SCRS/2001/048 Col.Vol.Sci.Pap. ICCAT, 54 (4): 1132-1149. (2002)

# SIZE-WEIGHT RELATIONSHIPS OF THE SWORDFISH (*Xiphias gladius)* AND SEVERAL PELAGIC SHARK SPECIES CAUGHT IN THE SPANISH SURFACE LONGLINE FISHERY IN THE ATLANTIC, INDIAN AND PACIFIC OCEANS

B. García-Cortés & J. Mejuto[1]

*SUMMARY*

*A total of 5096 observations of the standard size-dressed weight of different species were carried out by scientific observers on board Spanish longline fishing vessels primarily targeting the swordfish (Xiphias gladius) in different oceans. As a consequence of this activity, large pelagic shark species (Prionace glauca, Isurus oxyrhinchus, Carcharhinus falciformis, Carcharhinus longimanus, Alopias superciliosus, Sphyrna lewini, Sphyrna zygaena, etc.) may also be caught. A total of 1245 observations of swordfish and 3851 of large pelagic sharks were finally used in order to obtain the standard size-dressed weight relationships using non-linear regression analyses. General Linear Model (GLM) was used to determine the significance of the sex and/or area variables in the definitions of the size-weight relationships.*

*RÉSUMÉ*

*Les observateurs scientifiques à bord de palangriers espagnols visant principalement l'espadon (Xiphias gladius) dans les différents océans ont effectué en tout 5.096 observations sur la taille standard du poids manipulé de diverses espèces. Cette activité entraîne la capture éventuelle de grands requins pélagiques (Prionace glauca, Isurus oxyrhinchus, Carcharhinus falciformis, Carcharhinus longimanus, Alopias superciliosus, Sphyrna lewini, Sphyrna zygaena, etc.). On a utilisé 1.245 observations d'espadon et 3.851 de grands requins pélagiques pour obtenir la relation taille standard/poids manipulé au moyen d'analyses de régression non-linéaire. Le modèle linéaire généralisé (GLM) a servi à déterminer le sens des variables sexe et/ou zone dans la définition des rapports longueur/poids.*

*RESUMEN*

*Un total de 5096 observaciones de talla estándar-peso canal han sido obtenidas para diferentes especies por medio de observadores científicos a bordo de palangreros de superficie españoles que dirigen su actividad prioritariamente a la captura de pez espada (Xiphias gladius) en diferentes océanos. Como consecuencia de dicha actividad pueden ser tambien capturadas especies de grandes tiburones pelágicos (Prionace glauca, Isurus oxyrhinchus, Carcharhinus falciformis, Carcharhinus longimanus, Alopias superciliosus, Sphyrna lewini, Sphyrna zygaena etc.). Un total de 1245 observaciones de pez espada y 3851 de grandes tiburones pelágicos fueron analizadas finalmente para obtener relaciones talla estándar-peso canal utilizando regresiones no lineales. Test estadísticos basados en Modelos Lineales Generalizados (GLM) fueron usados para determinar la significación de las variables sexo y/o área en las definiciones de las relaciones talla-peso.*

## 1. INTRODUCTION

As a consequence of the swordfishing activity carried out by the Spanish surface longline fleet, other large pelagic species are also caught as a by-catch of this fishery (Castro et al. 2000). These species may occasionally turn into the target species of the fleet (bi-specific fishery in the North Atlantic: Swordfish and/or Blue Shark), although in other zones they are caught primarily as accessory species (in the South Atlantic, Indian and Pacific Oceans) (Mejuto & de la Serna, 2000). This by-catch of large pelagic sharks is comprised mainly of the blue shark (*Prionace glauca*), which is the most abundant species in number and biomass in many of the fishing zones, followed by the makos (*Isurus* spp.), group of C*archarhinus* spp., the thresher sharks (*Alopias* spp.) and the hammerhead sharks (*Sphyrna* spp.). These species have been the subject of study in groups pertaining to different International Commissions as well as National and International Scientific Groups.

[1]I.E.O. P.O. Box 130, 15080 La Coruña, España

Initially, the Spanish fleet of commercial surface longliners carried out or limited their activity to the Northeast Atlantic (stowing fish in round weight [RW]). Starting in the mid-1980's this fleet has gradually expanded geographically (Mejuto et al., 2000) towards new areas of the Atlantic (in the North: between 10º and 50º N, FAO 31-34-27; in the South from 5º N to 35º S, FAO 34-41-47) and, to a lesser extent, towards other oceans (Pacific, FAO87-77, and West Indian, FAO51). This has led to a change in the way fish are processed on board. Due to the long duration of the trips, they are now prepared in dressed weight to be stowed, frozen and marketed, which could present a problem in terms of achieving a wider sampling coverage.

Previous studies have presented standard size-total weight relationships for some pelagic sharks (Mejuto & González-Garcés, 1984; Kholer et al , 1995) and standard size-total weight and/or gutted weight for the swordfish (Mejuto et al., 1988; Mejuto & de la Serna, 1993; Skillman & Yong, 1974; Tsimenides & Tserpes, 1989). Therefore the aim of this paper is to present new standard size (LJFL or FL)-dressed weight (DW) relationships by spatial strata for swordfish and some species of pelagic sharks, which in addition to broadening the sampling coverage and providing the captains of the fleet with conversion tables, are necessary to be able to design the basic tasks and apply assessment models developed at the workshops of International Commissions.

Although the paired values were obtained over a broad period of time 1990-2000, this study should not be taken as complete or final. In some of the species/areas there are still very few observations, therefore the resulting standard size-dressed weight relationships should be considered as merely preliminary data.

## 2. MATERIAL AND METHODS

All the information compiled for the values of size-weight and sex of swordfish and large pelagic sharks has come from our On-board Observer Program started in 1990. Consequently, these data were obtained by scientific observers on board Spanish surface longline vessels targeting preferably the swordfish during their commercial fishery activities in the Atlantic, Pacific and Indian Oceans from 1990 to 2000. Data were also collected during Experimental Prospecting Expeditions that took place in the Indian and Pacific Oceans in zones and time periods when the activity of the Spanish surface longline fleet was sporadic.

Size was obtained by laying the fish out on the vessel floor and measuring them in a straight line to the lowest centimeter. The swordfish were measured from the lower jaw to the fork of the tail (LJFL, cm).The pelagic sharks were measured from the tip of the snout to the fork of the tail (FL, cm). Size was considered to be an independent variable. Processing on board consisted of emptying the body cavities and gills. The fins, tails and head were also removed. The resulting weight (dressed weight: DW, kg) was used as the dependent variable. Weight in kilograms was measured on board using scales with an accuracy of + - 500 g and/or 5-50 kg dynamometers (Kamoshita model). Therefore some errors associated with weight are to be expected. The sex was visually identified during dressing. Overall sex ratios males:females by species and areas were defined considering as 1.0 the less represented sex.

The paired values were initially classified by 5x5 degree squares, and later in 8 broader geographic areas (Fig. 1). In the Atlantic Ocean, the observations were finally classified into the following zones: Northeast Atlantic (NE), Tropical East Atlantic (TE), Tropical Central Atlantic (TC) and Southwest Atlantic (SW). The observations in the Pacific Ocean were classified as follows: North Pacific (PN) and South Pacific (PS). The data from the Indian Ocean (W1, W2) were finally grouped within an area called the West Indian Ocean.

The analyses did not take into account the "time" variable due to the small number of observations available in some cases. Therefore, the paired values obtained for the 1990-2000 period have been grouped for purposes of analysis.

The final analyses were performed using a total of 1245 swordfish (SWO) and 3851 pelagic sharks (SHK) representing 8 species: *Prionace glauca (*PGO), *Isurus oxyrinchus (*IOO), *Isurus paucus (*IPO), *Carcharhinus longimanus* (CLO), *Carcharhinus falciformis* (CFO), *Sphyrna lewini* (SLO), *Sphyrna zygaena* (SZO), *Alopias superciliosus* (ASO). Data were also collected on the genus *Sphyrna* although the species was not identified (SPO).

Since the variables "area" and "sex" were associated in each "size-weight" observation, a General Linear Model (GLM, Statgraphics *plus* vers. 4.1) was applied to test the statistical significance of the first two variables.

It was considered appropriate to use the potential function ($W=aL^b$, where *a* and *b* are constants) to define the relationship between "size" and "weight". Although the preliminary analyses used linear regression to fit the data, in the final analyses the data were fitted by means of non-linear regression (Marquardt's algorithm, Statgraphics *plus* vers. 4.1) to evaluate the goodness of fit and test the significance of the size-weight equations by species and area, since the observations were probably restricted or limited to small or medium sized individuals. Therefore, the number of observations per size class will probably not be evenly balanced. The behavior of the regression residuals was also examined (Draper & Smith, 1966). For each species/area there was a representation done of the residuals with respect to the dressed weight using the values *a* and *b* obtained in each case.

## 3. RESULTS AND DISCUSSION

Of the 5096 specimens observed, 16 SWO and 2158 SHK came from the Atlantic Ocean, 1229 SWO and 238 SHK from the Pacific and 1455 SHK from the Indian Ocean.

The total number of data obtained opportunistically over the course of each year are shown in Table 1 by species and area. In some cases very few observations were reported, so, if we were to include a temporal variable in the analyses, the result would probably be a small number of observations by area-time.

