SIZE CONVERSION FACTORS FOR MEDITERRANEAN SWORDFISH (*XIPHIAS GLADIUS* L.) CAUGHT BY ITALIAN AND MALTESE LONGLINE FLEETS IN THE MEDITERRANEAN SEA

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SUMMARY

*This document provides an update of the estimated size conversion factors between sLJFL (Straight Lower Jaw Fork Length) and cLJFL (Curved Lower Jaw Fork Length) for Mediterranean Swordfish (*Xiphias gladius*) caught by the Italian and Maltese longline fleets operating in the Mediterranean Sea. This study shows the analysis of data gathered under the Domestic Observer Programs – within the framework of the Data Collection Framework implemented by Italy and Malta. A total of 1,540 biometric measurements were collected by scientific observers employed both onboard longline fishing vessels and at landing ports, from May 2017 to August 2023.*

RÉSUMÉ

*Ce document fournit des informations actualisées sur les facteurs de conversion des tailles estimées entre la sLJFL (longueur droite fourche-maxillaire inférieur) et la cLJFL (longueur courbée fourche-maxillaire inférieur) pour l'espadon de la Méditerranée (*Xiphias gladius*) capturé par les flottilles italiennes et maltaises de palangriers opérant en Méditerranée. Cette étude présente l'analyse des données recueillies par les programmes nationaux d'observateurs dans le cadre du Cadre de collecte des données mis en œuvre par l'Italie et Malte. Au total, 1 540 mesures biométriques ont été collectées par les observateurs scientifiques employés tant à bord des palangriers que dans les ports de débarquements, de mai 2017 à août 2023.*

RESUMEN

*Este documento proporciona una actualización de los factores de conversión de talla estimados entre la longitud recta mandíbula inferior a horquilla (sLJFL) y la longitud curva mandíbula inferior a horquilla (cLJFL) para el pez espada del Mediterráneo (*Xiphias gladius*) capturado por las flotas palangreras italiana y maltesa que operan en el mar Mediterráneo. Este estudio muestra el análisis de los datos recogidos en el marco de los Programas de observadores nacionales, dentro del Marco de recopilación de datos aplicado por Italia y Malta. Un total de 1.540 mediciones biométricas fueron recogidas por observadores científicos empleados tanto a bordo de los buques de pesca de palangre como en los puertos de desembarque, de mayo de 2017 a agosto de 2023.*

KEYWORDS

Size Distribution, Morphometry, Mediterranean Sea, Swordfish.

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1. Introduction

Swordfish (*Xiphias gladius*) is an important migratory species heavily fished in the Atlantic and all over the Mediterranean Sea.

Med-SWO catches are regulated by the International Commission for the Conservation of Atlantic Tunas (ICCAT).

This work was carried out within the framework of the Domestic Observer Program implemented between 2017 and 2023, under the EU Data Collection Program on Large Pelagic Species funded by Masaf – Department of Fisheries and Aquaculture (Italy), in collaboration with Malta's Department of Fisheries and Aquaculture (Ministry for Agriculture, Fisheries and Animal Rights) which implements the EU Data Collection Multiannual Programme of fisheries and aquaculture.

According to the data collected so far, the National Observer Program has been of significant support in the data collection on large pelagic species improving the dataset concerning both biometric data and biological samples. The scientific monitoring of the swordfish fisheries in Italy and Malta has made a valuable contribution, especially in terms of updating and analyzing annual trends on data collected.

The main objective of the present work is to support scientific studies in providing the length conversion factors (s-LJFL / cLJFL) for Mediterranean swordfish (*Xiphias gladius*) by using data obtained from the Italian and Maltese longline fleets operating in different areas of the Mediterranean Sea.

Length frequency distribution measurements are fundamental to many aspects of fisheries science.

2. Materials and Methods

This study is based on scientific data collected by observers, trained and employed by OCEANIS srl and MAFA, in order to carry out the monitoring and data collection activities implemented between the year 2017 to 2023.

It defines an update of the previous papers SCRS/169/2021 and SCRS/146/2022 presented to the SCRS Swordfish Species Group. The full dataset was obtained from the catches of the Italian and Maltese fishing fleets targeting the Med-SWO (*Xiphias gladius*) in several areas of the Mediterranean Sea (**Figure 1**): Sardinian Sea, Tyrrhenian Sea, Adriatic Sea, Sicilian Channel, Ionian Sea, and Channel of Malta.

