Incidental capture of loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*) sea turtles by the pelagic longline fishery off southern Brazil

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Incidental capture in fishing gear is one of the main sources of injury and mortality of juvenile and adult sea turtles (NRC, 1990; Lutcavage et al., 1997; Oravetz, 1999). Six out of the seven extant species of sea turtles—the leatherback (*Dermochelys coriacea*), the green turtle (*Chelonia mydas*), the loggerhead (*Caretta caretta*), the hawksbill (*Eretmochelys imbricata*), the olive ridley (*Lepidochelys olivacea*), and the Kemp's ridley (*Lepidochelys kempii*)—are currently classified as endangered or critically endangered by the World Conservation Union (IUCN, formerly the International Union for Conservation of Nature and Natural Resources), which makes the assessment and reduction of incidental capture and mortality of these species in fisheries priority conservation issues (IUCN/Species Survival Commission, 1995).

Several studies have examined sea turtle bycatch by pelagic longline fisheries, especially in the North Atlantic and Pacific oceans (NRC, 1990; Nishemura and Nakahigashi, 1990; Tobias, 1991; Bolten et al., 1996; Williams et al., 1996; Lutcavage et al., 1997), but little is known about sea turtle bycatch in the South Atlantic. One of the most detailed reports on longline incidental captures in that area is that by Achaval et al. (2000), which documents the incidental capture of loggerhead and leatherback sea turtles in the southwestern Atlantic by longliners targeting swordfish (*Xiphias gladius*), tuna (*Thunnus obesus*), and other related species. Additional references, sometimes with scant detail, can be found in Weidner and Arocha (1999), Fallabrino et al. (2000), and Domingo et al.[1]

In this study, we report the incidental capture of loggerhead and leatherback sea turtles by the surface longline fishery operating off the southern coast of Brazil, within Brazil's 200 mile exclusive economic zone (EEZ) and in international waters, and present catch-per-unit-of-effort (CPUE) data and estimates of average probability of death at capture for these species. Preliminary results of incidental captures of sea turtles by longliners during one longline trip in this area were presented by Barata et al.[2] In the present study we provide more detailed data from additional trips, including information concerning leatherback sea turtles, as well as analyses of these data. To our knowledge, this is the first detailed report about the incidental capture of sea turtles by the Brazilian commercial longline fleet.

Materials and methods

Observations were carried out by three of the authors (JEK, SS, and VGA) during three trips aboard Brazil-flagged commercial longline vessels based in Itajaí, State of Santa Catarina, southern Brazil (Fig. 1). The trips occurred in 1998, the first (10 sets) between 13 March and 12 April (summer–fall), the second (13 sets) between 15 June and 5 July (fall–winter), and the third (11 sets) between 28 September and 13 October (spring), and took place between latitudes 27°30′S and 34°30′S and longitudes 36°00′W and 52°00′W (Fig. 1). The

[1] Domingo, A., A. Fallabrino, R. Forselledo, and V. Quirici. 2002. Incidental capture of loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*) sea turtles in the Uruguayan long-line fishery in Southwest Atlantic. Presented at the 22nd Annual Symposium on Sea Turtle Biology and Conservation, Miami, USA, 4–7 April 2002. [Available from A. Domingo: Dirección Nacional de Recursos Acuáticos, Constituyente 1497, C.P. 11.200, Montevideo, Uruguay.]

[2] Barata, P. C. R., B. M. G. Gallo, S. dos Santos, V. G. Azevedo, and J. E. Kotas. 1998. Captura acidental da tartaruga marinha *Caretta caretta* (Linnaeus, 1758) na pesca de espinhel de superfície na ZEE brasileira e em águas internacionais. *In* Resumos Expandidos da XI Semana Nacional de Oceanografia, Rio Grande, RS, outubro de 1998, p. 579–581. Editora Universitária-UFPel, Pelotas, RS, Brazil. [Available from FURG, Oceanologia, Av. Itália, km 8, Campus Carreiros, C.P 474, Rio Grande, RS 96201-900, Brazil.]

