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FISHERY AS ADMINISTRATIVE UNIT: IMPLICATIONS FOR SEA TURTLE CONSERVATION

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SUMMARY

The pelagic longline fishery in Brazil started in the mid-fifties. This fishery uses different strategies to catch swordfish, tunas, sharks and dolphinfish, however those strategies also affect the incidental capture of sea turtles. If fishing strategies change according to target species and if these strategies affect the sea turtle capture then classify and group the distinct longline fisheries based on its characteristic and according to the homogeneity principle becomes necessary to better understand the incidental capture of sea turtles, their causes and consequences. Nevertheless, this approach has not been used and, usually, pelagic longline fisheries have been analyzed as a unique administrative unit, as being homogeneous when affecting the biota. Here we used the information of sea turtle incidental capture in longline fishing from Tamar Project database (1999-2016) and have separated the Brazilian pelagic longline fishery in five distinct fisheries, according to its characteristics. The results show differences for sea turtle species composition, BPUEs and size classes by turtle specie captured on different longline fisheries. This fact has important implications for sea turtle conservation as well as for the management of fisheries.

RÉSUMÉ

La pêcherie brésilienne opérant à la palangre pélagique a débuté ses activités au milieu des années cinquante. Cette pêcherie utilise différentes stratégies pour capturer l'espadon, les thonidés, les requins et la coryphène commune ; or, ces stratégies affectent également les captures accidentelles de tortues de mer. Si les stratégies de pêche changent selon les espèces ciblées et si ces stratégies affectent la capture des tortues marines, il devient alors nécessaire de classer et de grouper les différentes pêcheries palangrières en se fondant sur leurs caractéristiques et selon le principe d'homogénéité, afin de mieux comprendre les captures accidentelles de tortues marines, leurs causes et leurs conséquences. Néanmoins, cette approche n'a pas été utilisée et, habituellement, les pêcheries palangrières pélagiques ont été analysées comme étant une entité administrative unique et homogène lorsqu'elle affecte le biote. Ici, nous avons utilisé les informations sur la prise accidentelle de tortues marines capturée à la palangre extraites de la base de données du Projet Tamar (1999-2016) et séparé la pêcherie palangrière pélagique du Brésil en cinq pêcheries distinctes, en fonction de ses caractéristiques. Les résultats montrent des différences en ce qui concerne la composition spécifique des tortues marines, les BPUE et les classes de taille par espèce de tortues marines capturées par différentes pêcheries palangrières. Ce fait a des conséquences importantes pour la conservation des tortues marines ainsi que pour la gestion des pêcheries.

RESUMEN

La pesquería de palangre pelágico de Brasil se inició a mediados de los cincuenta. Esta pesquería utiliza diferentes estrategias para capturar pez espada, túnidos, tiburones y dorado, sin embargo, dichas estrategias afectan también a la captura incidental de tortugas marinas. Si las estrategias de pesca cambian conforme a la especie objetivo y si dichas estrategias afectan a

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la captura de tortugas marinas, entonces es necesario clasificar y agrupar las diferentes pesquerías de palangre basándose en sus características y de acuerdo con el principio de homogeneidad para entender mejor la captura incidental de tortugas marinas, sus causas y sus consecuencias. No obstante, este enfoque no ha sido utilizado y, generalmente, las pesquerías de palangre pelágico se han analizado como una única unidad administrativa, como si fueran homogéneas al afectar a la biota. En este documento, se ha utilizado información sobre la captura incidental de tortugas marinas en la pesca con palangre procedente de la base de datos del Proyecto Tamar (1999-2016), y se ha separado la pesquería brasileña de palangre pelágico en cinco pesquerías diferentes, de acuerdo con sus características. Los resultados muestran diferencias en la composición por especies de las tortugas marinas, las BPUE y las clases de talla por especies de tortuga capturadas en las diferentes pesquerías de palangre. Este hecho tiene importantes implicaciones para la conservación de las tortugas marinas, así como para la ordenación de las pesquerías.

KEYWORDS

Sea turtles, Incidental capture, Longline fisheries, Administrative unit

1. Introduction

Large-scale pelagic longline fishing in Brazil started in 1956, in the northeastern region (Paiva, 1961; Moraes, 1962). By 1958, this fishing modality had expanded to southeastern Brazil, more specifically to the port of Santos in Sao Paulo state (Moraes, 1962). Until 1993, the catches were primarily tuna *(Thunnus albacares*, *Thunnus obesus*, and *Thunnus alalunga*). The longlines consisted of a multifilament main line and tuna hooks without light attractors. From 1994, the fleet based in Santos started to use a new longline configuration (American model) that consisted of a main line in nylon monofilament, a J-hook, and a light stick as a light attractor (Arfelli *et al.*, 2000). The fishing strategy was also modified and the main target species became the swordfish (*Xiphias gladiu*s) and blue shark (*Prionace glauca*).

In the late '90s and early 2000, some smaller bottom line fishing vessels from the port of Itaipava, in Espírito Santo state, started longline fishing using a new strategy toward to catch the common dolphinfish (*Coryphaena hippurus*) during its harvest season (October to February) (Martins *et al.*, 2014). In the other months of the year, these same vessels changed their fishing gear and way of fishing and targeted swordfish.

In 2003, according to a notice of fishing vessel leases issued by the Brazilian government, Chinese pelagic longline fishing was adopted in the northeast of Brazil, mainly targeting the capture of albacore (*Thunnus alalunga*).

Different fishing strategies were used to capture these target species (tuna, swordfish, and common dolphinfish). However, these different strategies do not merely change the capture of target species; they also seem to catch sea turtles as suggested by some authors (Ferreira, 2005; Camiñas *et al.*, 2006; Coluchi, 2006; Szablak, 2015). Therefore, if the fishing strategies change according to the desired target species, and if these changes also affect the incidental capture of sea turtles, classify and group the distinct longline fisheries based on its characteristic and according to the homogeneity principle becomes necessary to better understand the incidental capture of sea turtles, their causes and consequences.

In practice, however, this approach has not been used and, usually, pelagic longline fisheries have been analysed as a unique administrative unit, as being homogeneous when affecting the biota.

In this work, pelagic longline fishing in Brazil was subdivided according to its characteristics into five different fisheries, as proposed by TAMAR Project: 1) American pelagic longline fishery of the N/NE - EAN; 2) American pelagic longline fishery of the S/SE - EAS; 3) Chinese pelagic longline fishery - EPC; 4) Itaipava pelagic longline fishery that targets swordfish - EIM; and 5) Itaipava pelagic longline fishery that targets common dolphinfish - EID.

