SCRS/1988/043

Col.Vol.Sci.Pap. ICCAT, 30 (2) : 364-374 (1989)

DEVELOPMENT OF LENGTH REGRESSIONS FOR ATLANTIC ISTIOPHORIDAE

E. D. Prince, D. W. Lee
NMFS, Southeast Fisheries Center, 75 Virginia Beach Drive, Miami, Florida, U.S.A.

SUMMARY

Length regressions for blue marlin (Makaira nigricans), white marlin (Tetrapturus albidus), and sailfish (Istiophorus platypterus) were developed to allow estimates of lower jaw fork length (LJFL) for the major methods of dressing (cleaning) Atlantic istiophorids identified by ICCAT reporting nations.

Linear regression techniques were used to determine the relationship between LJFL (dependent variable) and four other measures of length (independent variables) including: eye orbit fork length (EOFL), pectoral fork length (PFL), pectoral second dorsal length (PDL), and dorsal fork length (DFL).

The most useful regressions for Atlantic methods of dressing billfish appear to be LJFL vs PFL and LJFL vs PDL. The LJFL vs PFL regressions will be used for billfish carcasses with heads and caudal peduncles removed. However, the regression of LJFL vs PDL was the weakest of all analysis categories (R^2 = 0.93 to 0.64). These relationships might be strengthened by the acquisition of additional samples for all species and sex categories, as well as a broader coverage of the size range of samples. In addition, it is suggested that alternative regressions be developed for estimating LJFL when billfish carcasses have heads and caudal peduncles removed. One possibility that might result in a stronger predictive regression include LJFL vs pectoral to anus length (PAL).

RESUME

Des calculs de régression de la taille du makaire bleu (Makaira nigricans), du makaire blanc (Tetrapturus albidus) et du voilier (Istiophorus platypterus) ont été effectués pour permettre d'estimer la longueur maxillaire-fourche pour les principales méthodes de manipulation (nettoyage) des istiophoridés atlantiques identifiés par les pays qui correspondent avec l'ICCAT. Les techniques de régression linéaire ont été utilisées pour déterminer le rapport entre la longueur maxillaire-fourche (variable dépendante) et quatre autre mesures de taille (variables indépendantes): longueur orbitaire-fourche, longueur pectorale-fourche, longueur pectorale-deuxième dorsale et longueur dorsale-fourche.

Les régressions les plus utiles pour les méthodes de préparation des istiophoridés dans l'Atlantique semblent être maxillaire vs. pectorale et maxillaire vs. pectorale-deuxième dorsale. Les régressions du premier cas seront utilisées pour les carcasses d'istiophoridés étêtées mais dont le pedoncule caudal est intact. Celles du deuxième cas serviront pour les carcasses étêtées et sans pédoncule caudal. Néanmoins, la régression maxillaire vs. pectorale-deuxième dorsale était la plus faible de toutes les catégories d'analyse (R^2 = 0.93 à 0.64). Ces rapports peuvent être renforcés par l'acquisition d'échantillons supplémentaires pour toutes les catégories d'espèce et de sexe, ainsi que par une plus ample couverture de la gamme des tailles dans l'échantillon. En outre, il est suggéré que d'autres régressions soient élaborées pour estimer la longueur maxillaire-fourche lorsque les carcasses sont sans tête ni pédoncule caudal. Une possibilité qui pourrait donner une meilleure projection par régression serait longueur maxillaire-fourche vs. longueur pectorale-anus.

RESUMEN

Se hallaron regresiones de talla para la aguja azul (Makaira nigricans), aguja blanca (Tetrapturus albidus) y pez vela (Istiophorus platypterus) que permitiesen establecer estimaciones de longitud mandibula inferior/horquilla (MIH) para los principales métodos de manipulación (limpieza) de istioforideos atlánticos identificados por los países que transmiten sus datos a ICCAT. Se emplearon técnicas de regresión lineal para determinal la relación entre MIH (variable dependiente) y otras cuatro medidas de talla (variables independientes) incluyendo: órbita del ojo/horquilla (OOH), pectoral/horquilla (PH), pectoral/segunda dorsal (PSD) y dorsal/horquilla (DH).