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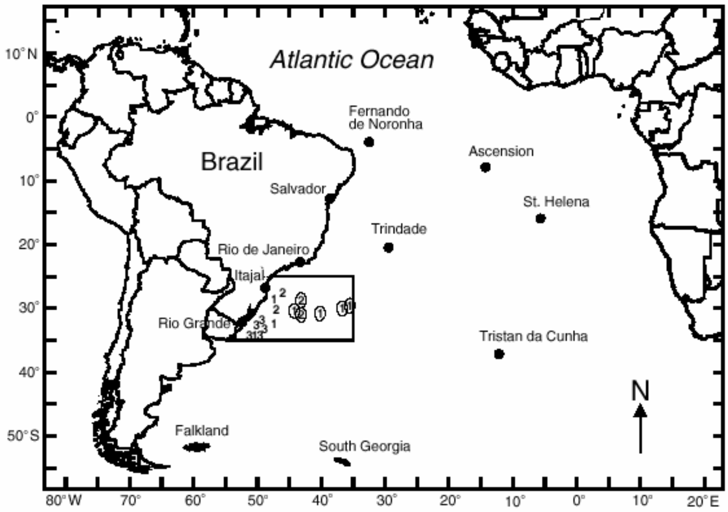

Figure 1

Fishing locations. Numbers 1, 2, and 3 indicate locations of the first, second, and third longline trips respectively; for each location, one or more sets were performed. Circled numbers indicate international waters outside the 200-mile Brazilian exclusive economic zone. The rectangular ocean area is limited by latitudes 25°S and 35°S and longitude 35°W. The fishing location farthest to the east is about 1320 km (713 nautical miles) from Itajaí, State of Santa Catarina, Brazil, the home port of the fishing vessels.

seabed in this area ranged from the continental shelf border to abyssal plains, including submarine elevations (e.g., Rio Grande). Operation depths, ranging from 170 to 4000 m, were obtained from nautical charts.

The first and second trips were aboard the *Yamaya III*, a 20.7-m, 325-hp engine, 30-t hold capacity, 10-crew longliner, and the third trip was aboard the *Basco*, a 24.4-m, 330-hp engine, 70-t hold capacity, 11-crew longliner. The vessels targeted swordfishes, sharks (mainly blue sharks, *Prionace glauca*) and tunas (*Thunnus albacares*, *T. alalunga* and *T. obesus*). Their fishing gear was the U.S.-style monofilament nylon longline, with 200–300 m sections between buoys, and each section contained four to five gangions set 40–60 m apart. Buoy dropper length ranged between 10 and 20 m, and gangion length ranged between 13 and 20 m. Each non-offset "J" hook (Swordfish 9/0) was baited with Argentine shortfin squid (*Illex argentinus*) and had a yellow chemical light stick hung over it. The average number of hooks per set was 1030, 992, and 950 on the first, second, and third trips, respectively.

On the first and second trips, the mainline was set off the stern by means of a line shooter so that a marked catenary was formed between buoys, allowing the hooks to operate at a greater depth. In this case, the maximum hook depth may have reached more than 40 m. On the third trip, the vessel *Basco* did not use a line shooter, and thus the hook depth for that trip may have been shallower. The longline gear was set around 5:30 PM, and was retrieved early in the morning. The average soak time was 7 h 30 min. For each set, the date, time, geographical position, number of hooks, and sea surface temperature were recorded. The species and condition (i.e., if the animal was alive or dead) of captured turtles were recorded; specimens with no apparent movement were considered dead.

Incidentally captured loggerhead turtles were taken aboard and hooks and lines were then removed. Whenever possible curved carapace length (CCL) and width were measured, and the turtles were double tagged (inconel tags style 681, National Band and Tag Co., Newport, KY), according to Projeto TAMAR's (Projeto Tartaruga Marinha, the Brazilian sea turtle conservation program) standard methods (Marcovaldi and Laurent, 1996). In some cases, it was not possible to bring loggerhead sea turtles on board the fishing vessel and, because of their great size, no leatherback sea turtles were brought on board. On these occasions, the turtles were pulled close to the boat and the gangions were then cut to free the turtles with the hooks still attached to them; however the length of the line remaining on the turtle was not recorded. None of these turtles was measured or tagged, although some of the leatherback sea turtles were filmed on video. No additional data and measurements, other than those presented in this study, were obtained.

