SCRS/2013/039 Collect. Vol. Sci. Pap. ICCAT, 70(5): 2416-2432 (2014)

PRELIMINARY OBSERVATIONS ON ELASMOBRANCHS BY-CATCH-AT-SIZE AND SEX-RATIOS ON THE PORTUGUESE PELAGIC LONGLINE FISHERY IN THE ATLANTIC OCEAN

Miguel N. Santos[1], Rui Coelho[1,2], Pedro G. Lino[1] & Joana Fernandez-Carvalho[1]

SUMMARY

This paper provides an overview of the elasmobranchs catch-at-size and sex-ratios on the Portuguese pelagic longline fishery in the Atlantic Ocean. The analysis was based on data collected from fishery observers, port sampling and from skippers logbooks (self sampling), collected between 1997 and 2012. Data was analyzed in terms of bycatch-at-size and comparisons were made between years, seasons (quarters), stocks (North and South, separated at 5º N) and major fishing areas for the Portuguese fleet (North, Tropical North, Equatorial and South). For the blue shark a general increasing trend on mean sizes was observed for both hemispheres with a decrease in the more recent years. For the shortfin mako the mean size has remained stable in the North and tended to decrease in the South. Some variability was noted in the seasonal and spatial comparisons. The sex-ratios proportions were compared between regions and seasons, and for the main species significant differences were found. The data presented in this working document is still preliminary, but provides new information on the catch-at-size trends and sex-ratios for the major pelagic sharks captured by the Portuguese pelagic longline fishery in the Atlantic Ocean.

RÉSUMÉ

Le présent document fournit un aperçu de la prise par taille et des ratios des sexes des élasmobranches dans la pêcherie de palangre pélagique portugaise opérant dans l'océan Atlantique. L'analyse se basait sur les données collectées par les observateurs des pêcheries, l'échantillonnage au port et les livres de bords des capitaines (auto-échantillonnage), compilées entre 1997 et 2012. Les données ont été analysées en termes de prise accessoire par taille et comparées entre les années, saisons (trimestres), stocks (Nord et Sud, séparés à 5º N) et zones de pêche principales pour la flottille portugaise (Nord, Tropicale Nord, Equatoriale et Sud). Pour le requin peau bleue, une tendance générale à la hausse pour les tailles moyennes a été observée pour les deux hémisphères, accompagnée d'une diminution pour les années les plus récentes. Pour le requin-taupe bleu, la taille moyenne est restée stable dans le Nord et tendait à diminuer au Sud. Une certaine variabilité a été constatée dans les comparaisons spatiales et saisonnières. Les proportions de ratios des sexes ont été comparées entre les régions et les saisons, et pour les principales espèces, d'importantes différences ont été notées. Les données présentées dans ce document de travail sont encore préliminaires mais apportent de nouvelles informations sur les tendances de la prise par taille et les ratios des sexes des principaux requins pélagiques capturés par la pêcherie palangrière pélagique portugaise dans l'océan Atlantique.

RESUMEN

Este documento presenta una visión global de la captura por talla y la proporción de sexos de los elasmobranquios capturados por la pesquería de palangre pelágico portuguesa en el Atlántico. El análisis se basó en datos recopilados por los observadores pesqueros, en los datos de muestreo en puerto y en los cuadernos de pesca de los patrones (automuestreo), recopilados entre 1997 y 2012. Los datos se analizaron en términos de captura fortuita por talla y se realizaron comparaciones entre años, temporadas (trimestres), stocks (norte y sur, separados en 5ºN) y principales caladeros de las operaciones de la flota portuguesa (norte, tropical norte, ecuatorial y sur). Para la tintorera se observó una tendencia creciente general en las tallas medias en ambos hemisferios con un descenso en los años más recientes. Para el marrajo dientuso la talla media se mantuvo estable en el Norte y tendió a

[1] Instituto Português do Mar e da atmosfera I.P./ IPMA, Avenida 5 de Outubro s/n, 8700-305 Olhão, Portugal
[2] Cento de Ciências do Mar, Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal, Email: mnsantos@ipma.pt

descender en el Sur. Se constató alguna variabilidad en las comparaciones estacionales y espaciales. Se comparó la proporción de sexos en las diferentes regiones y temporadas, y se hallaron importantes diferencias para las principales especies. Los datos presentados en este documento son todavía preliminares, pero proporcionan información nueva sobre las tendencias de la captura por talla y ratio de sexos para las principales especies de tiburones pelágicos capturadas por la pesquería de palangre pelágico portuguesa en el océano Atlántico.

KEYWORDS

Elasmobranchs bycatch, Catch-at-size distributions, Portuguese pelagic longline fishery, Sex-ratios

1. Introduction

Pelagic sharks are commonly by-catch in pelagic longline fisheries (e.g. Buencuerpo *et al.* 1998; Simpfendorfer et al. 2002) but still, information on their life history, population parameters and the effects of fisheries is limited. Elasmobranchs in general have K-strategy life cycles, characterized by slow growth rates and long lives, and reduced reproductive potential with few offspring and late maturity. The natural mortality rates of these species are usually low, thus increased fishing mortality may have severe consequences on the populations (Dulvy *et al.*, 2008), with declines occurring even at relatively low levels of fishing mortality (Smith *et al.*, 1998; Stevens *et al.*, 2000).

The Portuguese pelagic longline fishery started in the late 1970's. In the North Atlantic area the fishery started to develop mainly after 1986, while in the South Atlantic it gained importance after 1989 (Santos et al., 2002). The Portuguese fleet usually deploys a pelagic drift longline for targeting mainly swordfish (*Xiphias gladius*). Still, this is a multi-species fishery, where some other bony fishes as well as pelagic sharks (mainly blue shark *Prionace glauca*, and shortfin mako *Isurus oxyrinchus*) are frequently captured. In recent year, as a consequence of changes on the market which increased the demand and value of shark products, there has been higher catches of pelagic sharks in the ICCAT Convention area.

These facts have raised wide-word concern and the ICCAT has adopted a number Recommendations and Resolutions regarding sharks. These include recently implemented mandatory discards for the bigeye thresher (ICCAT Rec. 09-07), the oceanic whitetip (ICCAT Rec. 10-07), hammerheads (ICCAT Rec. 10-08) and silky sharks (ICCAT Rec. 11-08). Other Recommendations are also active concerning the conservation of sharks caught in association with fisheries managed by ICCAT (04-10, 05-05 and 06-10) and on the collection and harmonization of data on bycatch and discards in ICCAT fisheries (Rec. 11-10). Moreover, the SCRS Shark working group has consistently addressed the need for improved data and biological information required to produce better assessments for the different shark species that are of concern to ICCAT.

The general aims of this paper are to present information on the catch-at-size distribution of the major elasmobranchs species captured by the Portuguese pelagic longline fishery in the Atlantic Ocean between 1997 and 2012. Specific objectives were to present and compare catch-at-size and sex ratio information in terms of years, seasons and major fishing areas for this fleet.

2. Materials and methods

The data used for this study was collected by three sources, namely 1) fishery observers onboard Portuguese pelagic longline vessels, 2) landings on Portuguese ports, and 3) skippers logbooks (self-sampling) voluntarily provided to IPMA. The fishery observer data is usually the most complete and detailed, as apart from set data, it collects individual information on the catch sizes and sex for all specimens caught. During landings detailed information is also collected, although due to some procedure, sometimes it is difficult to collected individual size and sex data for the major species caught (blue shark). The skippers' logbooks have the data recorded and reported voluntarily by the vessel skippers, and usually also have detailed information regarding the catch, effort and location of the fishing sets. For some species, including the major fishery species (i.e. swordfish, tunas) and some sharks (i.e. blue and shortfin mako) detailed individual specimen information is also recorded, including individual specimen sizes or weights.

