SCIENTIFIC COMMITTEE
FOURTH REGULAR SESSION

11-22 August 2008
Port Moresby, Papua New Guinea

STANDARDIZED CATCH RATES IN BIOMASS FOR THE SOUTH CENTRAL AND WESTERN PACIFIC SWORDFISH (*Xiphias gladius*) FROM THE SPANISH LONGLINE FLEET FOR THE PERIOD 2004-2006

WCPFC-SC4-2008/SA-WP-5

J. Mejuto[1], B. García-Cortés & A. Ramos-Cartelle [1]

[1] Instituto Español de Oceanografía, P.O. Box. 130, 15080 A Coruña. Spain.

ABSTRACT

Standardized catch rates in weight were obtained using General Linear Modeling (GLM) from sets carried out by the Spanish surface longline fleet targeting swordfish in the South central and South western Pacific areas during the 2004-2006 period. Year, quarter, area, ratio between swordfish and blue shark species and gear were used for modeling. The model tested explained 75% of CPUE variability. As in the case of the Atlantic, most of the CPUE variability was attributed to the ratio between the two species and secondly, to the gear factor. Other significant, although less important factors were quarter and area and the interaction between the two, while the year was considered the least important of all the factors examined during this period. The time period covered is too short to be able to lead to any conclusions on the standardized CPUE trend, but the results suggest that activity was stable during the Spanish fleet's initial period of operation in these regions.

Key words: swordfish, CPUE, GLM, longline, Spanish fleet.

1. INTRODUCTION.

Catch per unit of effort data from commercial fleets have frequently been used as abundance indices in a great deal of fisheries targeting large pelagic species. The lack of available indicators from direct fishery covering broad fishing areas has made the CPUE from commercial fleets a reliable indicator of abundance in most large pelagic species. However, this interpretation may not necessarily be assumed 'a priori'. These indicators must be evaluated case by case, based on the empirical knowledge of the fishery, area-time coverage in relation to stock distribution, taking into account the limits and risks that are involved in this assumption (Mejuto *et al*., 1999). The consistency in the fishing patterns of the fleets over time facilitates the interpretation of these indices. Important changes in the fishing strategy of the traditional Spanish longline fleet in the Atlantic areas have been observed and reported in recent years (Mejuto *et al*., 1997; Mejuto & De la Serna, 1997, Mejuto *et al*., 1998; Mejuto *et al*., 1999). However, access to the fishing areas in regions within or around the WCPFC is very recent, starting in 2004 and fishing is done mostly with the monofilament "American style"gear. The Spanish surface longline fleet targeting swordfish have historically used similar hooks per basket because the fishing activity covers only the surface layers, usually above 50 m depth, with night sets. Other longline activities carried out by vessels flying other flags, targeting mostly tunas or having a mixed fishing strategy, may change the number of hooks per basket (or between buoys) and the hours of fishing operations depending on the targeted species. In such case, hooks per basket or between buoys, or other factors could help in CPUE modeling.

The Generalized Linear Modeling technique (GLM) (Robson, 1966; Gavaris, 1980; Kimura, 1981) is traditionally used as a tool to estimate standardized catch rates based on data from commercial fleets with unbalanced spatial and temporal activity. The standardized catch rates of the Atlantic swordfish were obtained in the recent decades on a routine basis by means of GLM based on data from commercial fleets, some of which targeted this species while others did not (Hoey *et al*., 1989; Anonymous, 1989; Anonymous, 1991; Hoey *et al*., 1993; Nakano, 1993; Mejuto, 1993; Scott *et al*., 1993; Mejuto, 1994; Mejuto & de la Serna, 1995, Mejuto *et al*., 1999). This has become a basic routine task in the assessment of stocks within the scientific dynamics of the ICCAT and other RFOs. The activity of the Spanish fleet in the Pacific regions has been carried out since 1990, mostly in the Eastern regions (Mejuto *et al*., 2007). Its progressive geographical expansion towards new South central and western zones has resulted in an increase in the number of observations by spatial-temporal cell with the passing of time, including the recent access to WCPFC regions. However, the very recent access to the Western-Central Pacific areas does not allow for a representative time series and assessments should be based principally on other fleet indicators with a more extensive fishing history in these areas.

