

CATCH DISPOSITION OF BLUE SHARKS (*PRIONACE GLAUCA*) CAUGHT BY LONGLINERS IN THE SOUTHWESTERN ATLANTIC

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SUMMARY

This study provides an overview of the catch disposition of blue sharks (Prionace glauca) caught by longliners over the Southwestern Atlantic Ocean and assess the relative magnitude of the non-retained catch. Data were gathered by scientific observers on board Uruguayan and Japanese flagged fishing vessels operating between 2009 and 2013. A total of 102 588 blue sharks were caught during the study period and catch disposition statistics (retained, discarded dead, released alive and lost) were assessed for each fishing fleet. Although results here presented should be considered preliminary, scientific observer data showed that the non-retained catch (not included in landing reports and logbooks) can be as high as 15% of total blue shark catch. Non-retained individuals were mainly comprised by smaller size classes than those typically retained. Most non-retained sharks were released alive, but because post-capture mortality is still little known for blue sharks some uncertainty remains regarding long term mortality. We suggest that these aspects should be considered in future evaluations as they may help improving fishing selectivity and mortality as well as relative abundance estimations.

RÉSUMÉ

La présente étude donne un aperçu de la disposition des prises de requins peau bleue (Prionace glauca) réalisées par des palangriers dans le Sud-Ouest de l'océan Atlantique et évalue l'importance relative des captures non retenues à bord. Les données ont été recueillies par des observateurs scientifiques présents à bord de navires de pêche battant le pavillon de l'Uruguay et du Japon ayant opéré entre 2009 et 2013. Un total de 102.588 requins peau bleue ont été capturés au cours de la période d'étude et des statistiques sur la disposition des captures (conservées, rejetées à l'état mort, relâchées à l'état vivant et perdues) ont été évaluées pour chaque flottille de pêche. Même si les résultats présentés dans le présent document doivent être considérés comme préliminaires, les données des observateurs scientifiques ont montré que les prises non retenues (non incluses dans les rapports de débarquement et les carnets de pêche) peuvent atteindre 15 % des captures totales de requin peau bleue. Les spécimens non retenus étaient principalement constitués de classes de taille plus petites que ceux généralement retenus. La plupart des requins non retenus ont été remis à l'eau vivants, mais, étant donné que les connaissances sur la mortalité suivant la capture du requin peau bleue sont encore lacunaires, une certaine incertitude persiste en ce qui concerne la mortalité à long terme. Nous suggérons que ces aspects soient pris en compte dans les évaluations futures car ils peuvent contribuer à améliorer la sélectivité de la pêche et la mortalité ainsi que les estimations de l'abondance relative.

RESUMEN

Este estudio ofrece un resumen del destino de las capturas de tintorera (Prionace glauca) realizadas por palangreros en el océano Atlántico sudoccidental y evalúa la magnitud relativa de la captura no retenida. Los datos fueron recogidos por observadores científicos a bordo de buques de pesca con pabellón uruguayo y japonés entre 2009 y 2013. Durante el periodo del estudio se capturó un total de 102.588 tintoreras y se evaluaron las estadísticas sobre el destino de la captura (retenida, descartada muerta, liberada viva y perdida) para cada flota de pesca. Aunque los resultados presentados deberían considerarse preliminares, los datos de los observadores científicos mostraron que las capturas no retenidas (no incluidas en los informes de desembarque ni en los cuadernos de pesca) pueden llegar a alcanzar hasta un 15% de las

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capturas totales de tintorera. Los ejemplares no retenidos eran sobre todo clases de talla más pequeñas que los ejemplares que se suelen retener. La mayoría de los tiburones no retenidos fueron liberados vivos, pero dado que todavía se tienen pocos conocimientos sobre la mortalidad de la tintorera tras la captura, sigue existiendo incertidumbre con respecto a la mortalidad a largo plazo. Sugerimos que este aspecto se considere en futuras evaluaciones, ya que podría contribuir a mejorar la selectividad de la pesca y a reducir la mortalidad, así como a mejorar las estimaciones de abundancia relativa.

KEYWORDS

Blue shark, Southwestern Atlantic, Catch disposition, Longline

1. Introduction

Data gathered by scientific observer programs can be useful to quantitatively assess the importance of the non-retained catch over fishing total catches (Huang and Liu 2010; Huang 2011). Non-retained catch, typically not included in landing reports and logbooks, includes all caught individuals that were either discarded dead, released alive or simply lost during hauling maneuvers, and can represent a considerable fraction of total catches depending on the species. The extent of the non-retained catch of a given species can be due to a combination of several reasons (Kelleher 2005, Huang and Liu 2010), including low commercial value, small sizes, damages by depredation, quota limitations, available space in the fish hold, fishing gear type, fishing gear configuration and materials (affecting the probability of catch loss during hauling).