The sex of 99.4% of the SWO and 92.8% of the SHK was determined. A total of 99.6% of PGO and IOO specimens were sexed. The 90.7% of the CLO were also sexed, while it was 100% in the IPO, CFO, SZO and SLO. However sex was unable to be determined in any of the ASO specimens (Table 2). Thanks to the wide-ranging sex coverage in the sampling, it was possible to obtain the overall male:female sex-ratio by species and area (Table 3). However, these overall sex-ratios should not be used for comparative purposes between areas to explain the spatial segregation by sex, owing to the fact that the overall sex-ratio is conditioned by the sizes ranges available in the sampling of each area. An analysis of the sex-ratio by size (size and/or age ranges) would generally be more advisable for this purpose.

The minimum, maximum, and mean length by species examined in this study is reported (Tables 4(a), (b)). In some species the mean is not representative of the data set analyzed, since the sampling covered both large and small specimens, as can be seen in the CFO size frequency histograms (Atlantic TC and Atlantic TE) (Fig. 3 and 4), SPO (Atlantic SW) (Fig. 5) and SZO (Pacific N) (Fig. 6). The size frequency histograms pertaining to the rest of the species/areas are given in Figures 2- 8.

The ANOVA obtained from the GLM applied, which tested the statistical significance of each of the factors considered, showed that the "sex" factor was not statistically significant at a 90% confidence interval, while the "area" factor showed a high level of significance. The lack of significance of the "sex" factor to explain the variability in weight in the swordfish has been described in previous papers (García & Mejuto, 1988; Mejuto & de la Serna, 1993) despite the fact that a substantial difference in growth was reported between males and females in most of these species.

The non-linear regression model was finally fitted to the size-weight values by species (combined sexes) and area, resulting in **2** relationships for the swordfish and **30** relationships for shark species. These relationships were highly significant, and in most cases, the model was able to explain over 90% of the variability in DW.

The $R^2$ values obtained suggest that these relationships might be good predictors of weight (Tables 4(a), (b)). Nonetheless it would be advisable to use some of these relationships on a provisional basis (Atlantic NE: SWO, IOO; Atlantic TC: IOO, CFO; Atlantic TE: CFO, SZO; Atlantic SW: ASO and in the North Pacific: IOO, CLO, CFO, SZO) due to the small sampling size available in some cases.

But in other cases, although the sampling size was small, the wide range of sizes used would indicate that they were accurately represented. (Atlantic TC: CLO; Atlantic TE: CLO, SLO, SPO; North Pacific: PGO; South Pacific : IOO).

The "a" and "b" values (intercept and slope) of the resulting relationships are exhibited in Tables 4(a) and 4(b). The graphic representations of the observations and their fits are shown in Figures 9-15. The residual analyses have a satisfactory pattern in most of the species-areas, particularly in the most frequently caught species (Fig. 16-22).

However, it must be remembered that the dressed weight (DW) observations were obtained by

different observers on board several different commercial vessels with “dressing” criteria that may slightly differ among vessels. Moreover, the weighing operations were carried out under different meteorological conditions with scales and dynamometers (with differences in accuracy), depending largely on the size of the specimen. Despite the above limitations, we believe that, on the whole, the results obtained were very satisfactory and that there is no reason to reject the assumption of constant variance, given that weight estimation may be affected by a number of factors that lead to errors during the weighing process.

Therefore, in our opinion, these relationships may be used, at least on a preliminary basis for the Spanish fleet, to do basic tasks and provide statistics to International Fisheries Commissions and for stock assessment. Similar efforts are recommended to be developed for others fleets in order to compare, validate and generalize the LJFL/FL-DW relationships obtained.

## 4. ACKNOWLEDGMENTS.

We would like to thank all the scientific observers for their effort and all the cooperating boat captains and crews for allowing us to examine their catches.

## 5. LITERATURE CITED.

Castro, J., J.M. de la Serna, D. Macías, J. Mejuto, 2000. Estimaciones científicas preliminares de los desembarcos de especies asociadas realizadas por la flota española de palangre de superficie en 1997 y 1998. ICCAT.Col. Vol. Sci. Pap. Vol.LI (CD vers. SCRS/99/82).

Draper, N.R., H. Smith, 1966. Applied regression analysis. John Wiley & Sons, N.Y., 407pp.

García B., J. Mejuto, 1988. Primeros datos sobre la biología de la reproducción del pez espada (*Xiphias gladius* L.) de las áreas 35º_45º N, 10º_40º W (BIL 94)".ICCAT. Col. Vol. Sci. Pap. Vol. XXVII: 164-175.(SCRS/87/29).

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

Mejuto, J., A. González-Garcés, 1984. Shortfin mako, *Isurus oxyrinchus*, and porbeagle, *Lamna nasus*, associated with longline swordfishery in NW and N Spain. International Council for the Exploration of the Sea, Council Meeting 1984/G 72:10pp.

Mejuto, J., S. Iglesias, J.C. Rey, E. Alot , B. García, 1988. Relaciones talla-peso del pez espada (*Xiphias gladius*, L.*)* en las áreas BIL 94 y BIL 95, por estratos espacio-temporales. ICCAT. Col. Vol. Sci. Pap. Vol.XVII: 214-221.

Mejuto, J., J.M. de la Serna, 1993. A preliminary analysis to obtain a size weight relationship for the Mediterranean Swordfish (*Xiphias gladius)*. ICCAT. Col. Vol. Sci. Pap. Vol. XL(1):149 (SCRS/92/87)

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 LI (CD vers. SCRS/99/056).

Mejuto, J., B. García, J.M. de la Serna, 2000. Activity of the Spanish surface longline fleet catching swordfish (*Xiphias gladius)* in the year 1998. ICCAT.Col. Vol. Sci. Pap. Vol. LI (CD vers. SCRS/99/075).

Skillman, R.A., M.Y.Y. Yong, 1974. Length-Weight relationships for six species of billfishes in the Central Pacific Ocean. Proceedings of the International Billfish Syposium Kailua-Kona, Hawaii, 9-12 August 1972. Part 2:126-137. Review and Contributed Papers. R.S. Shomura & F. Williams Editors.

Tsimenides, N. G. Tserpes, 1989. Age Determination and Growth of Swordfish *Xiphias gladius* L., 1758 in Aegean Sea. Fisheries Research, 8:159-168.

**Table 1.** Number of observations with size and weight, by species and area analyzed.

| species | ATL.NE | ATL.TE | ATL.TC | ATL.SW | PACI.N | PACI.S | INDI.W |
|---|---|---|---|---|---|---|---|
| SWO | 16 | - | - | - | - | 1229 | - |
| PGO | 354 | 743 | 164 | 166 | 77 | 65 | 289 |
| IOO | 17 | 166 | 22 | 97 | 7 | 25 | 171 |
| IPO | - | - | - | - | - | - | 17 |
| CLO | - | 31 | 39 | 61 | 35 | - | 567 |
| CFO | - | 14 | 8 | - | 21 | - | 411 |
| ASO | - | - | - | 29 | - | - | - |
| SZO | - | 10 | | - | 8 | - | - |
| SLO | - | 23 | | - | - | - | - |
| SPO | - | 43 | - | 171 | - | - | - |

**Table 2.** Percentage of fish sexed with respect to the total number of fish sampled in size and weight, by species and area analyzed.

| species | ATL.NE | ATL.TE | ATL.TC | ATL.SW | PACI.N | PACI.S | INDI.W |
|---|---|---|---|---|---|---|---|
| SWO | 100 | - | - | - | - | 99.3 | - |
| PGO | 100 | 98.9 | 100 | 100 | 100 | 100 | 100 |
| IOO | 100 | 98.8 | 100 | 100 | 100 | 100 | 100 |
| IPO | - | - | - | - | - | - | 100 |
| CLO | - | 77.4 | 100 | 0 | 100 | - | 100 |
| CFO | - | 100 | 100 | - | 100 | - | 100 |
| ASO | - | - | - | 0 | - | - | - |
| SZO | - | 100 | - | - | 100 | - | - |
| SLO | - | 100 | - | - | - | - | - |
| SPO | - | - | - | 0 | - | - | - |

**Table 3.** Overall sex ratio (all sizes combined) males: females, by species and area analyzed.

| species | ATL.NE | ATL.TE | ATL.TC | ATL.SW | PACI.N | PACI.S | INDI.W |
|---|---|---|---|---|---|---|---|
| SWO | 1.0:3.0 | - | - | - | - | 1.0:1.5 | - |
| PGO | 1.5:1.0 | 1.2:1.0 | 1.0:24.0 | 1.0:3.0 | 5.3:1.0 | 1.4:1.0 | 1.0:5.7 |
| IOO | 1.0:1.4 | 1.0:1.0 | 1.2:1.0 | 2.0:1.0 | 1.3:1.0 | 1.0:1.3 | 1.0:1.7 |
| IPO | - | - | - | - | - | - | 1.9:1.0 |
| CLO | - | 2.0:1.0 | 1.8:1.0 | - | 1.0:1.0 | - | 1.0:32.3 |
| CFO | - | 1.0:1.9 | 1.7:1.0 | - | 1.3:1.0 | - | 1.0:1.0 |
| ASO | - | - | - | - | - | - | - |
| SZO | - | 1.0:1.5 | - | - | 6.7:1.0 | - | - |
| SLO | - | 1.6:1.0 | - | - | - | - | - |
| SPO | - | - | - | - | - | - | - |

**Table 4 (a).** Standard length (LJFL or FL) – dressed weight (DW) relationships using a non-linear model for swordfish, 16 species of pelagic sharks and Sphyrna spp., from several areas of the Atlantic Ocean. Number of individuals sampled (*n*), size means and ranges of sizes.