The data analyzed refers to data from the fishery between the years of 1997 to 2012. In **Figure 1** it is shown the spatial distribution of 13,711 sets that were considered, which corresponded to a total 988 trips and 18,041,880 hooks. Over 92,000 specimens were measured (FL, fork length in cm) and/or weighted (TW, total weight in kg), as detailed in Table 1. For this paper the analysis was carried out in terms of size, and so for the specimens with only weight information available, conversion between TW-FL was used as follows:

$$TW = a * FL^b$$

where, TW is the total weight (in kg) and FL is the fork length (in cm), *a* is the intercept (initial growth coefficient or condition factor) and *b* is the slope (growth coefficient, i.e., fish relative growth rate). These coefficients were obtained from (Kohler *et al*., 1995), for the following species:

Blue shark (BSH): $a = 3.2*10^{-6}$; $b = 3.131$;
Shortfin mako (SMA): $a = 5.2*10^{-6}$; $b = 3.141$;
Bigeye thresher (BTH): $a = 9.1*10^{-6}$; $b = 3.0802$;
Common thresher (ALV): $a = 1.88*10^{-4}$; $b = 2.5188$;

The variations in the mean catch-at-size for the eight major species (most frequently captured) were plotted by year along the time series, by season and by major fishing area of operation for the Portuguese longline fleet. Histograms with the size frequency distributions were also plotted for those main species, with the sizes categorized into 10 cm FL size classes for all species except the crocodile shark, where size classes of 5 cm FL were used. In the yearly and seasonal plots and tests, separate analyses were carried out the North and South Atlantic, and for the purpose of this study the 5ºN parallel was used to separate the two hemispheres (stocks), as recommended in the ICCAT Manual for shark species (ICCAT, 2006-2009). However, additional four geographical sub-areas were considered, taking into consideration the major fishing grounds of the Portuguese fleet. These were assigned as follows:

Northern– above 25º N
Tropical North – between 5º N and 25º N
Equatorial– between 5º N and 5º S
Southern– below 5º S

These catch-at-size results were tested for significant differences with Kruskal-Wallis tests. Those non-parametric tests were chosen instead of parametric approaches (e.g. ANOVA) because the data for most species tended to be non-normally distributed (tested with Kolmogorov Smirnov tests with Lilliefors correction) and heterogeneous between groups (tested with Levene tests).

For those main species the proportions of the sex-ratios were compared between the four main areas of operation of the Portuguese pelagic longline fleet. For the two major species, namely the blue shark and the shortfin mako, seasonal differences in the sex-ratios were also tested, considering the two hemispheres (stocks) separately. These analyses were carried out with contingency tables, and the differences were tested with Chi^2 statistical tests, comparing the observed *versus* expected proportions in each cell of the contingency tables.

All statistical analysis for this paper was carried out with the R Project for Statistical Computing version 2.15.3 (R Core Team, 2013). Most analysis were carried out using functions in the core R program, except the Levene tests for homogeneity of variances that used library “car” (Fox and Weisberg, 2011) and the contingency table analysis that used functions from library “gmodels” (Warnes, 2012). Most graphics were plotted using library “ggplot2” (Wickham, 2009).

3. Results and Discussion

For the present working document a total of 92,141 specimens were sampled, belonging to 12 different species as detailed in **Table 1**. Overall, the blue shark was by far the most sampled species (77.8%), followed by the shortfin mako (17.6%), the bigeye thresher (1.4%) and the crocodile shark (1.2%). This pattern did not changed among the stocks, neither the four fishing areas considered, although in the case of the southern area the difference between the proportions for the two major species was much narrower (55.4% and 42.2%, for the blue and shortfin mako, respectively).

3.1. Yearly size distribution

The overall mean annual catch-at-sizes (and 95% confidence intervals) for the major pelagic sharks captured by the Portuguese pelagic longline fleet in the North and South Atlantic regions are presented in **Figure 2**. For the two main species caught, the blue and shortfin mako sharks, higher mean sizes were recorded in the South. A general increasing trend on mean sizes was observed for the time series for the blue shark in both hemispheres, although a decrease is noted in the most recent years. In the case of the shortfin mako, the mean size has been quite stable in the North, while a decreasing trend was noted in the South. These trends were also evident in the catch-at-size frequency distributions, which showed a general narrower size range in the Northern hemisphere for the study period (**Figures 3** and **4**).

As regards the two other most common species in the catches, the bigeye thresher (BTH) and crocodile shark (PSK), decreasing trends on the mean annual size were noted on the Northern hemisphere, while on the South the situation seems more stable (**Figure 2**). The size frequency distributions for these two species are provided in **Figures 5** and **6**.

In terms of statistical comparisons, and considering the two stocks (North and South) separately, significant differences were detected for all species and stocks, with the exception of the oceanic whitetip shark (OCS) in the North region (K-W: Chi^2=11.5, df=7, p-value < 0.119). On all other cases, the results of the tests resulted in p-values < 0.05.

3.2. Seasonal size distribution

Figure 7 shows the boxplots with the seasonal (quarter) variability of the catch-at-size for the major eight shark species, for the North and South stocks separately. Using the non-parametric Kruskal-Wallis tests, it were found significant differences in terms of the seasonal variability in the catch-at-sizes were significant for the BSH (K-W: Chi^2=9496.1, df=3, p-value < 0.001), FAL (K-W: Chi^2=48.9, df=3, p-value < 0.001), LMA (K-W: Chi^2=15.9, df=3, p-value=0.001), PSK (K-W: Chi^2=41.9, df=3, p-value < 0.001), SMA (K-W: Chi^2=373.4, df=3, p-value < 0.001) and SPZ (K-W: Chi^2=21.8, df=3, p-value < 0.001). In contrast, no significant differences were found for the seasonal catch-at-size-variability for the BTH (K-W: Chi^2=6.7, df=3, p-value < 0.080) and OCS (K-W: Chi^2=1.9, df=3, p-value < 0.597).

3.3. Spatial size distribution

Table 2 summarizes the overall mean sizes and size range by species for the two stocks separated at the 5ºN (see boxplots in **Figure 8**). In statistical terms, significant differences in the catch-at-sizes between the two stocks were detected for the BSH (K-W: Chi^2=5410.7, df=1, p-value < 0.001), BTH (K-W: Chi^2=122.1, df=1, p-value < 0.001), OCS (K-W: Chi^2=59.8, df=1, p-value < 0.001), SMA (K-W: Chi^2=407.8, df=1, p-value < 0.001) and SPZ (K-W: Chi^2=6.0, df=1, p-value=0.014). On the other hand, no significant differences were detected for the FAL (K-W: Chi^2=2.7, df=1, p-value=0.098), LMA (K-W: Chi^2=0.95, df=1, p-value=0.331) and PSK (K-W: Chi^2=1.8, df=1, p-value=0.177).

Table 3 summarizes the mean sizes and size range by species for the four major fishing areas of the Portuguese pelagic longline fishery, while **Figure 9** shows the corresponding boxplots. When those areas were compared statistically, significant differences were detected for all species, with specific tests results of: BSH (K-W: Chi^2=31891.1, df=3, p-value < 0.001), BTH (K-W: Chi^2=276.0, df=3, p-value < 0.001), FAL (K-W: Chi^2=26.6, df= , p-value < 0.001), LMA (K-W: Chi^2=15.4, df=3, p-value = 0.001), OCS (K-W: Chi^2=82.9, df=2, p-value < 0.001), PSK (K-W: Chi^2=52.9, df=2, p-value < 0.001), SMA (K-W: Chi^2=897.6, df=3, p-value < 0.001) and SPZ (K-W: Chi^2=46.3, df=3, p-value < 0.001).

