing turtles at different life stages, including gravid females, which have a high reproductive value for the larger population, because they are able to contribute new offspring to future generations. Considering these findings and what has been learned so far, even with proper application of all mitigation measures, we strongly discourage hopper dredging operations on sea turtle nesting grounds during nesting seasons. Additionally, in areas of high sea turtle concentration (*e.g.*, foraging grounds), care must be taken to ensure that there is minimum impact on these animals and other marine species. In high-density areas, it is recommended that hopper dredging operations should be carried out only if appropriate mitigation measures are sufficiently adopted, including but not limited to: the use of sea turtle deflector dragheads, intake and overflow screening, sea turtle relocation (away from the path of the dredge) and onboard observers. We hope our observations and recommendations will be used to assist future dredging project proponents and environmental agencies, in the selection of safe and appropriate mitigation measures.

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