Las regresiones más útiles con vistas a los métodos de manipulación de los marlines atlánticos parecen ser MIH vs. PH y MIH vs. PSD. La regresión MI vs. PH se empleará en las carcasas de marlines sin cabeza pero con los pedúnculos caudales intactos. La regresión MIH vs. PSD se empleará para las carcasas de marlines con cabeza pero sin pedúnculos caudales. Sin embargo, la regresión MIH vs. PSD era la más débil de todas las categorías de análisis (R^2 = 0.93 a 0.64). Estas relaciones pueden intensificarse con la adquisición de muestras adicionales de todas las especies y categorías de sexo, así como con una más amplia cobertura de la escala de tallas de las muestras. Además, se sugiere el desarrollo de regresiones alternativas para estimar MIH cuando las carcasas de los marlines se encuentren sin cabeza ni pedúnculos caudales. Una posibilidad que podría tener como resultado una regresión predictiva más fuerte incluye la longitud MIH vs. pectoral /ano (PA).

INTRODUCTION

The International Commission for the Conservation of Atlantic Tuna (ICCAT) established the Enhanced Research Program for Billfish at the 1986 SCRS meeting, in an attempt to develop the data necessary to assess the status of the stocks. One of the most important objectives in the program plan (ICCAT In press, COM-SCRS/88/14) is to obtain more detailed data on landings statistics, particularly size frequency data.

Size frequencies of istiophorids rarely appear in the ICCAT data base due, in part, to the incidental nature of most of the landings--the primary targets of longline fisheries are usually tunas (Thunnus spp.) and swordfish (Xiphias gladius). In addition, there are at least 10 different methods of dressing (cleaning) istiophorids (Prince and Miyake In press, SCRS/88/44) and in many instances the critical body parts necessary for obtaining the preferred measure of length (lower jaw fork length, LJFL) are removed prior to off-loading. When conducting a stock assessment for a species harvested by many different countries, it is usually necessary to convert size frequency samples to a common unit of measurement. Therefore, the objectives of this study were to develop length regression estimates of lower jaw fork length (dependent variable) given other measures of length (independent variables).

METHODS

Linear regression techniques were used to determine the relationships between LJFL (dependent variable) and the following four measures of length (independent variables): (1) Eye-orbit fork length (EOFL); (2) Pectoral fork length (PFL); (3) Dorsal fork length (DFL); and (4) Pectoral second dorsal length (PDL). Definitions of length measurements are given in the interim sampling instructions for the Enhanced Research Program for Billfish (Prince, Diouf, Miyake, and Brown, In press, SCRS/88/28) as follows: (1) LJFL--Distance from the tip of the lower jaw to the fork of the tail; (2) EOFL--Distance from the posterior edge of the eye orbit to the fork of the tail; (3) PFL--Distance from the most anterior insertion of the pectoral fin to the fork of the tail; (4) DFL--Distance from the most anterior insertion of the dorsal fin to the fork of the tail; and (5) PDL--Distance from the most anterior insertion of the pectoral fin to the most anterior insertion of the second dorsal fin. For consistency, all measures of length were taken along the lateral line contour with a fiberglass tape (curved body length).

Length measurements were obtained from blue marlin (Makaira nigricans), white marlin (Tetrapturus albidus), and sailfish (Istiophorus platypterus) caught in the Western Atlantic Ocean. Capture of longbill spearfish (Tetrapturus pfluegeri) in the western Atlantic Ocean are rare and data on this species could not be collected in sufficient quantity to be included in this analysis. Most samples were taken from U.S. recreational landings since these fish are landed intact and all five measures of length, weight, and sex can be obtained. Additional data used in this analysis was also acquired from the billfish observer sampling program centered in Cumana, Venezuela (Prince, Diouf, Miyake, Brown In press, COM-SCRS/88/10). Measurements in this case were taken prior to the fish being dressed.