This way, each pelagic longline fishery was considered as an administrative unit to assess, monitor and mitigate the interaction with sea turtles. The Information about the incidental capture and carapace size of sea turtles were analysed in each of the fisheries.

2. Material and methods

Data were obtained from the oceanic fishing database of the TAMAR Project. The longline fishing vessels listed in this database were monitored by onboard observers of the former *Programa Nacional de Observadores de Bordo da Frota Pesqueira do Brasil* - PROBORDO, the Brazilian Onboard Observers Program and by onboard observers from TAMAR Project and partners institution such as: Núcleo de Educação e Monitoramento Ambiental - NEMA, Projeto Albatroz, Universidade do Vale do Itajaí - UNIVALI, Universidade Federal Rural de Pernambuco - UFRPE, Museu Oceanográfico do Vale do Itajaí - MOVI. Only data of the pelagic longline fishing vessels that commercially operated between November 2000 and January 2016 were considered.

To characterize the five pelagic longline fisheries identified by the TAMAR Project we crossed information of previous works (Coluchi *et al.*, 2005; Martins *et al.*, 2005; Coluchi, 2006; Stein, 2006; Dallagnolo *et al.*, 2008; Maçaneiro *et al.*, 2013) with information from the database of the TAMAR Project. The information of this database was obtained from the characterizations of onboard observers during the monitored trips and from interviews with the captain of vessels on the ports of Itajaí/Navegantes - SC, as described by Maçaneiro *et al.* (2013). The pelagic longline fisheries were characterized according to 11 parameters: 1) target species, 2) type of hook, 3) number of hooks between floats, 4) length of secondary line, 5) length of float line, 6) light attractor, 7) kind of bait used, 8) steel wire, 9) fishing area, 10) fishing season, and 11) fishing effort (# hooks per set). Therefore, the Brazilian pelagic longline fisheries were grouped or separated according to the homogeneity principle. Although these parameters were chosen in this work to characterize the pelagic longline fisheries, they are not the only parameters that affect the capture of turtles. These captures are also affected by other features of longline fishing, by physical oceanographic conditions (currents, temperature etc.), biological oceanographic conditions (prey availability and presence of predators), and by the biological and ecological characteristics of sea turtles. The sets were spatially distributed using the programme ArcGis, version 9.3 (ESRI™). We assumed the turtle captured location as the initial position of the set, once we were not able to know the exactly point of the captures of sea turtles.

Whenever possible the onboard observers measured the curved carapace length (CCL) of the captured turtles. This measurement was taken from the nuchal notch to the posterior end of the shell, as described by Bolten *et al.* (1999). The measurements were taken using a flexible millimetre tape measure. The CCLs of the same species in different types of longline were compared using the Kruskal-Wallis Test (Gibbons *et al.*, 2003), with a 5% probability of making a type 1 error ($\alpha = 0.05$). In the case of a significant difference between the CCLs, the Simes-Hochberg method was used to make multiple comparisons between the fisheries. Statistical tests were run using the programme Action Stat version 3.1.43.702.667.

To separate the size class between adult and juvenile we adopted the minimum recorded CCL in Brazil for females in nesting beaches. Thus, all turtle captured with CCL equal or above that one were considered adult.

The fishing effort and captures of turtles were grouped, although possible inter-annual differences were disregarded in this work. The nominal BPUE (bycatch per unit effort) of each sea turtle species in each type of fishery was calculated as being the number of individuals captured every 1000 hooks (turtles/1000 hooks). The BPUEs per fishery for each species were compared using the Kruskal-Wallis test with a 5% probability of making a type 1 error ($\alpha = 0.05$). The Simes-Hochberg method was used to make multiple comparisons of the BPUEs between the fisheries.

3. Results and discussion

A total of 749 fishing trips were monitored, corresponding to a sampling effort of 21,740,533 hooks (**Table 1**). The sampling effort among the fisheries was very different (**Table 1**), especially for fisheries EIM and EID, where the sampled effort was too small compared to the sampled effort of the other three fisheries. Of the five longline fisheries, three of them primarily target swordfish and sharks (mainly blue shark) (EAS, EAN, and EIM), and the other two target tuna (EPC) and common dolphinfish (EID). **Table 2** summarises the characteristics of each pelagic longline fishery. The fishing area used by each fishery is shown in **Figure 1**.

In all, 4,562 turtles belonging to four species were captured. The only species that occurs in Brazil and that did not have a capture record in pelagic longline fisheries was the hawksbill turtle (*Eretmochelys imbricata*). Once the longline fisheries were grouped as a single fishery, the most captured turtle was the loggerhead (*Caretta caretta*) accounting for 61% of total catches (n = 2,786). Then came the leatherback turtle (*Dermochelys coriacea*) representing 24% of the total (n = 1088), the olive ridley turtle (*Lepidochelys olivacea*) with 13% (n = 608), and the green turtle (*Chelonia mydas*) with only 2% of the total catches (n = 80) (**Figure 2**). Considering the fishery approach, however, the capture of sea turtles in longline fisheries did not always follow the general pattern shown in **Figure 2** (**Figure 3**).

The EAN captured 1,261 turtles. Of these catches, the leatherback was the most captured specie (44%), followed by the olive ridley (41%), the loggerhead (12%), and the green turtle (3%) (**Figure 3a**). The EAS fishery captured 2,906 turtles, of which the loggerhead was the most captured with 85.4% of the catches, followed by the leatherback (14%), green sea turtle (0.4%), and olive ridley (0.2%) (**Figure 3b**). The EID fishery captured 88 turtles. The most common were the loggerhead turtle (45.5%), followed by the olive ridley (20.5%), the leatherback (18.2%), and the green turtle (15.9%) (**Figure 3c**). The EIM fishery captured 24 turtles and was the only one that caught just two species; the leatherback turtle (83%) and the loggerhead (17%) (**Figure 3d**). Finally, the EPC captured 283 turtles, of which the loggerhead was the most captured (37.8%), followed by the leatherback (32.2%), the olive ridley (24.4%), and the green turtle (5.7%) (**Figure 3e**).

It is important to note that among the 107 occurrences of loggerhead turtles in the EPC fishery, 101 were registered below the latitude of 20° S, which is not the main fishing area of this fishery (**Figure 1c**). This area was only used for 5 fishing trips in 2003 and 2004 performed by two vessels leased by a company based in Santos that was testing this type of longline in the S/SE region.