| | ATL. NE | | | | | |
|---|---|---|---|---|---|---|
| Species | *n* | Mean | Range cm | a | b | $r^2$ |
| Xiphiidae | *16* | | | | | |
| *Xiphias gladius* | 16 | 105 | 80-155 | 8,57027x10^-8 | 3,91763 | 99,36 |
| Carcharhinidae | *354* | | | | | |
| *Prionace glauca* | 354 | 158 | 75-250 | 8,04021x10^-7 | 3,23189 | 96,77 |
| Lamnidae | *17* | | | | | |
| *Isurus oxyrinchus* | 17 | 129 | 70-175 | 2,80834x10^-6 | 3,20182 | 98,45 |
| | ATL. TE | | | | | |
| Carcharhinidae | *788* | | | | | |
| *Prionace glauca* | 743 | 195 | 120-260 | 6,38223x10^-7 | 3,27843 | 85,88 |
| *Carcharhinus longimanus* | 31 | 112 | 80-200 | 4,27517x10^-4 | 2,14138 | 85,21 |
| *Carcharhinus falciformis* | 14 | 131 | 80-120 | 5,84008x10^-4 | 2,09283 | 91,43 |
| Lamnidae | *166* | | | | | |
| *Isurus oxyrinchus* | 166 | 166 | 95-250 | 1,22182x10^-5 | 2,89535 | 91,78 |
| Sphyrnidae | *76* | | | | | |
| *Sphyrna lewini* | 23 | 189 | 140-230 | 3,51406x10^-6 | 3,07754 | 85,79 |
| *Sphyrna zygaena* | 10 | 190 | 125-225 | 2,60995x10^-5 | 2,70878 | 87,11 |
| *Sphyrna sp.* | 43 | 198 | 120-245 | 5,64889x10^-5 | 2,57425 | 87,67 |
| | ATL. TC | | | | | |
| Carcharhinidae | *211* | | | | | |
| *Prionace glauca* | 164 | 194 | 140-245 | 9,55993x10^-7 | 3,20939 | 91,06 |
| *Carcharhinus longimanus* | 39 | 134 | 80-200 | 2,46974x10^-5 | 2,693 | 85,61 |
| *Carcharhinus falciformis* | 8 | 107 | 80-145 | 1,80698x10^-6 | 3,24027 | 99,28 |
| Lamnidae | *22* | | | | | |
| *Isurus oxyrinchus* | 22 | 161 | 120-185 | 2,52098x10^-5 | 2,76078 | 92,80 |
| | ATL. SW | | | | | |
| Carcharhinidae | *227* | | | | | |
| *Prionace glauca* | 166 | 181 | 135-250 | 1,5726x10^-6 | 3,10446 | 91,10 |
| *Carcharhinus longimanus* | 61 | 145 | 75-185 | 4,13531x10^-5 | 2,60579 | 82,09 |
| Lamnidae | *97* | | | | | |
| *Isurus oxyrinchus* | 97 | 184 | 95-240 | 3,1142x10^-5 | 2,7243 | 92,55 |
| Alopiidae | *29* | | | | | |
| *Alopias superciliosus* | 29 | 196 | 110-225 | 8,61821x10^-6 | 2,99765 | 77,51 |
| Sphyrnidae | *171* | | | | | |
| *Sphyrna sp.* | 171 | 194 | 110-255 | 9,95643x10^-6 | 2,9073 | 94,23 |

**Table 4 (b)**. Standard length (LJFL or FL) – dressed weight (DW) relationships using a non-linear moder for swordfish and 7 species of pelagic sharks from the North and South Pacific Ocean and for 5 species of pelagic sharks from the Indian Ocean. Number of individuals sampled (*n*), mean size and sizes ranges.

| | **PACI.N** | | | | | |
|---|---|---|---|---|---|---|
| Species | *n* | Mean | Range cm | a | b | *r2* |
| Carcharhinidae | *133* | | | | | |
| *Prionace glauca* | 77 | 159 | 100-215 | 3,4996x10^ -7 | 3,40368 | 94,62 |
| *Carcharhinus longimanus* | 35 | 116 | 85-175 | 1,4976x10^ -5 | 2,76957 | 92,18 |
| *Carcharhinus falciformis* | 21 | 130 | 90-160 | 1,93378x10^ -6 | 3,20046 | 95,83 |
| Lamnidae | *7* | | | | | |
| *Isurus oxyrinchus* | 7 | 151 | 130-175 | 1,58407x10^ -8 | 4,21721 | 85,37 |
| Sphyrnidae | *8* | | | | | |
| *Sphyrna zygaena* | 8 | 138 | 100-155 | 3,00909x10^-5 | 2,64805 | 97,36 |
| | **PACI.S** | | | | | |
| Xiphiidae | *1229* | | | | | |
| *Xiphias gladius* | 1229 | 165 | 95-285 | 2,81999x10^-6 | 3,24586 | 96,32 |
| Carcharhinidae | *65* | | | | | |
| *Prionace glauca* | 65 | 149 | 85-220 | 1,456X10^-6 | 3,12282 | 94,51 |
| Lamnidae | *25* | | | | | |
| *Isurus oxyrinchus* | 25 | 119 | 75-170 | 2,36674X10^-5 | 2,76449 | 96,08 |
| | **INDI.W** | | | | | |
| Carcharhinidae | *1267* | | | | | |
| *Prionace glauca* | 289 | 201 | 150-260 | 1,60945x10^-6 | 3,09904 | 94,65 |
| *Carcharhinus longimanus* | 567 | 140 | 65-215 | 2,98446x10^-6 | 3,15417 | 93,22 |
| *Carcharhinus falciformis* | 411 | 123 | 50-220 | 1,13294x10^-5 | 2,91484 | 96,83 |
| Lamnidae | *188* | | | | | |
| *Isurus oxyrinchus* | 171 | 176 | 105-235 | 1,41832X10^-5 | 2,88231 | 92,96 |
| *Isurus paucus* | 17 | 209 | 150-250 | 2,54378X10^-4 | 2,31947 | 90,01 |

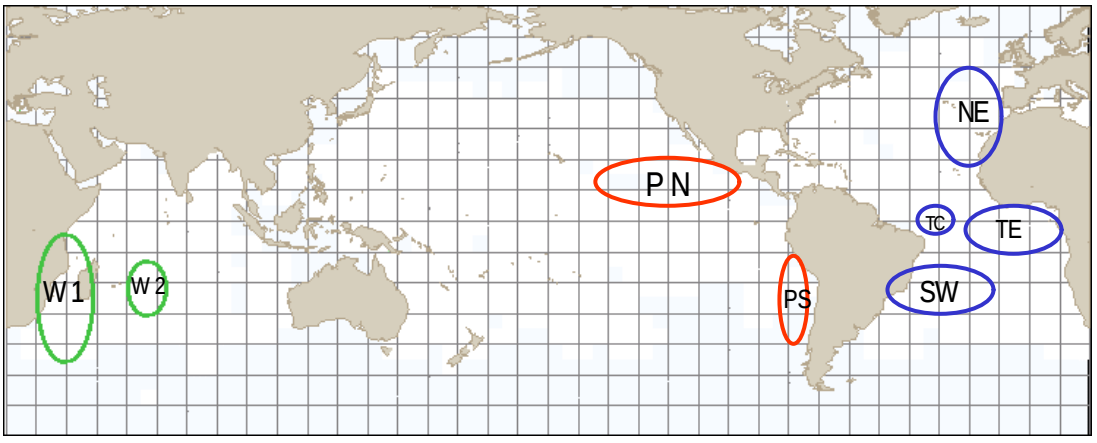
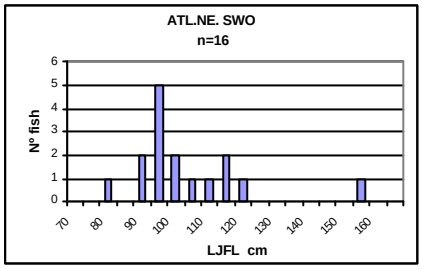
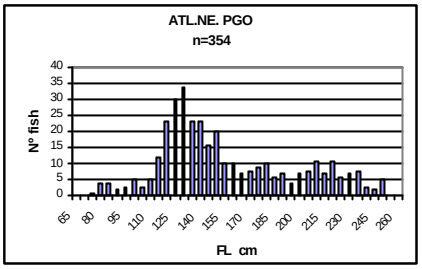



**Fig. 1.** Area definition by ocean showing the grouping of the paired values obtained for the different species analyzed. NE: Northeast Atlantic, TE: Tropical East Atlantic, TC: Tropical Central Atlantic, SW: Soutwest Atlantic; PN: North Pacific, PS: South Pacific, W1 and W2 grouped within the West Indian Ocean.