RESULTS AND DISCUSSION

Regressions of LJFL and four other measures of length (EOFL, PFL, DFL, PDL) were computed separately by sex for each of the three species (Figs. 1-6), since sexual dimorphic growth has been reported for most istiophorids (Wilson 1984). The regression equation, coefficient of determination (R^2), and sample size (N) are also given for each relationship (Figs. 1-6). The coefficient of determination is the proportion of the sum of squares of the dependent variable that can be attributed to the independent variable and as such is particularly useful in assessing the reliability of the regressions (Steel and Torrie 1960).

The range in R^2's for all regressions for female and male blue marlin were 0.97 to 0.90 and 0.97 to 0.75, respectively; for white marlin the range in values were somewhat lower--0.90 to 0.64 for females and 0.95 to 0.80 for males (Figs. 1-4). The range in R^2's for female and male sailfish regressions were comparable to blue marlin; R^2's ranged from 0.98 to 0.93 for females and 0.98 to 0.92 for males (Figs. 5 and 6).

The strongest relationships with LJFL were generally achieved with EOFL and PFL for the various sex and species categories, while the LJFL vs PDL usually had the weakest relationship for each species and sex (Figs. 1-6). Nineteen of the 24 regression R^2's were $\geq$ 0.90 and these relationships appear to be very reliable for estimating LJFL from other measures of length (Table 2). Two of the regression R^2's were $\geq$0.80 to 0.89 (Figs. 3 and 4) and although these relationships are still useful, stronger relationships are preferred. Three of the regression R^2's were $<$ 0.80 (Figs. 2 and 3) and we consider these regressions of marginal value for estimating LJFL for these species, sex, and length categories.

Prince and Miyake (In press, SCRS/88/44) reported that regressions of LJFL vs PFL and LJFL vs PDL would be the most important relationships for estimating LJFL for the 10 different types of methods used to dress Atlantic istiophorids. The LJFL vs PFL regression can be used for carcasses that have heads removed and caudal peduncles intact. The LJFL vs PDL regression can be used for carcasses that have both heads and caudal peduncles removed. However, the LJFL vs PDL relationship consistently had the lowest R^2 values for each analysis category and we do not recommend use of regressions with R^2's that fall below 0.80 (i.e. female white marlin and male blue marlin). Increasing the number of samples and covering a larger size range for each of these species and sex categories may strength these regressions. In addition, because of the importance of estimating LJFL from billfish carcasses with heads and caudal peduncles removed, development of an alternative regression might be justified as a backup to the LJFL vs PDL relationship. One possible solution to this problem is developing a regression for LJFL vs pectoral to anus length (PAL)--PAL is defined as the distance from the anterior insertion of the pectoral fin to the posterior rim of the anal opening.

Small sample sizes also resulted for each species when the data were partitioned by sex. This was particularly true for males which were generally less abundant in the samples and available in a narrower and smaller size range compared to females (Table 1). For example, sample sizes for male categories of sailfish and white marlin were both below 50. Targeting future data collections to increase sample size and improve the size range covered also appears warranted for these categories of the analysis.

LITERATURE CITED

International Commission for the Conservation of Atlantic Tunas. In press. Program plan for the ICCAT enhanced research program for billfish. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid. COM-SCRS/88/14.

Prince, E. D., and P. M. Miyake. In press. Methods of dressing Atlantic Billfishes (Istiophoridae) by ICCAT reporting countries. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid. SCRS/88/44.

Prince, E. D., T. Diouf, P. M. Miyake, and B.E. Brown. In press. Interim sampling instructions for the ICCAT enhanced research program for billfish, 1988. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid. COM-SCRS/88/28.

