SIZE DISTRIBUTION OF SWORDFISH (*XIPHIAS GLADIUS*) IN THE CARIBBEAN SEA AND ADJACENT WATERS OF THE WESTERN CENTRAL ATLANTIC, FROM OBSERVER DATA OF THE VENEZUELAN LONGLINE FISHERIES

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SUMMARY

*Swordfish (*Xiphias gladius*) is caught by the Venezuelan large pelagic fisheries over the past 29 years. The document analyzes the size distribution of swordfish caught by the pelagic longline fishery, namely, the industrial/tuna pelagic longline for the period of 1987-2016, recorded by at-sea scientific observers. A total of 9,327 swordfish records collected were analyzed. Sizes recorded ranged between 41 and 300 cm LJFL. The mean annual sizes were 140.5 cm LJFL for females (n=4577) and 129.8 cm LJFL for males (n=4120); a group of 630 fish with no sex id had a mean annual size of 111.7 cm LJFL, most likely juvenile fish. The largest volume of the overall swordfish catch was around 120 cm LJFL. The size variability in the mean size of males and females was evident in across years and season (months). Annual and seasonal mean sizes of females and males varied between swordfish target fishing years and non-target years.*

RÉSUMÉ

*L'espadon (*Xiphias gladius*) est capturé par les pêcheries du Venezuela ciblant les grands pélagiques depuis 29 ans. Le document analyse la distribution des tailles de l'espadon capturé par la pêcherie palangrière pélagique, à savoir la palangre industrielle/thonière pélagique pour la période 1987-2016, enregistrée par des observateurs scientifiques en mer. Au total, 9.327 registres d'espadon recueillis ont été analysés. Les tailles enregistrées oscillaient entre 41 et 300 cm LJFL. Les tailles annuelles moyennes étaient de 140,5 cm LJFL pour les femelles (n=4577) et 129,8 cm LJFL pour les mâles (n=4120) ; un groupe de 630 poissons dont le sexe n'était pas identifié avait une taille moyenne annuelle de 111,7 cm LJFL, très probablement des spécimens juvéniles. La plus grande partie des prises totales mesurait environ 120 cm LJFL. La variabilité de la taille moyenne des mâles et des femelles était évidente pour toutes les années et saisons (mois). Les tailles moyennes annuelles et saisonnières des femelles et des mâles variaient entre les années de pêche au cours desquelles l'espadon était ciblé et les années au cours desquelles il ne l'était pas.*

RESUMEN

El pez espada (Xiphias gladius) *ha sido capturado por las pesquerías de grandes pelágicos de Venezuela durante los últimos 29 años. Este documento analiza la distribución por tallas del pez espada capturado por la pesquería de palangre pelágico, a saber, el palangre pelágico atunero/industrial para el periodo 1987-2016, consignada por observadores científicos en el mar. Se analizaron en total 9.327 registros consignados de pez espada. Las tallas consignadas oscilaron entre 41 y 300 cm LJFL. Las tallas medias anuales fueron 140,5 cm LJFL para las hembras (n=4577) y 129,8 cm LJFL para los machos (n=4120); un grupo de 630 peces sin sexo determinado tenía una talla media anual de 111,7 cm LJFL, y eran probablemente juveniles. La mayor parte de la captura total de pez espada era de aproximadamente 120 cm LJFL. En todos los años y temporadas (meses) se evidenció una variabilidad en la talla media de machos y hembras. Las tallas medias anuales y estacionales de las hembras y los machos variaban entre los años en que el pez espada era la especie objetivo de la pesca y los que no lo era.*

KEYWORDS

Swordfish, Size composition, Pelagic longline, Caribbean Sea, Venezuela

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Introduction

Swordfish (*Xiphias gladius*) have been an important component of the large pelagic fish landings in Venezuela operating in the Caribbean Sea and adjacent waters of the North Atlantic (Weidner et al., 1999). Sworfish fishing in Venezuela started in the late 1980, by several US longline vessels chartered by local companies. The swordfish fishery seemed to expand through the 1990s, but it was slowed down by ICCAT management measures taken in the late 1990s. Basically, by setting a size limit on the landed catch, which affected most of the landed catch by the Venezuelan fleet which consisted mostly of undersized fish (<125 cm LJFL). After 2000, all the Venezuela longline fleet was exclusively targeting tropical tunas, and swordfish became part of the by-catch.