Although the turtle captures were measured according to the fishing effort, the BPUEs obtained in the EIM and EID fisheries should be viewed with caution due to the small size of the sample. Wallace *et al.* (2010) suggest there is a universal pattern where high bycatch rates are associated with low sample coverage. The fisheries EIM and EID should be more intensely monitored to allow for more robust data that can help us to better understand the interaction of these fisheries with sea turtles. **Table 3** shows the absolute capture, the relative capture, and the BPUE by species for each longline fishery.

The Kruskal-Wallis test showed significant differences ($p < 0.05$) between the BPUEs in the different longline fisheries (**Table 4**), thus corroborating that the fisheries approach can improve the assess of the incidental capture of turtles in pelagic longline fisheries.

In this work, the EAS fishery alone captured almost 90% (n = 2,481) of the total loggerhead turtles caught in all the longline fisheries (**Table 3**) and the BPUE obtained for this specie was also significantly higher than the BPUEs registered in other fisheries (**Table 4**). The EAS fishery, however, captured only 1% (n = 6) of the olive ridley turtles (**Table 3**) and registered a lower BPUE for this specie (**Table 3**). If protecting the loggerhead turtle is a priority, it would be logical to direct resources and efforts toward the EAS fishery. Contrarily, the EAN fishery, for example, captured almost 85% (n = 515) of the olive ridley turtle (**Table 3**), and this fishery, together with EID fishery, had the highest BPUEs for this specie of turtle (**Table 3**). The EAN fishery, on the other hand, only captured 5.5% (n = 154) of loggerhead turtles (**Table 3**) and registered one of the lowest BPUEs for this specie (**Table 3**). Therefore, if protecting the olive ridley turtle is a priority, instead loggerhead turtle, it is important to propose mitigating measures primarily directed toward the EAN fishery and possibly toward the EID fishery. However, the sampling effort of this fishery should also be extended so that the magnitude of interaction with the olive ridley turtle can be more safely assessed. These examples make it clear that approaching incidental catches by fisheries helps to better address conservation measures and streamline the available conservation resources.

The curved carapace length of 60.6% (n = 2,765) of the captured turtles was measured. The CCL data, especially of the leatherback turtle, should be viewed with caution since turtles of this species are rarely loaded because of their large size. This is especially true of the EIM and EID fleets that use smaller vessels than those used by the other pelagic longline fisheries. Thus, it is possible that larger animals have been captured, but have not been hauled and measured.

In the case of the loggerhead turtle, 2,163 specimens were measured (77.64% of the total) and their lengths ranged from 29 cm to 109 cm (**Figure 4a**). Both juvenile and adult turtles were captured. Adults were considered those with a CCL greater than or equal to 83 cm, which is the minimum recorded CCL in Brazil for females of this species in spawning beaches (Baptistotte *et al.*, 2003; Lima *et al.*, 2012). Although some adults were captured, they only represented 1.02% of the total measured loggerhead turtles. The Brazilian longline fishing vessels that operate in the South Atlantic capture loggerhead turtles of other populations than the Brazilian population, as shown by some authors (Reis *et al.*, 2010; Shamblin *et al.*, 2014). The other populations include turtles from Australia, Oman, South Africa, USA, and Mexico. For these populations, the minimum length recorded for females in reproductive activity may differ slightly from the length recorded for the Brazilian population. Studies conducted with telemetry show that adult females that nested in Bahia (Brazil) migrated after nesting season and navigated areas near the coast (Marcovaldi *et al.*, 2010) where there is no pelagic longline fishing. Juvenile individuals, however, preferably used oceanic areas on the talude and continental slope (Barceló *et al.*, 2013) that overlap the areas used extensively by some longline fisheries. This behavioural difference found can help to explain why the young individuals of the loggerhead turtle were most captured than adults.

In the case of total captured green turtles, the carapace length of 54 turtles was measured (67.5% of the total) and the CCL ranged between 25 cm and 90 cm (**Figure 4b**). Only one individual reached a CCL of 90 cm, which is precisely the smallest size registered for females that nest on Trindade Island, the main nesting site of the green turtle in Brazil and one of the most important for this species in the Atlantic Ocean (Almeida *et al.*, 2011). Although there is no study of genetics in Brazil that could provide information on the origin of green turtles captured in longline fishing, we already know that coastal areas located in the states of Ceará, São Paulo, and Santa Catarina harbour a mixed stock of juvenile green turtles from the Rocas Atoll, Trindade Island, and Fernando de Noronha Island (Brazil), Ascension Island; Suriname; Aves Island (Venezuela); Guinea-Bissau; and other locations (Naro-Maciel *et al.*, 2007; Proietti *et al.*, 2009). Therefore, it is also possible that the juveniles of these populations are being captured by Brazilian longline vessels.

The leatherback turtle had the lowest percentage of animals measured (n = 107) in relation to total captured, with only 9.83%. The CCL varied between 40 cm and 194 cm (**Figure 4c**). Brazil is home to one of the smallest populations of this specie in the world, and the only area with regular nesting is on the northern coast of the state of Espírito Santo (around latitude 19° S). The smallest female registered in that area had a CCL of 139 cm (Thomé *et al.*, 2007). Considering this curved carapace length, the catches in the longline fishing vessels included young individuals (63.5%) and adults (36.5%). The average length of the leatherback turtles that nest in Brazil (159.8 cm) is slightly higher than the lengths recorded for other populations in the Atlantic (St. Croix, Virgin Islands – Tortuguero – Costa Rica, French Guiana and Trinidad) (Thomé *et al.*, 2007).

The eastern side of the Atlantic Ocean, more precisely in Gabon, harbours one of the largest populations of leatherback turtles in the world (Witt *et al.*, 2009). The Brazilian longline vessels are known to capture females of this population (Billes *et al.*, 2006). The females that nest in Gabon have an average CCL of 151.4 cm, and the smallest female in reproductive activity in this area had a CCL of 130 cm (Verhage *et al.*, 2006). Therefore, the Brazilian vessels may be capturing a higher percentage of adults than reported in this work.

Recently, Fossette *et al.* (2014) analysed telemetry data of 106 leatherbacks and found a clear overlap between the areas in the South Atlantic Ocean with high concentrations of longline effort and areas widely used by these turtles. These authors identified nine areas considered at high risk for this specie due to the high probability of incidental capture, and two of these areas are located within or adjacent to the Brazilian EEZ.