The data consists of a collection of length and weight measurements taken on an individual level. Moreover, information associated with each length/weight observation, such as date of catch (year, month, day), fishing area, vessel name, and gear type of each fish were also reported.

The observers recorded the Straight-lower jaw fork length (s-LJFL), which is the straight line from the edge of the lower jaw to the fork of caudal fin, using a measuring tape placed flat on the deck of the fishing vessel mainly during the landing operations or else on the floor of the processing site before the evisceration. The Curved-lower jaw fork length (c-LJFL) which is the curved line from the edge of the lower jaw to the fork of the caudal fin, was collected using a flexible measuring tape placed along the body of the fish. The round weight (RWT) was obtained by using digital scales.

As regards the Maltese dataset, it is composed of the scientific data which was collected by the Fisheries Research Unit within the Department of Fisheries and Aquaculture (Malta) in 2022 and 2023 from swordfish samples that were landed at Malta's fish market. The measurement protocol was similar to the one used by the observers on the Italian longline fleet, with the measurements being recorded at the Fisheries Research Unit's laboratory.

The length dataset was clustered in 5 cm intervals to estimate the size-frequency distributions.

The length conversion factors were determined using the equation:

$$Y_{c\text{-}LJFL} = a*X_{s\text{-}LJFL} + b$$

Where Y is the response variable (dependent), X is the predictor variable (independent); a is the estimated slope; b is the estimated intercept, and R^2 is the coefficient of determination. The evaluation of the equations was carried out in RStudio, meanwhile the geographical distribution of the catches was illustrated in ArcGis 10.3 for the respective spatial analysis.

The data was used to provide size conversion factors for the Mediterranean swordfish.

3. Results and Discussion

In total 1.540 units of Med-SWO were sampled from specimens caught by both the Italian and Maltese longline fleets operating in the Mediterranean Sea (**Figure 1**). The data was collected for both length measurements as straight and curved LJFL. The size samples of the Med-SWO refer to the sampling period from May 2017 to August 2023. The s-LJFL distribution of 1.540 swordfish catches is represented based on the size-length classes (cm), with a range of 5 cm each (**Figure 2**). The total dataset ranged in size between 59 cm to 242 cm (s-LJFL) with a mean value of 129,74 cm. The swordfish size distribution of all data shows a uni-modal trend, with a peak at 115 cm. The c-LJFL distribution of 1.540 swordfish catches is represented by a size range included between 61 cm to 248 cm (c-LJFL) with a mean value of 132,50 cm.

The dataset includes n° 140 females, within the range between 90 and 181 cm sLJFL and n° 135 males, within the range of 96 and 242 cm sLJFL.

Table 1 shows a summary of the descriptive statistics of the data analyzed in the present study to determine the size-frequency distributions (2017-2023).

Table 2 shows the descriptive statistics and size conversion factors for Mediterranean Swordfish referring to the entire sampling period and obtained from Italian and Maltese catches of swordfish. The following equations outline the overall size conversion equation and the sex-specific size conversion equations regarding the entire sampling period (2017-2023):

- c-LJFL / s-LJFL overall equation from 1.540 Med-SWO samples:

$$c\text{-}LJFL = 1{,}0322 * (s\text{-}LJFL) - 1{,}424 \qquad (R^2 = 0{,}9968)$$

- c-LJFL / s-LJFL equation from 135 male specimens of Med-SWO:

$$c\text{-}LJFL = 1{,}0285 * (s\text{-}LJFL) - 0{,}9595 \qquad (R^2 = 0{,}9960)$$

- c-LJFL / s-LJFL considering 140 female specimens of Med-SWO:

$$c\text{-}LJFL = 1{,}0321 * (s\text{-}LJFL) - 1{,}3168 \qquad (R^2 = 0{,}9991)$$

- s-LJFL / c-LJFL overall equation from 1.540 Med-SWO samples:

$$s\text{-}LJFL = 0{,}9657 * (c\text{-}LJFL) + 1{,}7887 \qquad (R^2 = 0{,}9968)$$

- s-LJFL / c-LJFL equation considering 135 male specimens of Med-SWO:

$$s\text{-}LJFL = 0{,}9684 * (c\text{-}LJFL) + 1{,}4384 \qquad (R^2 = 0{,}9960)$$