The present document analyzes the annual and seasonal size distribution of swordfish caught during the time when swordfish was targeted and when it became part of the landed by-catch.

Materials and Methods

Data sources

Swordfish size-composition information was obtained from data recorded by ICCAT sponsored Enhanced Program for Billfish Research in Venezuela´s at-sea Observer Program (Arocha et al., 2013) for the period 1987-2011 and from INSOPESCA's National Observer Program (PNOV) for the period 2012-2016 (Gassman et al., 2014). The Venezuelan industrial pelagic longline fishery that targets primarily tropical tunas, is based out of Cumaná and Puerto La Cruz in northeastern Venezuela.

Size by sex data was recorded by scientific observers while aboard pelagic longline fishing vessels operating in the southwestern North Atlantic between 5°N and 25°N (west of 40°W). The size measurement recorded was the lower-jaw-fork-length (LJFL) in cm, but in some cases when fish were dressed, the recorded measurement was cleithrum-fork-length (CK) which was later converted to LJFL using ICCAT Manual's conversion equations. Sex determination was based on macroscopic characteristics of the reproductive organs; although the accuracy of sex identification for the smaller size fish (<130 cm LJFL) may be biased due to the subtle differences between sexual organs and were identified as unknown (UNK).

Data analysis

Size data were tested for normality with Kolmogorov-Smirnov normality test with the Lillifors correction (KSL test), and Welch's ANOVA was used to compare size distribution data when variances are heterogeneous. All statistical test were carried out using JMP v.11 (2014).

Results and Discussion

Spatial distribution of swordfish

The overall spatial distribution of swordfish by sex caught by the Venezuelan industrial pelagic longline fleet recorded by at-sea observer programs (EPBR-VPLOP 1987-2011, and INSOPESCA-PNOB 2012-2016), covers three distinct areas; the entire eastern Caribbean Sea, the Guyanas-Amazon area southeast of Trinidad, and the northern part of the Antilles Island chain (**Figure 1**). Most of the swordfish recorded is localized in the Caribbean Sea, followed by the Guyana-Amazon area, due to the increased activity of the fleet in that area in recent years (Arocha et al., 2017).

Size distribution

A total of 9,327 swordfish were sampled and measured during the collection time period of the present document. Overall swordfish mean size was 133.8 cm LJFL, ranging in size between 41 and 300 cm LJFL. A total of 4577 female swordfish were recorded during the sampling period with a mean size of 140.5 cm LJFL, ranging in size between 49 and 300 cm LJFL; while 4120 male swordfish recorded had a mean size of 129.8 cm LJFL, from fish sizes between 41 and 286 cm LJFL (**Table 1**). A group 630 of unsexed swordfish had a mean of 111.7 cm LJFL, most likely juvenile fish difficult to sex. However, noting that large fish were unsexed in some years, a likely cause is the confusion between females with gonads in regressed stage and those of adult males (see Arocha 1997).

Overall swordfish size is centered between 110 and 150 cm LJFL, and the majority of the swordfish catch is between 100 and 170 cm LJFL (**Figure 2**). The size data was not normally distributed (KSL test, $D = 0.080$, $p < 0.0100$). The Welch's ANOVA test revealed that swordfish size data were significantly different between years (Welch's test, $F = 20.76$, $df = 29$, $p < 0.0001$). The overall size distribution showed a relatively stable annual trend from the early period through 1998, thereafter the trend in size increased through to 2003. After, the trend oscillated downward until the most recent years when it increased to sizes around 150 cm LJFL (**Figure 3**). The seasonal (monthly) trend in swordfish sizes did not show any strong variations, it varied between 130 and 140 cm LFJL (**Figure 3**). However, the Welch's ANOVA test also showed that swordfish size data were significantly different between months (Welch's test, $F = 11.48$, $df = 11$, $p < 0.0001$).