Table 1

Data referring to fishing practices, sea surface temperature (°C), and capture of loggerhead and leatherback sea turtles, by trip. CPUE = catch-per-unit-of-effort (number of captured turtles/1000 hooks).

					Loggerheads				Leatherbacks			
Trip	Date	No. of sets	Average hooks/set	Average sea surface temperature	Alive (tagged)	Dead	Condition not recorded	CPUE	Alive	Dead	Condition not recorded	CPUE
1	13 Mar 98–12 Apr 98	10	1030	13.6	84 (17)	15	9	10.49	1	—	—	0.10
2	15 Jun 98–5 Jul 98	13	992	21.4	28 (12)	4	—	2.48	13	1	—	1.09
3	28 Sep 98–13 Oct 98	11	950	18.9	5 (5)	—	—	0.48	5	—	—	0.48
Total		34	990		117 (34)	19	9	4.31	19	1	—	0.59

CPUE (number of captured turtles/1000 hooks) was calculated separately for each species. Straight carapace lengths in published data were converted to CCL by using the formula in Teas (1993) to compare the CCL of captured loggerhead sea turtles to carapace length data found in the literature. To assess the significance of the difference in the proportion of dead loggerhead or leatherback sea turtles among trips, exact tests were applied, because ordinary chi-square tests are not reliable when expected cell frequencies are too small. The test statistics were $\chi^2 = \Sigma[(Observed - Expected)^2/Expected]$, and exact probabilities were computed for all tables with marginal frequencies fixed at the observed values (Lindgren, 1993, p. 376). These probability calculations were performed by a Turbo Pascal vers. 7 program (Borland International, Scotts Valley, CA). The confidence interval for overall probability of death at capture was calculated by the method in Zar (1996, p. 524). Ordinary chi-square tests and analysis of variance (ANOVA) tests followed Zar (1996) and were carried out with the software Systat vers. 9 (SPSS Inc., Chicago, IL). In the statistical tests, type-I error α was equal to 0.05. In the construction of Figure 2, to avoid overlapping of data points, the temperatures (but not the CPUEs) were jittered, that is, a small amount of uniform random noise was added to the temperature measurements (Cleveland, 1993).

Results

From a total of 34 sets and 33,650 hooks, 145 loggerhead (CPUE=4.31/1000 hooks) and 20 leatherback (CPUE=0.59/1000 hooks) sea turtles were captured. There was a significant difference in loggerhead CPUE among the trips (chi-square test, χ^2=137.3, P<0.001), but the proportion of dead loggerhead sea turtles was not significantly different among the trips (exact test, P=0.656). The average probability of death at capture for loggerhead sea turtles for the three trips was 0.140 (95% confidence interval=[0.086, 0.210]). For leatherback sea turtles, the difference in CPUE among the trips was significant (chi-square test, χ^2=9.76, P<0.01), and the proportion of dead leatherback sea turtles was not significantly different among the trips (exact test, P=1.000). The average probability of death at capture for leatherback sea turtles for the three trips was 0.050 (95% confidence interval=[0.001, 0.249]).

Table 2

Curved carapace length (CCL, cm) for loggerhead sea turtles, by trip.

Trip	Sample size	Average CCL	Standard deviation	Minimum	Maximum
1	19	56.9	7.3	46.0	70.0
2	30	57.2	7.5	46.0	68.0
3	5	67.0	5.9	58.0	73.0
Total	54	58.0	7.7	46.0	73.0

The average sea surface temperature (Table 1) was significantly different among the trips (ANOVA, n=34, F=55.37, P<0.001). The average temperature on the first trip was significantly lower than those on the second and third trips, and the average temperature on the second trip was significantly higher than that on the third trip (Tukey's *post hoc* test). For loggerhead sea turtles, CPUEs were generally higher on the first trip, which had the lowest average temperature (Fig. 2). For leatherback sea turtles, on the contrary, the lowest CPUEs were found on the first trip, on which only one leatherback sea turtle was captured (Table 1).