Prince, E. D., T. Diouf, P. M. Miyake, and B. E. Brown. In press. Progress of the ICCAT enhanced research program for billfish during 1988. Int. Comm. Conserv. Atl. Tunas, Coll. Vol. Sci. Pap., Madrid. COM-SCRS/88/10.

Steel, G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Company, Inc., New York.

Wilson, C. A. 1984. Age and growth aspects of the life history of billfish. Ph.D. Thesis, University of South Carolina, Columbia, SC, 180 p.

Table 1. Species, sex, length measurement, length range (cm), mean length (cm), and sample size for length regressions developed for Atlantic istiophorids. Length measurements are defined as lower jaw fork length (LJFL), eye orbit fork length (EOFL), dorsal fork length (DFL), pectoral fork length (PFL), and pectoral second dorsal fork length (PDL).

Species sex	Length measurement	Length range (cm)	Mean length (cm)	Sample size
Blue marlin				
female	LJFL	149.8 - 331.5	252.0	111
	EOFL	132.0 - 292.7	221.4	111
	DFL	124.4 - 274.3	201.9	110
	PFl	115.5 - 260.4	193.9	110
	PDL	88.9 - 182.9	135.5	109
male	LJFL	147.3 - 246.0	187.8	57
	EOFL	127.0 - 211.0	163.3	56
	DFL	113.0 - 198.0	148.9	57
	PFL	113.0 - 189.0	143.8	56
	PDL	81.2 - 150.0	102.6	50
White marlin				
female	LJFL	150.5 - 189.0	165.3	74
	EOFL	129.5 - 163.0	142.5	64
	DFL	119.0 - 147.0	129.5	74
	PFL	110.0 - 140.0	121.1	74
	PDL	81.0 - 106.0	91.4	63
male	LJFL	135.0 - 182.0	162.1	47
	EOFL	118.0 - 159.0	141.5	30
	DFL	108.0 - 150.0	127.9	47
	PFL	96.0 - 138.0	119.9	47
	PDL	71.0 - 105.0	93.3	30
Sailfish				
female	LJFL	101.1 - 200.7	163.1	51
	EOFL	84.4 - 172.7	141.3	50
	DFL	78.0 - 162.6	132.3	51
	PFL	74.2 - 154.3	124.1	51
	PDL	54.4 - 116.8	92.3	50
male	LJFL	127.8 - 177.8	153.9	22
	EOFL	106.7 - 152.4	132.5	22
	DFL	104.1 - 144.8	124.9	22
	PFL	96.5 - 134.6	116.5	22
	PDL	73.6 - 101.6	87.8	22

Table 2. Equations and coefficient of determination (R^2) for length regressions of LJFL (dependent variable) and four other measures of length (EOFL, DFL, PFL, PDL) for male and female blue marlin, white marlin, and sailfish.

Species	Sex	Dependent variable	Regression equation	R^2
Blue marlin	female	EOFL	LJFL = 10.52 + 1.09(EOFL)	0.97
		PFL	LJFL = 19.23 + 1.20(PFL)	0.97
		DFL	LJFL = 10.02 + 1.20(DFL)	0.96
		PDL	LJFL = 33.29 + 1.61(PDL)	0.90
	male	EOFL	LJFL = 7.15 + 1.10(EOFL)	0.97
		PFL	LJFL = 9.34 + 1.24(PFL)	0.95
		DFL	LJFL = 9.08 + 1.20(DFL)	0.95
		PDL	LJFL = 50.15 + 1.33(PDL)	0.75
White marlin	female	EOFL	LJFL = 17.75 + 1.04(EOFL)	0.90
		PFL	LJFL = 36.91 + 1.05(PFL)	0.83
		DFL	LJFL = 35.14 + 1.00(DFL)	0.78
		PDL	LJFL = 72.07 + 1.02(PDL)	0.64
	male	EOFL	LJFL = 6.89 + 1.11(EOFL)	0.92
		PFL	LJFL = 27.19 + 1.12(PFL)	0.94
		DFL	LJFL = 17.48 + 1.13(DFL)	0.95
		PDL	LJFL = 53.03 + 1.19(PDL)	0.80
Sailfish	female	EOFL	LJFL = 9.14 + 1.08(EOFL)	0.98
		PFL	LJFL = 10.02 + 1.23(PFL)	0.98
		DFL	LJFL = 11.75 + 1.14(DFL)	0.96
		PDL	LJFL = 18.79 + 1.55(PDL)	0.93
	male	EOFL	LJFL = 8.01 + 1.10(EOFL)	0.98
		PFL	LJFL = 5.06 + 1.27(PFL)	0.97
		DFL	LJFL = -0.18 + 1.23(DFL)	0.96
		PDL	LJFL = 9.83 + 1.64(PDL)	0.92