3.4. Sex-ratios

In terms of sex-ratios, the comparison showed significant differences for BSH, BTH, PSK and SMA for the major areas of operation of the Portuguese pelagic longline fleet, but not for the other species (**Table 4**). In terms of seasonal changes and within each hemisphere separately, significant differences were also found for the two major species (BSH and SMA) (**Table 5**).

3.5. Final remarks

This paper presents new information on the catch-at-size trends for the major pelagic sharks captured by the Portuguese pelagic longline fishery in the Atlantic Ocean. While the information presented is valuable, it should be noted that it is preliminary as an effort is currently being carried out to collect, compile and further analyze these data. We hope, in the near future, to incorporate more data from other trips not yet included, and eventually expand the analysis to the earlier years of the fishery for the two major shark species caught.

Even though still preliminary, the results presented provide important information that may be considered for stock assessments (e.g. Ecological Risk Assessment) and future management and/or conservation initiatives of these elasmobranchs species.

Acknowledgments

The data used for this study was mostly collected within the scope of the EU Data Collection Framework, but also during other project carried out by IPMA in recent years (e.g. SELECT-PAL). The authors wish to thank the fishery observers for the onboard data collection, and the skippers for participating in the self sampling data collection program. Rui Coelho was supported by a grant from FCT (Ref: BDP 40523 / 2007), co-funded by “POCI-2010, Programa Operacional Ciência e Inovação 2010” and “FSE, Fundo Social Europeu”. Joana Fernandez-Carvalho was supported by a grant from FCT, the Portuguese Foundation for Science and Technology (Ref: BD 60624 /2009).

References

Buencuerpo, V., Rios, S. and Moron, J. 1998. Pelagic sharks associated with the swordfish, *Xiphias gladius*, fishery in the eastern North Atlantic Ocean and the Strait of Gibraltar. Fish. Bull., 96: 667-685.

Dulvy, N.K., Baum, J.K., Clarke, S., Compagno, L.J.V., Cortés, E., Domingo, A., Fordham, S., Fowler, S., Francis, M.P., Gibson, C., Martinéz, J., Musick, J.A., Soldo, A., Stevens, J.D., Valenti, S. 2008. You can swim but you can’t hide: the global status and conservation of oceanic pelagic sharks and rays. Aquatic Conserv: Mar. Freshw. Ecosyst. 18, 459-482.

Fox, J., Weisberg, S. 2011. *An {R} Companion to Applied Regression*, 2nd Ed. Sage, Thousand Oaks CA.

ICCAT. 2006-2009. ICCAT Manual. International Commission for the Conservation of Atlantic Tuna. In: ICCAT Publications [on-line]. Updated 2009. http://www.iccat.int/en/ICCATManual.htm.

Kohler, N.E., Casey, J.G. and Turner, P.A. 1995. Length-weight relationships for 13 species of sharks from the western North Atlantic. Fish. Bull., 93: 412-418.

R Core Team. 2013. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Santos, M.N., Garcia, A. and Pereira, J.G. 2002. A historical review of the by-catch from the Portuguese surface long-line fishery: observations on blue shark (*Prionace glauca*) and short-fin mako (*Isurus oxyrinchus*). Col. Vol. Sci. Pap. ICCAT, 54: 1333-1340.

Simpfendorfer, C.A., Hueter, R.E., Bergman, U. and Connett, S.M.H. 2002. Results of a fishery-independent survey for pelagic sharks in the Western North Atlantic, 1977-1994. Fish. Res., 55: 175-192.

Stevens, J.D., Bonfil, R., Dulvy, N.K., Walker, P.A. 2000. The effects of fishing on sharks, rays, and chimaeras (Chondrichthyans), and the implications for marine ecosystems. ICES J. Mar. Sci. 57: 476-494.

Warnes, G.R. 2012. *gmodels: various R programming tools for model fitting*. R package version 2.15.3. http://CRAN.R-project.org/package=gmodels.

Wickham, H. 2009. *ggplot2: elegant graphics for data analysis*. Springer, New York.

Table 1. Number of specimens sampled by species, stock (north and south, separated at 5ºN) and major fishing area (North – above 25º N; NTropical North – between 5º N and 25º N; Equatorial – between 5º N and 5º S; and South – below 5º S). In the case of the pelagic stingray (PLS) size refers to disc width (cm).

			Northern stock		Southern stock		
Species	**Common name**	**Scientific name**	**North**	**Tropical North**	**Equatorial**	**South**	**Total**
ALV	Common thresher	*Alopias vulpinus*	13		1	2	16
BSH	Blue shark	*Prionace glauca*	29787	16602	13565	11775	71729
BTH	Bigeye thresher	*Alopias superciliosus*	248	797	168	102	1315
FAL	Silky shark	*Carcharhinus falciformis*		54	319	9	382
GAG	Tope	*Galeorhinus galeus*	2	20			22
LMA	Longfin mako	*Isurus paucus*	22	100	109	110	341
OCS	Oceanic whitetip	*Carcharhinus longimanus*		178	239	12	429
PLS	Pelagic stingray	*Pteroplatytrygon violacea*			19	3	22
PSK	Crocodile shark	*Pseudocarcharias kamoharai*		420	410	255	1085
SMA	Shortfin mako	*Isurus oxyrinchus*	4759	1574	932	8969	16234
SPZ	Smooth hammerhead	*Sphyrna zygaena*	4	252	263	33	552
TIG	Tiger	*Galeocerdo cuvier*	1	6	7		14
		Total number of fish sampled	34836	20003	16032	21270	92141

Table 2. Mean size (±standard deviation) and size range (Min – minimum; Max – maximum) by species, for the northern and southern stocks (separated at 5ºN) and the overall study area. In the case of the pelagic stingray (PLS) size refers to disc width (cm).

	Northern stock			Southern stock			Overall		
Species	**Mean**	**StDev**	**Min-Max**	**Mean**	**StDev**	**Min-Max**	**Mean**	**StDev**	**Min-Max**
ALV	195.5	30.39	130-235	212.3	10.79	200-220	198.6	28.30	130-235
BSH	171.9	43.92	45-320	197.6	26.50	55-311	180.5	40.80	45-320
BTH	164.3	29.26	80-265	186.0	27.17	98-265	168.6	30.11	80265
FAL	129.4	42.05	67-213	122.3	43.04	57-242	124.0	42.87	57-242
GAG	96.4	19.57	80-159				96.4	19.57	80-159
LMA	148.7	27.93	76-235	142.8	42.84	68-266	145.7	36.26	68-266
OCS	135.6	34.15	65-227	114.5	27.65	63-225	125.5	32.90	63-227
PLS	49.8	4.11	45-55	46.4	16.27	30-103	46.9	15.03	30-103
PSK	83.6	9.26	38-102	82.7	9.72	38-105	83.1	9.51	38-105
SMA	141.9	27.80	68-340	153.0	35.43	66-310	148.7	33.09	66-340
SPZ	197.9	28.96	96275	193.2	23.19	136-260	195.4	26.19	96-275
TIG	214.0	39.81	165-300	186.3	31.34	139-220	203.8	38.53	139-300

Table 3. Mean size (±standard deviation) and size range (Min – minimum; Max – maximum) by species, for the major fishing areas of the Portuguese pelagic longline fleet (North – above 25º N; NTropical North – between 5º N and 25º N; Equatorial – between 5º N and 5º S; and South – below 5º S). In the case of the pelagic stingray (PLS) size refers to disc width (cm).