For the olive ridley turtle, 72.5% of the captured animals were measured (n = 441), and the CCL ranged between 27 cm and 80 cm (**Figure 4d**). The main nesting site of this specie in Brazil is the coast of the state of Sergipe, where the smallest nesting female registered had a CCL of 62.5 cm (da Silva *et al.*, 2007). In this context, the longline vessels captured both young individuals (82.8%) and adults (17.2%). There are no genetic studies for this specie that can report the origin of the individuals captured by Brazilian longline vessels.

On the Western coast of the Atlantic Ocean, there are few reproductive sites of the olive ridley turtle and, besides the areas in Brazil, the most representative areas are in French Guiana and Suriname (Marcovaldi, 2001; Godfrey *et al.*, 2004). There are more nesting areas on the coast of Africa, from Guinea-Bissau to Angola (Fretey, 2001). Considering that sea turtles are highly migratory animals, it is possible that the turtles from these other populations are interacting with pelagic longline fishing performed by the Brazilian vessels.

A summary of the complementary statistical information for the CCLs of turtle species captured by Brazilian pelagic longline fisheries is showed on **Table 5** and a comparative box plot graphic for the CCLs registered for each specie in five distinct longline fisheries is showed on **Figure 5**

The Kruskal-Wallis test showed that there was a significant difference ($p < 0.05$) between the CCLs of turtles from the same specie, but caught in the different fisheries (**Table 6**). As only one leatherback turtle was measured in the EID fishery (CCL = 130 cm), this animal was disregarded for the Kruskal-Wallis test. In the EIM fishery, only the carapace sizes of the leatherback turtles were compared; although the loggerhead sea turtle was also captured, only two specimens were measured (CCL = 56.5 cm and 66.5 cm), so they were disregarded for the test as well.

For the loggerhead turtle, the size distribution of the animals captured and measured was significantly different for all the fisheries. For the green turtle and the leatherback turtle, significant differences in the CCL of the captured animals were observed in three pairs of fisheries, while for the olive ridley turtle significant differences were found in four pairs of fisheries (**Table 6**). These results show that in addition to the differences in the specific composition of the captured turtles, the sizes of the animals captured also differ among some longline fisheries.

Understanding which size classes are being captured in the longline fisheries is fundamental for the conservation of sea turtles since larger turtles, especially turtles that are almost sexually mature, have a relatively higher reproductive value than the juvenile and sexually immature individuals. Therefore, increasing the survival rate of sub-adults (identifying which fisheries interact with this phase of life and mitigating such interaction) also increases the number of turtles likely to reach sexual maturity, and consequently expands the entry of individuals with high reproductive value in the adult stages (Crouse *et al.*, 1987). Lewison *et al.* (2007) compiled and reviewed existing data about the relative impact of pelagic longline fishing on sea turtle populations and concluded that longline fishing demographically affects the older age classes of turtles. In this work, however, we identified that this finding should not be considered a rule for all types of longline fishing and that the sizes of the captured turtles vary significantly among the fisheries. This observation reinforces the need to assess the incidental capture of sea turtles by fishery approach, considering each longline fishery as an independent administrative unit.

Considering that sea turtles species are classified with different conservation status by the IUCN (http://www.iucnredlist.org/) and that each specie interact differently with the different longline fisheries, as shown in this work, the fishery approach proposed here essentially helps to prioritize conservation actions by specie of turtle and direct mitigating measures to a specific longline fishery or to a pertinent group of longline fisheries.

4. Conclusion

Viewing pelagic longline fisheries as a single and homogeneous fishery generates a big problem, especially for the management of threatened species such as sea turtles. The grouping of pelagic longline fisheries with different characteristics into a single fishery makes it more difficult to understand why certain species of sea turtles, or size classes within the same species, are more susceptible to capture than others (Sales *et al.*, 2015). Consequently, any planning or fishing management measures that target the conservation of endangered species (such as sea turtles) do not always reach the desired result. In some cases, these measures are incorrectly aimed at fisheries that have low captures of turtles due to gear configuration and/or strategies adopted by them, forcing these fisheries to make unnecessary changes.

The results presented in this study show that the five pelagic longline fisheries identified so far in Brazil interact differently with different species and sizes of sea turtles. This finding has relevant implications for the conservation of sea turtles, as well as for the economy, planning and management of fisheries.

Finally, we recommend using the fishery as the administrative unit to monitor, assess and to mitigate the incidental capture of sea turtles in pelagic longline fishing. Although the approach to the incidental capture of sea turtles used in this study is based on the analysis of longline fishing, it may also works for other fishing modalities (e.g. trawls, gillnets etc.), and should, therefore, be tested for these modalities.

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Table 1. Numbers of trips, sets and hooks monitored in each of the pelagic longline fisheries that operated in Brazil between 2000 and 2016. EPC = Chinese pelagic longline fishery; EAN = American pelagic longline fishery of the N/NE; EAS = American pelagic longline fishery of the S/SE; EIM = Itaipava pelagic longline fishery for swordfish; EID = Itaipava pelagic longline fishery for dolphinfish.

Fishery	***Trips***	***Sets***	***Hooks***
EPC	237	4.941	8.832.920
EAN	310	7.905	9.705.487
EAS	164	2.530	2.950.965
EIM	26	218	129.733
EID	12	184	121.428
Total	**749**	**15.778**	**21.740.533**

Table 2. Characteristics of the Brazilian pelagic longline fisheries identifyed. Effort = number of hooks per set. * mainly mackerel (*Scomber spp*); ** mainly mackerel and milk-fish (*Chanos chanos*); *** mainly skipjack tuna (*Katsuwonus pelamis*); **** mainly skipjack tuna and sardine (*Sardinella spp*). EPC = Chinese pelagic longline fishery; EAN = American pelagic longline fishery of the N/NE; EAS = American pelagic longline fishery of the S/SE; EIM = Itaipava pelagic longline fishery for swordfish; EID = Itaipava pelagic longline fishery for dolphinfish.

