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DISCARDS OF SHARKS BY THE BRAZILIAN LEASED FLEET IN 2010

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SUMMARY

The pelagic longline fishery catches not only tuna and tuna-like species but also sharks as by-catch. There are some concerns about the populations of sharks that are probably very vulnerable to fisheries. Also, there are some enforcement and international recommendations indicating that discards of dead fish should be prohibited. Therefore, after the longline is retrieved, the sharks that are still alive should be released. In this paper we have calculated the proportions of discards and also the mean number of sharks dead per fishing set by the leased fleet off the Brazilian coast. The results indicate that valuable species like mako and blue shark are hardly discarded, dead or alive. Nevertheless, close to half of the threshers were discarded and most of them were alive.

RÉSUMÉ

La pêcherie palangrière pélagique capture non seulement les thonidés et les espèces apparentées mais également les requins comme prise accessoire. Des préoccupations existent en ce qui concerne les populations de requins qui sont probablement très vulnérables à la pêche. Il existe également quelques réglementations et des recommandations internationales qui indiquent que les rejets de poissons morts devraient être interdits. C'est pourquoi, une fois que la palangre est retirée, les requins encore vivants devraient être remis à l'eau. Dans ce document, nous avons calculé les proportions de rejets et également le nombre moyen de requins morts par opération de pêche de la flottille affrétée opérant au large de la côte brésilienne. Les résultats indiquent que de précieuses espèces, comme le requin-taupe bleu et le requin peau bleue, sont à peine rejetés, morts ou vivants. Néanmoins, près de la moitié des requins renards sont rejetés et la plupart d'entre eux vivants.

RESUMEN

La pesquería de palangre pelágico no captura únicamente túnidos y especies afines, sino también tiburones de forma fortuita. Existe cierta inquietud generada por las poblaciones de tiburones que son probablemente muy vulnerables a las pesquerías. Además, existen algunas disposiciones y recomendaciones internacionales que indican que debería prohibirse el descarte de ejemplares muertos. Por tanto, tras halar el arte de palangre, deberían liberarse los tiburones que siguen vivos. En este documento se han calculado las proporciones de los descartes, así como el promedio en número de tiburones muertos por operación de pesca de la flota fletada que opera en aguas frente a la costa brasileña. Los resultados indican que especies de gran valor como los marrajos y la tintorera se descartan muy pocas veces, ya sea muertos o vivos. Sin embargo, casi la mitad de los tiburones zorro son descartados, la mayoría de ellos vivos.

KEYWORDS

By-catch, shark fisheries, catch composition

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1. Introduction

In the Atlantic Ocean commercial longline fleets aiming at tuna catches several species including elasmobranchs. Pelagic longline fisheries started in Brazil in the 1950s when vessels of other countries were chartered and home based in ports of the northeast coast (Zavala-Camin and Tomás, 1990). Currently, the fleet is composed of several vessels but most of these are national boats. Besides the large vessels, there are also several small artisanal boats also fishing tuna at least during some periods of the year (ICCAT, 2010).

The Brazilian fleet is large but the annual catch is only 6% of total tuna caught in the Atlantic Ocean. Catches of swordfish (*Xiphias gladius*) rank first (close to 40%), while blue shark (*Prionace glauca*) (close to 16%) if compared to the catches of other species (ICCAT, 2010). Besides blue shark, several other species of shark are often caught by the Brazilian longline fleet and, some of the sharks are discarded (Amorim *et al.*, 2002).

The word "discard" is used here to define the fraction of the catch comprised of fish that are not valuable, due to their small size or because they are not marketable, and which are thrown back to the sea after fishermen have selected the part they are interested in. To discard part of the catch is not an uncommon practice all around the world and, most of the fish discarded are dead or will die due to injuries (Saila, 1983; Alverson *et al*., 1994). Fish may be discarded entire or in parts. Estimates of the total weight of fish discarded in fisheries all around the world were close to 30 million tons in the 1990s (Alverson *et al*., 1994; Moore and Jennings, 2000). In some circumstances those fish could be used as food source in many different ways for several animals (Furness, 2003; Valeiras, 2003).

Most of the reasons for discarding fish are commercial. The fishermen are not interested in keeping onboard the fish that are not as valuable as some of the others, that are not marketable or that do not compensate the costs of the fishing operation (Pikitch *et al*., 1988). Nevertheless, discards may also me motivated by management enforcements like restrictions on size and on the species of fish allowed to be landed and sold (Hilborn and Walters, 1992). Discards motivated by an excessive catch are very rare (Alverson *et al*., 1994).