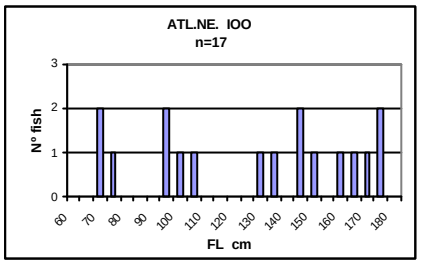
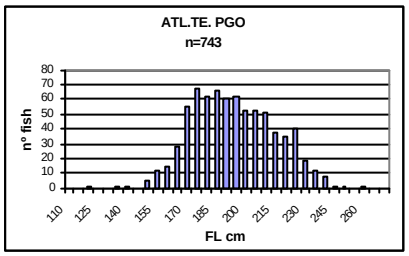
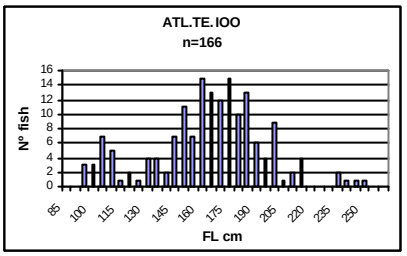
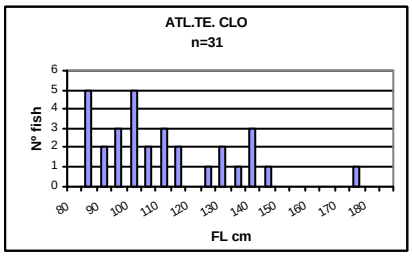
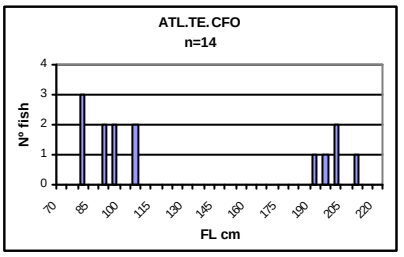



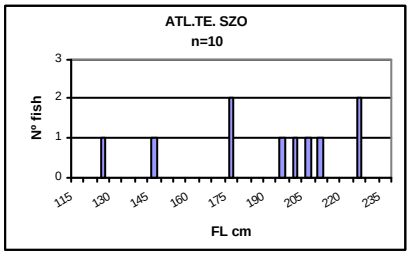

Fig. 2. Histogram of size frequencies of specimens of swordfish (SWO), blue shark (PGO) and shortfin mako (IOO) sampled in the Northeast Atlantic Ocean (NE).

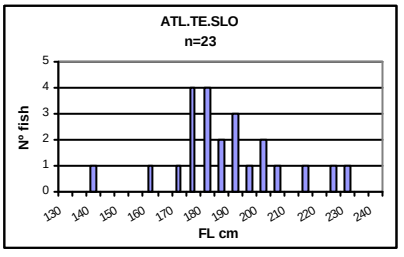


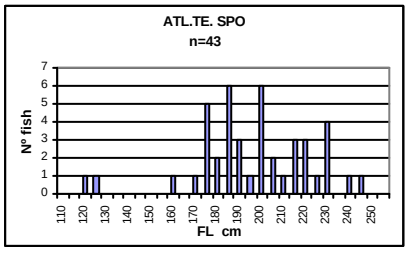




Fig. 3. Histogram of size frequencies of specimens of blue shark (PGO), shortfin mako (IOO), whitetip shark (CLO), silky shark (CFO) and hammerhead sharks (SZO, SLO and SPO) sampled in the Tropical East Atlantic Ocean (TE).

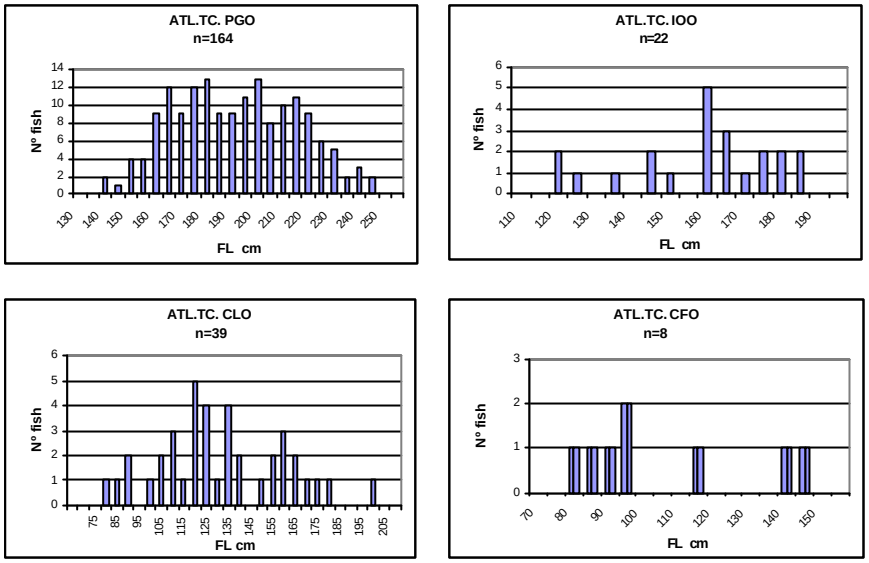



**Fig. 4.** Histogram of the size frequencies of specimens of blue shark (PGO), shortfin mako (IOO), whitetip shark (CLO) and silky shark (CFO) sampled in the Tropical Central Atlantic Ocean (TC).

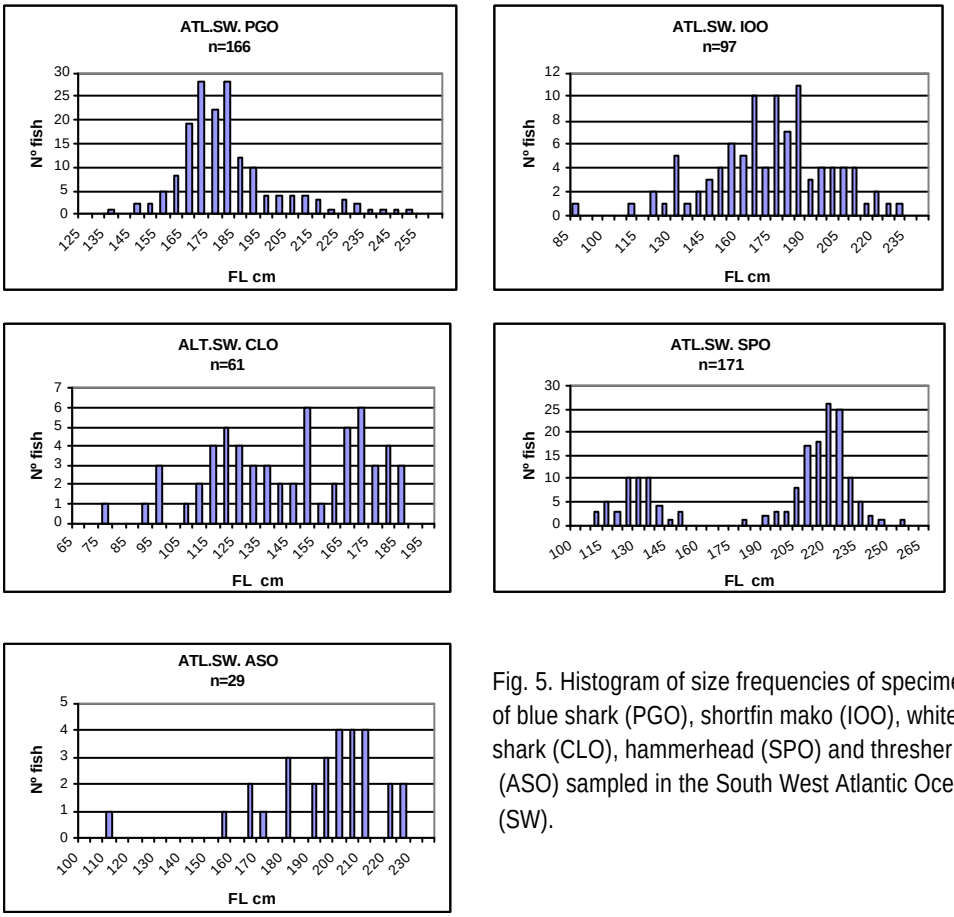



Fig. 5. Histogram of size frequencies of specimens of blue shark (PGO), shortfin mako (IOO), whitetip shark (CLO), hammerhead (SPO) and thresher (ASO) sampled in the South West Atlantic Ocean (SW).

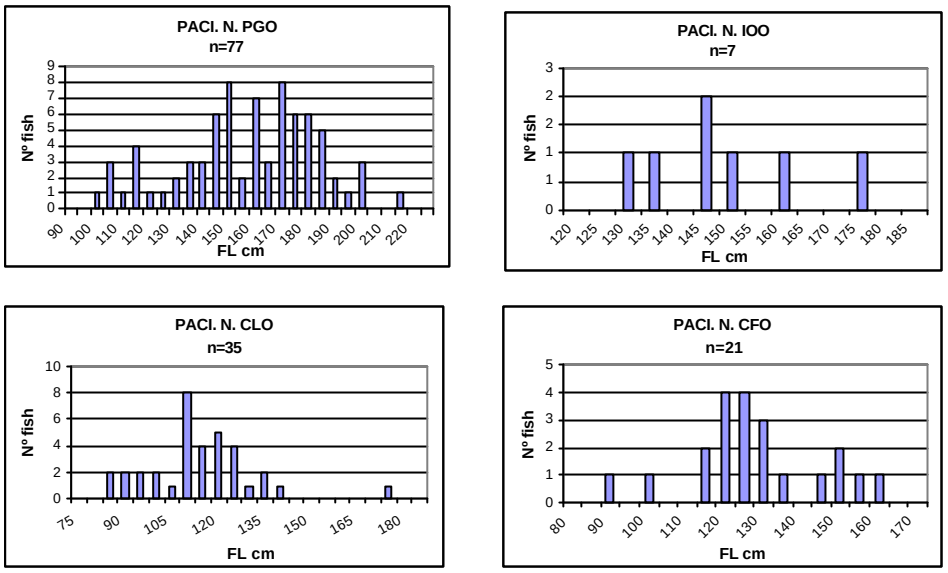



Fig. 6. Histogram of size frequencies of specimens of blue shark (PGO), shortfin mako (IOO), whitetip shark (CLO), silky shark (CFO) and hammerhead (SZO) sampled in the North Pacific Ocean (PN).