- s-LJFL / c-LJFL equation from 140 female specimens of Med-SWO:

$$s\text{-}LJFL = 0{,}9681 * (c\text{-}LJFL) + 1{,}4054 \qquad (R^2 = 0{,}9991)$$

Table 3 and **Table 4** shows the coefficients and the analysis of variance table for the linear models. The estimated parameters of the relationship between straight and curved LJFL, with Sex and Month as covariates, is provided in **Table 3**. The analysis of variance table for the regression is provided in **Table 4**, and indicates that the Month is highly significant, while a data collection activity is still ongoing to implement the data as regards the Sex in order to improve the robustness and significancy of the analysis. The comparison between the estimated values provided in **Table 6.a** and **Table 7.a** shows an increase of the differences for the larger sizes if compared to the smaller ones, and tends to be larger for females compared to males. The linear plot of the equations on monthly basis are shown in **Figure 3.**

Table 5 (a,b), Table 6 (a,b) and **Table 7 (a,b)** shows respectively, for the overall and sex-specific equations, the estimated values for cLJFL (cm) and sLJFL (cm) and the relative 95% confidence intervals, presented for the purpose of information.

4. Conclusion

This study shows the updated equations for the Mediterranean swordfish's size conversion factors. Considering that a data collection activity is still ongoing in order to improve the size of the dataset which is available for further analysis. However, the above-mentioned equations can be used in converting the size measurements for both curved and straight LJFL for Mediterranean swordfish (overall or sex-specific) as requested.

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Table 1. Descriptive statistics of the data used in the present study as regards length measurements.

Descriptive Statistics		*Med-Swordfish dataset – 2017-2023 (n°= 1.540)*				
	N°	*sLJFL (cm)*	*Average sLJFL (cm)*	*cLJFL (cm)*	*Average cLJFL (cm)*	
May 2017 – August 2023	1.540	59-242	129,74	61-248	132,50	

Table 2. Descriptive statistics and estimated parameters for the size conversion factors for Mediterranean Swordfish caught by the Italian and Maltese longline fleets implemented during the sampling period 2017-2023. N - sample size; sLJFL- Straight Lower Jaw Fork Length (cm); cLJFL – Curved Lower Jaw Fork Length (cm); min - minimum; max - maximum; SD - standard deviation; SE - standard error; CI – confidence interval; a - slope and b - intercept. * - Refer to the equation: Y(sLJFL) = a * X(cLJFL) + b.

N	*sLJFL mean ±SD (min-max)*	*cLJFL mean ±SD (min-max)*
1.540	129,74 ± 24,0148 (59-242)	132,50 ± 24,8281 (61-248)

– Overall equation to convert from Straight LJFL to Curve LJFL

Relationship	*Equation*	*R2*	*a*	*b*	*SE of a* (95% C.I. of a)*	*SE of b* (95% C.I. of b)*
sLJFL-cLJFL	c-LJFL = 1,0322 * (s-LJFL) – 1,424	0,9968	1,0322	-1,424	0,001488 (1,0292) – (1,0351)	0,196386 (-1,8092) – (-1,0387)

– Equation for male specimens

Relationship	*Equation*	*R2*	*a*	*b*	*SE of a* (95% C.I. of a)*	*SE of b* (95% C.I. of b)*
sLJFL-cLJFL	c-LJFL = 1,0285 * (s-LJFL) – 0,9595	0,996	1,0285	-0,9595	0,005680 (1,0172) – (1,0397)	0,721643 (-2,3868) – (0,4678)

– Equation for female specimens

Relationship	*Equation*	*R2*	*a*	*b*	*SE of a* (95% C.I. of a)*	*SE of b* (95% C.I. of b)*
sLJFL-cLJFL	c-LJFL = 1,0321 * (s-LJFL) – 1,3168	0,9991	1,0321	-1,3168	0,002652 (1,0268) – (1,0373)	0,387565 (-2,0830) – (-0,5504)

– Overall equation to convert from Curve LJFL to Straight LJFL

Relationship	*Equation*	*R2*	*a*	*b*	*SE of a* (95% C.I. of a)*	*SE of b* (95% C.I. of b)*
cLJFL-sLJFL	s-LJFL = 0,9657 * (c-LJFL) + 1,7887	0,9968	0,9657	1,7887	0,001392 (0,9629) – (0,9684)	0,187711 (1,4205) – (2,1569)