Conducting abundance, fishing mortality and selectivity estimations based solely on logbooks and/or landing reports are at risk of being biased when the non-retained catch is not negligible. This is because size distribution on logbooks may be skewed to larger size classes (higher commercial value), therefore failing to account for the true size distribution of catches for a given species, which at the same time affects selectivity estimations and effective recruitment size to fisheries. In the same manner, disregarding the non-retained fraction of total catch could also lead to underestimations in relative abundance indexes such as CPUE as well as fishing mortality estimations due to cryptic mortality (Gilman *et al.* 2013).

The objective of this study was to quantitatively assess the catch disposition of blue sharks (*Prionace glauca*, BSH) caught by longline fisheries in the Southwestern Atlantic Ocean.

2. Material and methods

Data was obtained by scientific observers from the National Observer Program on board the Uruguayan Tuna Fleet (PNOFA) between 2009 and 2012. Two longline fleets were considered, the Uruguayan longline fleet (URU) and the Japanese longline fleet (JAP).

The Uruguayan fleet operated between 2009 and 2012 in Uruguayan jurisdictional waters (UEEZ) and international waters of the Southwestern Atlantic Ocean. The effort observed between 2009 and 2012 reached 866,748 hooks in 56 fishing trips. Observer's coverage in relation to the total effort of the Uruguayan fleet averaged 62.4% (range: 54.7-81.3%). For the purpose of this study, URU was further divided in two groups: URUi and URUo. The first group operated mainly within the UEEZ and adjacent waters targeting swordfish (*Xiphias gladius*) and tunas (*Thunnus obesus* and *T. albacares*), while URUo operated almost exclusively in international waters targeting BSH using stainless steel leaders on the branch-lines (**Figure 1a**). Both fleets fishing gear operated at similar depths and shallower than 80 m. Japanese-flagged vessels operated almost exclusively within the UEEZ with an experimental fishing license during austral autumn and winter of 2009-2011 and under a leasing agreement in 2013 (**Figure 1b**). Coverage of this fleet was 100%, representing a total effort of 2 808 202 hooks in 30 fishing trips. This fleet targeted bigeye and albacore tuna at depths ranging from 95 to 210 m. Further details of both fleets fishing gear characteristics can be found in Jiménez *et al.* (2009) and Domingo *et al.* (2011).

Data recorded for each fishing trip included: effort (number of hooks), total catch (regardless of species), total BSH catch, and catch disposition. Catch disposition was further classified into four categories: retained, released alive, discarded dead, or lost. The lost catch refers to the proportion of total capture that becomes detached from the gear at the moment of hauling. This can be caused by operating problems (i.e. the tension of the gear, if contrary to the direction of the ship, may cause the fish to be lost if the ship does not stop in time), or if the species caught is of low commercial value, in which case the skipper will not stop the vessel (Domingo 2002). The nominal CPUE was calculated as the number of individuals every 1,000 hooks (ind./1,000 hooks). Sharks measured by observers were used to assess the size distribution of BSH within different catch disposition categories. Type of measurement used was fork length (FL, in cm) and all others (total and precaudal lengths) were converted using the conversion factors reported by Mas *et al.* (2014). All BSH measured were then grouped in 10 cm FL classes in order to assess possible differences between size distributions of BSH being retained, discarded dead and released alive.

3. Results

A total of 102 588 BSH were caught between 2009 and 2013. Frequency of occurrence in all observed fishing sets ($n = 1\ 647$) was 90.0%, and BSH catches accounted for 33.8% of all fleets total catch combined. Of all BSH caught, 6 209 were not retained on board (6.1%), of which 10.6% were discarded dead, 69.5% were released alive and 19.9% were lost during hauling maneuvers.

Blue shark catch statistics showed differences among fishing fleets (**Table 1**). Combining all years, nominal CPUE was consistently higher for URUo and lower for JAP, while URUi showed intermediate values (**Figure 2a**). These differences were consistent among years, although JAP and URUi showed some increase in CPUE values over the last years (**Figure 3**). Blue sharks were the dominant component of URUo's total catch, reaching up to 96.9% (**Figure 2b**). Percentage of BSH over total catches showed great variation among fishing trips for URUi, while it generally accounted for less than 20% of total catches for JAP. These percentages remained relatively constant for the URUo across years, and showed an increasing trend for JAP and URUi by the end of the study period (**Figure 4**). Non-retention rates were relatively low in all fleets, being generally below 30% of total blue shark catch (**Figure 2c**). However, average non-retention rates by JAP (15.8%) were 1.7 and 6.1 times higher than URUi (9.3%) and URUo (2.6%). Between years, greater variability was observed in JAP, whereas URUo showed fairly constant rates and always below 10% (**Figure 5**).