FIGURE LEGEND

Figure 1. Length regressions for female blue marlin. Dependent variable is lower jaw fork length (LJFL) and independent variables are eye orbit fork length (EOFL), pectoral fork length (PFL), dorsal fork length (DFL), and pectoral second dorsal length (PDL). Regression equation, coefficient of determination (R^2), and sample size (N) are given for each relationship.

Figure 2. Length regressions for male blue marlin. Dependent variable is lower jaw fork length (LJFL) and independent variables are eye orbit fork length (EOFL), pectoral fork length (PFL), dorsal fork length (DFL), and pectoral second dorsal length (PDL). Regression equation, coefficient of determination (R^2), and sample size (N) are given for each relationship.

Figure 3. Length regressions for female white marlin. Dependent variable is lower jaw fork length (LJFL) and independent variables are eye orbit fork length (EOFL), pectoral fork length (PFL), dorsal fork length (DFL), and pectoral second dorsal length (PDL). Regression equation, coefficient of determination (R^2), and sample size (N) are given for each relationship.

Figure 4. Length regressions for male white marlin. Dependent variable is lower jaw fork length (LJFL) and independent variables are eye orbit fork length (EOFL), pectoral fork length (PFL), dorsal fork length (DFL), and pectoral second dorsal length (PDL). Regression equation, coefficient of determination (R^2), and sample size (N) are given for each relationship.

Figure 5. Length regressions for female sailfish. Dependent variable is lower jaw fork length (LJFL) and independent variables are eye orbit fork length (EOFL), pectoral fork length (PFL), dorsal fork length (DFL), and pectoral second dorsal length (PDL). Regression equation, coefficient of determination (R^2), and sample size are given for each relationship.

Figure 6. Length regressions for male sailfish. Dependent variable is lower jaw fork length (LJFL) and independent variables are eye orbit fork length (EOFL), pectoral fork length (PFL), dorsal fork length (DFL), and pectoral second dorsal length (PDL). Regression equation, coefficient of determination (R^2), and sample size (N) are given for each relationship.

Figure 1. Length regressions for female blue marlin. Dependent variable is lower jaw fork length (LJFL) and independent variables are eye orbit fork length (EOFL), pectoral fork length (PFL), dorsal fork length (DFL), and pectoral second dorsal length (PDL). Regression equation, coefficient of determination (R^2), and sample size (N) are given for each relationship.