– Equation for male specimens

Relationship	*Equation*	*R2*	*a*	*b*	*SE of a* (95% C.I. of a)*	*SE of b* (95% C.I. of b)*
cLJFL-sLJFL	s-LJFL = 0,9684 * (c-LJFL) + 1,4384	0,996	0,9684	1,4384	0,005348 (0,9578) – (0,9789)	0,693761 (0,0661) – (2,8106)

– Equation for female specimens

Relationship	*Equation*	*R2*	*a*	*b*	*SE of a* (95% C.I. of a)*	*SE of b* (95% C.I. of b)*
cLJFL-sLJFL	s-LJFL = 0,9681 * (c-LJFL) + 1,4054	0,9991	0,9681	1,4054	0,002488 (0,9631) – (0,9729)	0,371975 (0,6698) – (2,1408)

Table 3. Estimated coefficients of the linear model between straight and curved LJFL, including sex and months as covariates.

```
Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.554844   0.386387   4.024    6e-05 ***
cLJFL        0.963295   0.001517 634.798   <2e-16 ***
Sex          0.076848   0.064352   1.194   0.2326
Month 5      0.497927   0.356861   1.395   0.1631
Month 6      0.852994   0.351986   2.423   0.0155 *
Month 7      0.458393   0.352008   1.302   0.1930
Month 8      0.240763   0.359822   0.669   0.5035
Month 9      0.625271   0.361871   1.728   0.0842 .
Month 10     0.367131   0.532750   0.689   0.4908
Month 11    -0.566378   0.388689  -1.457   0.1453
Month 12     0.779515   0.466035   1.673   0.0946 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.376 on 1529 degrees of freedom
Multiple R-squared:  0.9967,   Adjusted R-squared:  0.9967
F-statistic: 4.676e+04 on 10 and 1529 DF,  p-value: < 2.2e-16
```