Fishery	Target specie	Hook type	Hooks between floats	Effort average (min/max)	Branchline average length (m)	Float line average length (m)	Luminous attractor	Steel wire	Bait	Temporal distribution	Search
EAN	swordfish and sharks	J 9/0	5	1228 (100/2560)	19	10	yes	yes	squid	All year	Coluchi *et al.* 2005; Coluchi 2006; TAMAR Project Database
EAS	swordfish and sharks	J 9/0	5	1166 (250/2520)	18,86	16,99	yes	yes	squid and fish*	All year	Coluchi *et al.* 2005; Maçaneiro *et al.* 2013; TAMAR Project Database
EPC	tunas	Tuna hook	6	1788 (300/2730)	22,5	15	no	yes	fish **	All year	Coluchi *et al.* 2005, Coluchi 2006; TAMAR Project Database
EIM	swordfish and sharks	J 9/0	(5/6)	595 (270/800)	14,84	14,82	yes	yes	fish ***	All year	Martins *et al.* 2005; Stein 2006; Maçaneiro *et al.* 2013; TAMAR Project Database
EID	dolphinfish	J 5/0 or J 4/0	2	660 (200/1000)	4,36	3,37	no	no	fish ****	Oct - Feb	Martins *et al.*2005; Stein 2006; Dallagnolo *et al.* 2008; Maçaneiro *et al.* 2013; TAMAR Project Database

Table 3. Sea turtle capture by specie and Fishery. Nominal catch (n), relative catch (%) and BPUE (turtles/1000 hooks). EPC = Chinese pelagic longline fishery; EAN = American pelagic longline fishery of the N/NE; EAS = American pelagic longline fishery of the S/SE; EIM = Itaipava pelagic longline fishery for swordfish; EID = Itaipava pelagic longline fishery for dolphinfish.

Fishery	Cc			Dc			Cm			Lo		
	n	**%**	**BPUE**	**n**	**%**	**BPUE**	**n**	**%**	**BPUE**	**n**	**%**	**BPUE**
EAN	154	5,5	0,0162	554	50,9	0,0589	38	47,5	0,0044	515	84,7	0,0536
EAS	2481	89,1	0,8658	407	37,4	0,1415	12	15,0	0,0032	6	1,0	0,0018
EID	40	1,4	0,2791	16	1,5	0,1072	14	17,5	0,1300	18	3,0	0,2554
EIM	4	0,1	0,0281	20	1,8	0,1634	0	-	-	0	-	-
EPC	107	3,8	0,0127	91	8,4	0,0098	16	20	0,0016	69	11,3	0,0074
Total	2786	100		1088	100		80	100		608	100	

Table 4. Multiple comparisons among BPUEs from longline fisheries. Significant *p* values in bold ($p<0,05$). Cc = *Caretta caretta*, Cm = *Chelonia mydas*, Dc = *Dermochelys coriacea*, Lo = *Lepidochelys olivacea*. EPC = Chinese pelagic longline fishery; EAN = American pelagic longline fishery of the N/NE; EAS = American pelagic longline fishery of the S/SE; EIM = Itaipava pelagic longline fishery for swordfish; EID = Itaipava pelagic longline fishery for dolphinfish.

Fishery	**Cc Kruskal-Wallis (*p*=0) *p-value***	**Cm Kruskal-Wallis (*p*=0) *p-value***	**Dc Kruskal-Wallis (*p*=0) *p-value***	**Lo Kruskal-Wallis (*p*=0) *p-value***
EAN - EAS	**0**	0,83530	**0**	**0**
EAN - EID	**0**	**0**	0,98643	0,06514
EAN - EIM	0,74608	0,83530	**0,03798**	**0,00011**
EAN - EPC	0,74608	0,73217	**0**	**0**
EAS - EID	**0**	**0**	**0,01801**	**0**
EAS - EIM	**0**	0,83530	0,96237	0,84305
EAS - EPC	**0**	0,83530	**0**	0,06514
EID - EIM	**0**	**0**	0,23173	**0,00002**
EID - EPC	**0**	**0**	**0,03798**	**0**
EIM - EPC	0,74608	0,83530	**0**	0,59894

Table 5. Sea turtle captured and measured, curve carapace lenght (CCL) by specie and fishery; avg = average; sd = standard deviation. Cc = *Caretta caretta*, Cm = *Chelonia mydas*, Dc = *Dermochelys coriacea*, Lo = *Lepidochelys olivacea*. EPC = Chinese pelagic longline fishery; EAN = American pelagic longline fishery of the N/NE; EAS = American pelagic longline fishery of the S/SE; EIM = Itaipava pelagic longline fishery for swordfish; EID = Itaipava pelagic longline fishery for dolphinfish.

	Cc				**Cm**				**Dc**				**Lo**			
Fishery	captured (measured)	CCL (cm) min - max	avg (sd)	median	captured (measured)	CCL (cm) min - max	avg (sd)	median	captured (measured)	CCL (cm) min - max	avg (sd)	median	captured (measured)	CCL (cm) min - max	avg (sd)	median
EAN	154 (40)	33-80	64,3 (8,12)	65,5	38 (18)	27-90	52,7 (17,38)	51,5	554 (47)	40-170	119 (33,14)	130,0	515 (366)	30-80	55,4 (7,6)	56,3
EAS	2481 (1997)	29-109	58,9 (7,36)	59,0	12 (11)	30,5-44	36,3 (3,8)	35,0	407 (30)	90-194	145,1 (21,89)	141,5	6 (6)	35-70	59,8 (12,9)	65,0
EID	40 (27)	48-92	71,9 (8,03)	72,0	14 (13)	25-75	42,9 (12,37)	39,0	16 (1)	130-130	130	130,0	18 (16)	50-69	63 (4,7)	63,5
EIM	4 (2)	56,5-65,5	61 (6,36)	61,0	0 (0)	-	-	-	20 (4)	115,5-131	128,8 (7,33)	122,5	0 (0)	-	-	-
EPC	107 (97)	43-71	56,4 (6,32)	56,0	16 (12)	47-72	54,3 (7,13)	54,0	91 (25)	50-170	102,6 (27,45)	110,0	69 (53)	27-73	49,2 (10,6)	50,0

Table 6. Multiple comparisons among CCLs of the sea turtle captured in longline fisheries. Significant *p* values in bold ($p < 0,05$). Cc = *Caretta caretta*, Cm = *Chelonia mydas*, Dc = *Dermochelys coriacea*, Lo = *Lepidochelys olivacea*. EPC = Chinese pelagic longline fishery; EAN = American pelagic longline fishery of the N/NE; EAS = American pelagic longline fishery of the S/SE; EIM = Itaipava pelagic longline fishery for swordfish; EID = Itaipava pelagic longline fishery for dolphinfish.