Sex specific size distributions of swordfish show marked variations between them (**Figure 4**). The Welch's ANOVA test indicated that swordfish size data were significantly different between sex (Welch's test, $F = 263.30$, $df = 2$, $p < 0.0001$), where females sizes were higher, although an important number were similar to the largest volume of size in males (120 cm LJFL). The elevated density of unsexed swordfish sizes was between 90 and 120 cm LJFL, mostly juvenile fish.

Annual trend in the size distribution of female and male swordfish varied, in females the trend in sizes oscillated around 130 and 160 cm LJFL between years; that of males was relatively stable across all years with small increases and decreases after 2002 (**Figure 5**). The monthly trend in sex specific size distributions was relatively stable in both sexes (Figure 5), size varied between 130 and 145 cm LJFL.

Target vs non-target fishery

Swordfish size caught when there was a directed fishery (between 1987 and 1999) varied with the fish caught as by catch after 2000. The Welch's ANOVA test showed that swordfish size data were significantly different between periods of target *vs* non-target fishery (Welch's test, $F = 270.85$, $df = 1$, $p < 0.0001$). At-sea observer coverage was relatively evenly distributed between tuna target and swordfish target trips between 1991 and 1999 (**Figure 6**), thereafter the fishery became a tuna target fishery, and swordfish a by-catch.

Sex specific size distribution across years of swordfish between the target and no-target period varied, female and male sizes remained stable across years during the target period (**Figure 7**). In the non-target period, female sizes increased over time during the first part through to 2006, thereafter it oscillated; while male sizes remained relatively stable across years with little variations in size.

Seasonal size variations of female and male swordfish between the target and no-target period were more evident than across years (**Figure 7**). During the target period, female sizes were more stable than males, which showed a smooth progressive decline in sizes over months; while female and male sizes were equally stable during the non-target period, but mean sizes were slightly higher in both sexes during this period.

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Table 1. Descriptive statistics of swordfish size data caught by the Venezuelan pelagic longline fishery during the period of 1987-2016 and recorded from Venezuelan at-sea observer programs.