Table 4. Analysis of variance table for the linear model between straight and curved LJFL, including sex and months as covariates.

```
Analysis of Variance Table

Response: sLJFL
            Df Sum Sq Mean Sq    F value    Pr(>F)
cLJFL        1 885377  885377 4.6755e+05 < 2.2e-16 ***
Sex          1      1       1 4.4370e-01    0.5055
Month        8    121      15 8.0112e+00 1.251e-10 ***
Residuals 1529   2895       2
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Table 5a. Estimated cLJFL (cm) and C.I. 95%.

X Value (sLJFL)	*Estimated value (cLJFL)*	*C.I. 95% Lower*	*C.I. 95% Upper*
50	50,18686	49,94335	50,43036
55	55,34794	55,11835	55,57753
60	60,50903	60,29327	60,72479
65	65,67012	65,46807	65,87216
70	70,8312	70,64274	71,01966
75	75,99229	75,81725	76,16733
80	81,15337	80,99156	81,31519
85	86,31446	86,1656	86,46332
90	91,47555	91,33932	91,61177
95	96,63663	96,5126	96,76066
100	101,7977	101,6853	101,9101
105	106,9588	106,8573	107,0604
110	112,1199	112,0281	112,2116
115	117,281	117,1976	117,3643
120	122,4421	122,3652	122,5189
125	127,6031	127,5304	127,6759
130	132,7642	132,6929	132,8356
135	137,9253	137,8523	137,9983
140	143,0864	143,009	143,1638
145	148,2475	148,1634	148,3316
150	153,4086	153,3159	153,5013
155	158,5697	158,467	158,6723
160	163,7308	163,6172	163,8443
165	168,8918	168,7666	169,0171
170	174,0529	173,9154	174,1904
175	179,214	179,0638	179,3642
180	184,3751	184,2119	184,5383
185	189,5362	189,3598	189,7126
190	194,6973	194,5074	194,8871
195	199,8584	199,6549	200,0618
200	205,0194	204,8023	205,2366

Table 5b. Estimated sLJFL (cm) and C.I. 95%.

X Value (cLJFL)	*Estimated value (sLJFL)*	*C.I. 95% Lower*	*C.I. 95% Upper*
50	50,07374	49,83806	50,30941
55	54,90224	54,67959	55,12489