There is an additional motivation for fishermen to discard sharks. Shark fins are very valuable in some markets such as the Japanese market, but some of the body is not marketable. In this case, to cut the fin and to discard the body is the more efficient commercial action for fishermen. This practice, known as "finning", has been seriously criticized. There are several management enforcements, restrictions and recommendations for the purpose of eliminating "finning" (e.g., FAO, 2000; ICCAT, 2004; ICCAT, 2009). Recently, the Brazilian government has decided on some management enforcement based on those international recommendations (MPA, 2011).

The concern about shark discards is not motivated only by ethic and economic issues; ecological issues also play an important role. Sharks have slow growth, late maturity and low fecundity (Camhi *et al.*, 1998). Hence, their populations have low intrinsic rates of increase (Smith *et al.*, 1998) and low resilience to fishing mortality (Hoenig and Gruber, 1990). As a matter of fact, there are some popular approaches to assess the status of populations in which several types of information are used, like estimations of post-capture mortality (the proportion of the individuals captured that were either retained or discarded dead) (*e.g.* Cortés *et al*., 2010).

Quantitative estimations of discards before and after management enforcements are very important in the decision making process. Nevertheless, in some fisheries systems, the data available on discards is not enough and/or is biased. When the source of information is the fishermen, the data may be strongly biased if it is not expected of them to report information concerning illegal discards or that cast opinions against themselves. Assuring that an independent observer is onboard is an alternative. In Brazil, a program concerning onboard observers called the "Programa Nacional de Observadores de Bordo da Frota Pesqueira" (PROBORDO) was started in the mid-2000s. Currently, the PROBORDO does not cover the entire tuna longline fleet but only the chartered vessels. While the information generated by the PROBORDO is not comprehensive, it may be useful to estimate discards for at least some part of the Brazilian fleet. Hence, in this paper we have carried out a preliminary analysis of part of PROBORDO database. We started with the 2010 subset but the goal is to analyze all data available in the near future. In order to do the calculations we have used the Bayesian approach that has proved to be very useful when analyzing ecological databases (McCarthy, 2007; Andrade and Kinas, 2008).

2. Data and analysis

2.1 Database

In this paper we have analyzed the report of observers onboard of four Spanish chartered vessels home based in the northeast coast. Fishermen of those monitored vessels were targeting swordfish. Usually those fishermen set a longline in the water with close to 1200 hooks which sinks slowly until the hooks reach close to 50 m depth. Nevertheless, several structural and operational components may change according to the fishermen strategy. For example, they can change the number of hooks, the length of the secondary lines, the number of hooks per basket, etc.

On-board observers gather information about fishermen activity but especially about the fishing operation. The database build based in the data provided by onboard observers contains for each fishing set information about geographic location (latitude and longitude), the number of hooks, the number of baskets, the bait, the sea surface temperature, the time of the day the longline was set and retrieved, among others. Onboard observers also report the amount of fish caught and loaded and, of fish caught but discarded alive or dead for some of the species. That detailed information is available mainly for marketable and for species that can easily to be identified and whose names explicitly appears in the forms they are supposed to fulfill. Catches of other species are reported in generic categories like “other sharks”. An important issue concerning catches and discards as reported by observers in 2010 is that there is not information whether the fish was alive when the fishermen retrieved it onboard. Hence there is information about the number of fish discarded alive but not about the number of fish that was alive. Some of the fish still alive after the longline retrieval could dye onboard and be loaded or could dye and then discarded.

2.2 Variables and parameters

Discards were assessed for the following categories of elasmobranchs: blue shark (BSH) (*Prionace glauca*), mako non identified (MAK) (*Isurus spp.*), thresher shark non identified (THR) (*Alopias spp.*), crocodile shark (PSK) (*Pseudocarcharias kamoharai*) and, other sharks non identified (OTH). The primary variables are the number of fish hooked and retrieved (c), the number of fish caught and loaded (a), the number of fish caught but discarded alive (v) and the number of fish caught but discarded dead (m). Hence the following equation holds for each of the i^{th} fishing set:

(1) $$c_i = a_i + v_i + m_i$$

Other quantities of interest are the proportion of the fish caught that was discarded