2. MATERIAL AND METHODS.

The methodology used was based on previous works carried out on the Spanish longline fleet in the Atlantic and used in the CPUE analysis of the Spanish as well as other Atlantic longline fleets (Mejuto & De la Serna, 2000; Ortiz, 2007). The data used consisted of scientific records obtained under research projects, covering the period 2004-2006. Data from 2007 are incomplete so far, and have not been included in this analysis. Following the traditional criteria, nominal effort was defined by thousands of hooks set. The nominal CPUE was calculated as kilograms of dressed weight caught per thousand hooks. Two types of gear were categorized, the monofilament or 'American style' and a traditional gear. Data on blue shark catches in dressed weight were also used. The variable 'ratio' was defined as the percentage of swordfish related to both the swordfish and blue shark caught. After analyzing the behavior of the Spanish fleet in different oceans, it was concluded that this ratio might be a good proxy indicator of target intensity mainly directed towards swordfish vs. a more diffuse activity aimed at the two main species combined (Anonymous, 2001). The ratio values were categorized into ten 'ratio' levels of 10% intervals for modeling.

The spatial definition for GLM runs considered regions 45, 46 and 47 (figure 1). The temporal definition corresponding to 'quarters' was: Q1 = January, February, March; Q2 = April, May, June; Q3 = July, August, September; Q4 = October, November, December.

The surface longline gear of the Spanish fleet in the Atlantic has remained relatively constant over few decades in terms of general structure and configuration (Rey *et al*., 1988; Hoey *et al*., 1988). However, there have been some technological improvements in the traditional fishing gear over this period within Atlantic ocean. The most common improvements consisted of introducing new elements in order to make it easier to carry out handling, involving setting out and hauling back the fishing gear. These improvements tended to allow for a greater number of hooks per set which were appropriately considered as nominal effort in the Atlantic analysis. However, in more recent years, the monofilament units or so call "American style" were largely introduced in most fishing areas of the Atlantic, Indian and Pacific oceans.

The standardized log CPUE analyses were done using the GLM procedure (*SAS 9.1*). The model defined includes 'year', 'quarter', 'area', 'ratio' and 'gear' as the main effects. As in the case of several fleets operating in the Atlantic Ocean, the ratio was considered an indirect indicator of 'target intensity' or of the fishing criteria of the skipper during the fishing activity: $LOG(CPUE) = u + Y + Q + A + R + G + A*Q + e$. Where, u = overall mean, Y= effect year, Q =effect time, A =effect area, R= effect ratio, G = effect gear, e = logarithm of the normally distributed error term.

3. RESULTS AND DISCUSSION

A total of 2,472 set records were available for this short period 2004-2006, for the 3 areas and 4 quarters considered. The very recent access of the Spanish fleet to South central-western Pacific areas constrained the availability of observations by areas-quarters. So, some of these cells are not properly represented (table 1).These spatial-temporal limitations are often observed in data from most of the oceanic longline fleets, especially during new entries in fishing areas, geographical expansion periods or shifts to other fishing areas. Area 46 included in this analysis covers straddling observations between WCPFC and IATTC convention areas. However, the whole area has similar thermal conditions, with the fish having similar biological characteristics and an apparent continuity in fish distribution.

The ANOVA summary, including R-square, mean square error (root), F statistics and significance level, is also provided (table 2). The model tested explained 75% of CPUE variability. Most of the CPUE variability (Type III SS) may be attributed to the ratio and, secondly, to the gear factor. The quarter and area factors and the interaction between the two are also significant, although less important. The year factor was considered the least important of all factors examined during this short period.