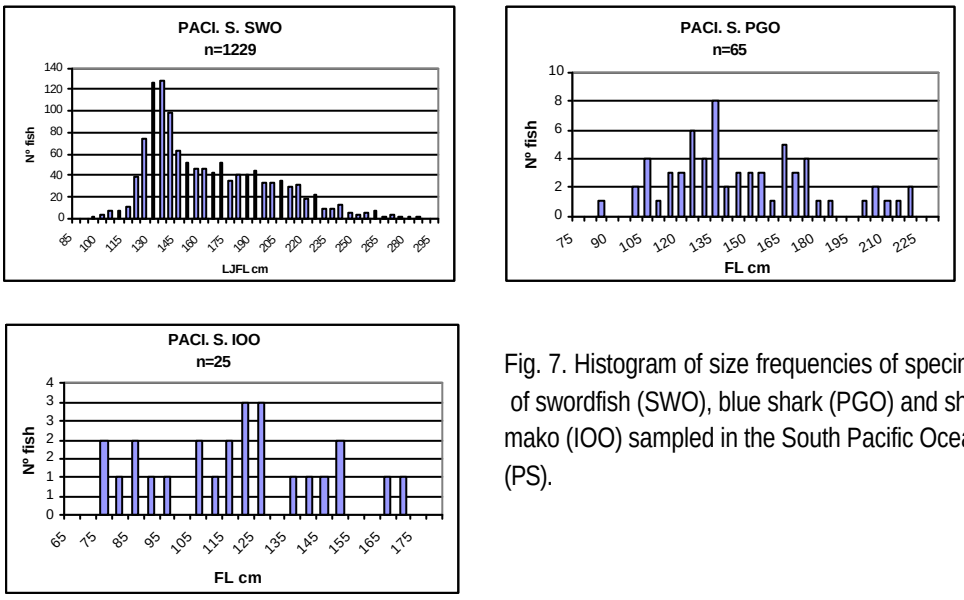



Fig. 7. Histogram of size frequencies of specimens of swordfish (SWO), blue shark (PGO) and shortfin mako (IOO) sampled in the South Pacific Ocean (PS).

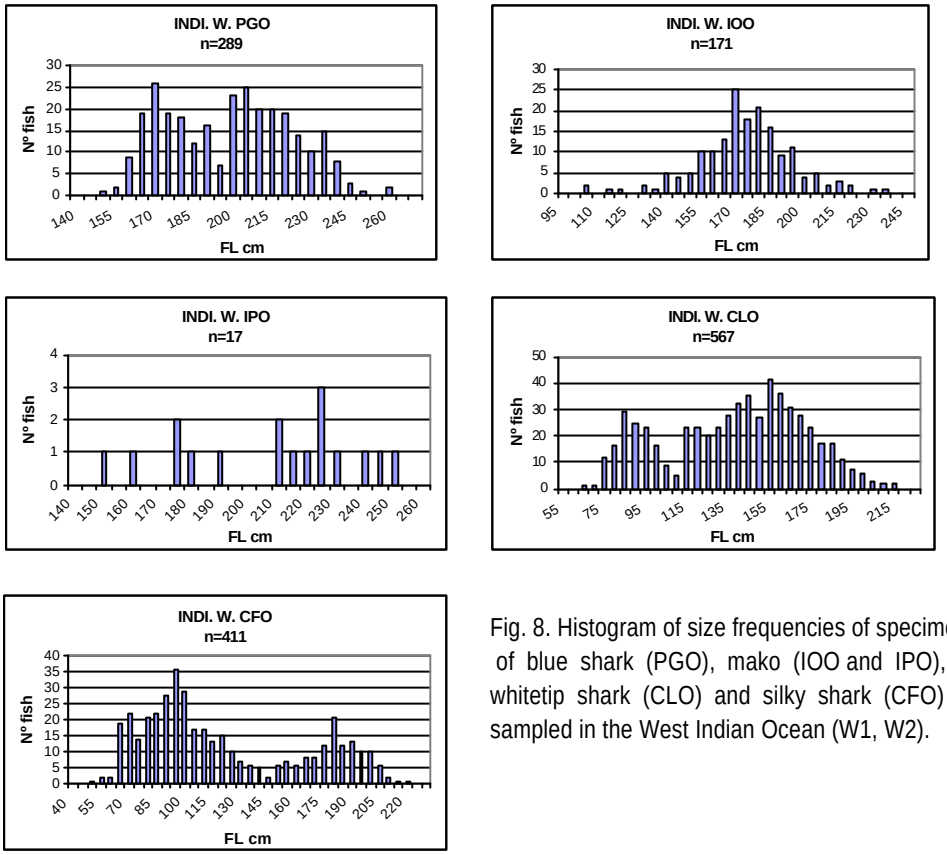



Fig. 8. Histogram of size frequencies of specimens of blue shark (PGO), mako (IOO and IPO), whitetip shark (CLO) and silky shark (CFO) sampled in the West Indian Ocean (W1, W2).

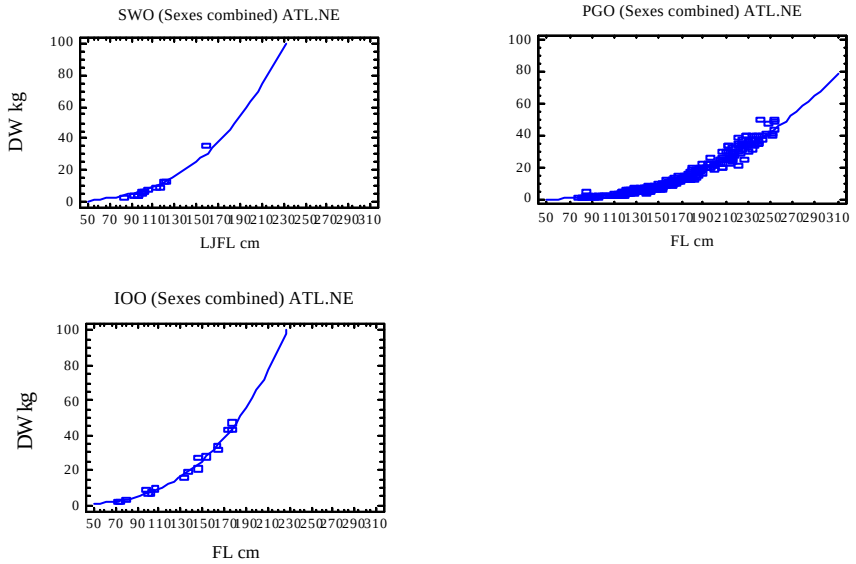



**Fig. 9.** Adjustment curves between standard size and dressed weight used in the non-linear regression model for the swordfish (SWO), blue shark (PGO) and shortfin mako (IOO), for the North East Atlantic.

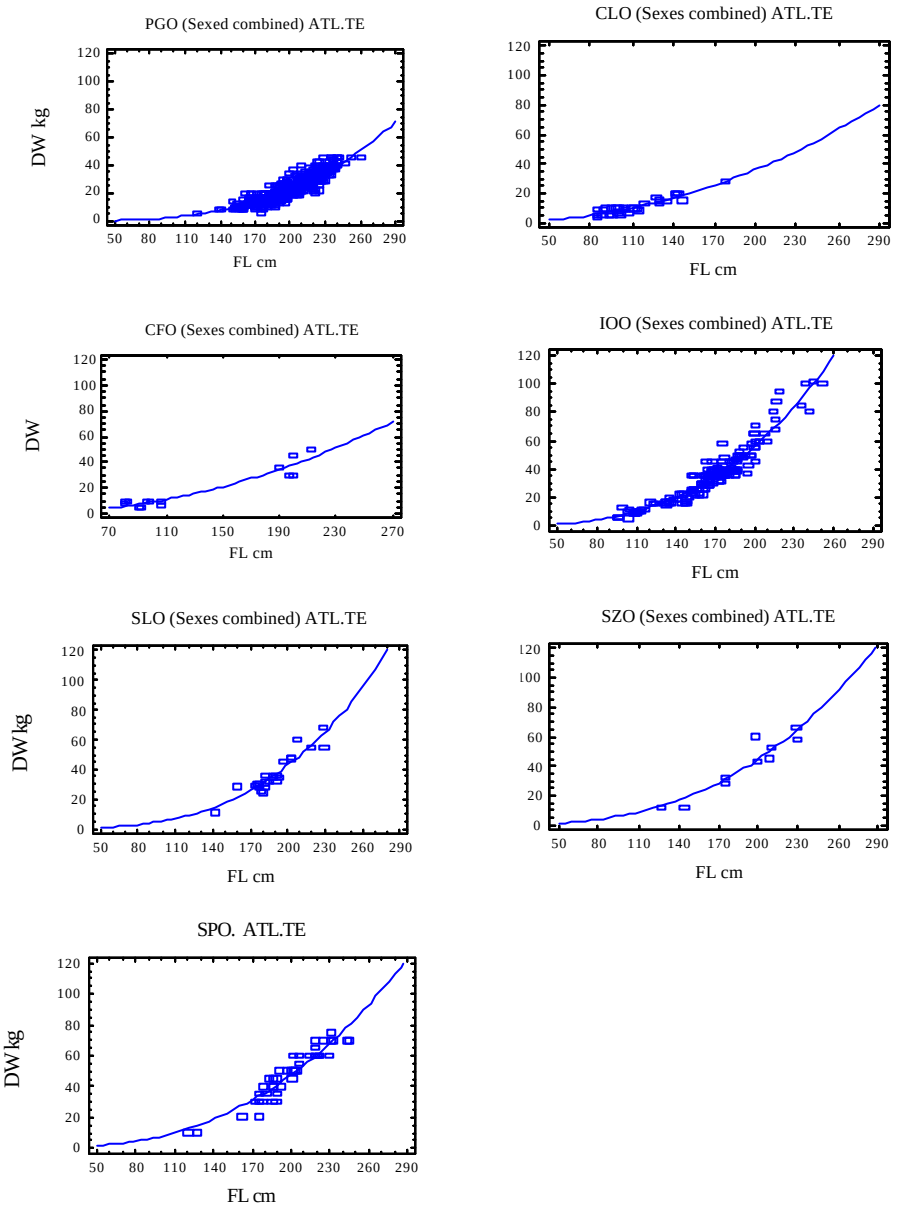



**Fig.10.** Adjustment curves between standard size and dressed weight for data obtained on different species in the Tropical East Atlantic Ocean.