60	59,73074	59,52103	59,94045
65	64,55924	64,36238	64,75611
70	69,38774	69,2036	69,57189
75	74,21625	74,04469	74,3878
80	79,04475	78,8856	79,2039
85	83,87325	83,72629	84,02021
90	88,70175	88,56669	88,83681
95	93,53025	93,40673	93,65377
100	98,35875	98,2463	98,47121
105	103,1873	103,0852	103,2893
110	108,0158	107,9233	108,1082
115	112,8443	112,7603	112,9282
120	117,6728	117,5957	117,7498
125	122,5013	122,4293	122,5733
130	127,3298	127,2604	127,3991
135	132,1583	132,0889	132,2276
140	136,9868	136,9148	137,0588
145	141,8153	141,7383	141,8923
150	146,6438	146,5598	146,7277
155	151,4723	151,3798	151,5647
160	156,3008	156,1988	156,4028
165	161,1293	161,0168	161,2417
170	165,9578	165,8343	166,0813
175	170,7863	170,6512	170,9213
180	175,6148	175,4678	175,7617
185	180,4433	180,2841	180,6024
190	185,2718	185,1002	185,4433
195	190,1003	189,9161	190,2844
200	194,9288	194,7319	195,1256

Table 6a. Estimated cLJFL (cm) and C.I. 95% for male specimens.

X Value (sLJFL)	*Estimated value (cLJFL)*	*C.I. 95% Lower*	*C.I. 95% Upper*
50	50,46	49,59	51,34
60	60,75	59,99	61,51
70	71,03	70,38	71,69
80	81,32	80,77	81,87
90	91,6	91,16	92,05
100	101,89	101,54	102,23
110	112,17	111,92	112,43
120	122,46	122,26	122,65
130	132,74	132,55	132,93
140	143,03	142,79	143,27
150	153,31	152,99	153,64
160	163,6	163,17	164,02
170	173,88	173,35	174,41
180	184,17	183,53	184,8
190	194,45	193,71	195,19
200	204,74	203,88	205,59

Table 6b. Estimated sLJFL (cm) and C.I. 95% for male specimens.

X Value (cLJFL)	*Estimated value (sLJFL)*	*C.I. 95% Lower*	*C.I. 95% Upper*
50	49,86	49,01	50,71
60	59,54	58,79	60,29
70	69,23	68,58	69,87
80	78,91	78,36	79,45
90	88,59	88,15	89,04
100	98,28	97,93	98,63
110	107,96	107,7	108,23
120	117,64	117,45	117,84
130	127,33	127,15	127,51