Within BSH non-retained catch, most individuals were released alive by all fleets (54.4-77.4%; **Table 2**). Higher percentages of dead discards were observed in URUo, while JAP had the lowest values (**Figure 6a**). The amount of individuals lost or release alive showed larger variability within and between fleets, although URUo seemed to have lower lost catch rates in comparison with URUi and JAP (**Figure 6b, c**).

A total of 73 999 BSH were measured during 2009-2013, accounting for 72.1% of blue shark total catch. Fork length ranges of BSH captured by each fleet were similar, but differences on average catch size by fleet were statistically significant (Kruskal-Wallis run sum test, $\chi^2 = 6\ 311.73$, $df = 2$; $p < 0.01$). URUi tended to catch larger sizes (average \pm s.d., 163 ± 29 cm FL) and URUo smaller sizes (136 ± 28 cm FL) (**Figure 7a,b**). Size structure of JAP catches was intermediate between the other two (152 ± 25 cm FL).

Regarding catch disposition, BSH size distributions showed differences among the different categories here addressed (retained, discarded dead and released alive) (**Figure 7c,d**). Size distribution of individuals retained on board were skewed to larger sizes in comparison to the other categories, being 140 and 150 cm FL the most frequent size classes. Sharks discarded dead or released alive showed similar size distributions comprised by smaller individuals, being 110 and 120 cm the most frequent size classes.

4. Discussion

Differences observed between fleets regarding BSH CPUE and catch disposition were most certainly related to each fleet target species and gear characteristics, as well as the fishing area. As it was expected, higher catch and retention rates were observed in the fishery that actively targeted this species (URUo). Overall, URUi had an average CPUE 14.0 and 2.8 times higher than JAP and URUi, respectively. This fleet operated in oceanic and international waters of the southwest Atlantic using a terminal section of their branch-lines made of three twisted wire threads, which probably accounts for the low percentage of blue sharks lost during hauling maneuvers.

The Japanese and URUi fleets operated almost exclusively over Uruguayan national waters. None of these fleets targeted BSH, and both operated less often over distant oceanic waters, which may explain their lower catch rates. In the case of JAP, the rise in BSH CPUE observed in 2013 could be related to the hydrocarbons prospecting activities carried on over the external continental shelf and adjacent waters during that year. This activity caused this fleet to shift their fishing grounds to more distant oceanic waters where blue sharks are more abundant. The CPUE increase of URUi over the last years may be due to some opportunistic fishing sets targeted to BSH. Regarding the lost catch, both the URUi and JAP fleets used nylon leaders on their branch-lines. Nylon leaders can be rather easily cut by sharks with the aid of their teeth, therefore increasing their probability of escape during hauling maneuvers. These differences on branch-lines material may explain the higher average lost catch rates of these two fleets relative to URUo. Lost catch can also be related to the lower commercial value of BSH relative to some tunas and swordfish. In these cases, the skipper may not stop the vessel while retrieving the branch-line, which can result in the loss of the fish as the leader break due to the increased tension (Domingo 2002).

Although different fishing gear selectivity among fleets cannot be ruled out, the lower average size captured by URUo may be related to the fishing area. This fleet operated at higher latitudes than JAP and URUi and also over colder waters, where juvenile and sub-adult BSH are thought to be more abundant (Mejuto & García-Cortés 2005; Nakano & Stevens 2008; Carvalho *et al.* 2011). JAP and URUi fishing distribution largely overlapped during the study period. However, JAP operated only during autumn-winter in the UEEZ, while URUi was the only fleet that operated during summer, when water temperatures are higher and adults seem to be more abundant (Mas 2012). Given the temporal offset between these two fleets it is not possible to determine if URUi has a larger selectivity compared to JAP. In any case, both fleets size distributions were rather similar, suggesting that blue sharks of a wide range of sizes are using a broad range of the water column which makes them readily available for both surface and deep set longline vessels.ç

Regarding catch disposition, the left skewed size distribution of retained blue sharks reflected the higher commercial value of larger individuals relative to the smaller ones, which at the same time explains the predominantly smaller sizes of blue sharks that were discarded dead or released alive.

Although results here presented should be considered preliminary, scientific observer data showed that the non-retained catch (not included in landing reports and logbooks) can be as high as 15% of total blue shark catch. Non-retained individuals were mainly comprised by smaller size classes than those typically retained. Most non-retained sharks were released alive, but because post-capture mortality is still little known for blue sharks some uncertainty remains about long term mortality. We suggest that these aspects should be considered in future evaluations as they may help improving fishing selectivity and mortality as well as relative abundance estimations.

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Table 1. Blue shark catch disposition for the Japanese (JAP) and Uruguayan (URU) pelagic longline fleet operating in Uruguayan jurisdictional waters and adjacent international waters.