The great importance of the 'ratio' factor among the different species retained onboard was described in the some of the most important oceanic longline fleets fishing in the North and South Atlantic areas and these ratios have been used for modeling (Chang *et al*., 2007; Hazin *et al*., 2007; Mejuto & De la Serna, 2000; Mourato *et al*., 2007; Ortiz, 2007; Ortiz *et al*., 2007; Paul & Neilson, 2007; Yokawa, 2007). The Working Group on Stock Assessment Methods of the International Commission for the Conservation of the Atlantic Tunas (ICCAT) have recently review this matter. Of the different proxy methods simulated by the Working Group the use of catch ratios was found to perform best, on average, and remained the preferred proxy, although this method may not necessarily provide the best performance in all cases (Anonymous, 2001). The inclusion of this factor in the modeling has improved the fit levels and CPUE interpretation as an abundance index in many fisheries when changes in the fishing strategy or other skipper's factors are detected. The importance of the ratio versus other factors in the Spanish longline fleet fishing in the Atlantic was previously studied and explained based on micro-scale area shifts among trips-sets or undetectable shifts in the fishing practices and the respective local prevalence of the two most prevalent species in the catch (Mejuto & De la Serna, 2000). Both species frequently overlap in their areas of distribution, but their respective maximum local abundance are probably not coincident or even their maximum are mutually exclusive. The low CPUEs of swordfish were regularly observed in the Atlantic associated with high rates of blue shark bycatch. In contrast, high swordfish CPUEs were typically related to low rates of blue shark bycatch. This assumption is not surprising since in different Atlantic areas and fleets fishermen have frequently reported that the optimal CPUEs of swordfish and blue shark rarely coincide in space and time. This may be due to different reasons, such as the spatial-temporal exclusion between the maximum of two species and/or the different ranges of optimum temperatures-behavior sought by each of them for their respective biological processes in the epipelagic layers.

Table 3 presents information on estimated parameters, their standard error, relative CPUEs and upper and lower 95% confidence limits obtained by year. The CPUE trends by year and standardized residual pattern are plotted in figure 2. The time period covered is too short to be able to lead to any conclusions on the standardized CPUE trend, but the results suggest that activity was stable during the Spanish fleet's initial period of operation in these regions.

ACKNOWLEDGMENTS.

The authors would like to give their deepest thanks to all the members of the indefatigable team who were involved in the scientific recording and processing the basic data. Without the help of qualified and dedicated people such as I. González, M. Quintans, E. Alot, M. Marin, E. Majuelos, J.L. González, A. Carroceda, J.L. Cebrian, M. Quinzan, to name only a few, this paper would not have been possible. We would also like to thank the scientific observers and skippers involved in this scientific collaboration. This research was carried out exclusively with funds and staff from the project SWOATL0710 of the Spanish Institute of Oceanography (IEO).

LITERATURE CITED.

ANONYMOUS , 1989. Second ICCAT Swordfish Workshop. ICCAT. Col. Vol. Sci. Pap. Vol. XXIX: 71- 162.

ANONYMOUS, 1991. Informe del período bienal 1990-1991. I part. ICCAT.

ANONYMOUS, 2001. Report of the ICCAT working group on stock assessment methods *(Madrid, Spain - May 8 to 11, 2000*). Col. Vol. Sci. Pap. Vol. 52(5): 1569-1662.

CHANG S.-K.I, H.-H. LEE; H.I. LIU, 2007. Standardization of south Atlantic swordfish by-catch rate for Taiwanese longline fleet. ICCAT Col. Vol. Sci. Pap. Vol. 60(6): 1974-1985.

GAVARIS, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37: 2272-2275.

HAZIN, H. G., F. HAZIN, P. TRAVASSOS,F. C. CARVALHO, K. ERZINI, 2007. Fishing strategy and target species of the Brazilian tuna longline fishery, from 1978 to 2005,inferred from cluster analysis. ICCAT Col. Vol. Sci. Pap. Vol. 60(6): 2029-2038.

HOEY, J., J. MEJUTO, S. IGLESIAS, R. CONSER , 1988. A comparative study of the United States and Spanish longline fleet targeting swordfish in the Atlantic Ocean, north of 40º latitude. ICCAT. Col. Vol. Sci. Pap. Vol. 27: 230-239.