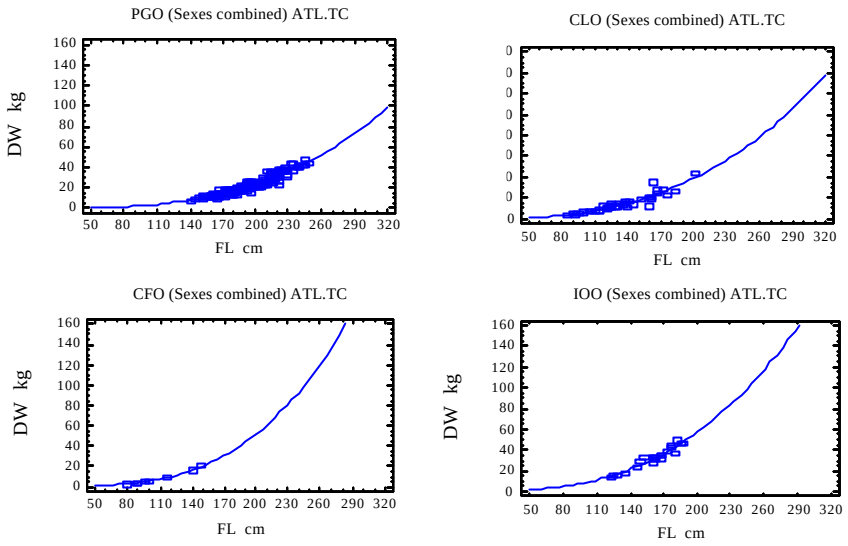



**Fig. 11** Adjustment curves between standard size and dressed weight for data obtained on different species in the Tropical Central Atlantic Ocean.

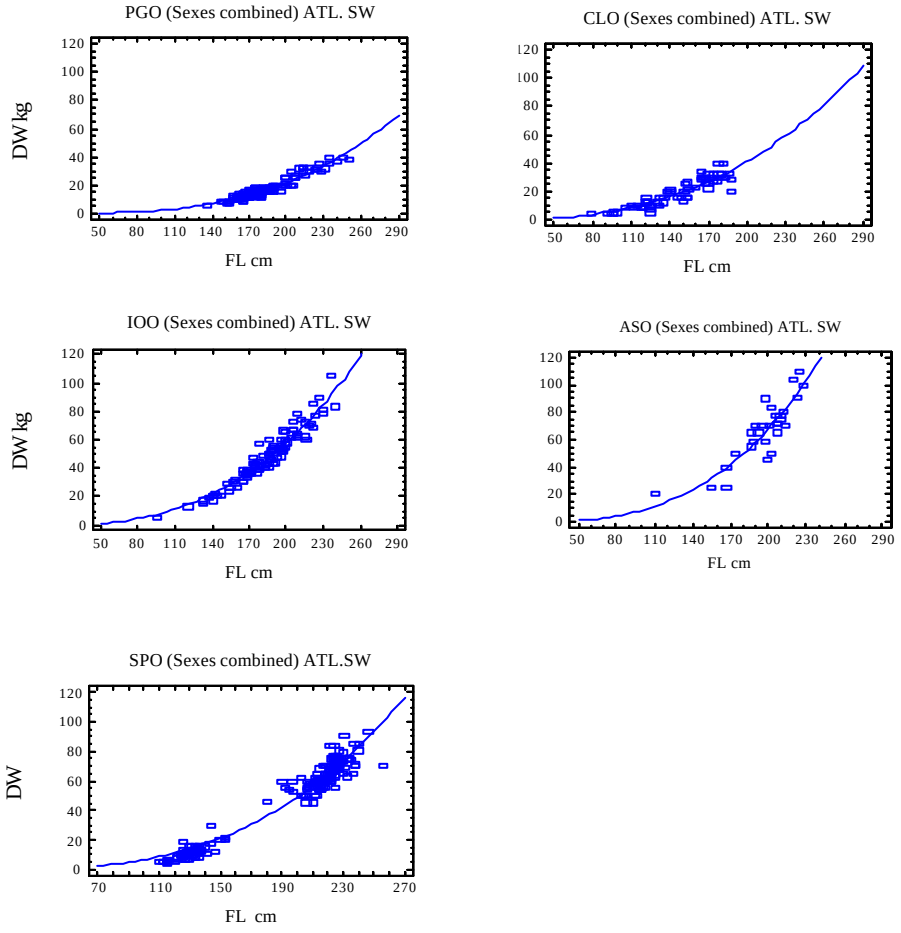



**Fig. 12.** Adjustment curves between standard size and dressed weight for data obtained on different species in the South West Atlantic Ocean.

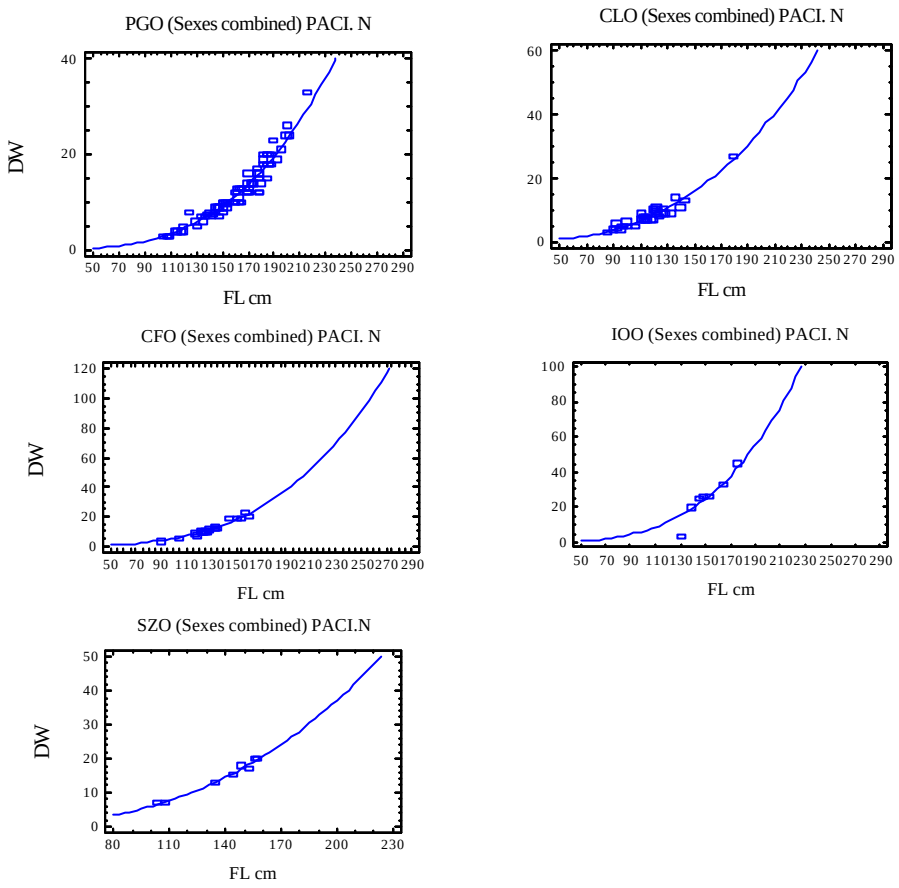



**Fig.13.** Adjustment curves between standard size and dressed weight for data obtained on different species in the North Pacific Ocean.

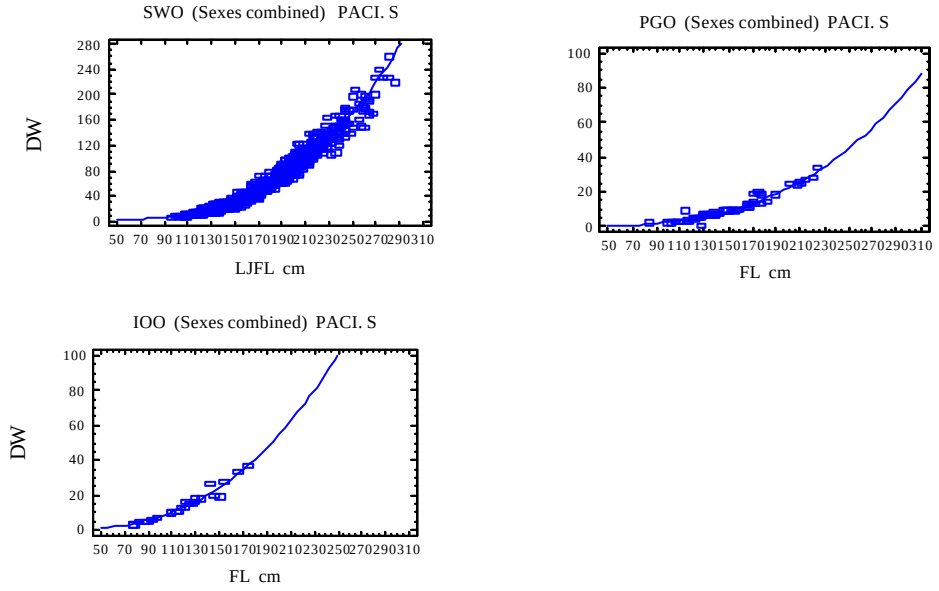



**Fig. 14.** Adjustment curves between standard size and dressed weight for data obtained on different species in the South Pacific Ocean.