	FEMALES					MALES					UNK				
	Mean	**SE**	**LJFL min**	**LJFL max**	**n**	**Mean**	**SE**	**LJFL min**	**LJFL max**	**n**	**Mean**	**SE**	**LJFL min**	**LJFL max**	**n**
1987	197,0	19,00	178	216	2	130,8	10,20	84	198	13	79,0	.	79	79	1
1988	100,0	.	100	100	1	121,3	10,32	64	242	18	91,0	.	91	91	1
1989	131,6	6,02	88	227	32	124,5	5,84	93	187	16	122,2	35,88	74	188	14
1990	129,0	.	129	129	1	132,8	8,99	110	154	4	86,8	17,95	69	118	8
1991	138,1	3,37	82	241	90	120,6	3,15	80	169	53	96,3	16,34	70	138	29
1992	139,0	1,38	79	285	632	125,9	1,26	74	278	445	97,0	21,51	68	164	45
1993	131,3	1,39	69	260	601	120,5	1,23	68	208	420	83,8	19,56	44	148	36
1994	141,2	1,96	74	300	344	125,6	1,51	66	205	226	102,5	32,26	58	175	26
1995	146,1	2,04	59	295	330	124,0	1,46	76	198	245	122,5	34,59	62	223	95
1996	144,0	1,96	49	266	378	120,6	1,76	43	194	255	108,5	30,64	43	195	109
1997	136,5	1,46	69	258	540	127,9	1,30	62	227	548	107,4	35,84	57	222	51
1998	134,2	1,52	70	252	369	126,2	1,15	60	246	468	84,3	25,06	60	133	8
1999	143,3	2,55	68	267	153	132,6	1,59	76	237	217	123,2	21,52	89	143	5
2000	139,4	1,62	56	272	331	134,7	1,32	70	250	281	89,3	30,06	43	131	6
2001	144,0	1,45	75	243	235	140,9	1,07	103	198	314	142,4	11,12	127	156	8
2002	154,7	1,52	83	228	282	145,6	1,52	74	236	265	150,3	27,90	113	189	14
2003	166,5	9,48	65	224	18	160,6	9,47	101	286	24	110,0	.	110	110	1
2004	159,2	4,74	90	266	70	145,0	2,33	110	250	83	88,0	16,97	76	100	2
2005	143,9	5,34	102	280	51	134,4	2,16	110	199	74	70,0	.	70	70	1
2006	158,8	10,46	105	250	16	147,0	5,18	97	254	38	72,0	.	72	72	1
2007	143,0	3,98	104	215	35	138,9	2,64	115	188	39	111,9	24,96	90	163	7
2008	135,7	4,99	120	148	6	134,0	29,00	105	163	2	86,7	23,01	64	110	3
2009	142,4	4,05	128	156	7	140,3	6,44	132	153	3	99,0	.	99	99	1
2010	142,8	8,88	102	232	13	141,6	5,37	98	166	12	-	-	-	-	-
2011	147,4	6,55	126	173	7	132,7	10,65	92	168	9	124,5	19,68	100	170	11
2012	122,3	16,80	81	161	4	124,9	7,39	76	161	11	120,3	31,12	73	199	40
2013	-	-	-	-	-	137,0	27,00	110	164	2	96,8	28,19	41	196	30
2014	-	-	-	-	-	136,5	14,68	70	211	11	114,8	40,88	59	216	26
2015	145,8	16,07	118	189	4	149,0	15,48	107	201	6	145,0	59,22	57	222	6
2016	171,0	7,12	97	223	25	145,7	7,96	98	201	18	142,6	36,04	72	222	45
All years	**140,5**	**0,50**	**49**	**300**	**4577**	**129,8**	**0,42**	**43**	**286**	**4120**	**111,7**	**34,45**	**41**	**223**	**630**