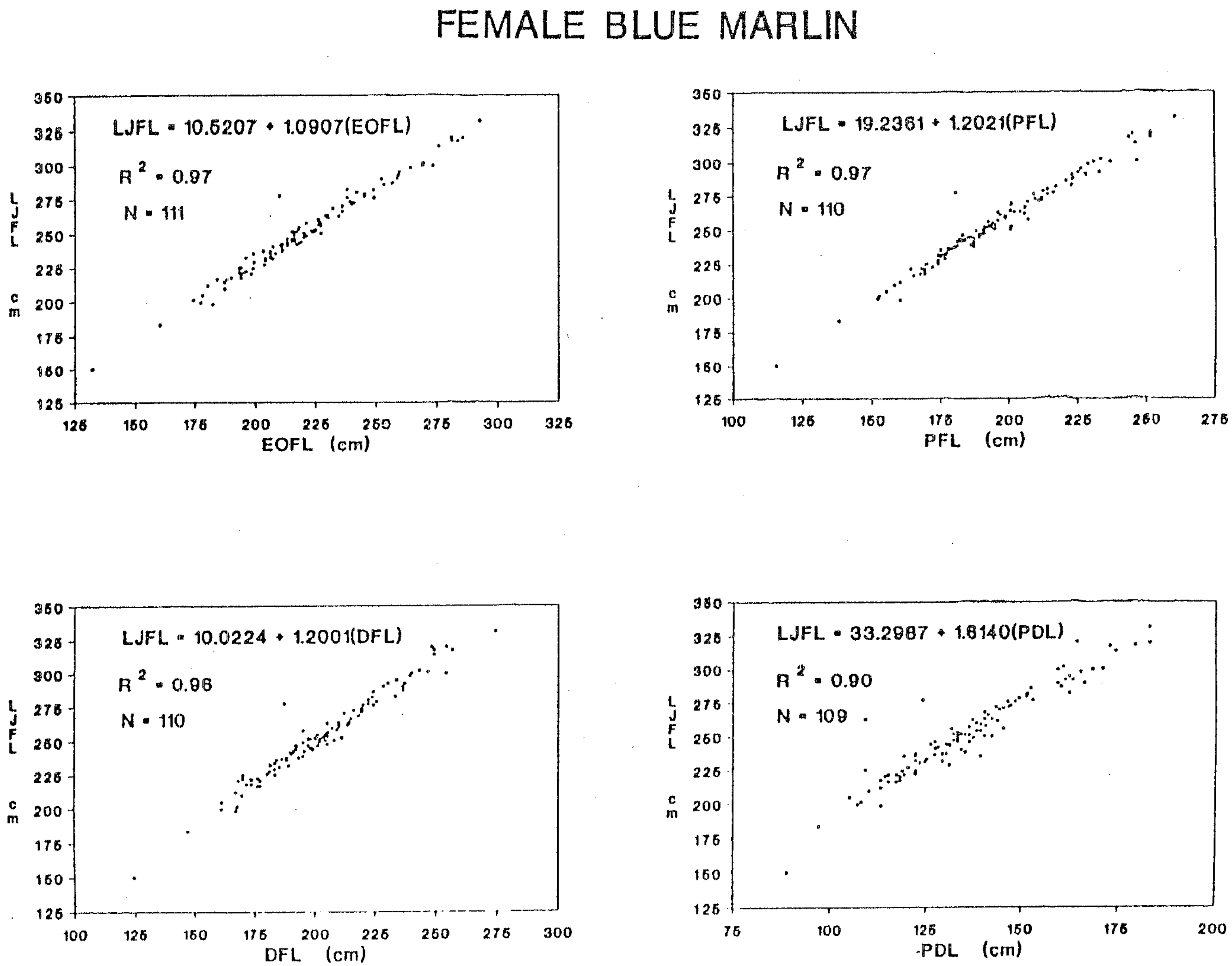

Figure 2. Length regressions for male blue marlin. Dependent variable is lower jaw fork length (LJFL) and independent variables are eye orbit fork length (EOFL), pectoral fork length (PFL), dorsal fork length (DFL), and pectoral second dorsal length (PDL). Regression equation, coefficient of determination (R^2), and sample size (N) are given for each relationship.