(2) $$\widehat{pd} = \frac{\sum v_i + \sum m_i}{\sum c_i}$$

the proportion of fish caught that was discarded alive

(3) $$\widehat{pv} = \frac{\sum v_i}{\sum c_i}$$

the proportion of fish caught that was discarded dead

(4) $$\widehat{pm} = \frac{\sum m_i}{\sum c_i}$$

the proportion of fish discarded that was discarded alive

(5) $$\widehat{pa} = \frac{\sum v_i}{\sum v_i + \sum m_i}$$

the minimum number of sharks dead in each of the *s* fishing sets

(6) $$\hat{\mu} = \frac{\sum(a_i + m_i)}{s}$$

The word minimum is used because the number of dead fish due to fishing set is probably larger once part of the sharks discarded alive may dye due to injuries. Parameters related to the statistics showed in equations 2 to 6 are the ones of interest in this paper.

2.3 Inference

We have used a Bayesian approach for inference of the parameters. We have assumed binomial distribution $Bin(n,p)$ to calculate the likelihood and $Bin(n,p)$ prior distributions for parameters, pd, pv, pm and pa that are proportions. n is the number of tries while p is the probability of a "success". α and β are parameters of the beta distribution. That option is convenient because those distributions are conjugated hence, the posterior is also a beta distribution $Beta(\alpha + x, \beta + n - x)$. In the analyses for the proportions n may be the total number of fish caught ($\sum c_i$) like in equations 2, 3 and 4, or the total number of fish discarded ($\sum v_i + \sum m_i$) (equation 5) according to the case being analyzed. Because there is not previous information about the issued we have assumed non informative priors for all the proportions $Beta(\alpha = 1, \beta = 1)$. This beta distribution is equivalent to a uniform distribution $U(0,1)$.

Because the number of fish dead by fishing set is a counting data we have assumed the Poisson distribution for calculating the likelihood. Soak time period (t) is similar for each of i^{th} fishing sets ($CV = 0.11$) hence one alternative is to model the mean number of dead fish as a Poisson process $Pois(s.\mu)$ with s as the number of intervals of soak time, all of them holding for the same (or a similar) time period. Notice that s is also the number of fishing sets already mentioned in equation 6. While the Poisson distribution was used for likelihood, the prior is $Gamma(\alpha, \beta)$ in which α is the shape and β is the inverse of the scale. This choice for prior is again convenient because gamma and Poisson distributions are conjugated, hence the posterior distribution is $Gamma(\alpha + x, \beta + s)$ in which $x = \sum(a_i + m_i)$ is the total number of fish dead in all s fishing sets. In the parameterization we have adopted for gamma distributions the expectation is α/β while the variance is α/β^2. Expectation and variance of priors are different for the several species or fish categories we have analyzed. Because blue shark is more often caught than any other shark (ICCAT, 2010) hence the expectation of the prior is high in this case. In opposition the expectations for thresher and crocodile sharks is low. We have chosen intermediate expectations for mako and other sharks non identified. Finally, the variance is high in all the cases hence, in this sense, the priors are non-informative. All the parameters of the priors are in **Table 1**.

3. Results

Most of longline fishing sets were in tropical water. Few fishing sets were located south of 20º S (**Figure 1**). There are few fishing set whose location is suspicious (*e.g.* too close to the coast) as reported by the onboard observers. Nevertheless, we have assumed that the reports about catches and discards were reliable and those data were considered in the analysis. In 2010 the fishermen onboard of the four monitored vessels have carried out 827 longline fishing sets in the water. The number of hooks used in those fishing sets ranged from 249 to 1883 (**Figure 2**). Nevertheless, in most of fishing sets the number of hooks was between 800 and 1700. Because we opted to calculate the number of dead fish per fishing, we have opted to analyze only those typical or standard fishing sets. Hence reports of fishing set with number of hooks low than 800 or high than 1700 were not considered to calculate the results showed hereafter. Anyway we also did a sensitivity analyses by including that small quantity (8) of non-typical fishing sets but the results of the calculations did not change much.

Most of fish caught and loaded are blue sharks and mako while few are threshers (**Table 2**). Crocodile sharks were never loaded as reported by the onboard observers. The amount of other sharks loaded as non identified sharks are intermediate, not so large as blue shark but, not so low as threshers and crocodile sharks. Most of fish discarded were blue shark (28), while very few mako sharks (3) were discarded. The amount of crocodile, thresher and other non-identified sharks discarded ranged from 7 a 13. Overall, the number of fish discarded alive was larger than that discarded dead but the crocodile shark is an exception. In spite of the sample size is very small when the data is split by quarter it is remarkable the large amounts of blue and mako sharks loaded and, of the blue and thresher sharks discarded (**Table 2**).