	Northern stock						Southern stock					
	North area			Tropical North area			Equatorial area			South area		
Species	**Mean**	**StDev**	**Min-Max**	**Mean**	**StDev**	**Min-Max**	**Mean**	**StDev**	**Min-Max**	**Mean**	**StDev**	**Min-Max**
ALV	195.5	30.39	130-235				200.0		200	218.5	2.12	217-220
BSH	147.7	38.00	45-320	207.8	24.50	75-320	201.4	21.84	85-285	193.5	29.53	55-311
BTH	185.6	27.08	83-262	158.8	27.00	80265	169.6	26.60	98243	200.6	26.91	143-265
FAL				143.9	37.43	74-212	119.0	42.27	57-242	176.2	25.66	126-204
GAG	154.0	7.07	149-159	90.7	6.04	80-107						
LMA	152.1	47.54	76215	149.4	27.06	103-235	151.5	27.23	100-266	130.2	49.43	68-250
OCS				142.3	31.82	65-227	113.6	27.61	63-212	135.0	45.65	68-225
PLS							44.8	10.30	30-81	63.0	34.87	39-103
PSK				82.1	9.75	38-101	82.2	10.33	38-102	86.8	5.41	67-105
SMA	138.8	27.04	74-340	150.0	27.42	68-283	167.6	29.56	80-300	151.6	35.71	66310.00
SPZ	225.8	20.27	197-240	197.2	29.35	96-275	190.7	22.04	136-260	218.2	16.51	189-252
TIG	180.0		180	220.3	49.26	165-300	197.5	32.89	139-265			

Table 4. Contingency table with the *sex-ratios* for the main pelagic shark species captured in the major fishing areas of operation of the Portuguese pelagic longline fleet. The contingency table Chi^2 analysis is presented, with indication of the Chi^2 statistics, the degrees of freedom and the corresponding p-values for each species tested.

Species	**Stock**	**% Observed**		**Chi^2 test**		
		Females	**Males**	**Chi^2**	**Df**	**p-value**
BSH	North	35.4	64.6	3472.3	3	< 0.01
	Tropical North	69.4	30.6			
	Equatorial	44.6	56.0			
	South	48.5	51.5			
BTH	North	39.5	60.5	97.9	3	< 0.01
	Tropical North	66.7	33.3			
	Equatorial	41.2	58.8			
	South	29.4	70.6			
FAL	Tropical North	56.6	43.4	0.13	1	0.72
	Equatorial	52.9	47.1			
LMA	North	62.5	37.5	1.99	3	0.58
	Tropical North	59.1	40.9			
	Equatorial	53.0	47.0			
	South	61.8	38.2			
OCS	Tropical North	46.0	54.0	5.90	2	0.05
	Equatorial	52.9	47.1			
	South	81.8	18.2			
PSK	Tropical North	53.2	46.8	215.3	2	< 0.01
	Equatorial	66.9	33.1			
	South	11.8	88.2			
SMA	North	36.9	63.1	29.3	3	< 0.01
	Tropical North	56.0	44.0			
	Equatorial	51.3	48.7			
	South	50.3	49.7			
SPZ	Tropical North	45.0	55.0	0.89	2	0.64
	Equatorial	43.0	57.0			
	South	36.4	63.6			

Table 5. Contingency table with the seasonal *sex-ratios* by stock (North and South) for the two major pelagic shark species captured by the Portuguese pelagic longline fleet in the Atlantic Ocean. The contingency table Chi^2 analysis is presented, with indication of the Chi^2 statistics, the degrees of freedom and the corresponding p-values for each species and stock tested.

Species	Stock	Quarter	% observed		Chi^2 test		
			Females	Males	Chi2	Df	p-value
BSH	North	Q1	56.2	43.8	2519.2	3	< 0.01
		Q2	36.4	63.6			
		Q3	55.9	44.1			
		Q4	72.3	27.7			
	South	Q1	32.6	67.4	362.0	3	< 0.01
		Q2	59.8	40.2			
		Q3	40.7	59.3			
		Q4	48.6	51.4			
SMA	North	Q1	51.4	48.6	15.3	3	< 0.01
		Q2	36.8	63.2			
		Q3	47.2	52.8			
		Q4	54.3	45.7			
	South	Q1	27.5	72.5	47.3	3	< 0.01
		Q2	77.8	22.2			
		Q3	58.8	41.2			
		Q4	51.4	48.6			

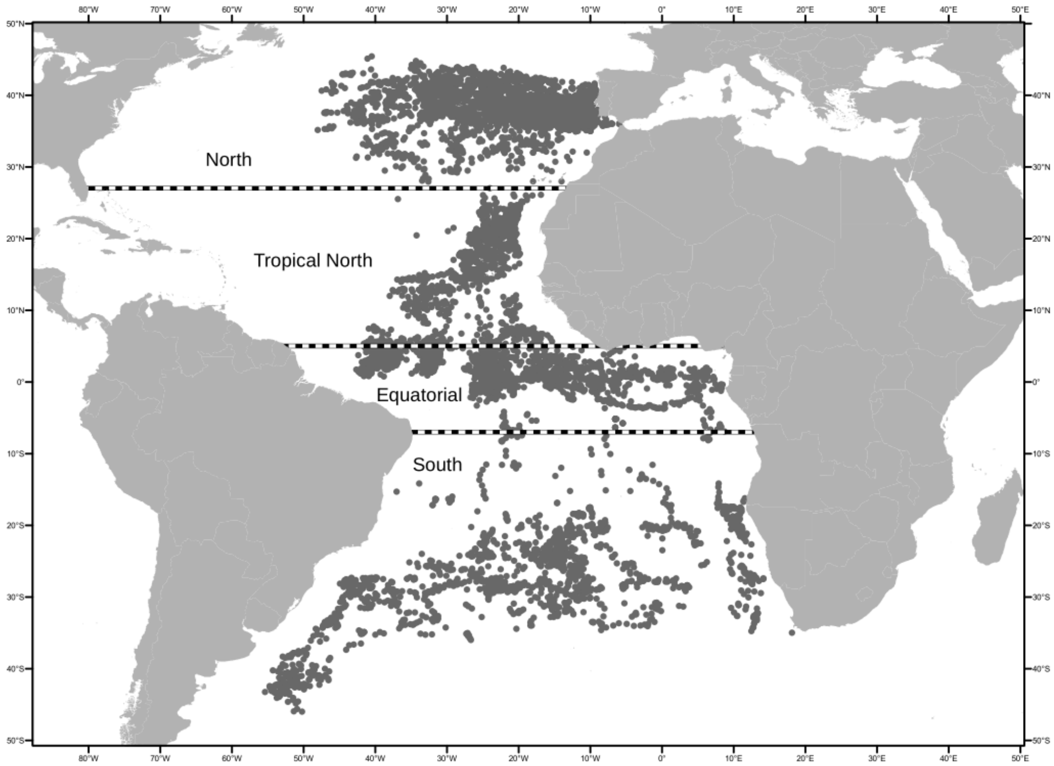

Figure 1. Geographic distribution of the sampling effort in terms of number of sets.