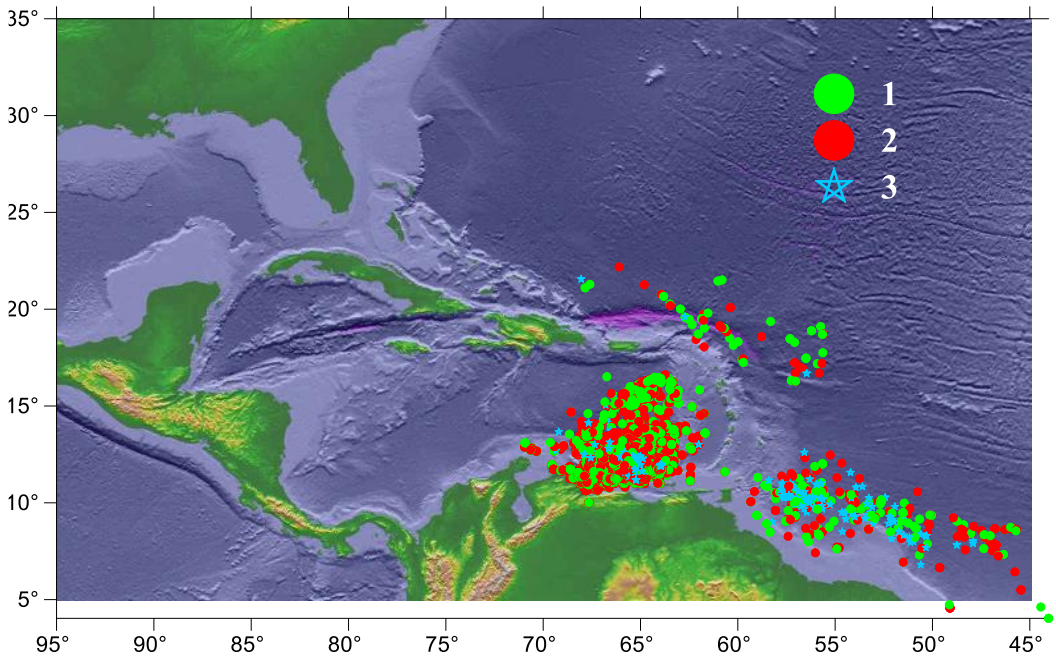

Figure 1. Spatial distribution of swordfish caught by the Venezuelan pelagic longline fishery during the period of 1987-2016, with recorded information on size, and sex identification (1:males; 2:Females; 3:unknown sex).

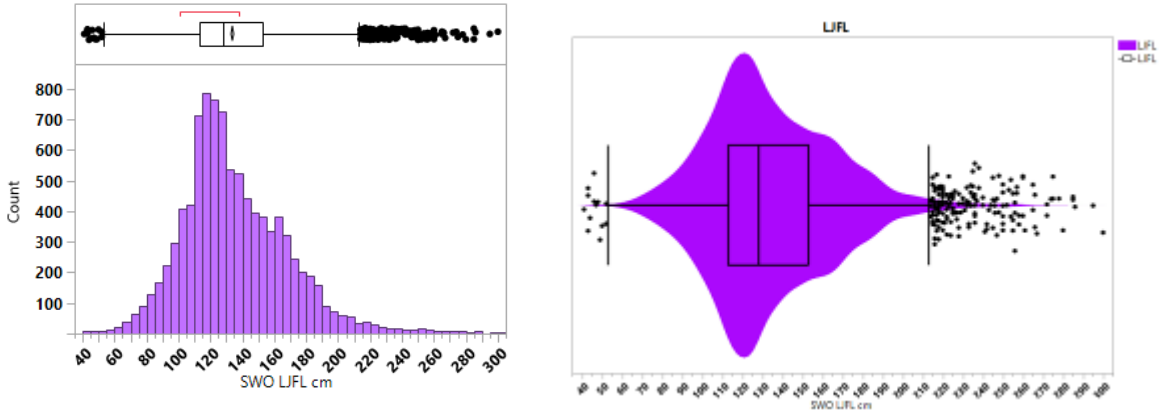

Figure 2. Overall size distribution of swordfish; left, size frequency distribution; right, density distribution of swordfish sizes, the median size of swordfish, its interquartile range, its 10th and 90th percentiles, and outliers.