Frequency distributions of the minimum number of fish dead per fishing set are in **Figure 3**. All the distributions of the minimum number of fish dead are positively skewed (**Figure 3**). Overall the zero is more often observed than the other values but the blue shark case is an exception. The right tail of the distribution for blue shark is heavy and, it covers very large values. There reports that indicate that close to 100 sharks were dead in just one fishing set. Nevertheless that was an extreme case. In most of the fishing sets no more than 30 blue sharks have died. The number of fish dead per fishing set was barely larger than 2 for all other sharks.

The posterior distributions and the summary for them are in **Figure 4** and **Table 3** respectively. Most of them are skewed. In the five graphs at the most right columns of panels of **Figure 4** there are the posteriors for the proportion of fish discarded with respect to the total of fish caught. In spite of the wide curve and credibility confidence intervals it is evident that most of crocodile sharks are discarded $IC_{99\%} \rightarrow [0.516; 0.999]$ (**Table 3**). The credibility interval for threshers are also wide but it indicates that a reasonable part of the catch was discarded $IC_{99\%} \rightarrow [0.218; 0.712]$. In opposition, other sharks non identified, mako and specially the blue shark are hardly discarded. If one relies in the narrow credibility intervals the conclusion is that the probability of a hooked blue shark being discarded is very close to zero.

In the second column of panels (from left to right) of **Figure 4** there are the posterior densities fo the proportion of fish discarded alive or dead with respect to the total fish caught. The low probability of being discarded is again evident for the blue, the mako and the other not identified sharks whatever their conditions (alive or dead). The posteriors for threshers contrasts with those calculated for crocodile sharks (**Figure 4**). The proportion of threshers discarded dead is low $IC_{99\%} \rightarrow [0.005; 0.218]$ in comparison with the proportion discarded alive $IC_{99\%} \rightarrow [0.185; 0.674]$, though the credibility intervals are slightly superposed. In opposition, proportion of crocodile shark discarded dead is high $IC_{99\%} \rightarrow [0.368; 0.986]$ in comparison to the proportion of fish discarded alive $IC_{99\%} \rightarrow [0.014; 0.632]$. Notice also that for crocodile shark, both proportions (discarded dead or alive) as calculated with respect to the total fish hooked are complementary because the amount of crocodile shark reported as loaded is zero hence.

Posterior distributions of the proportion of discarded alive with respect to the total fish discarded are shown in the third column of panel (from left to right) of **Figure 4**. Most of fish discarded was alive but the crocodile shark is the exception. Indeed, the probability that a crocodile shark is alive when fishermen discard it is probably not high $IC_{99\%} \rightarrow [0.014; 0.632]$.

Finally, the posteriors for the mean of minimum number of fish dead per fishing set are shown in the five panels at most right column of **Figure 4**. The mean for blue shark is high $IC_{99\%} \rightarrow [9.170; 9.723]$ because the most of the hooked fish are loaded and the number of fish discarded alive is not large. The mean for the mako $IC_{99\% = [0.489; 0.623]}$ is probably twenty times lower than for the blue shark because the catches are lower than that of blue shark and, the number of fish discarded alive is small. The means for the threshers, crocodile sharks and, other sharks non-identified are all low because the catches are also low. The practice of discarding some of the alive fish also reduces the mean in the threshers case.

4. Discussion

The amount of blue shark hooked and loaded is large. Despite to identify which species were the fishing targets was not the scope of this paper, the results gathered here suggest that blue shark is considered very valuable by fishermen and may be one of the fishing targets. Andrade (2011) also suggest that blue shark may be one a fishing target at least for part of the Brazilian longline fishermen that were supposed to be aiming at swordfish only. The low probability that fishermen discard a blue shark in comparison to the other species is an evidence of the high commercial interest they have on the blue shark.