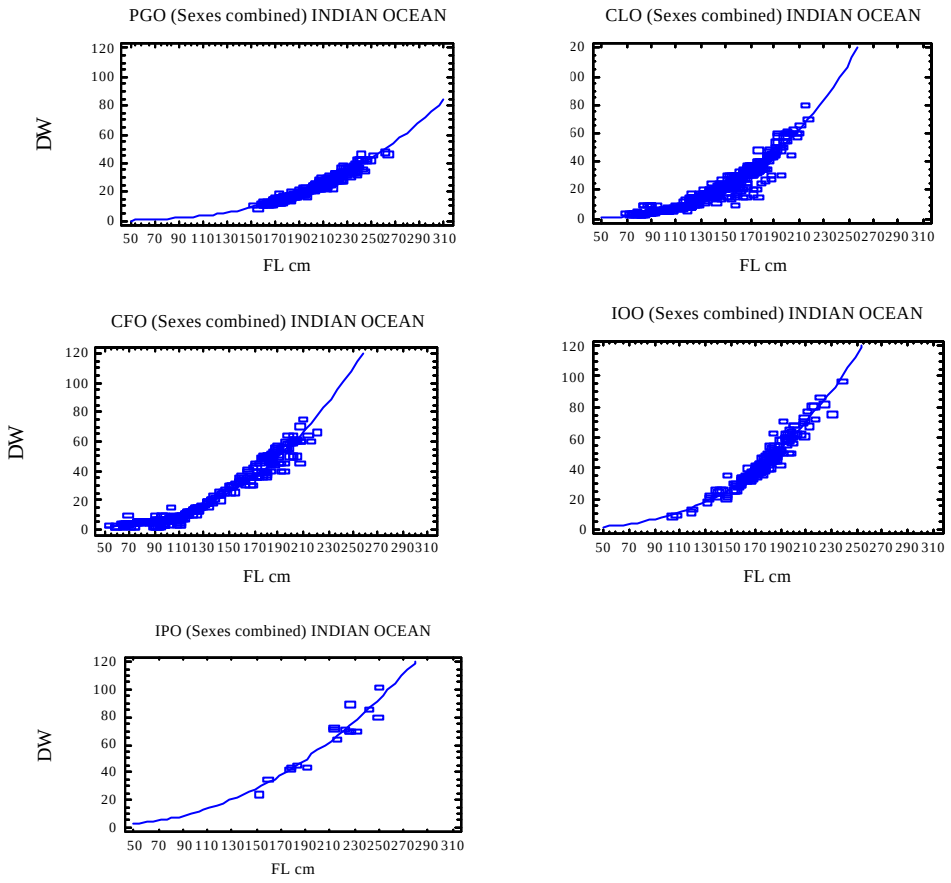



**Fig. 15.** Adjustment curves between standard size and dressed weight for data obtained on different species in the West Indian Ocean.