Fleet		Effort	Tot. Cap.	BSH Tot. Cap.	CPUE	% BSH	% Ret.	% not Ret.
JAP	Total	2 808 202	206 556	20 884	7.44	10.11	83.04	16.96
	Mean	93 607	6 885	696	8.52	11.97	84.19	15.81
	s.d.	41 238	3 765	720	8.20	11.55	14.26	14.26
URUi	Total	206 104	14 759	7 602	36.88	51.51	92.91	7.09
	Mean	12 124	868	447	41.77	44.86	90.73	9.27
	s.d.	12 482	695	535	40.46	26.04	7.25	7.25
URUo	Total	660 644	82 554	74 102	112.17	89.76	97.13	2.87
	Mean	73 405	9 173	8 234	118.98	88.59	97.40	2.60
	s.d.	20 122	2 956	3 044	48.34	9.92	1.58	1.58

JAP: Japanese longline fishery; **URUi:** Uruguayan longline fishery not targeting blue sharks; **URUo:** Uruguayan longline fishery targeting blue sharks; **Tot. Catch:** fleet total catch; **BSH Tot. Catch:** blue shark total catch; **CPUE:** blue shark nominal catch per unit of effort (ind./1,000 hooks); **% BSH:** blue shark percentage of total catch; **% Ret.:** percentage of total blue shark catch that was retained on board; **% not Ret.:** percentage of total blue shark captured that was not retained on board; *s.d.:* standard deviation.

Table 2. Blue shark catch disposition for the Japanese (JAP) and Uruguayan (URU) pelagic longline fleet operating in Uruguayan jurisdictional waters and adjacent international waters.

Fleet		N° Ret.	% Ret.	N° not Ret.	% not Ret.	N° Disc.	% Disc.	N° Lost	% Lost	N° RA	% RA
JAP	Total	17 342	83.04	3 542	16.96	281	7.93	885	24.99	2 376	67.08
	Mean	578	84.19	118	15.81	9	3.94	30	45.60	79	50.46
	s.d.	628	14.26	166	14.26	22	6.11	47	35.20	128	33.23
URUi	Total	7 063	92.91	539	7.09	63	11.69	183	33.95	293	54.36
	Mean	415	90.73	32	9.27	4	5.75	11	58.85	17	35.39
	s.d.	515	7.25	38	7.25	7	7.37	10	36.89	29	33.96
URUo	Total	71 976	97.13	2 126	2.87	317	14.91	163	7.67	1 646	77.42
	Mean	7 997	97.40	236	2.60	35	23.93	18	10.82	183	65.25
	s.d.	2 909	1.58	192	1.58	36	26.87	20	12.80	183	32.19

JAP: Japanese longline fishery; **URUi:** Uruguayan longline fishery not targeting blue sharks; **URUo:** Uruguayan longline fishery targeting blue sharks; **N° Ret.:** number of blue sharks retained on board; **% Ret.:** percentage of total blue shark catch that was retained on board; **N° not Ret.:** number of blue sharks captured but not retained on board; **% not Ret.:** percentage of total blue shark captured that was not retained on board; **N° Disc.:** number of blue sharks discarded dead (regardless if they were bitten or not); **% Disc.:** percentage of total blue shark captured but not retained that was discarded dead (regardless if they were bitten or not); **N° Lost:** number of blue sharks lost during hauling; **% Lost:** percentage of total blue shark captured but not retained that was lost during hauling; **N° RA:** number of blue sharks released alive; **% RA:** percentage of total blue shark captured but not retained that was released alive; *s.d.:* standard deviation.