HOEY, J; J. MEJUTO; R. CONSER, 1989. CPUE indices derived from combined Spanish and U.S. catch and effort data. ICCAT. Col. Vol. Sci. Pap. Vol. 29: 228-249.

HOEY, J., J.; J. MEJUTO; J. PORTER; Y.UOZUMI, 1993. A standardized biomass index of abundance for north Atlantic swordfish. ICCAT Col. Vol. Sci. Pap. Vol 40(1):344-352.

KIMURA, D. K., 1981. Standardized measures of relative abundance based on modeling log (CPUE) and their application to Pacific Ocean Perch. J. Cons. Int. Explor. Mer. 39: 211-218.

MEJUTO, J. , 1993. Age specific standardized indices of abundance for Swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, 1983-1991. ICCAT Col. Vol. Sci. Pap. Vol. 40(1):371-392.

MEJUTO, J. , 1994. Standardized indices of abundance at age for Swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, 1983-1992. ICCAT Col. Vol. Sci. Pap. Vol. 42(1):328-334.

MEJUTO, J., B. GARCÍA-CORTÉS, A. RAMOS-CARTELLE, J. ARIZ, 2007. Preliminary overall estimations of bycatch landed by the Spanish surface longline fleet targeting swordfish (*Xiphias gladius*) in the Pacific Ocean and interaction with marine turtles and sea birds: years 1990-2005. IATTC Working Group on Bycatch 6th Meeting. La Jolla, California (USA) 9-10 February 2007 Document ByC-6-INF A.

MEJUTO, J. B. GARCÍA, J. M. de la SERNA, 1997. Activity of the Spanish surface longline fleet catching swordfish (*Xiphias gladius*) in the Atlantic, years 1994 and 1995.. ICCAT Col. Vol. Sci. Pap. Vol. 46(3):308-310.

MEJUTO, J., J.M. de la SERNA, 1995. Standardized catch rates by age and length groups for swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, 1983-93. ICCAT Col. Vol. Sci. Pap. Vol. 19(3):114-125.

MEJUTO, J., J.M. de la SERNA, 1997. Updated standardized catch rates by age for swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, using commercial trips from the period 1983-1995. ICCAT Col. Vol. Sci. Pap. Vol. 46(3):323-335.

MEJUTO, J., J.M. de la SERNA , 2000. Standardized catch rates by age and biomass for the North Atlantic swordfish (*Xiphias gladius*) from the Spanish longline fleet for the period 1983-1998 and bias produced by changes in the fishing strategy. ICCAT. Col. Vol. Sci. Pap. Vol. 51(5): 1387-1410.

MEJUTO, J. J.M. de la SERNA, B. GARCÍA, 1998. Updated standardized catch rates by age, sexes combined, for the swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, for the period 1983-1996. ICCAT Col. Vol. Sci. Pap. Vol. 48(1):216-222.

MEJUTO, J. J.M. de la SERNA, B. GARCÍA, 1999. Updated standardized catch rates by age, combined sexes, for the swordfish (*Xiphias gladius*) from the Spanish longline fleet in the Atlantic, for the period 1983-1997. ICCAT Col. Vol. Sci. Pap. Vol. 49(1): 439-448.

MOURATO B.L.; H. A. ANDRADE; A. F. AMORIM; C. A. ARFELLI, 2007. Standardized catch rate of swordfish (X*iphias gladius*) caught by Santos longliners off southern brazil (1971-2005) ICCAT Col. Vol. Sci. Pap. Vol. 60(6): 1943-1952.

NAKANO, H., 1993. Estimation of standardized CPUE for the Atlantic swordfish using the data from the Japanese longline fishery. ICCAT Col. Vol. Sci. Pap. Vol. 40(1):357-370.

ORTIZ. M., 2007. Update of standardized catch rates by sex and age for swordfish (X*iphias gladius*) from the U.S. longline fleet 1981-2005. ICCAT Col. Vol. Sci. Pap. Vol. 60(6): 1994-2017.