CCLs of captured loggerheads were in the range of 46–73 cm. Detailed loggerhead CCL data are presented in Table 2. There was a significant difference in average loggerhead CCL among the trips (Table 2); the average CCL on the third trip was greater than those on the first and second trips (ANOVA, n=54, F=4.209, P=0.020, Tukey's

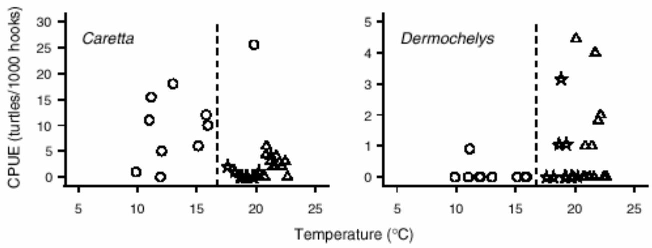

Figure 2

CPUE (number of captured turtles/1000 hooks) by sea surface temperature (°C) in each set, by species. Circles = first trip, triangles = second trip, stars = third trip. In each graph, the dashed vertical line, arbitrarily placed at 16.7 °C, marks a separation between the temperatures in the first trip and those in the second and third trips (except for one set in the first trip). Note that the two graphs have different vertical scales, and that, in the construction of this figure, temperature measurements (but not the CPUEs) have been jittered (see "Materials and methods" section).

post hoc test). Although leatherback sea turtles could not be hauled aboard for measurements, on board observations and video recordings indicated that they were subadult or adult animals.

Most of the loggerhead turtles were hooked through their mouths or esophagus, but a small number were hooked through their flippers or were found to be simply entangled in the lines. Loggerhead sea turtles taken aboard had their hooks removed, sometimes in a careless way that caused severe injury, and they were then returned to the sea. Leatherback sea turtles were found entangled in the lines or hooked either through the flippers or carapace or through the mouth. Because no leatherback sea turtle was hauled aboard, we could not tell if any were hooked in the esophagus.

Discussion

Achaval et al. (2000) reported data obtained from nine trips aboard two different longline vessels operating within the Uruguayan EEZ and in international waters in the South Atlantic in different seasons of the year, and employing different longline methods. Those authors reported that 28 loggerhead and 28 leatherback sea turtles were captured in 86 sets with 75,033 hooks in zones I and II, that correspond approximately to the fishing area covered in this study, yielding a CPUE of 0.37/1000 hooks for both loggerhead and leatherback sea turtles. For loggerhead sea turtles, there was a significant difference between our CPUE (Table 1) and that of Achaval et al. (chi-square test, χ^2=226.4, P<0.001); whereas for leatherback sea turtles no significant difference was found (chi-square test, χ^2=1.97, P=0.161).

Although the variations in CPUE observed in our study could be explained by differences in temperatures (Fig. 2), other physical, spatial, or temporal factors (or a combination of these factors) could be involved. The trips were carried out at different times of the year (Table 1); the third trip was more to the south and closer to the coast, and the first trip had sets more to the east (Fig. 1).

Our estimates of sea turtle mortality at capture may be lower than the actual mortality rates from longlines because our estimates do not consider postrelease deaths derived from 1) wounds caused by hooks removed from turtles on board, 2) embedded hooks and lines, and 3) stress caused by capture itself. Other researchers have also recognized that, because of factors such as these, there is great uncertainty in the estimates of mortality levels for sea turtles captured in longline gear (Balazs and Pooley, 1994; Eckert, 1994).

Captured loggerhead sea turtles were smaller (Table 2) than loggerhead sea turtles nesting in Brazil (minimum CCL=83.0 cm, average CCL= 103.0 cm, nesting season 1982–83 through nesting season 1999–2000; Projeto TAMAR[3]) and in several places in the North Atlantic and the Caribbean (minimum CCL=75.4 cm, average CCL in the range of 94.0–105.1 cm; Dodd, 1988). However, loggerhead sea turtles nesting in Cape Verde, in the northeastern Atlantic, are smaller than those nesting in those other places: minimum CCL=68.0 cm, average CCL=82.9 cm, data from 1998 (Cejudo et al., 2000). There is an overlap between the observed CCL range and that of adult Cape Verde loggerhead sea turtles (seven loggerhead turtles out of 54 observed, or 13.0%, had a CCL equal or greater than the minimum Cape Verde CCL), but the average CCL of the captured loggerhead sea turtles (Table 2) was well below that of loggerhead sea turtles nesting in Cape Verde. We estimate that the captured loggerhead sea turtles were generally juveniles, although a small number of them could have been adult turtles. However, size is