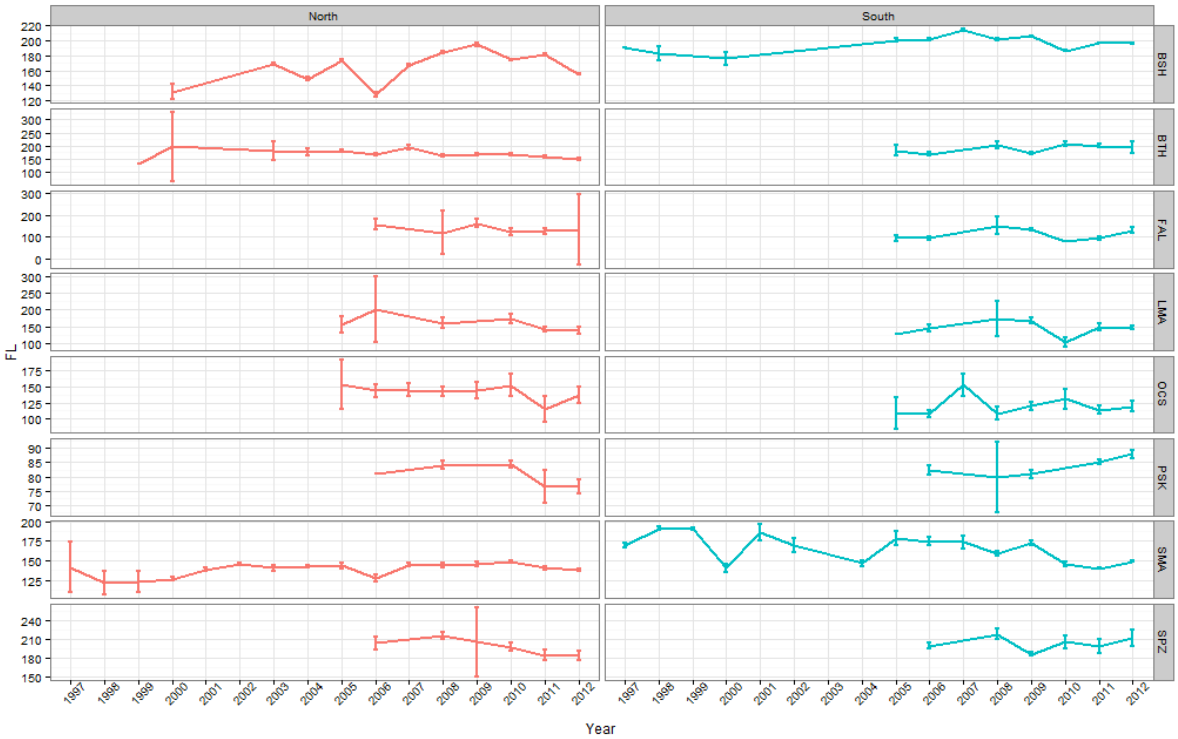

Figure 2. Catch-at-size variations for the main pelagic sharks captured by the Portuguese pelagic longline fleet in the North and South Atlantic regions. The line represents the annual mean and the error bars represent the 95% confidence intervals of the mean.

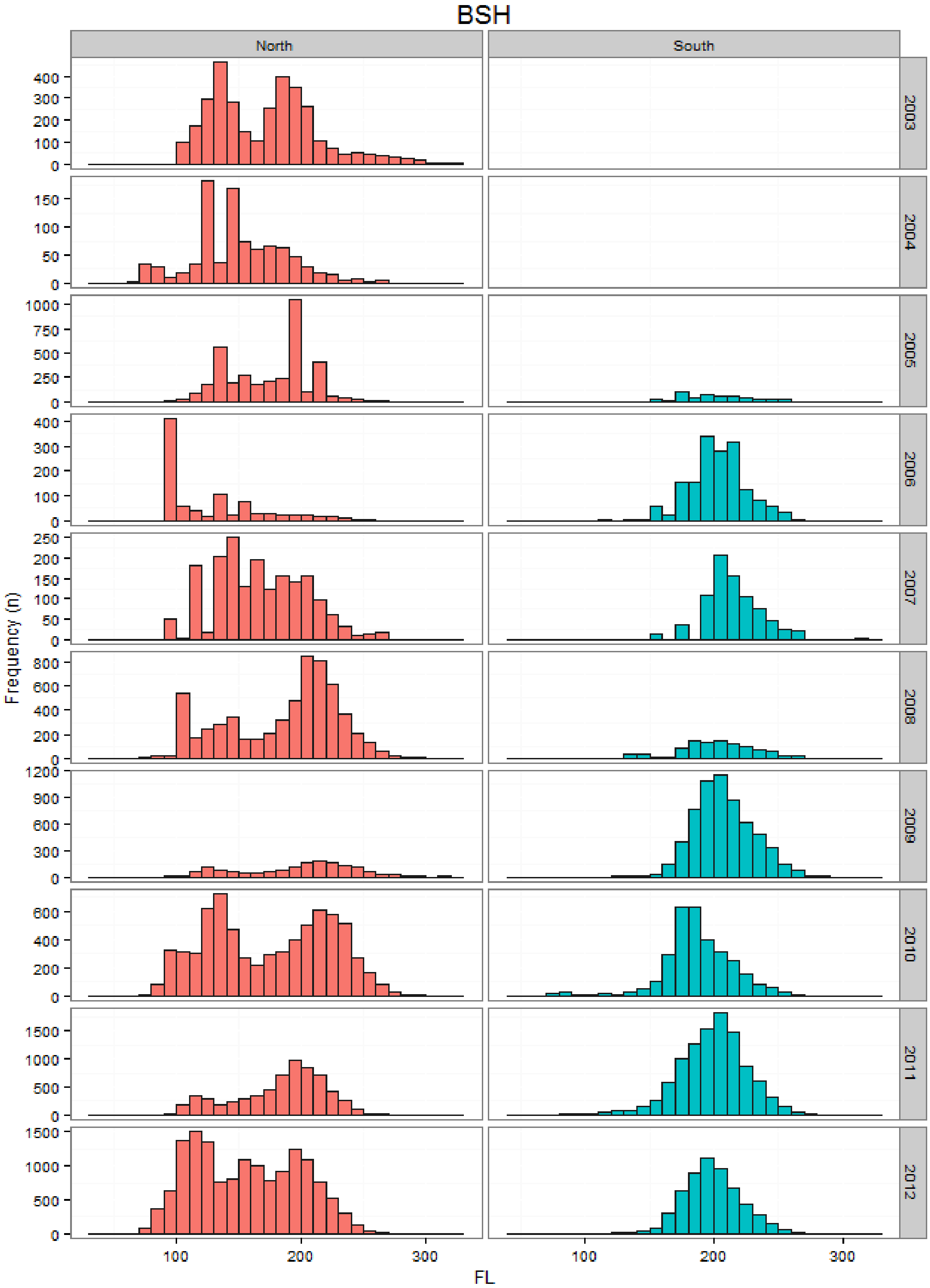

Figure 3. Size frequency distribution (FL, cm) of the blue shark (BSH, *Prionace glauca*) captured by the Portuguese longline fleet in the North and Southern Atlantic Ocean between 2003 and 2012.