All the few blue sharks discarded were alive. Although there is not available data on size, we suspect that those fish discarded alive were low size or damaged after the longline was retrieved because the probability that fishermen discard a large blue shark alive with valuable fins and meet is low. Therefore many other blue sharks than those discarded alive were probably alive when the longline was retrieved. Diaz and Serafy (2005) report that the proportion of the blue shark that survives to the USA longline fishing operation when the soak time is 14 hours is between 0.4 and 0.8 depending on the size. Ward and Curran (2004) reported similar proportions for the longline set off western Australia when fishermen were aiming at swordfish. If one relies on the idea that the blue shark survival when hooked by Brazilian fleet is similar to those observed worldwide (80%) it becomes evident that a large amount of fish retrieved alive was dead because the proportion of discarded alive is very small $IC_{99\% = [0.002; 0.006]}$. That result contrasts with those gathered by Ward and Curran (2004) in the Australia because there, most of the blue shark was released.

Few mako sharks were discarded alive and none was discarded dead in the Brazilian fisheries. Nevertheless, Ward and Curran (2004) report that the survival more than 50% of mako sharks were alive when the longline was retrieved off western Australia and, all of them were released. Again, if one assumes that the survival of mako is similar for Australian and Brazilian longline when the fishermen is aiming at swordfish, the contrast between the results mentioned above indicates that many mako sharks were probably alive when the Brazilian fishermen retrieved the longline. No doubt Brazilian fishermen consider mako shark a valuable species. As a matter of fact not only the fin but also the meet of mako are valuable (Castro *et al*., 1999). In spite the Brazilian fishermen is prone to load mako, this species is barely regarded as fishing target because the population abundance or vulnerability to longline is not so high. The catches of blue shark are more than times larger than those of mako.

The amount of non identified sharks loaded is lower but the amount of discards is larger than those of mako and of blue shark that are considered valuable. That was an expected outcome because in that category there are a mixture of species and sizes that are and that are not valuable. That miscellaneous category may include species that are classified as endangered or in risk of extinction but detailed analysis are not possible. Hence further training of the onboard observers are encouraged in order to improve identification of species.

The proportion of thresher sharks discarded is larger in comparison with those of the valuable blue shark and mako. Hence at first glance threshers are not of primary interest for Brazilian fishermen. Nevertheless, in 2009 ICCAT has published a recommendation asking contracting parties, and cooperating non-contracting parties, entities or fishing entities to "prohibit, retaining onboard, transshipping, landing, storing, selling, or offering for sale any part or whole carcass of bigeye thresher sharks (*Alopias superciliosus*) in any fishery with exception of a Mexican small-scale coastal fishery with a catch of less than 110 fish" but where possible, "research on thresher sharks of the species *Alopias* spp in the Convention area in order to identify potential nursery areas" should be implemented. Consequently brazilian government has published in 2011 a normative instruction that says that all the bigeye threshers hooked might be left in the sea dead or alive (MPA, 2011). The data we have analyzed was sampled in 2010 before the Brazilian fishery enforcement but it is possible that the relatively high proportion of threshers discarded in the Brazilian fishery was motivated by the ICCAT recommendation. We have analyzed just one year (2010) but further studies about discards of threshers before and after the ICCAT recommendation and the Brazilian normative instruction are encouraged to assess how efficient those fishery enforcements are. Moreover, it remains to be assessed if all the threshers are being discarded this year (2011) in accordance with the Brazilian enforcement, because in 2010 only close to half of the threshers were discarded dead or released.

The proportion of thresher sharks discarded alive with respect to the total catch was higher (median of the posterior is 0.41) than those proportions calculated for the other sharks. Our estimation for threshers is close to the estimation of Ward and Curran (2004) about the proportion that is alive after longline retrieve off western Australia. Hence if the threshers indeed survive after release, that practice may promote a decrease of the fishing mortality. That result is not negative but it is not also so optimistic because close to half of threshers dye if hooked.

A research program about crocodile shark biology was carried out during 2010 and, it is possible those fish sampled for research were not reported by onboard observers. Hence proportions and the mean of minimum fish dead by fishing set should be carefully considered because the data may be biased. Nevertheless, some speculations are warranted. The proportion of discarded dead is larger than those of released fish. This may be an indication that the hooked crocodile shark often do not survive. If the result we gather holds it contrasts with that gathered by Ward and Curran (2004) that found high survival rate. Moreover, the amount of crocodile shark caught off northeastern Brazil seems to be not as large as off western Australia where it was the third most frequently species caught (Ward and Curran, 2004).