Cc (Kruskal-Wallis, *p*=0, n=2,163)		**Cm (Kruskal-Wallis, *p*=0,0005, n=54)**		**Dc (Kruskal-Wallis, *p*=0, n= 107)**		**Lo (Kruskal-Wallis, *p*=0, n=441)**	
Fishery	***p-value***	**Fishery**	***p-value***	**Fishery**	***p-value***	**Fishery**	***p-value***
EAN - EAS	**0,00000**	EAN - EAS	**0,00232**	EAN - EAS	**0,00148**	EAN - EAS	0,12695
EAN - EID	**0,01547**	EAN - EID	0,12839	EAN - EIM	0,81929	EAN - EID	**0,00012**
EAN - EPC	**0,00000**	EAN - EPC	0,24020	EAN - EPC	**0,01627**	EAN - EPC	**0,00011**
EAS - EID	**0,00000**	EAS - EID	0,20908	EAS - EIM	0,19316	EAS - EID	0,51733
EAS - EPC	**0,00053**	EAS - EPC	**0,00025**	EAS - EPC	**0,00000**	EAS - EPC	**0,00383**
EID - EPC	**0,00000**	EID - EPC	**0,01697**	EIM - EPC	0,52254	EID - EPC	**0,00000**

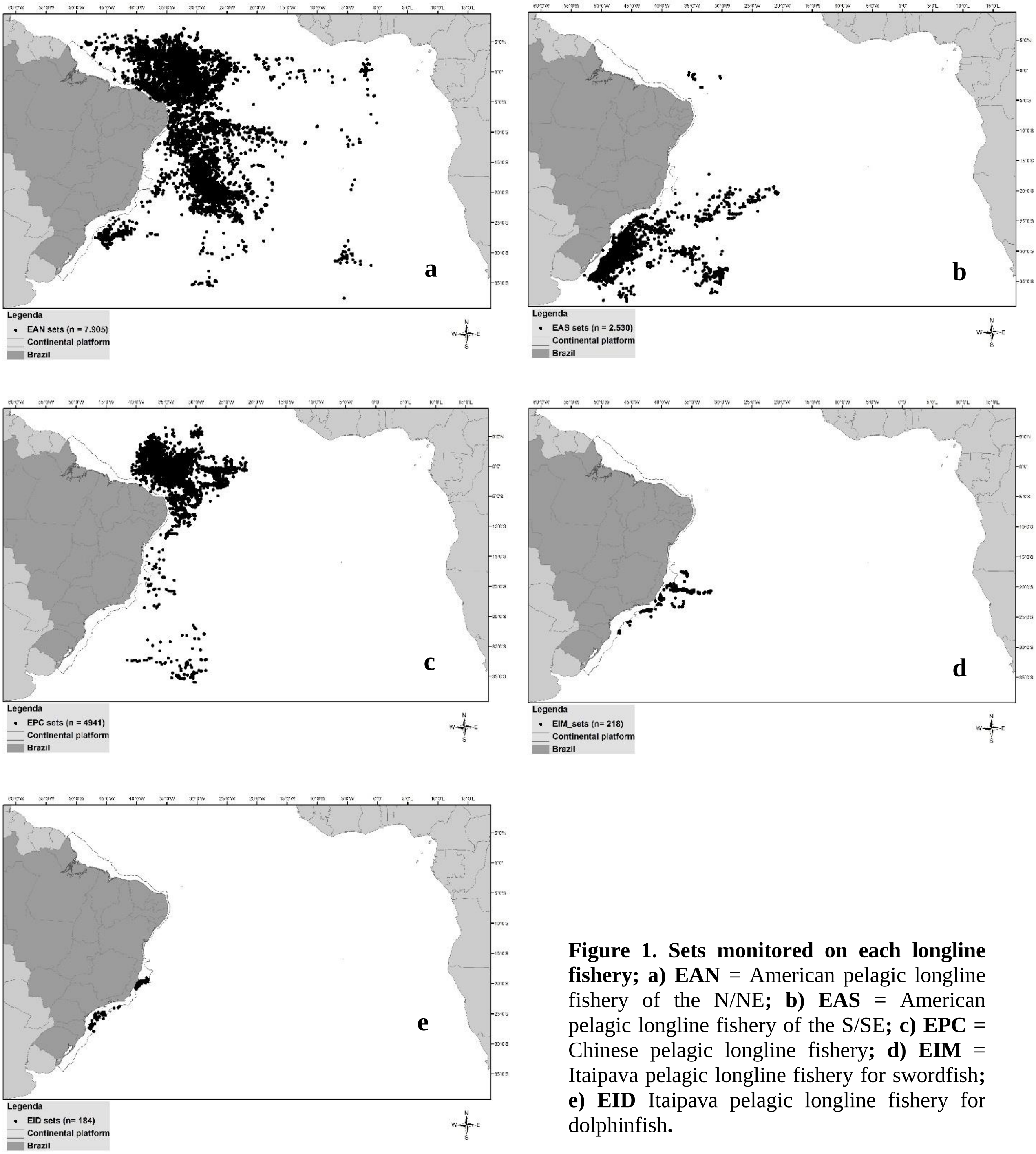


Figure 1. Sets monitored on each longline fishery; a) EAN = American pelagic longline fishery of the N/NE**; b) EAS** = American pelagic longline fishery of the S/SE**; c) EPC** = Chinese pelagic longline fishery**; d) EIM** = Itaipava pelagic longline fishery for swordfish**; e) EID** Itaipava pelagic longline fishery for dolphinfish**.**