[3] Projeto TAMAR. 2000. Unpubl. data. Caixa Postal 2219, Salvador, BA 40210-970, Brazil.

not a reliable indicator of maturity or breeding status for sea turtles (Miller, 1997).

Along the southern coast of Brazil (between latitudes 23°S and 33°S), loggerhead sea turtles stranded or incidentally captured in fishing gear with CCLs as small as 32.5 cm have been observed (Projeto TAMAR[4]), but usually loggerhead sea turtles found in that region have CCLs greater than 50 cm, most commonly in the range of 60–90 cm (Pinedo et al., 1998; Bugoni et al., 2001; Projeto TAMAR[4]). Loggerhead sea turtles have also been found in Uruguay and Argentina (Frazier, 1984; Fallabrino et al., 2000). Their CCLs in those countries have been reported to be in the approximate range of 50–115 cm (Frazier, 1984). The loggerhead sea turtles reported here have an average CCL smaller than that usually observed for loggerhead sea turtles stranded or captured in southern Brazil, Uruguay, and Argentina, although most of the turtles (45 out of 54, or 83%) had CCLs equal to or greater than 50 cm, that is, they were within the size range for that region.

Cumulative evidence obtained from genetic and size-distribution data around oceanic basins, as well as tag returns, shows that the ontogenetic development of loggerhead sea turtles involves a pelagic juvenile stage (Carr, 1987; Musick and Limpus, 1997; Bolten et al., 1998). Transoceanic developmental migrations establishing a link between juveniles in feeding grounds and hatchlings from nesting beaches on opposite sides of the ocean basin have been demonstrated through genetic analysis for the North Atlantic and North Pacific (Bowen et al., 1995; Bolten et al., 1998). It has been suggested that a similar pattern may be expected for the South Atlantic (Bolten et al., 1998), where loggerhead sea turtles nest in Brazil and possibly in Africa (Marcovaldi and Laurent, 1996; Fretey, 2001). The incidental captures reported in our study, indicating the use of the pelagic environment by juvenile loggerhead sea turtles in the South Atlantic, support the hypothesis of transoceanic developmental migrations for those turtles in that ocean. Future genetic analysis of turtles incidentally captured in the South Atlantic would help to clarify their natal origin.

For leatherback sea turtles, there are important nesting grounds in the Atlantic, mainly in French Guiana and Suriname in South America, and Gabon and Congo in Africa (Spotila et al., 1996; Fretey, 2001). Leatherback sea turtles are known to travel long distances from their nesting beaches into pelagic waters (Goff et al., 1994; Morreale et al., 1996; Eckert and Sarti, 1997; Eckert, 1998). Satellite telemetry data indicate that leatherback sea turtles nesting in eastern South Africa can enter the South Atlantic (Hughes et al., 1998; Hughes[5]). In the southwestern Atlantic, leatherback sea turtles have been observed or captured in Brazil, Uruguay, and Argentina (Frazier, 1984; Pinedo et al., 1998; Achaval et al., 2000; Fallabrino et al., 2000; Bugoni et al., 2001).