Overall, discarding dead fish is a practice recriminated by public opinion and entities related to fishery management. Nevertheless, that practice still occurred in 2010 but, not often. The exception was the crocodile shark but, as mentioned above, the data we have analyzed about that species may be biased. Hopefully onboard observer program future improvements will eliminate that source of bias. Further training of observers on identification of the species is also encouraged not only to eliminate the "other non identified sharks" category but also to be more specific about fish of genus *Alopias* and *Isurus.* Although the database contains reports of *Alopias superciliosus* and *Isurus oxyrinchus* there are also several reports of *Alopias spp.* and *Isurus spp.* hence we have opted to simplify and to analyze all data pooled by genus. Nevertheless, more detail about the species are necessary specially in the case of *Alopias* because currently there are management enforcement for one of the species classified in that genus. Finally we would like to highlight that the proportions and generally the number related to discards may varies over the space and the time (Diaz and Serafy, 2005). In this paper we have carried out an analysis just for data of 2010 pooled but not split by area and season of the year but, more detailed studies should be carried out in the future.

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Table 1. Parameters of the gamma priors used to calculate the posteriors of the mean number of dead fish. Blue shark (BSH) (*Prionace glauca*), mako non identified (MAK) (*Isurus spp.*), thresher shark non identified (THR) (*Alopias spp.*), crocodile shark (PSK) (*Pseudocarcharias kamoharai*) and, other sharks non identified (OTH).

Species (or category)	*alfa*	*Beta*
BSH	10	1
MAK	1	1
THR	0.1	1
PSK	0.1	1
OTH Sharks	0.1	1

Table 2. Number of fish loaded and discarded by quarter and category. Blue shark (BSH) (*Prionace glauca*), mako non identified (MAK) (*Isurus spp.*), thresher shark non identified (THR) (*Alopias spp.*), crocodile shark (PSK) (*Pseudocarcharias kamoharai*) and, other sharks non identified (OTH).

Species/Category	*Variable*	*Quarter*				*Total*
		1	2	3	4	
BSH	Loaded	909	1404	1433	3988	7734
	Discarded Alive	0	1	0	27	28
	Discarded Dead	0	0	0	0	0
MAK	Loaded	26	26	117	284	453
	Discarded Alive	1	0	0	2	3
	Discarded Dead	0	0	0	0	0
OTH	Loaded	16	60	52	43	171
	Discarded Alive	0	7	3	1	11
	Discarded Dead	0	0	2	0	2
THR	Loaded	0	3	2	7	12
	Discarded Alive	0	0	0	9	9
	Discarded Dead	0	0	0	1	1
PSK	Loaded	0	0	0	0	0
	Discarded Alive	1	0	0	0	1
	Discarded Dead	5	1	0	0	6
Total		958	1502	1609	4362	8431

Table 3. Summary of the posterior densities. Blue shark (BSH) (*Prionace glauca*), mako non identified (MAK) (*Isurus spp.*), thresher shark non identified (THR) (*Alopias spp.*), crocodile shark (PSK) (*Pseudocarcharias kamoharai*) and, other sharks non identified (OTH).

	Quantiles				
	0.005	*0.25*	*0.5*	*0.75*	*0.995*
Proportion of fish discarded with respect to total catch					
BSH	0.00219	0.00325	0.00369	0.00418	0.00576
MAK	0.00147	0.00555	0.00803	0.01115	0.02381
THR	0.21756	0.38874	0.45716	0.52668	0.71165
PSK	0.51567	0.84090	0.91700	0.96468	0.99937
OTH	0.03432	0.06152	0.07375	0.08737	0.13319
Proportion of fish discarded alive with respect to total catch					
BSH	0.00219	0.00325	0.00369	0.00418	0.00576
MAK	0.00147	0.00555	0.00803	0.01115	0.02381
THR	0.18475	0.34723	0.41431	0.48361	0.67365
PSK	0.01374	0.12063	0.20113	0.30270	0.63152
OTH	0.02717	0.05166	0.06296	0.07568	0.11924
Proportion of fish discarded dead with respect to total catch					
BSH	6.457E-07	3.706E-05	8.928E-05	0.00018	0.00068
MAK	1.097E-05	0.00063	0.00152	0.00303	0.01153
THR	0.00459	0.04184	0.07191	0.11284	0.28144
PSK	0.36848	0.69730	0.79887	0.87937	0.98626
OTH	0.00183	0.00934	0.01443	0.02108	0.04915
Proportion of fish discarded alive with respect to total fish discarded					
BSH	0.83302	0.95332	0.97638	0.99013	0.99983
MAK	0.26591	0.70711	0.84090	0.93060	0.99875
THR	0.49144	0.77337	0.85204	0.91239	0.99018
PSK	0.01374	0.12063	0.20113	0.30270	0.63152
OTH	0.48769	0.73878	0.81353	0.87525	0.97429
Mean number of dead fish per fishing set					
BSH	9.16976	9.37130	9.44350	9.51606	9.72262
MAK	0.48902	0.53592	0.55325	0.57096	0.62288
THR	0.00688	0.01282	0.01557	0.01869	0.02961
PSK	0.00193	0.00525	0.00704	0.00919	0.01744
OTH	0.17206	0.20007	0.21069	0.22169	0.25471