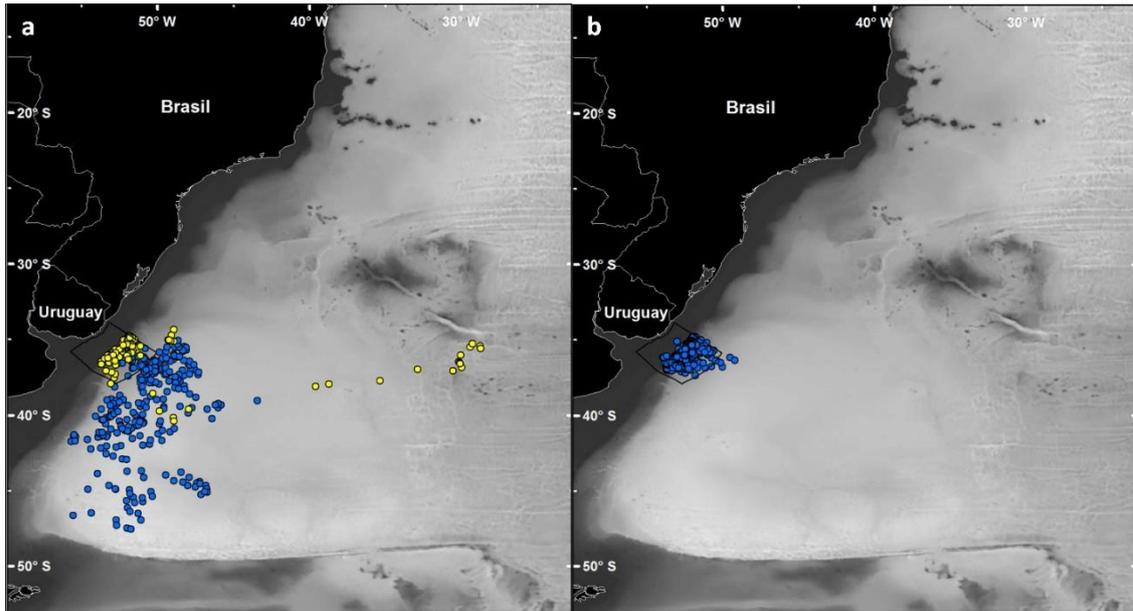


Figure 1. Fishing set locations of the Uruguayan (a) and Japanese (b) longlie fleets in the Southwestern Atlantic ocean. For the Uruguayan fleet, blue and yellow circles represents fishing sets in which blue sharks were considered as a target species or not, respectively. The black polygon depicts the Uruguayan Exclusive Economic Zone. Background shade gradient depicts bottom depths according to the GEBCO database (lighter shades indicate greater depths).

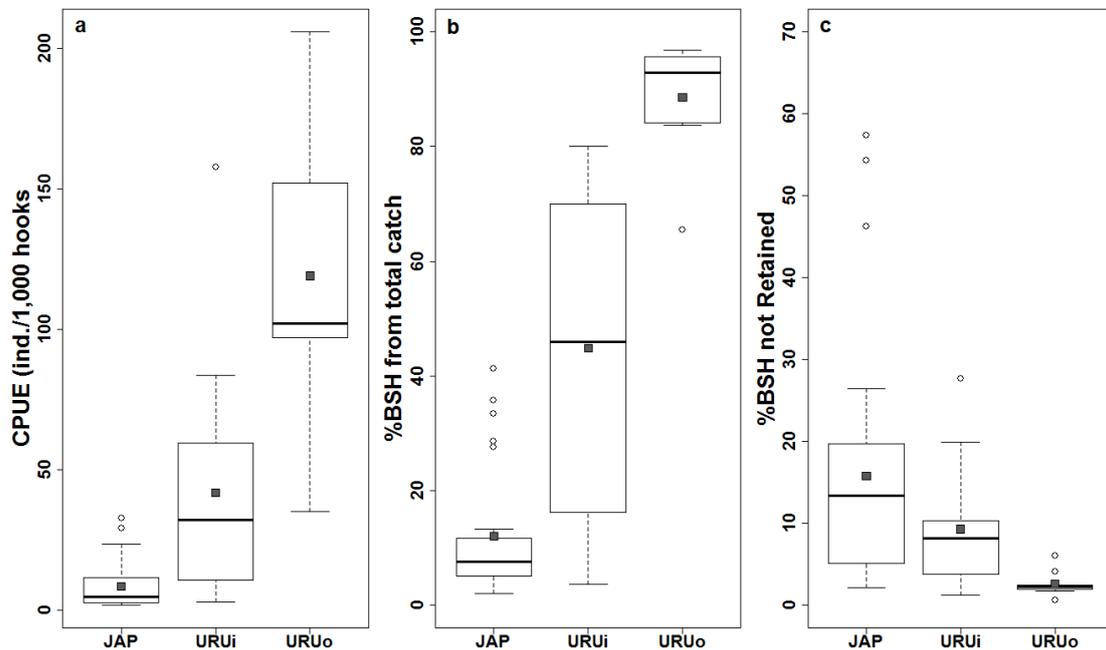


Figure 2. Total catch statistics for the Japanese longline fleet (JAP), and the Uruguayan fleet targeting (URUo) and not targeting (URUi) blue sharks. (a) Total blue sharks catch per unit of effort (CPUE, individuals/1,000 hooks), (b) overall percentage of the blue shark catch over each fleet total catch, (c) fraction of total blue shark catch that was not retained. Dark grey filled squares indicate the mean value for each fleet.