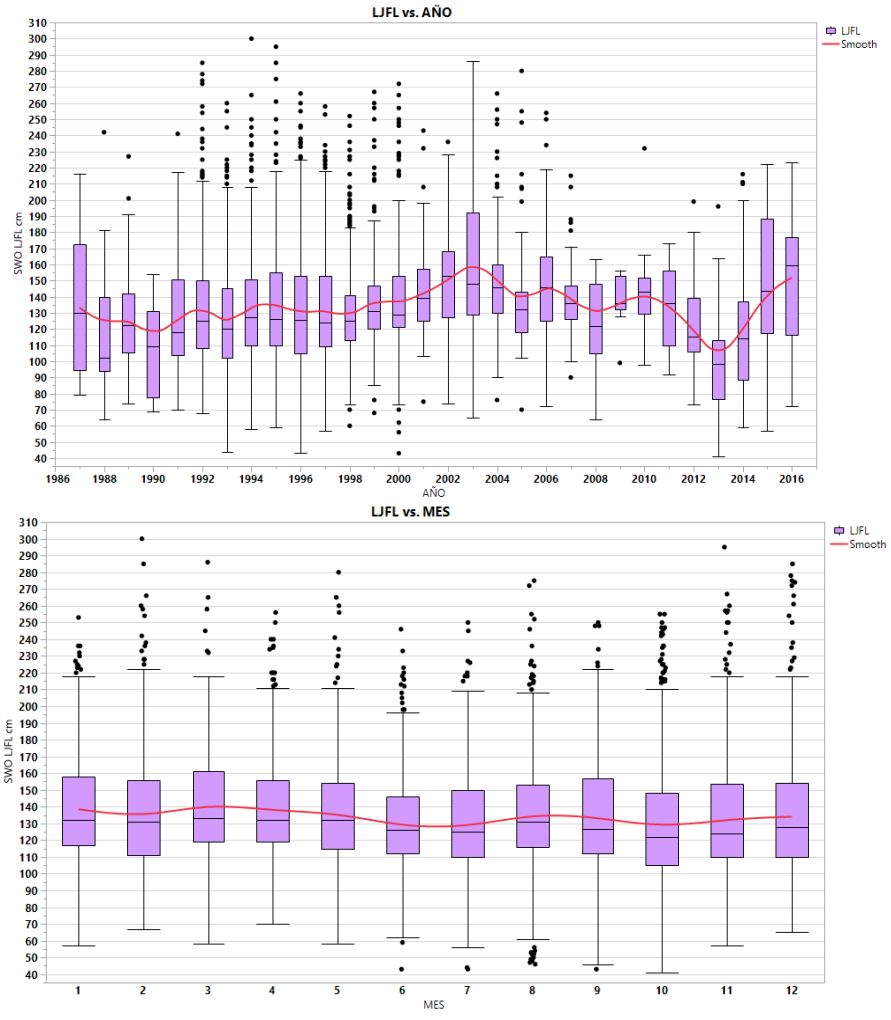

Figure 3. Annual and seasonal (monthly) size distribution analyses showing box-plots for the effect of changes in time on the median size of swordfish, its interquartile range, its 10th and 90th percentiles, and outliers. The smooth line (red) trend represents a *lamba* of 0.5.

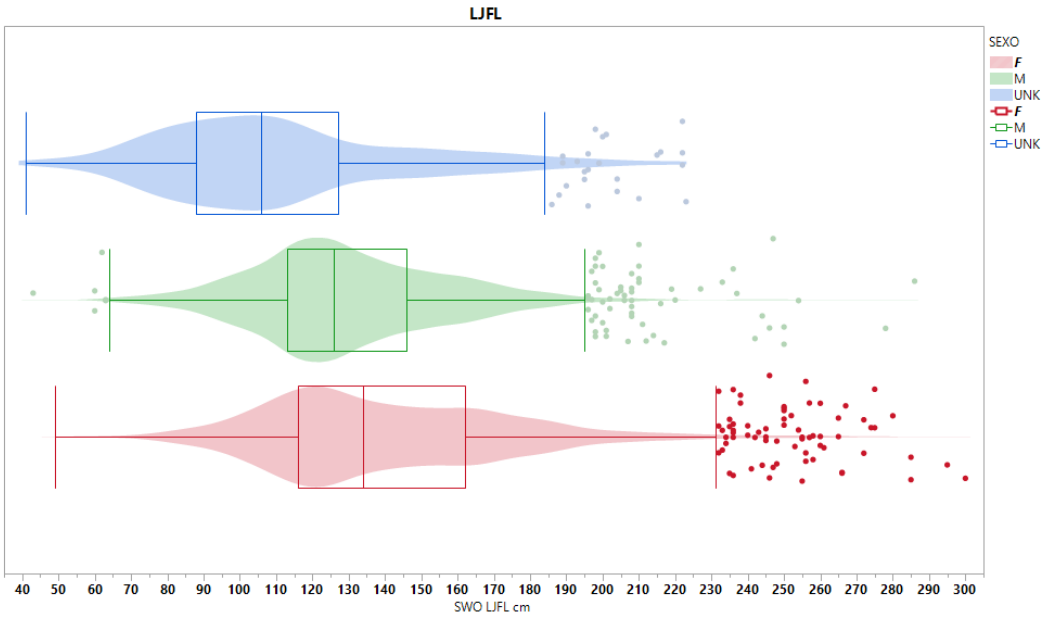

Figure 4. Overall size distribution (density plots) of male (green), female (red), and unsexed (blue) swordfish recorded by the at-sea observer programs in the Venezuelan pelagic longline fishery during the period of 1987-2016.