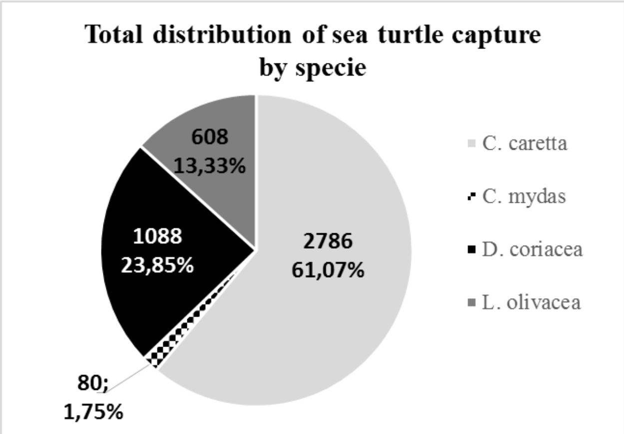
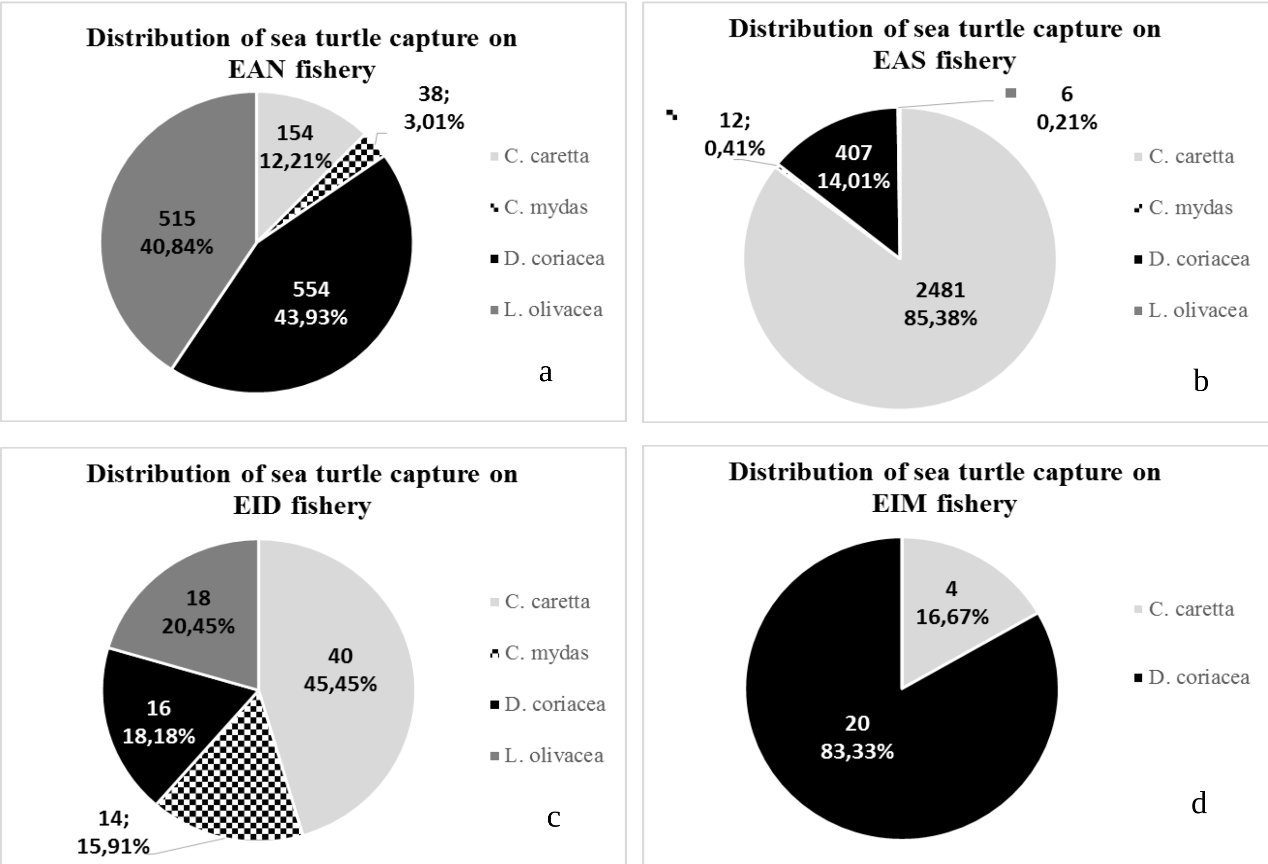


Figure 2. Relative distribution of the sea turtle species captured in all longline fisheries. EPC = Chinese pelagic longline fishery; EAN = American pelagic longline fishery of the N/NE; EAS = American pelagic longline fishery of the S/SE; EIM = Itaipava pelagic longline fishery for swordfish; EID = Itaipava pelagic longline fishery for dolphinfish.



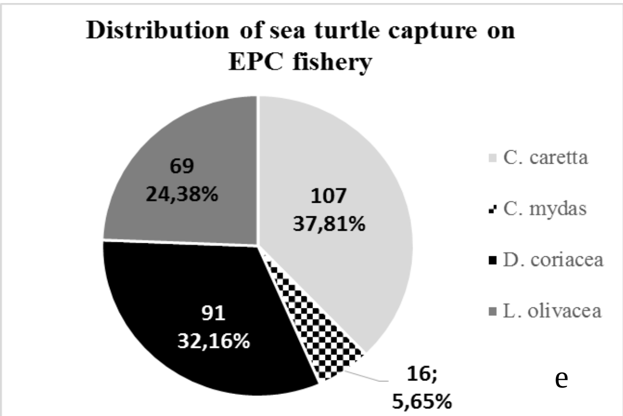


Figure 3. Relative distribution of the sea turtle species captured, by longline fishery; a) EAN = American pelagic longline fishery of the N/NE**; b) EAS** = American pelagic longline fishery of the S/SE**; c) EID** = Itaipava pelagic longline fishery for dolphinfish**; d) EIM** = Itaipava pelagic longline fishery for swordfish**; e) EPC** = Chinese pelagic longline fishery**.**