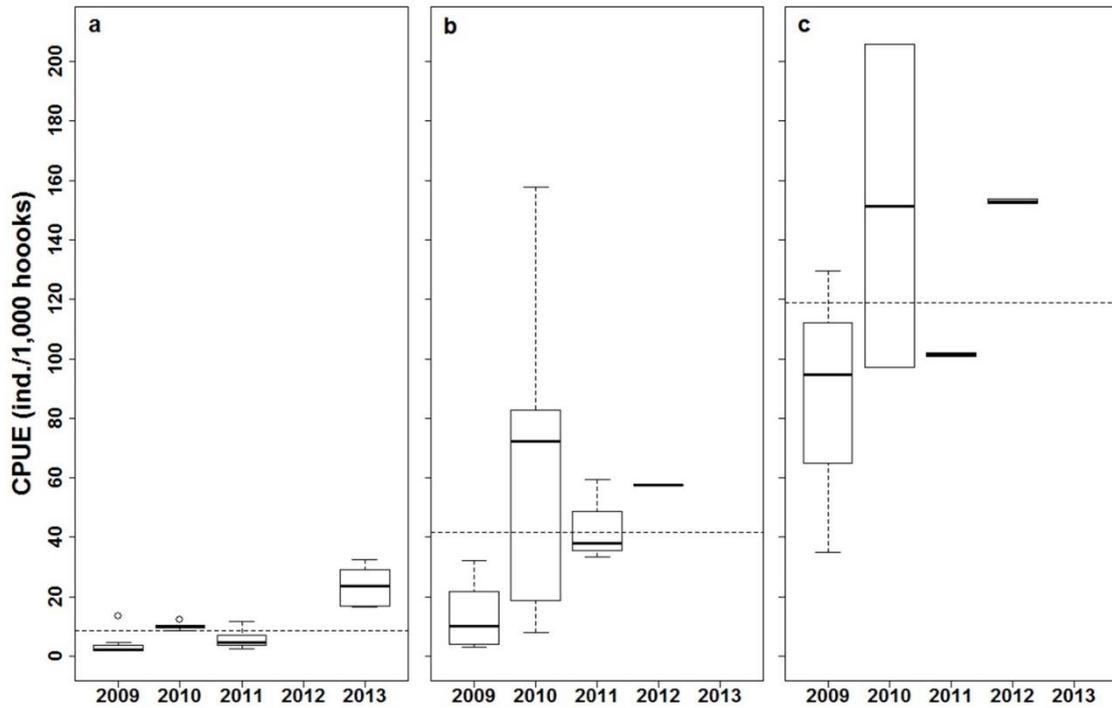


Figure 3. Blue shark yearly catch per unit of effort (CPUE) for the Japanese longline fleet (a), and the Uruguayan fleet not targeting (b) and targeting (c) blue sharks. Horizontal dashed lines indicates overall average CPUE for each fleet.

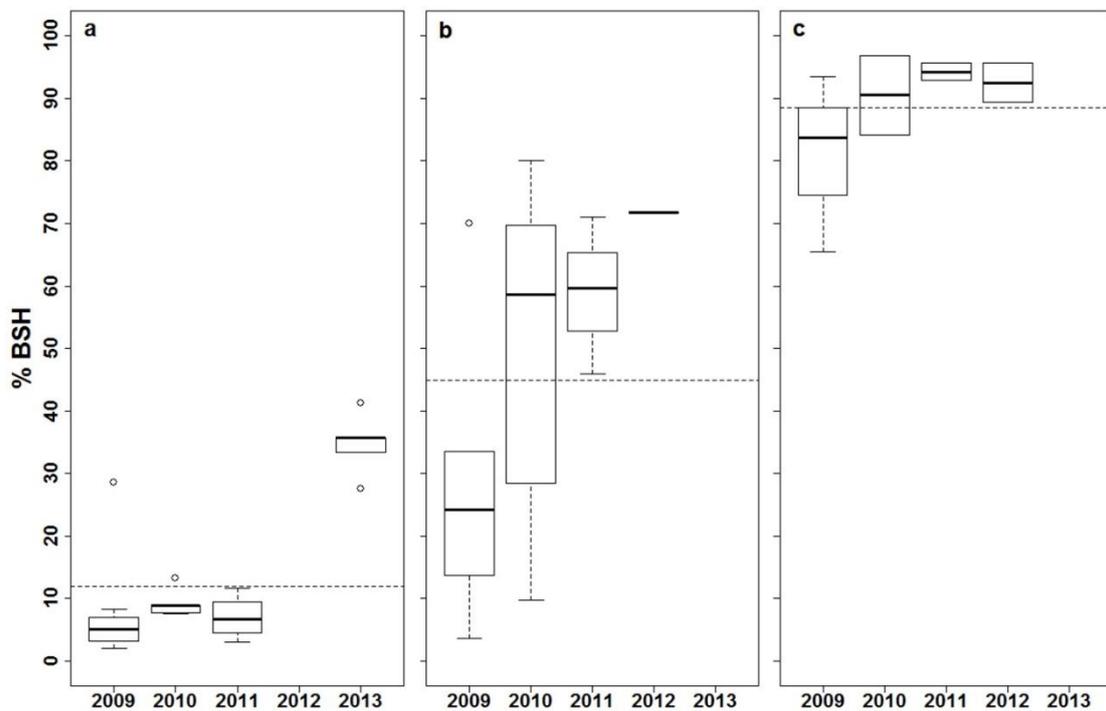


Figure 4. Percentage of blue sharks in the total catch for the Japanese longline fleet (a), and the Uruguayan fleet not targeting (b) and targeting (c) blue sharks. Horizontal dashed lines indicates overall average percentages for each fleet.