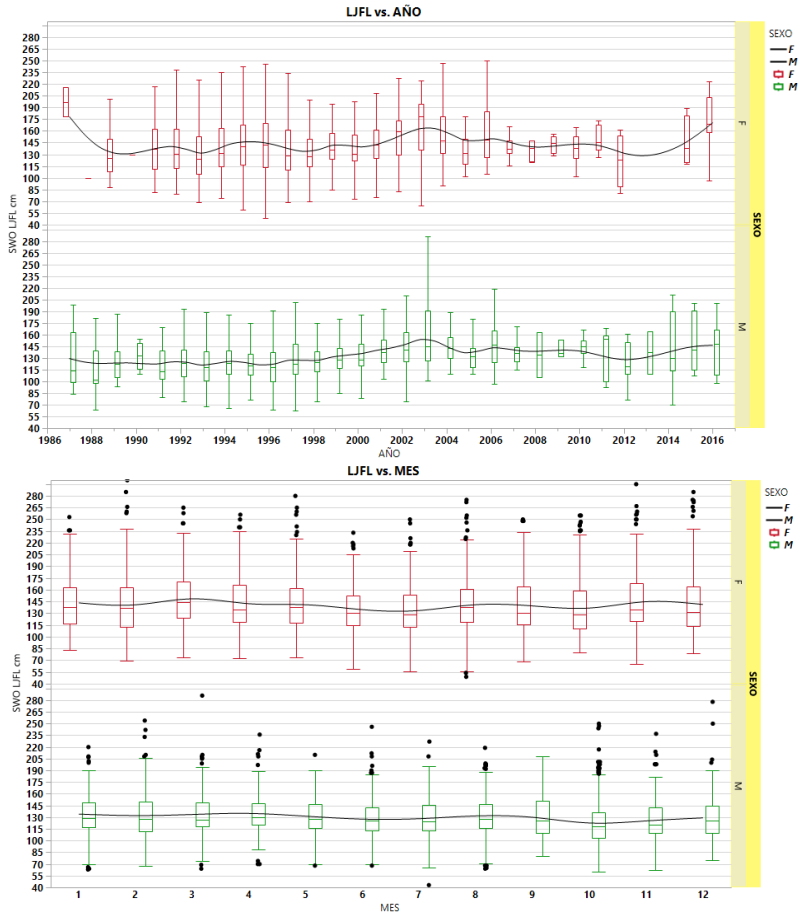

Figure 5. Annual and seasonal (monthly) size distribution analyses showing box-plots for the effect of changes in time on the median size of female and male swordfish, its interquartile range, its 10th and 90th percentiles, and outliers. The smooth line (red) trend represents a *lamba* of 0.5.