140	137,01	136,8	137,23
150	146,7	146,41	146,98
160	156,38	156	156,76
170	166,06	165,59	166,54
180	175,75	175,18	176,32
190	185,43	184,76	186,1
200	195,12	194,34	195,89

Table 7a. Estimated cLJFL (cm) and C.I. 95% for female specimens.

X Value (sLJFL)	*Estimated value (cLJFL)*	*C.I. 95% Lower*	*C.I. 95% Upper*
50	50,29	49,77	50,8
60	60,61	60,15	61,07
70	70,93	70,52	71,34
80	81,25	80,88	81,61
90	91,57	91,25	91,88
100	101,89	101,62	102,16
110	112,21	111,98	112,44
120	122,53	122,34	122,72
130	132,85	132,69	133,01
140	143,17	143,02	143,32
150	153,49	153,34	153,64
160	163,81	163,64	163,98
170	174,13	173,93	174,33
180	184,45	184,21	184,69
190	194,77	194,49	195,06
200	205,09	204,76	205,43

Table 7b. Estimated sLJFL (cm) and C.I. 95% for female specimens.

X Value (cLJFL)	*Estimated value (sLJFL)*	*C.I. 95% Lower*	*C.I. 95% Upper*
50	49,81	49,31	50,3
60	59,49	59,04	59,94
70	69,17	68,77	69,57
80	78,85	78,49	79,21
90	88,53	88,22	88,84
100	98,21	97,94	98,48
110	107,89	107,66	108,12
120	117,57	117,38	117,77
130	127,25	127,09	127,42
140	136,93	136,79	137,08
150	146,61	146,47	146,76
160	156,29	156,14	156,45
170	165,98	165,79	166,16
180	175,66	175,44	175,87
190	185,34	185,08	185,59
200	195,02	194,72	195,31

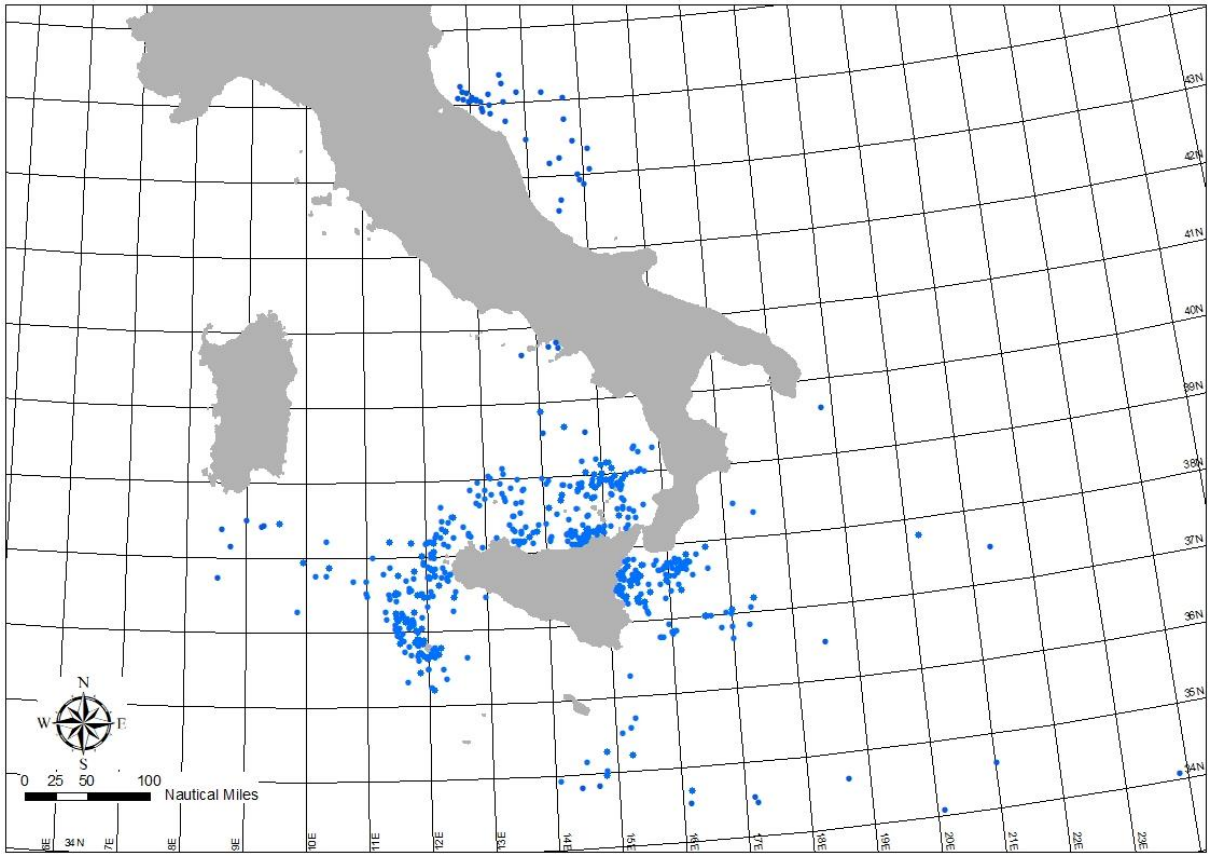

Figure 1. Distribution of the considered SWO catches monitored during the sampling period 2017-2023.

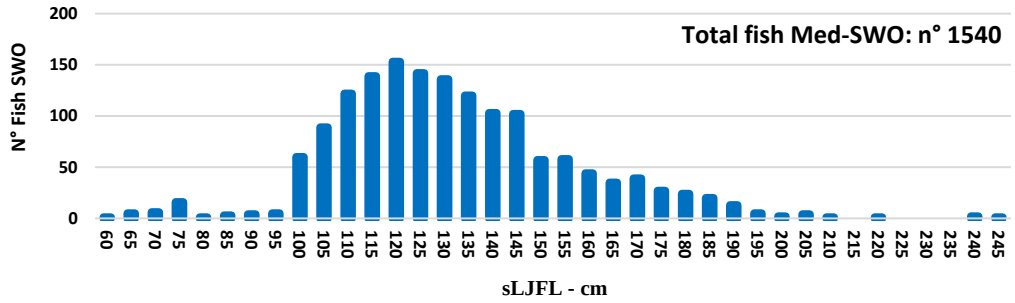

Figure 2 Length frequency distribution for Med-SWO caught during the sampling period 2017-2023 (s-LJFL cm).

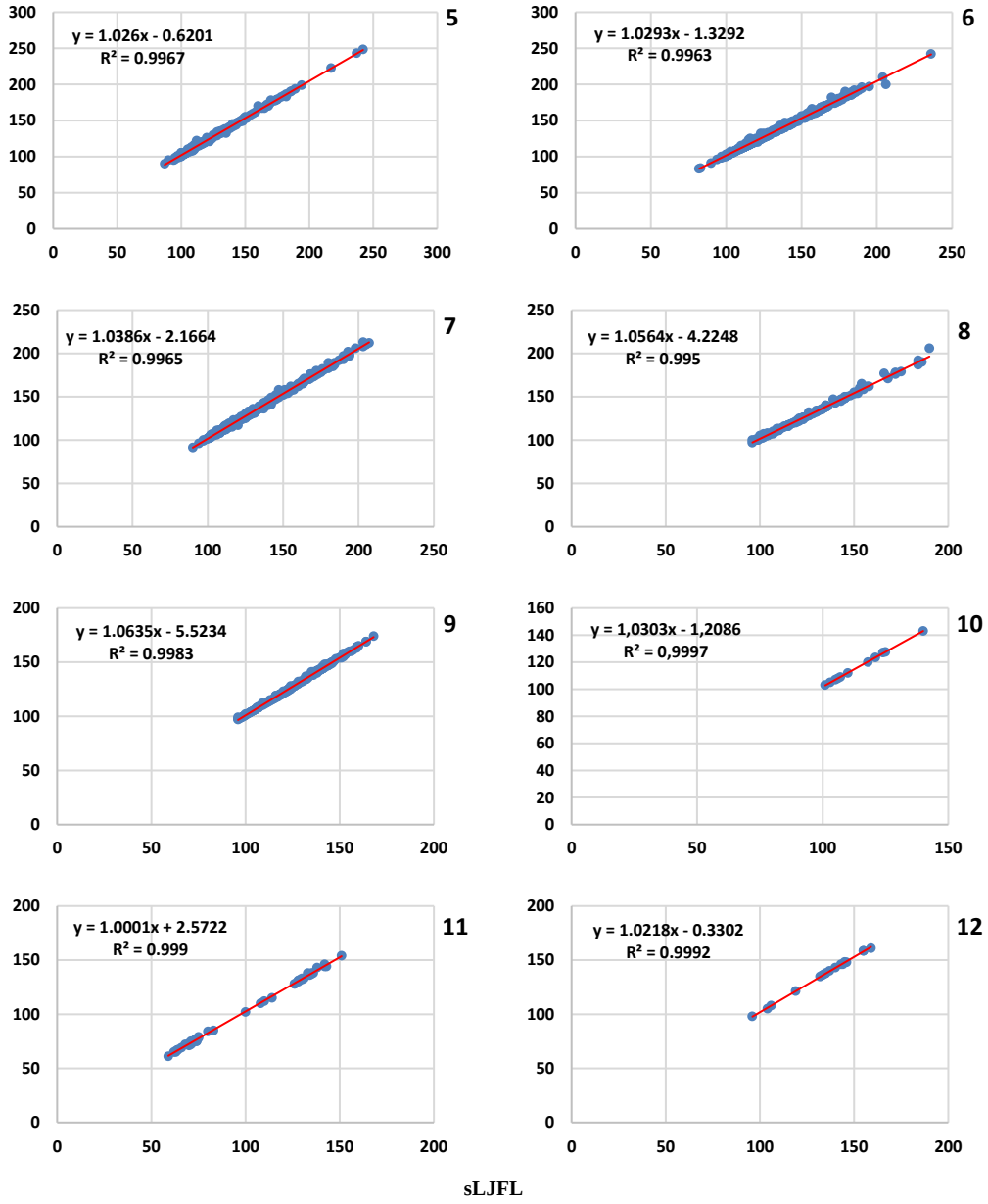

Figure 3 Monthly length/length size relationships (c-LJFL/s-LJFL) obtained by the analysis of the data collected for the present study (2017-2023) during the entire sampling period.