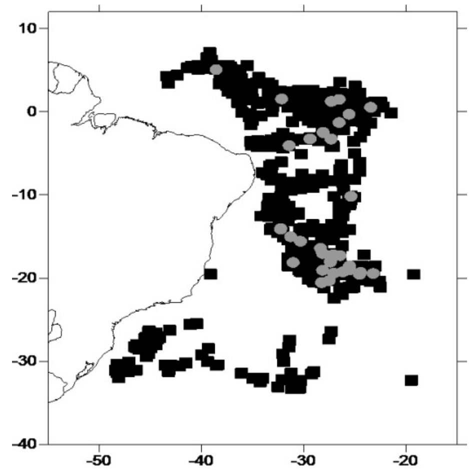

Figure 1. Location of the Brazilian longline fishing sets monitored by onboard observers in 2010 (black squares) and the location of fishing set where discards were reported.

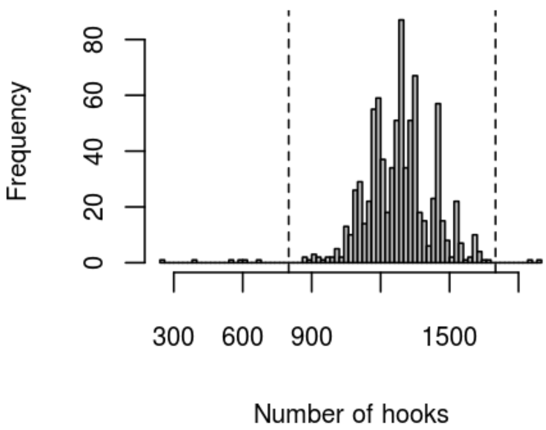

Figure 2. Frequency distribution of the number of hooks in each longline set. Dashed lines stand for the cut-off values used to eliminate suspect data from the database.

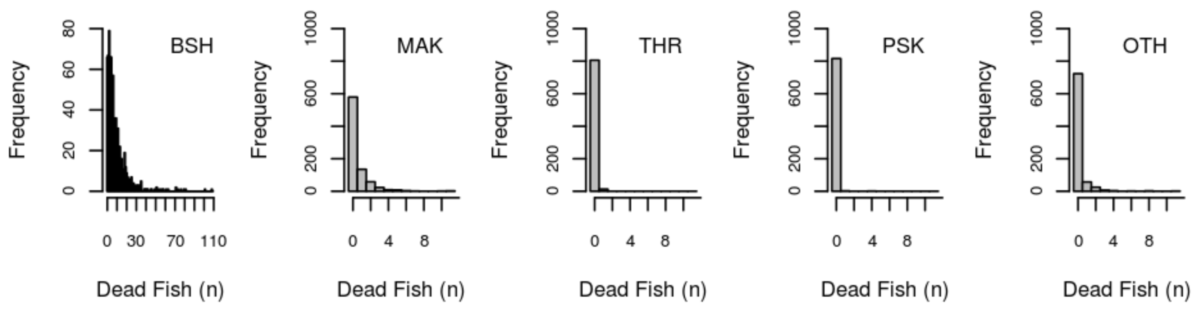

Figure 3. Frequency distribution of the number of dead fish per longline set. Blue shark (BSH) (*Prionace glauca*), mako non identified (MAK) (*Isurus spp.*), thresher shark non identified (THR) (*Alopias spp.*), crocodile shark (PSK) (*Pseudocarcharias kamoharai*) and, other unidentified sharks (OTH).