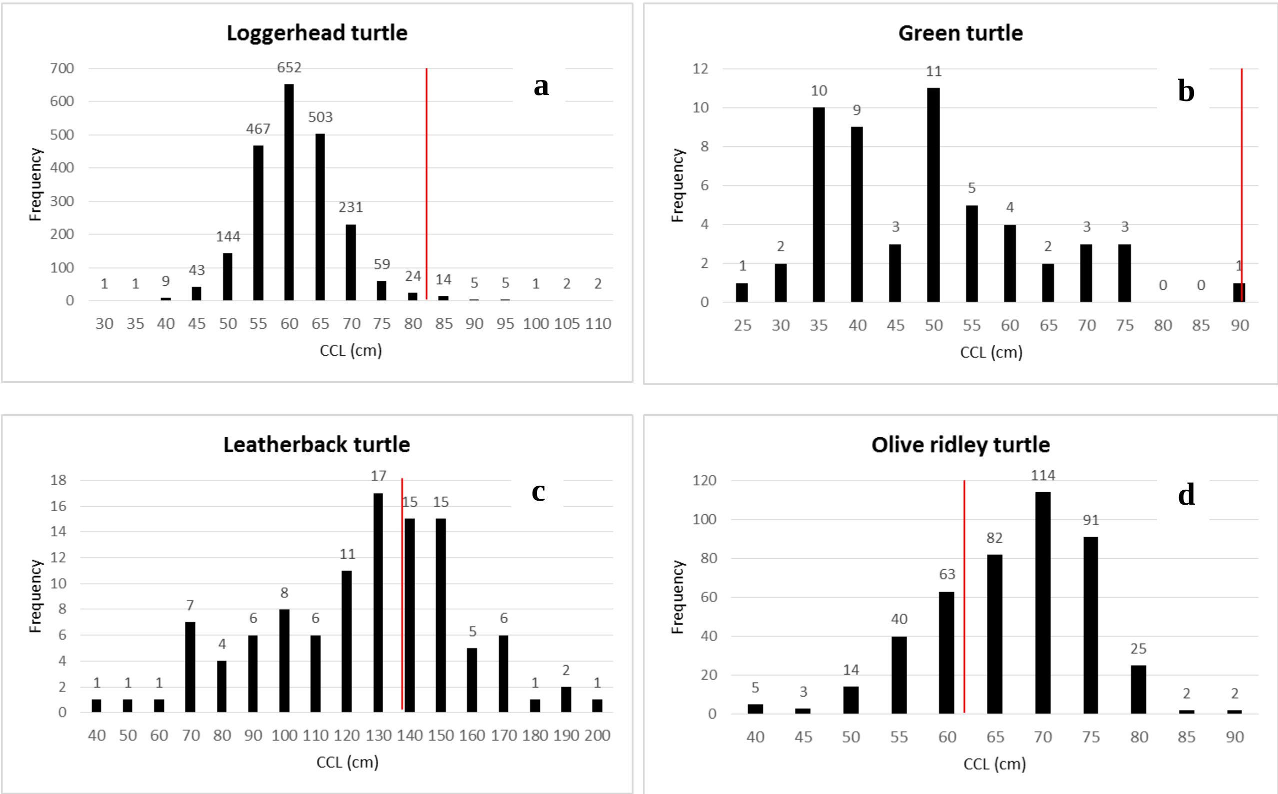


Figure 4. CCLs frequencies of the sea turtle species captured. Red bars indicate the minimum CCL registered for the females in Brazilian nesting site

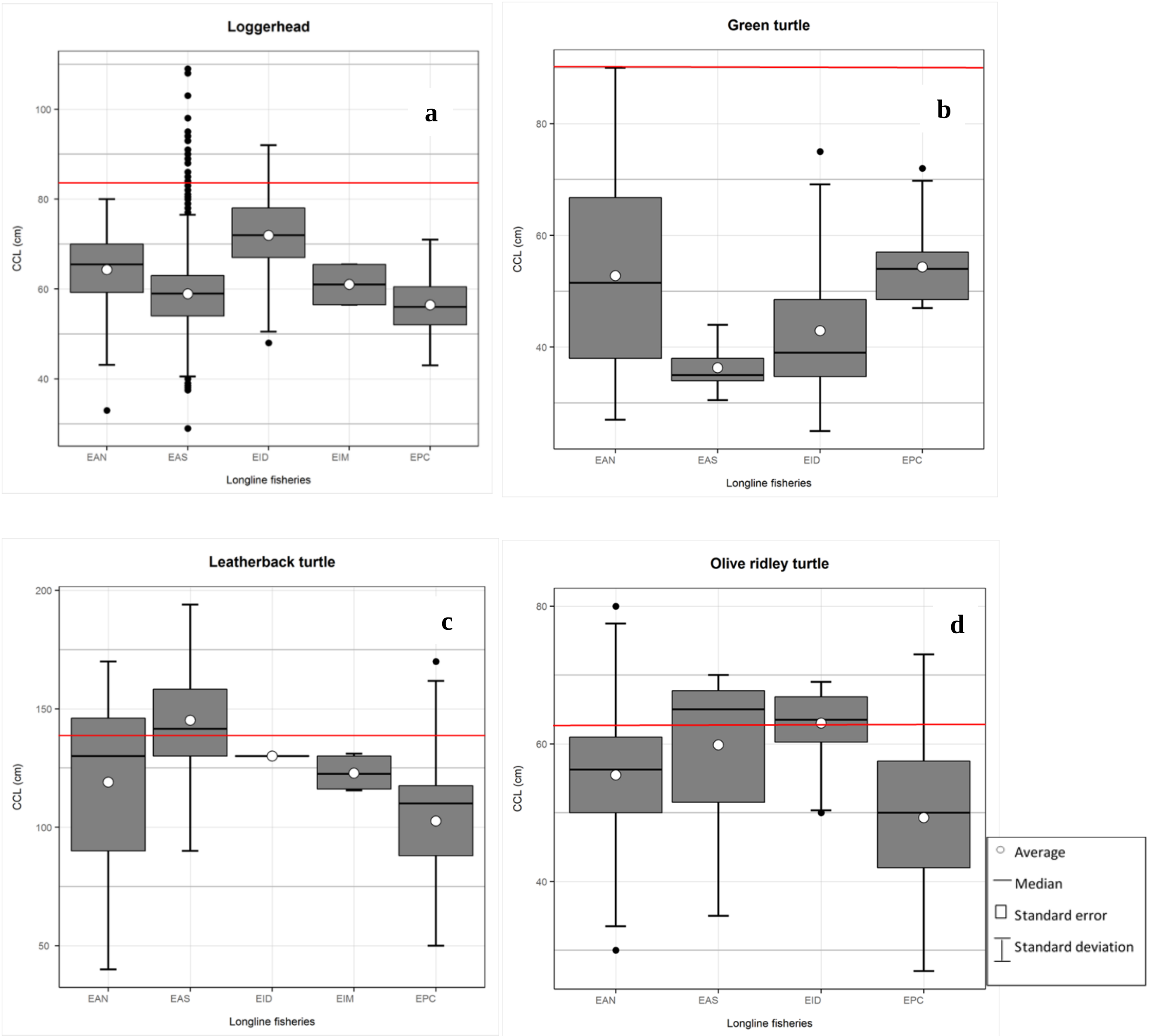


Figure 5. CCLs of the sea turtle species captured by longline fisheries. Red bars indicate the minimum CCL registered for the females in Brazilian nesting sites. EPC = Chinese pelagic longline fishery; EAN = American pelagic longline fishery of the N/NE; EAS = American pelagic longline fishery of the S/SE; EIM = Itaipava pelagic longline fishery for swordfish; EID = Itaipava pelagic longline fishery for dolphinfish.