ORTIZ, M., J. MEJUTO, S. PAUL, K. YOKAWA, M. NEVES, J. HOEY, 2007. An updated biomass index of abundance for North Atlantic swordfish 1963-2005. ICCAT Col. Vol. Sci. Pap. Vol. 60(6): 2048-2058.

PAUL, S. D., J.D. NEILSON, 2007. Updated sex- and age-specific CPUE from the Canadian swordfish longline fishery, 1988-2005. ICCAT. Col. Vol. Sci. Pap. Vol. 60(6): 1914-1942.

REY, J. C., J. MEJUTO, S. IGLESIAS, 1988. Evolución histórica y situación actual de la pesquería de pez espada (*Xiphias gladius*). ICCAT. Col. Vol. Sci. Pap. Vol. 27: 202-213.

ROBSON, D. S., 1966. Estimation of relative fishing power of individual ships. Res. Bull. Int. Comm. N.W. Atl. Fish, 3: 5-14.

SCOTT, G.P.; V.R. RESTREPO; A. BERTOLINO, 1993. Standardized catch rates for swordfish (*Xiphias gladius*) from the U.S. longline fleet though 1991. ICCAT Col: Vol. Sci. Pap. Vol, 40(1):458-468.

YOKAWA, K., 2007. Update of standardized CPUE of swordfish caught by Japanese longliners. ICCAT Col. Vol. Sci. Pap. Vol. 60(6): 1986-1993.

Table 1. Number of observations per cell used in the GLM analysis, for the period 2004-2006. Areas (45, 46 ,47), quarters (1-4) and year-ratio (1-10).

FREQ

AREA- QTR

YR=2004

Area / Freq (QTR)	1	2	3	4	Total
45	0	284	54	0	338
46	0	0	20	388	408
47	0	0	258	285	543
Total	0	284	332	673	1289

YR=2005

Area / Freq (QTR)	1	2	3	4	Total
45	8	7	0	3	18
46	243	5	21	6	275
47	122	58	79	67	326
Total	373	70	100	76	619

YR=2006

Area / Freq (QTR)	1	2	3	4	Total
45	0	0	0	17	17
46	21	0	42	124	187
47	50	2	116	192	360
Total	71	2	158	333	564

YR -RATIO

YR / Freq (ratio)	1	2	3	4	5	Total
2004	28	58	54	59	111	1289
2005	2	11	14	24	49	619
2006	2	12	14	25	27	564
Total	32	81	82	108	187	2472

Tabla de YR por ratio

YR / Freq (ratio)	6	7	8	9	10	Total
2004	104	154	157	234	330	1289
2005	68	84	111	145	111	619
2006	32	40	65	99	248	564
Total	204	278	333	478	689	2472

Table 2. Summary of the ANOVA results. The model includes factors: year, area, quarter, ratio, gear, area*quarter.

Proc. GLM SW & SC PACIFIC LL SWO, CPUE bio Kg. Mod: YR QT AR RAT GEAR AR*QT
Areas: 45, 46, 47.
Variable dependiente: cpue.

Fuente	DF	Suma de cuadrados	Cuadrado de la media	F-Valor	Pr > F
Modelo	23	1939.451448	84.323976	321.62	<.0001
Error	2448	641.838007	0.262189		
Total correcto	2471	2581.289455			

R-cuadrado	Coef Var	Root MSE	cpue Media
0.751350	8.552652	0.512044	5.986958

Fuente	DF	Tipo I SS	Cuadrado de la media	F-Valor	Pr > F
YR	2	106.6547744	53.3273872	203.39	<.0001
QTR	3	696.1488045	232.0496015	885.05	<.0001
area	2	219.7137182	109.8568591	419.00	<.0001
ratio	9	672.7751783	74.7527976	285.11	<.0001
GEAR	1	173.2993879	173.2993879	660.97	<.0001
QTR*area	6	70.8595846	11.8099308	45.04	<.0001