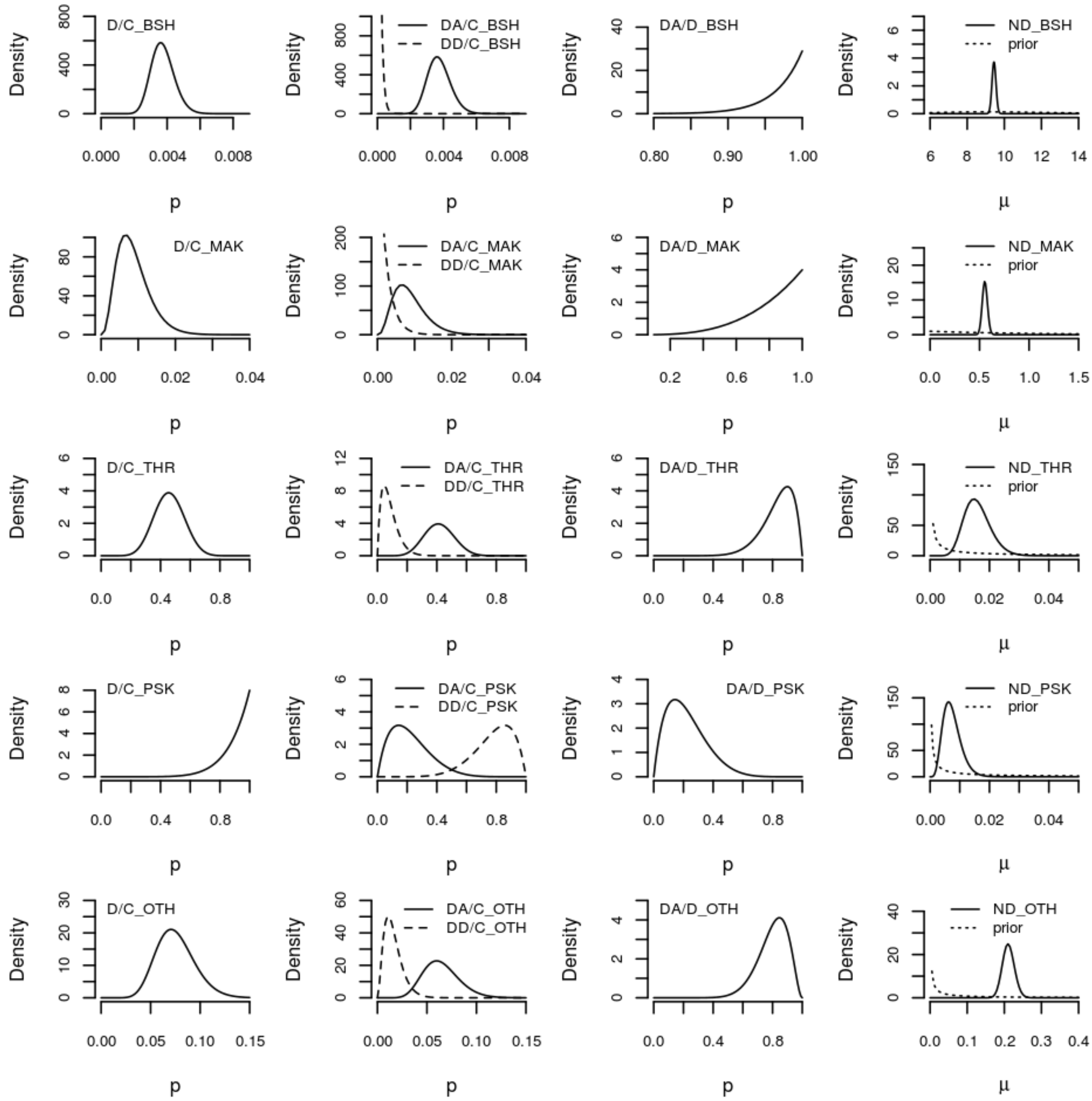

Figure 4. Posterior density distributions of the mean number of dead fish per longline set (ND) and, of the proportions of total discarded fish (D/C), of discarded alive (DA/C) and of discarded dead (DD/C) with respect to the total fish caught and, of the proportion of discarded alive with respect to the total discarded fish (DA/D). Blue shark (BSH) (*Prionace glauca*), mako non identified (MAK) (*Isurus spp.*), thresher shark non identified (THR) (*Alopias spp.*), crocodile shark (PSK) (*Pseudocarcharias kamoharai*) and, other sharks non identified (OTH). Priors for the proportions that are all uniforme *U(0,1)* are not showed while gamma priors for the mean of dead fish are showed in the five most right panels.