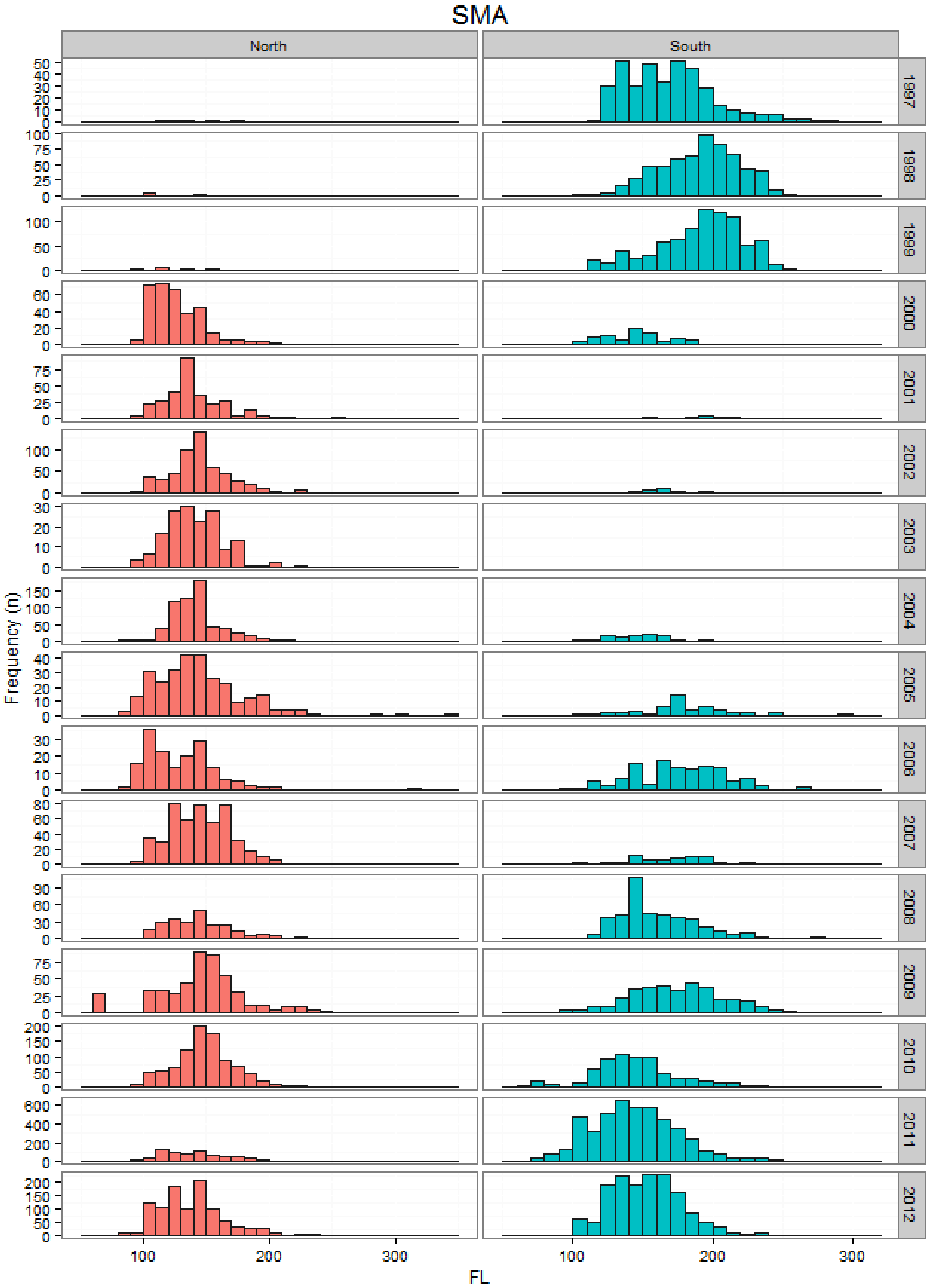

Figure 4. Size frequency distribution (FL, cm) of the shortfin mako shark (SMA, *Isurus oxyrinchus*) captured by the Portuguese longline fleet in the North and Southern Atlantic Ocean between 1997 and 2012.

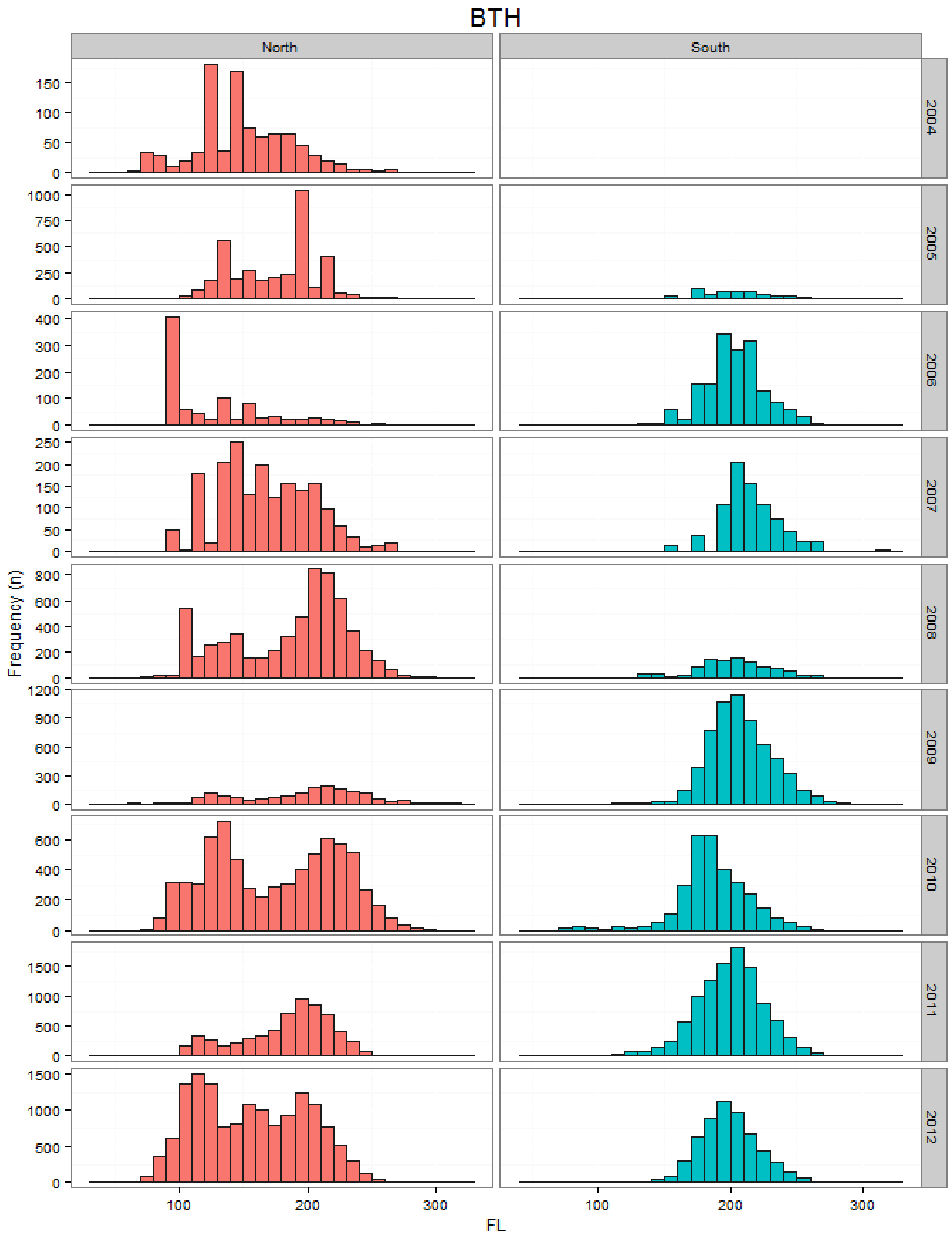

Figure 5. Frequency distribution of the bigeye thresher (BTH, *Alopias superciliosus*) sizes (FL, cm) captured by the Portuguese longline fleet in the North and Southern Atlantic Ocean between 2004 and 2012.