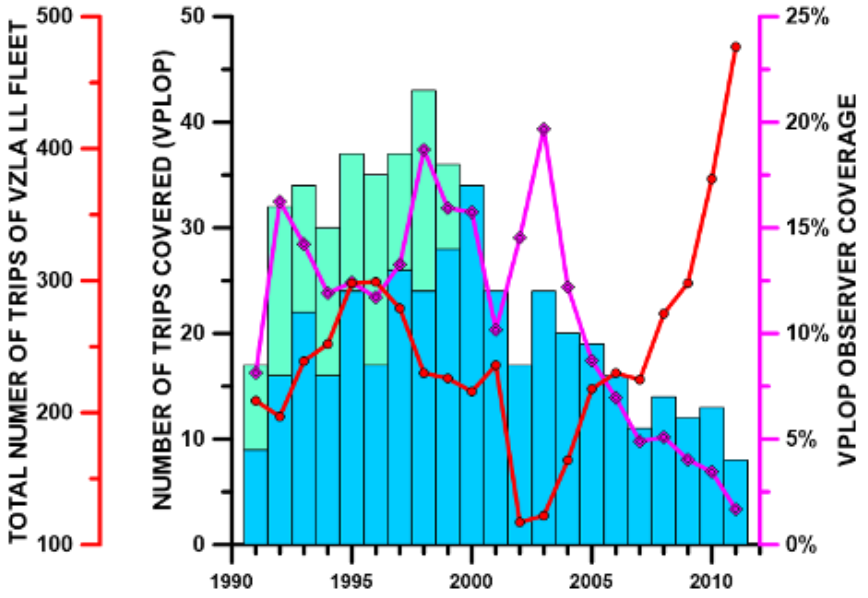

Figure 6. Distribution of observed longline trips made by the ICCAT sponsored Billfish Program in Venezuela during 1991-2011. The green bars represent SWO target trips and blue bars represent TUN target trips. The red line represents the total number of trips made by the Venezuelan LL fleet in a given year, and the magenta line represents the observer coverage of trips made in a given year.

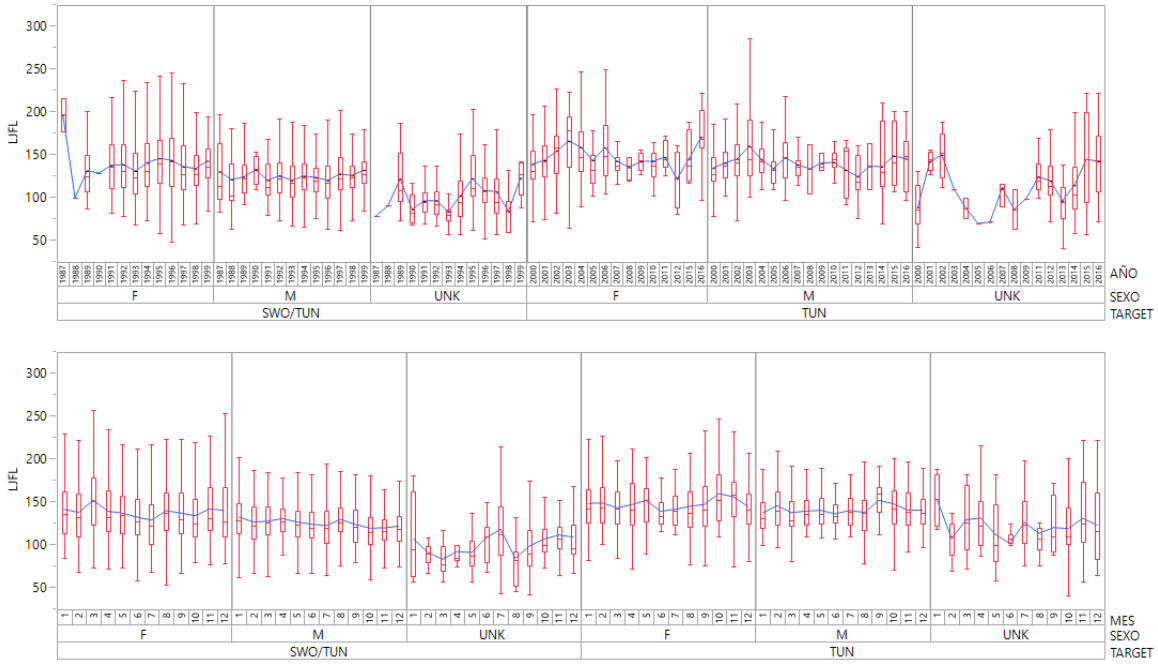

Figure 7. Annual and seasonal (monthly) size distribution analyses showing box-plots for the effect of changes in time on the median size of female, male, and unsexed swordfish, its interquartile range, its 10th and 90th percentiles, and outliers, in the target vs non-target time period. The blue line connects mean of each time period.