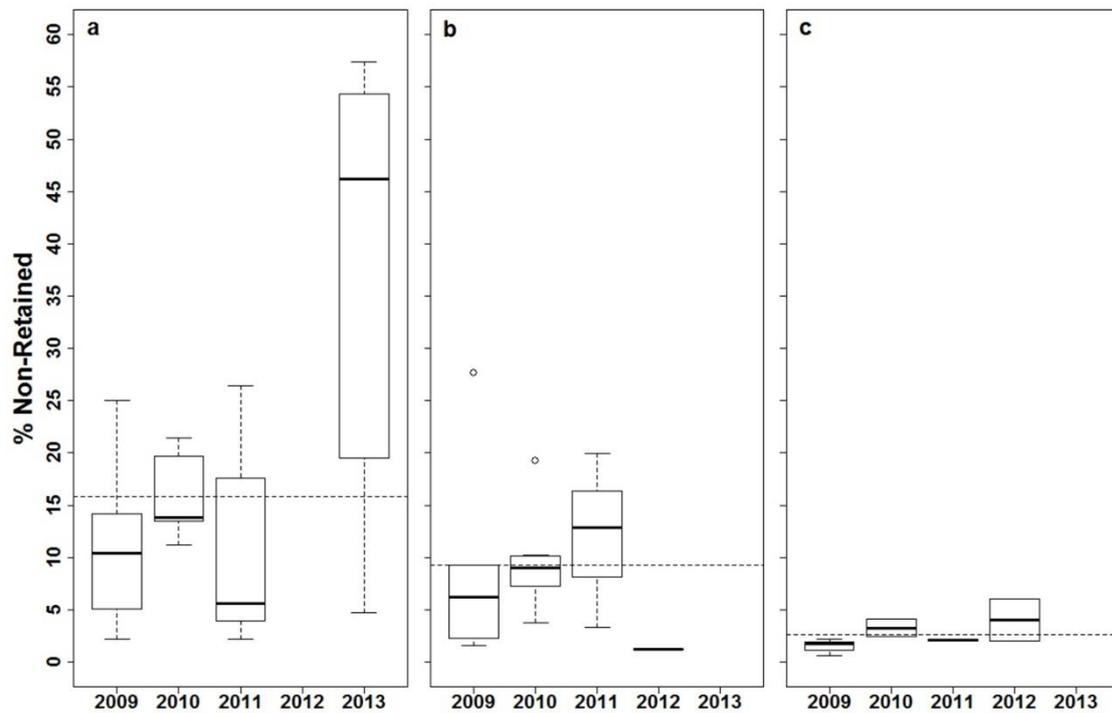


Figure 5. Percentage of non-retained blue sharks from total blue shark catch for the Japanese longline fleet (a), and the Uruguayan fleet not targeting (b) and targeting (c) blue sharks. Horizontal dashed lines indicates overall average percentages for each fleet.