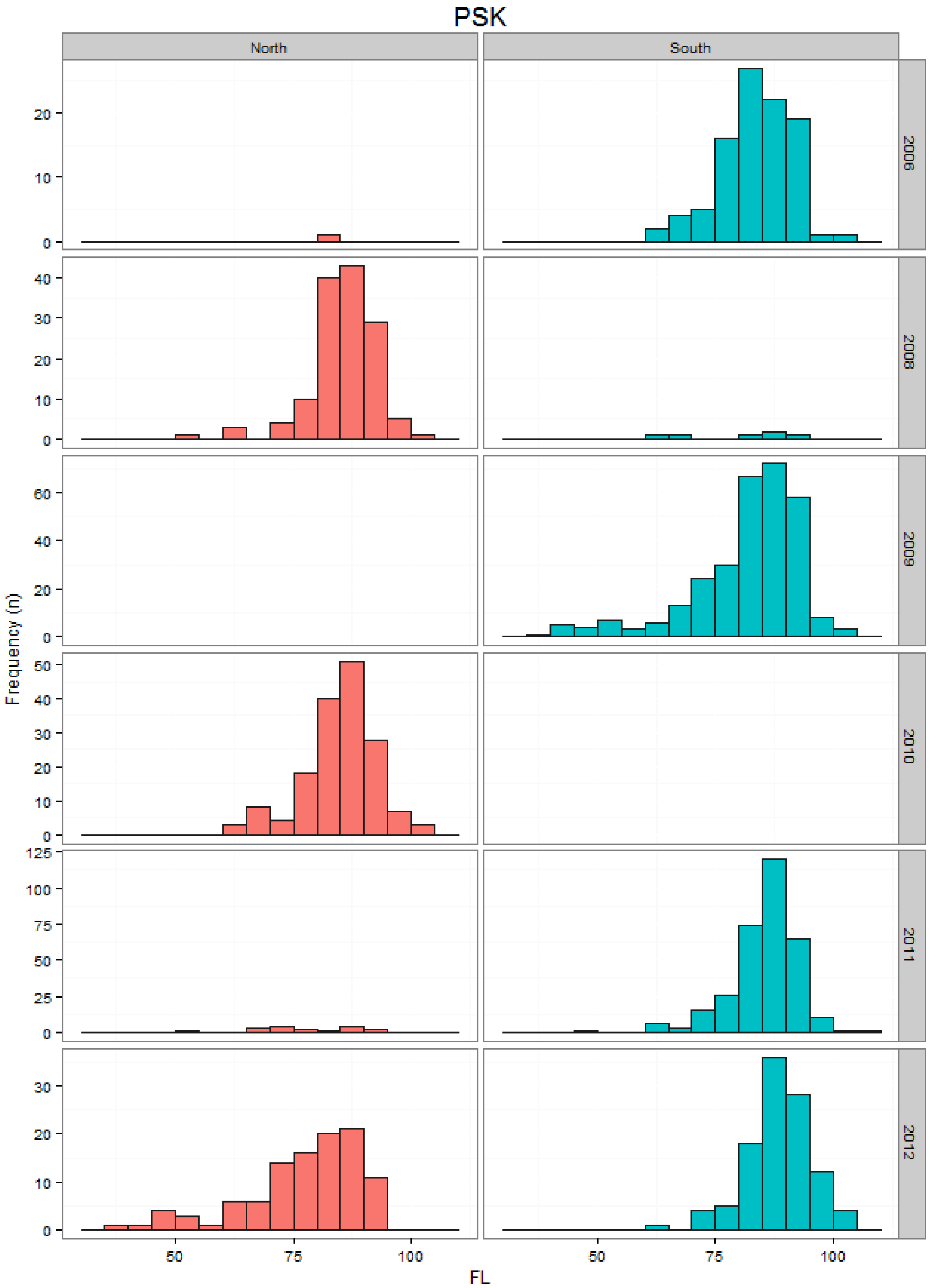

Figure 6. Frequency distribution of the crocodile shark (PSK, *Pseudocarcharias kamoharai*) sizes (FL, cm) captured by the Portuguese longline fleet in the North and Southern Atlantic Ocean between 2006 and 2012.

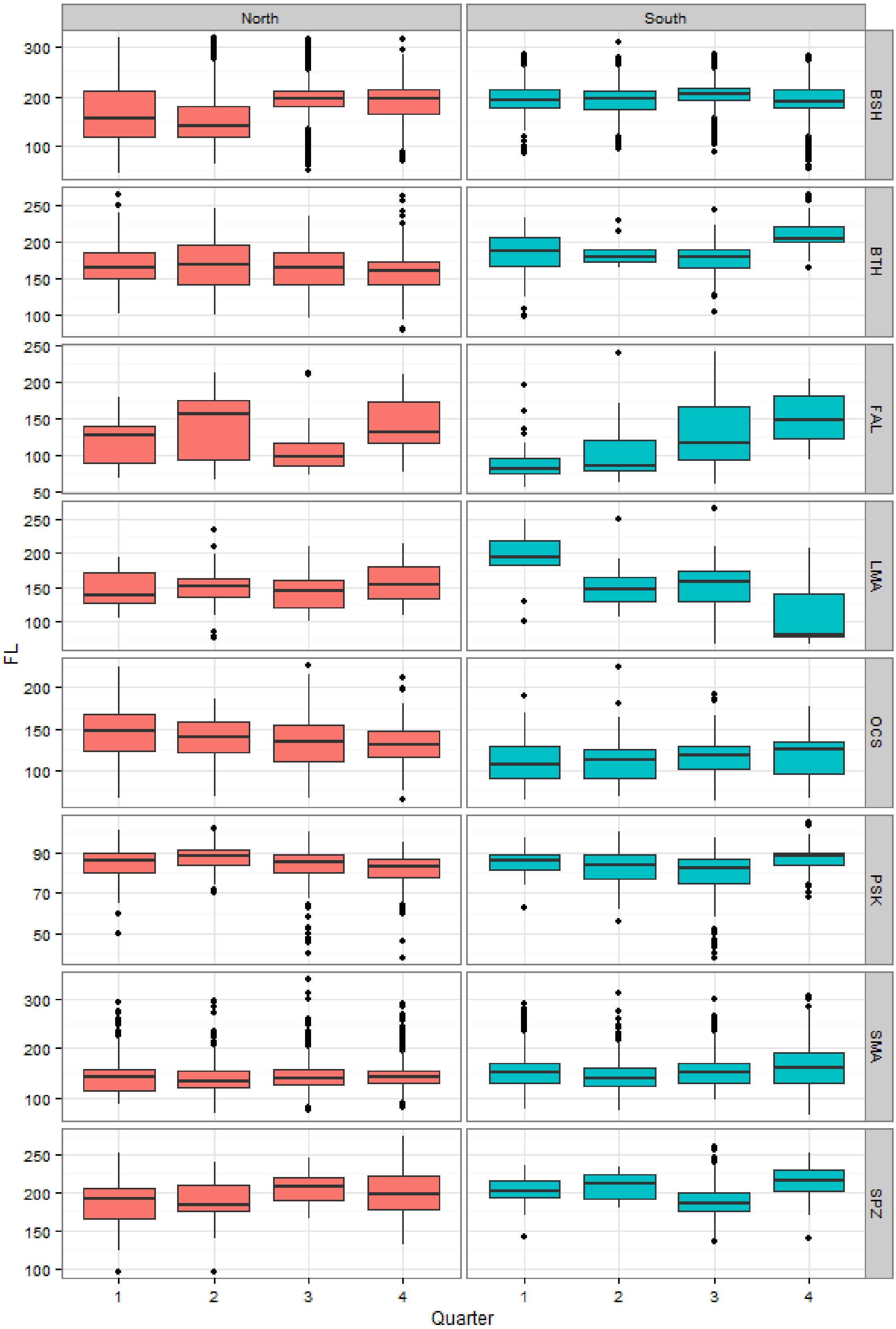

Figure 7. Seasonal catch-at-size variations for the main pelagic shark species captured by the Portuguese pelagic longline fleet in the Atlantic Ocean. The boxplots are represented by quarter of the year and stock (North and South Atlantic, separated at 5ºN).