Some measure of the significance of the three trips reported in the present study in terms of the potential for turtle capture and mortality in the South Atlantic longline fishery can be obtained by looking at information concerning the total fishing effort in the study area. In 1999, the Brazilian longline fleet consisted of 70 longliners (42 Brazilian and 28 leased foreign vessels); among them, 33 vessels were operating out of ports in southern Brazil, in the states of São Paulo, Santa Catarina, and Rio Grande do Sul. In that year, the total number of hooks of that longline fleet (both Brazilian and leased vessels) amounted to 13,598,260 hooks (ICCAT[6]). However, the southwestern Atlantic is fished not only by Brazil-based longliners, but also by longliners from Uruguay, Chile, Japan, Taiwan, and Spain (Folsom, 1997; Weidner and Arocha, 1999; Weidner et al., 1999). According to ICCAT's (International Commission for the Conservation of Atlantic Tunas) CATDIS data set (ICCAT)[7] longliners operating during 1995–97 in the area delineated by the present study (latitudes 25°S and 35°S and longitude 35°W, or eight ICCAT $5\times5°$ statistical blocks, Fig. 1) had an average annual catch of tunas and swordfishes of 6885 metric tons (t) (the total hold capacity of the vessels on the three trips reported in this study was 130 t). However, due to unreported landings by vessels flying flags of convenience (FAO, 2001; FAO[8]) and other sources, the estimate obtained from ICCAT data should be considered a minimum estimate of the total annual tuna and swordfish catch (ICCAT[9]). Furthermore, because North Atlantic stocks of swordfishes and some species of tuna are considered overfished (NMFS[10]), quota or closure regulations (or both) in the North Atlantic may be driving longline fleets to the South Atlantic, increasing the risk of incidental capture of sea turtles there.

In Brazil, sea turtle capture is prohibited by federal legislation (Marcovaldi and Marcovaldi, 1999), and measures have been taken to address the problem of incidental capture by longlines and other kinds of fishing

[4] Projeto TAMAR. 2000. Unpubl. data. Rua Antonio Athanásio 273, Ubatuba, SP 11680-000, Brazil.

[5] Hughes, G. R. 2002. Personal commun. Ezemvelo KZN Wildlife, P O Box 13053, Cascades 3202, South Africa.

[6] ICCAT (International Commission for the Conservation of Atlantic Tunas). 2001. National report of Brazil. Report for biennial period, 2000–2001, part I (2000), vol. 1, English version, p. 312–315. Calle Corazón de María, 8, 28002 Madrid, Spain.

[7] ICCAT (International Commission for the Conservation of Atlantic Tunas). 2002. CATDIS dataset. Calle Corazón de María, 8, 28002 Madrid, Spain. [Available from http://www.iccat.org.]

[8] FAO (Food and Agriculture Organization of the United Nations). 2001. International plan of action to prevent, deter and eliminate illegal, unreported and unregulated fishing, 24 p. FAO, Rome. [Available from http://www.fao.org/docrep/003/y1224e/y1224e00.htm.]

[9] ICCAT (International Commission for the Conservation of Atlantic Tunas). 1999. Detailed report for swordfish, ICCAT SCRS swordfish stock assessment session (Madrid, Spain, September 27 to October 4, 1999), 176 p. Calle Corazón de María, 8, 28002 Madrid, Spain.

[10] NMFS (National Marine Fisheries Service). 2000. 2000 stock assessment and fishery evaluation for Atlantic highly migratory species, 150 p. U.S. Dep. Commer., NOAA, NMFS, Highly Migratory Species Management Division, 1315 East-West Highway, Silver Spring, MD 20910.

gear. Since 2001, Projeto TAMAR has been developing and implementing (through partnerships with other institutions) an action plan whose main objective is to reduce incidental sea turtle capture, including captures occurring in the open sea (Marcovaldi et al., 2002). The action plan includes, among other things, an assessment of fishery-related sea turtle mortality, the development of mitigation methods, and a proposal of adequate conservation and enforcement policies (Marcovaldi et al., 2002). However, because the longline fleet is composed of vessels from many nations, the reduction of incidental capture in the open sea calls for international cooperation (Eckert and Sarti, 1997; Trono and Salm, 1999; Crowder, 2000).

The observations reported in this study and the presence of a sizable longline fleet operating in the southwestern Atlantic indicate 1) the need for research to clarify habitat use by sea turtles in that part of the ocean (Eckert and Sarti, 1997; Bolten et al., 1998), 2) the need for continued research to quantify the impact of longline fishing on sea turtles in the pelagic realm of that ocean (Balazs and Pooley, 1994; Eckert, 1994), and 3) the implementation of conservation measures for sea turtles in that environment. We suggest the implementation of an International Observers Program on board longliners operating throughout the South Atlantic ocean.

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