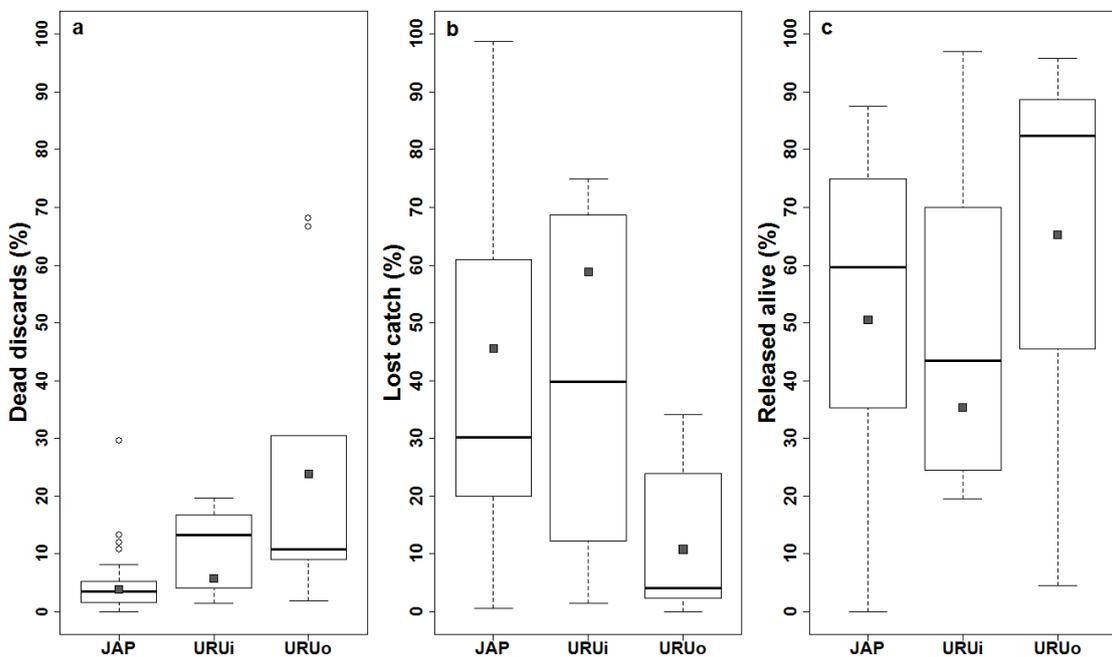


Figure 6. Relative composition of the non-retained blue shark catch for the Japanese longline fleet (JAP), and the Uruguayan fleet targeting (URUo) and not targeting (URUi) blue sharks. (a) Percentage of blue sharks discarded dead, (b) percentage of the blue sharks lost during hauling maneuvers, (c) percentage of blue sharks released alive. Dark grey filled squares indicates the mean value for each year.

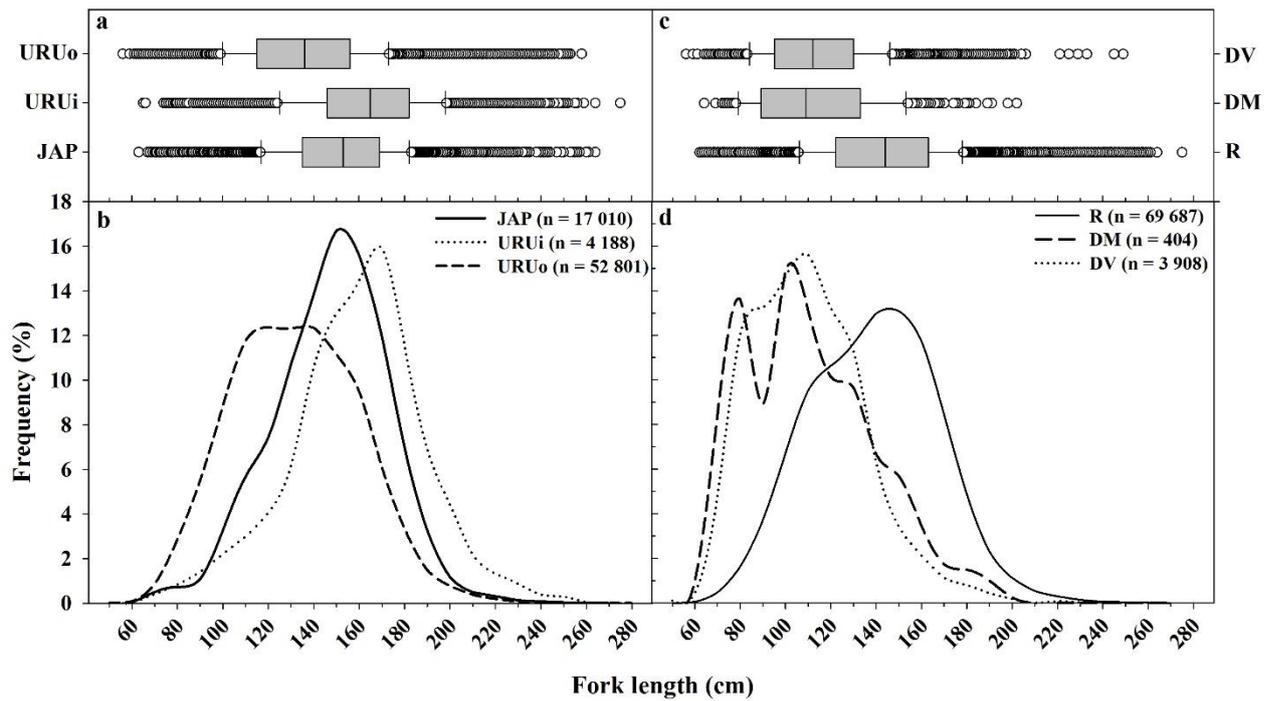


Figure 7. Size distribution of blue sharks caught by longline fisheries in the Southwestern Atlantic Ocean. (a-b) Size structure of captures for the Japanese longline fleet (JAP) and both the blue shark targeted (URUo) and not targeted (URUi) Uruguayan longline fleet. (c-d) Size structure of total blue sharks catch (fleets combined) as a function of catch disposition: retained on board (R), discarded dead (DM) and released alive (DV). Left and right boundaries of the boxes in a and c indicates the 25th and 75th percentile, respectively. The vertical line within each box marks the median, and whiskers indicates the 10th and 90th percentiles. White circles are all values that fell outside the 10th-90th percentile boundary.