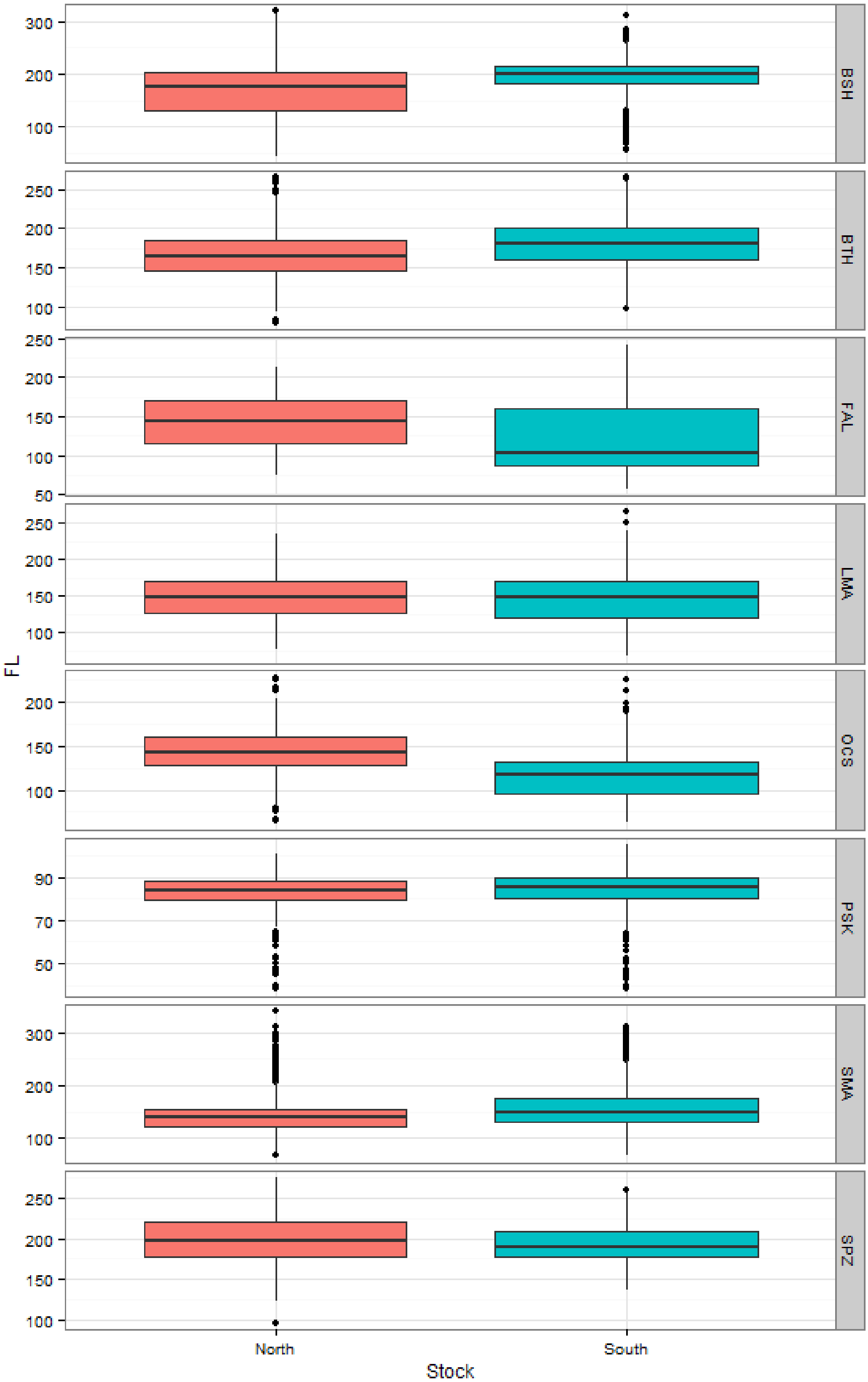

Figure 8. Catch-at-size variations for the major pelagic shark species captured by the Portuguese pelagic longline fleet in the Atlantic Ocean by stock (North and South Atlantic, separated at 5ºN).

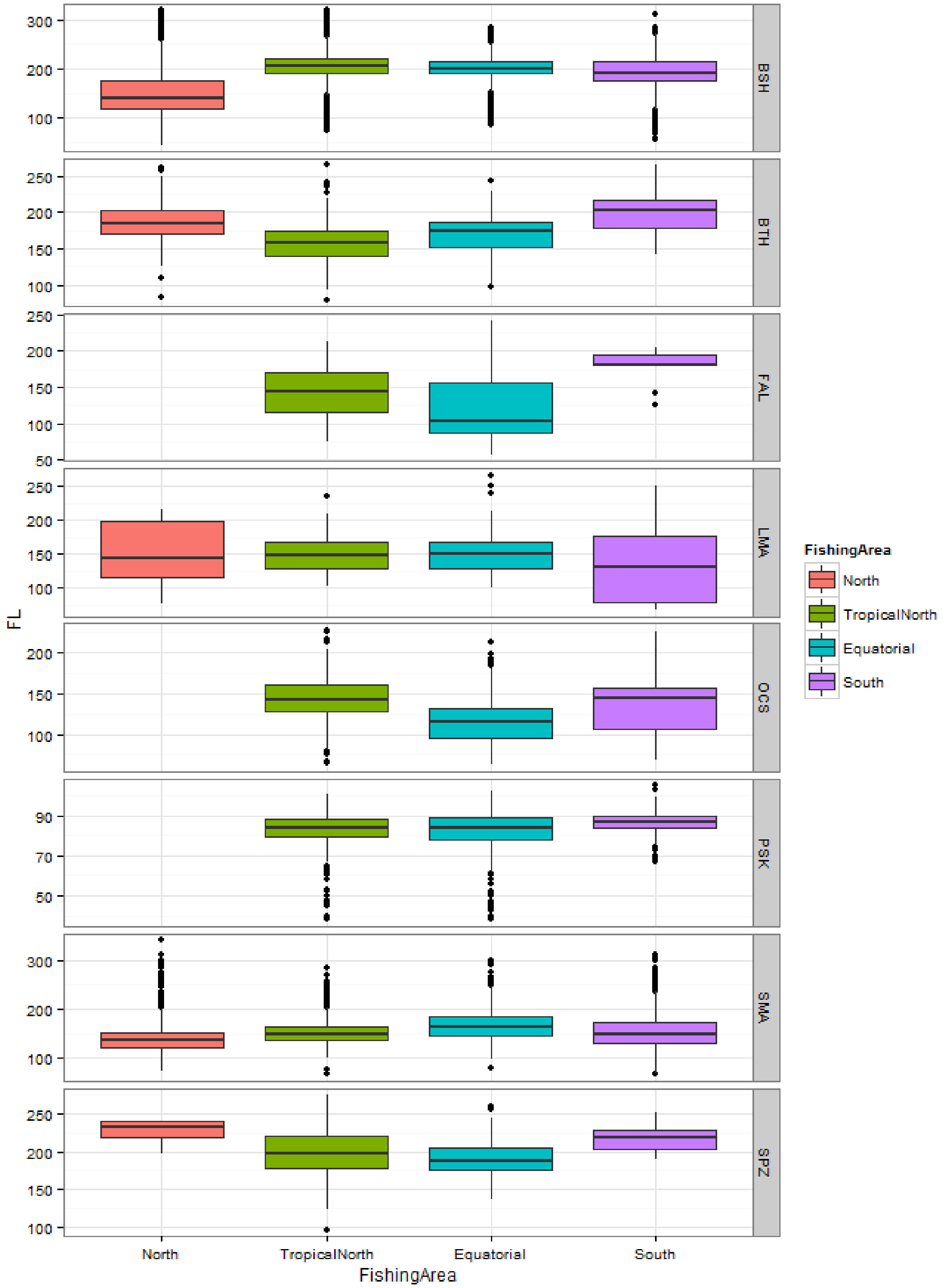

Figure 9. Catch-at-size variations for the major pelagic shark species captured by the Portuguese pelagic longline fleet in the Atlantic Ocean. The boxplots are represented by major fishing areas of operation for the Portuguese.