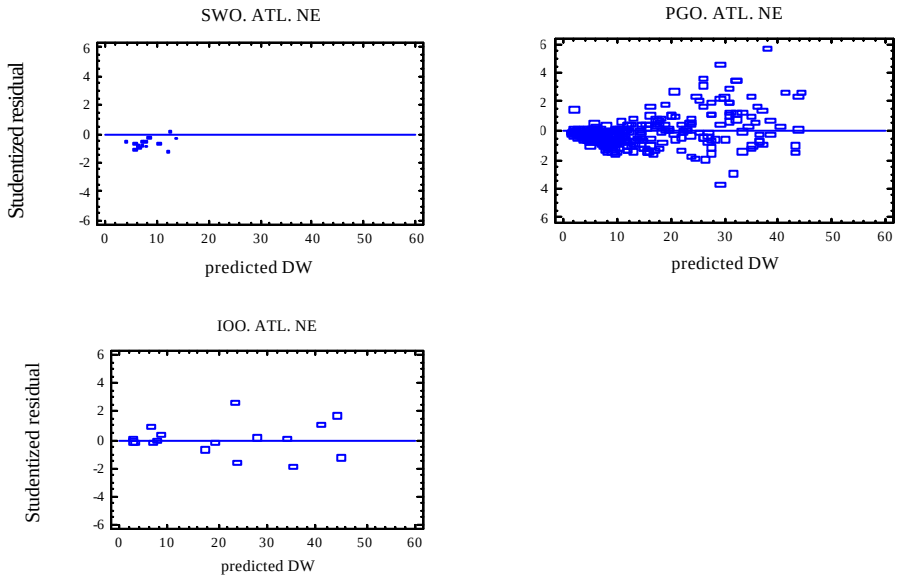



**Fig. 16.** Plot of residuals obtained by applying the non-linear regression model. Nort East Atlantic Ocean.

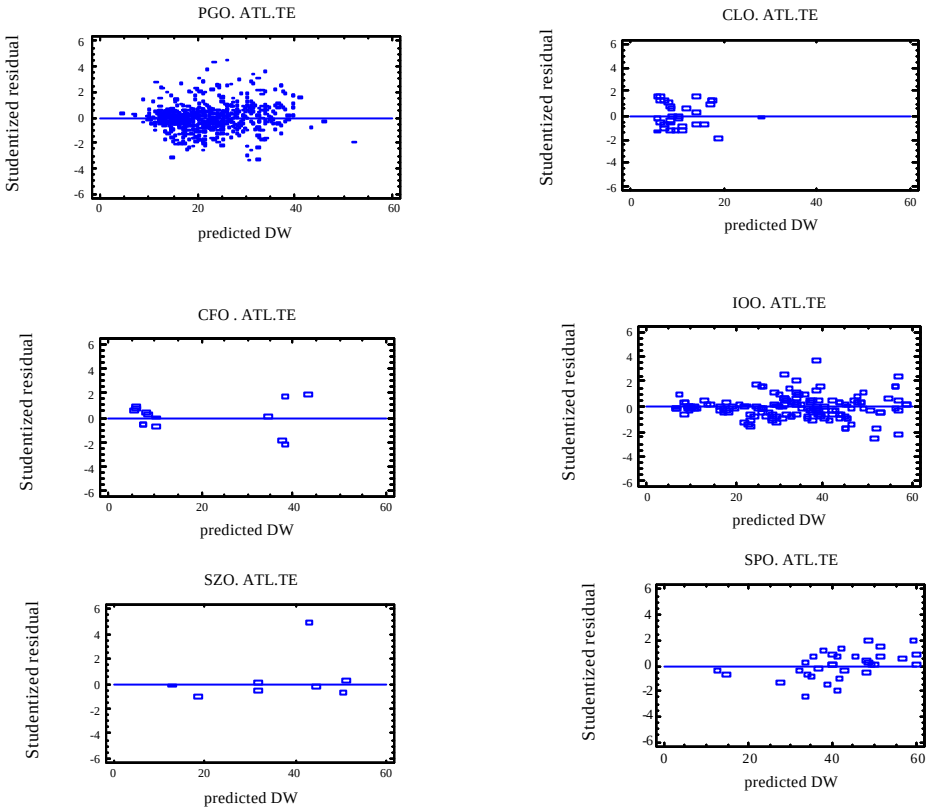



**Fig. 17.** Plot of residuals obtained by applying the non-linear regression model. Tropical East Atlantic Ocean.

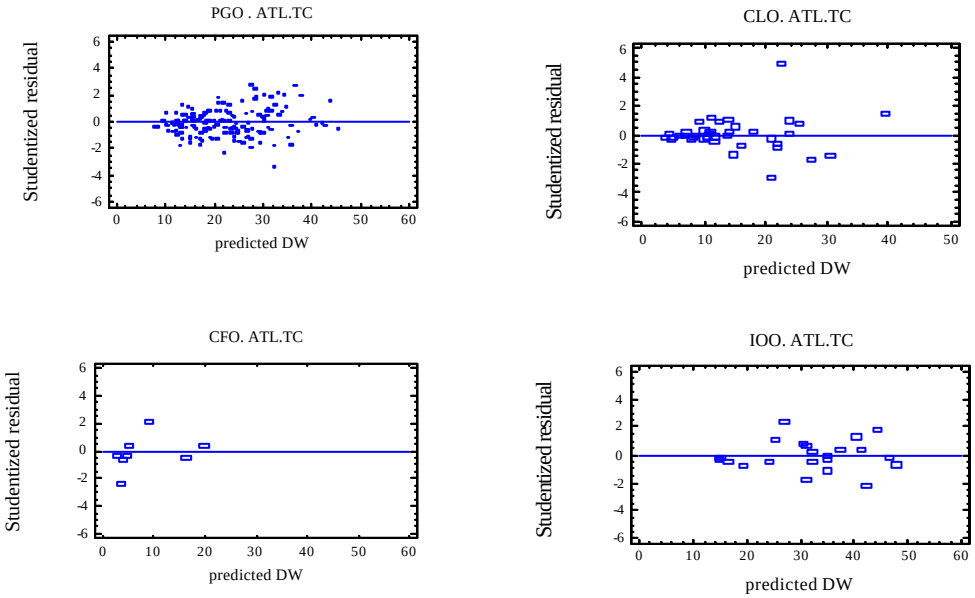



**Fig. 18.** Plot of residuals obtained by applying the non-linear regression model. Tropical Central Atlantic Ocean.

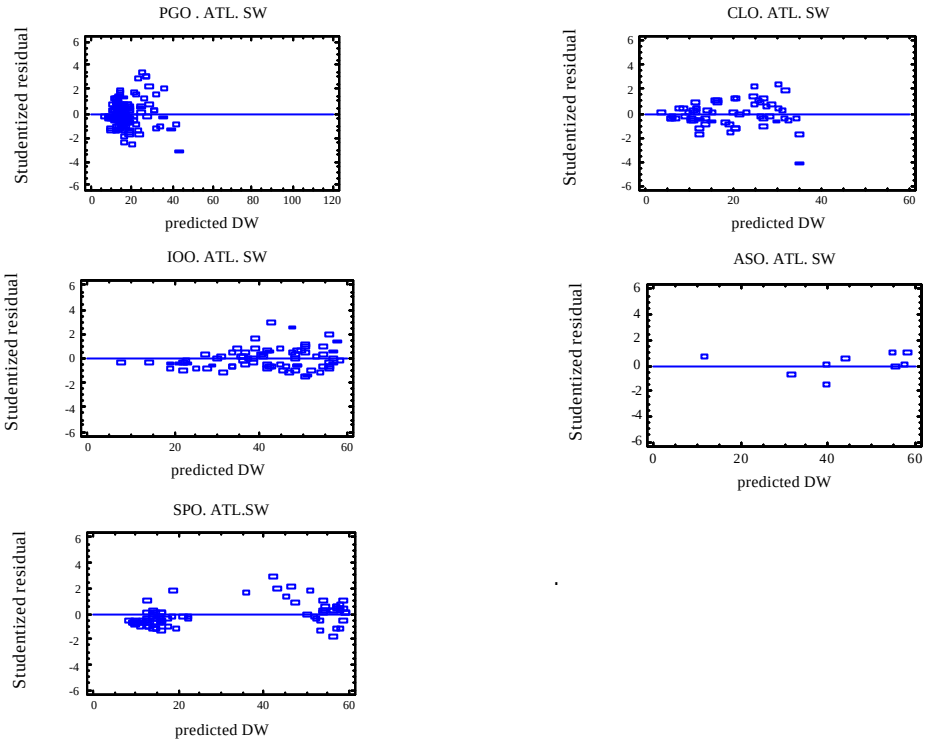



**Fig. 19.** Plot of residuals obtained by applying the non- linear regression model. South West Atlantic Ocean.

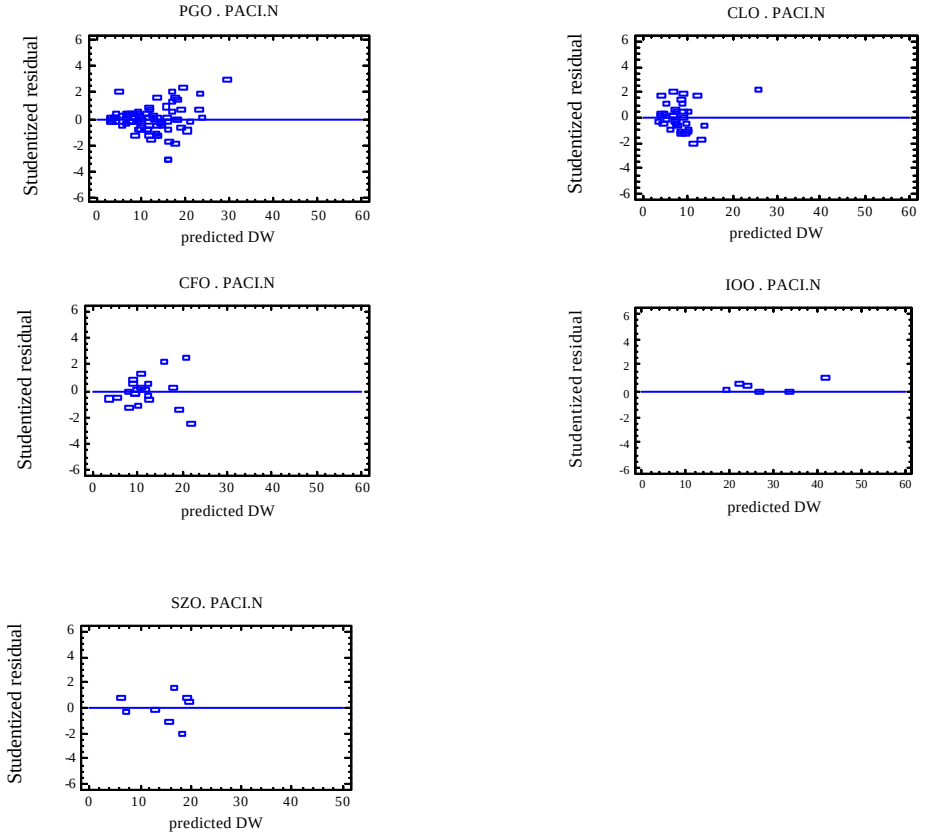



**Fig. 20.** Plot of residuals obtained by applying the non- linear regression model. North Pacific Ocean.

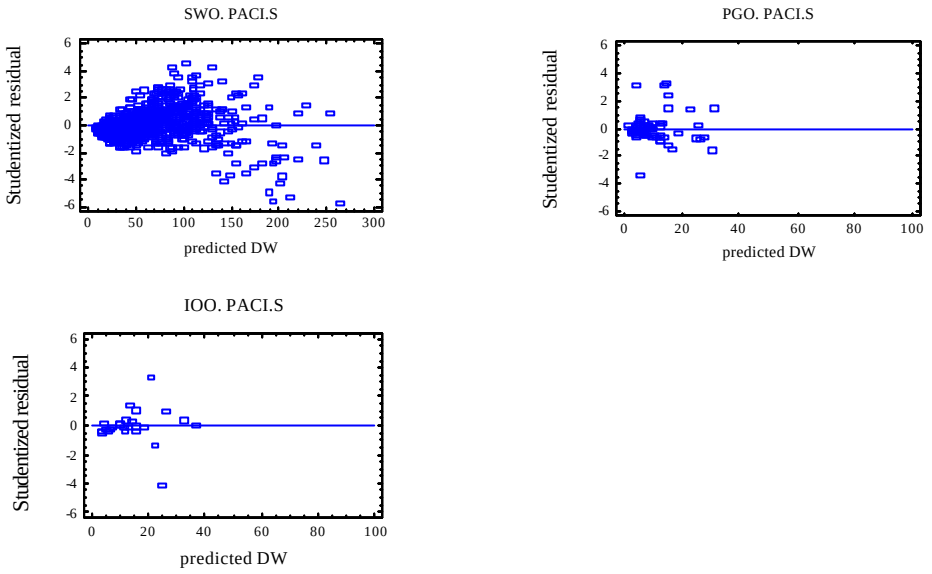



**Fig. 21.** Plot of residuals obtained by applying the non- linear regression model. South Pacific Ocean.

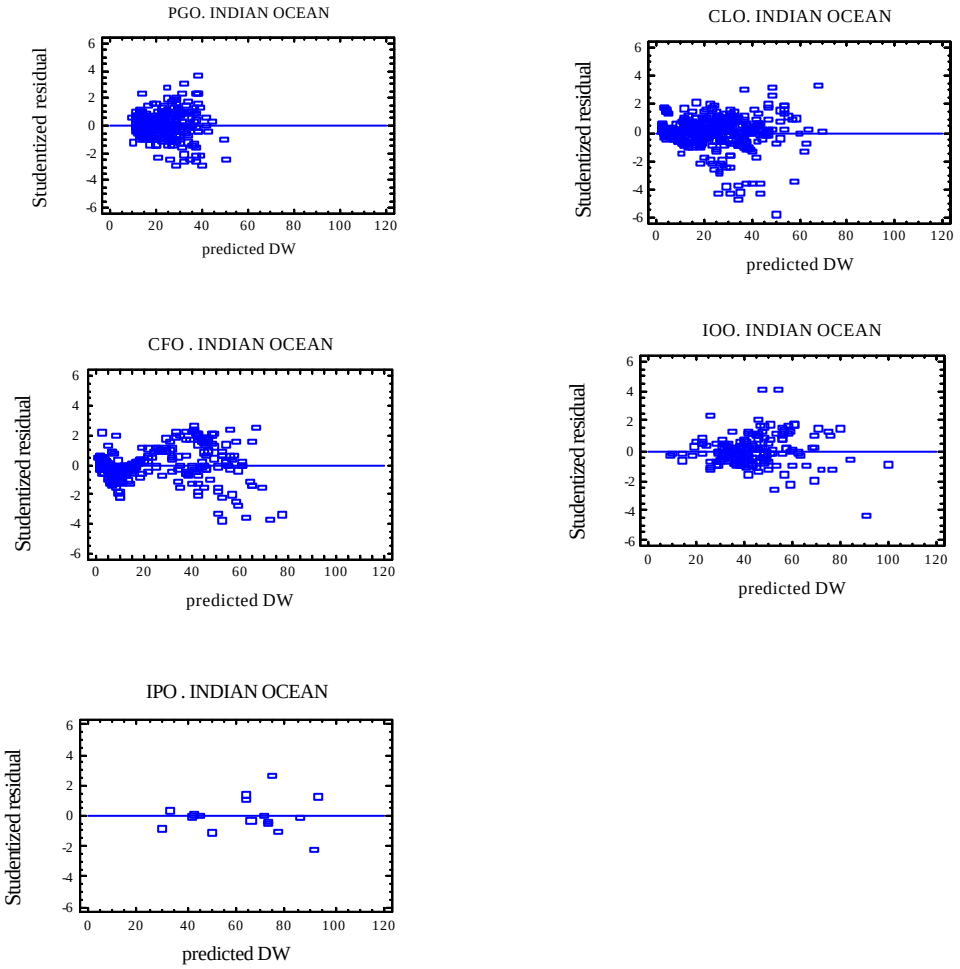



**Fig. 22.** Plot of residuals obtained by applying the non- linear regression model. West Indian Ocean.