Fuente	DF	Tipo II SS	Cuadrado de la media	F-Valor	Pr > F
YR	2	2.9305010	1.4652505	5.59	0.0038
QTR	3	17.7453540	5.9151180	22.56	<.0001
area	2	242.7373431	121.3686716	462.91	<.0001
ratio	9	685.6164135	76.1796015	290.55	<.0001
GEAR	1	109.6391302	109.6391302	418.17	<.0001
QTR*area	6	70.8595846	11.8099308	45.04	<.0001

Fuente	DF	Tipo III SS	Cuadrado de la media	F-Valor	Pr > F
YR	2	2.9305010	1.4652505	5.59	0.0038
QTR	3	64.7181563	21.5727188	82.28	<.0001
area	2	74.9708906	37.4854453	142.97	<.0001
ratio	9	685.6164135	76.1796015	290.55	<.0001
GEAR	1	109.6391302	109.6391302	418.17	<.0001
QTR*area	6	70.8595846	11.8099308	45.04	<.0001

Table 3. Estimated parameters, standard error, relative CPUE and upper and lower 95% confidence limits. Regions 45, 46 and 47, years 2004-2006.

Proc. GLM SW & SC PACIFIC LL SWO, CPUE bio Kg. Mod: YR QT AR RAT GEAR AR*QT

YR	LSMEAN	STDERR	ucpu	cpue	lcpu
2004	5.16689	0.038926	189.415	175.501	162.609
2005	5.10994	0.040398	179.457	165.796	153.174
2006	5.06832	0.039082	171.688	159.028	147.301

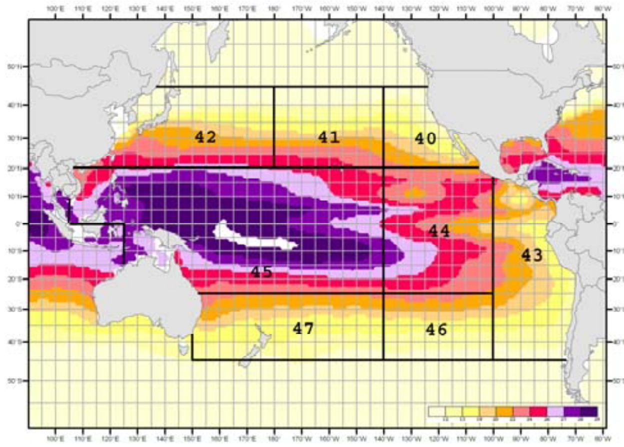

Figure 1. Area definition for all the Pacific regions, taking into consideration the thermal structure at 50 m depth. Only areas 45, 46 and 47 were included in the analysis.

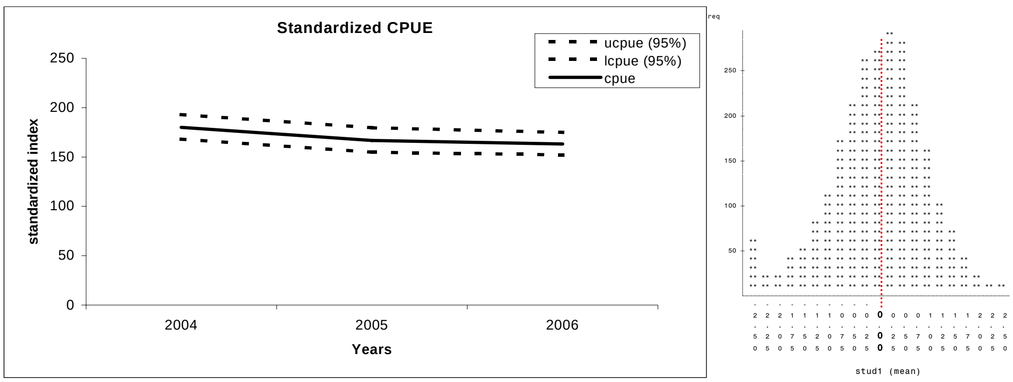

Figure 2. Annual change in the standardized catch rates in weight and 95% confidence intervals obtained for the period 2004-2006 (left panel) and standardized residuals (right panel).