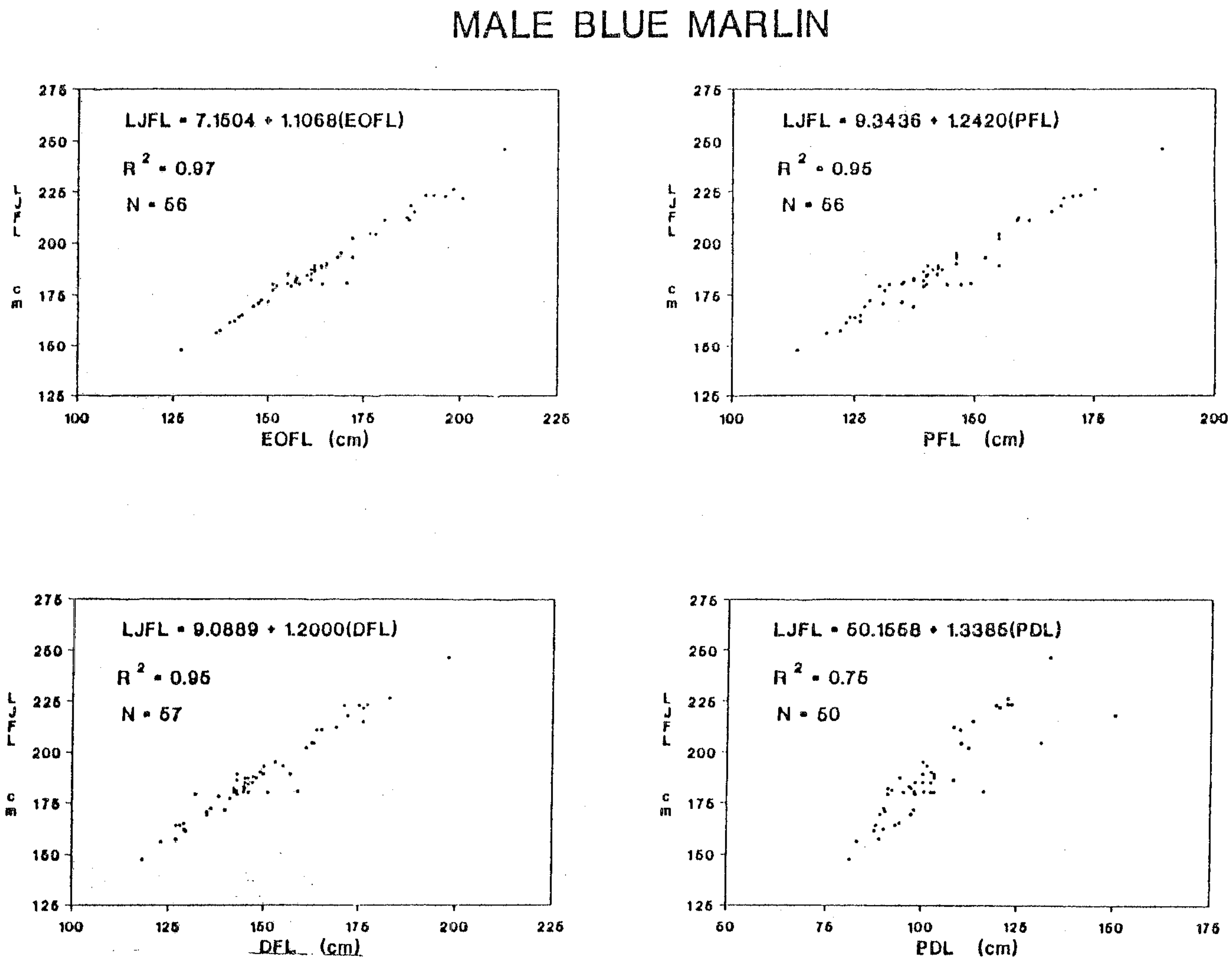

Figure 3. Length regressions for female white marlin. Dependent variable is lower jaw fork length (LJFL) and independent variables are eye orbit fork length (EOFL), pectoral fork length (PFL), dorsal fork length (DFL), and pectoral second dorsal length (PDL). Regression equation, coefficient of determination (R2), and sample size (N) are given for each relationship.

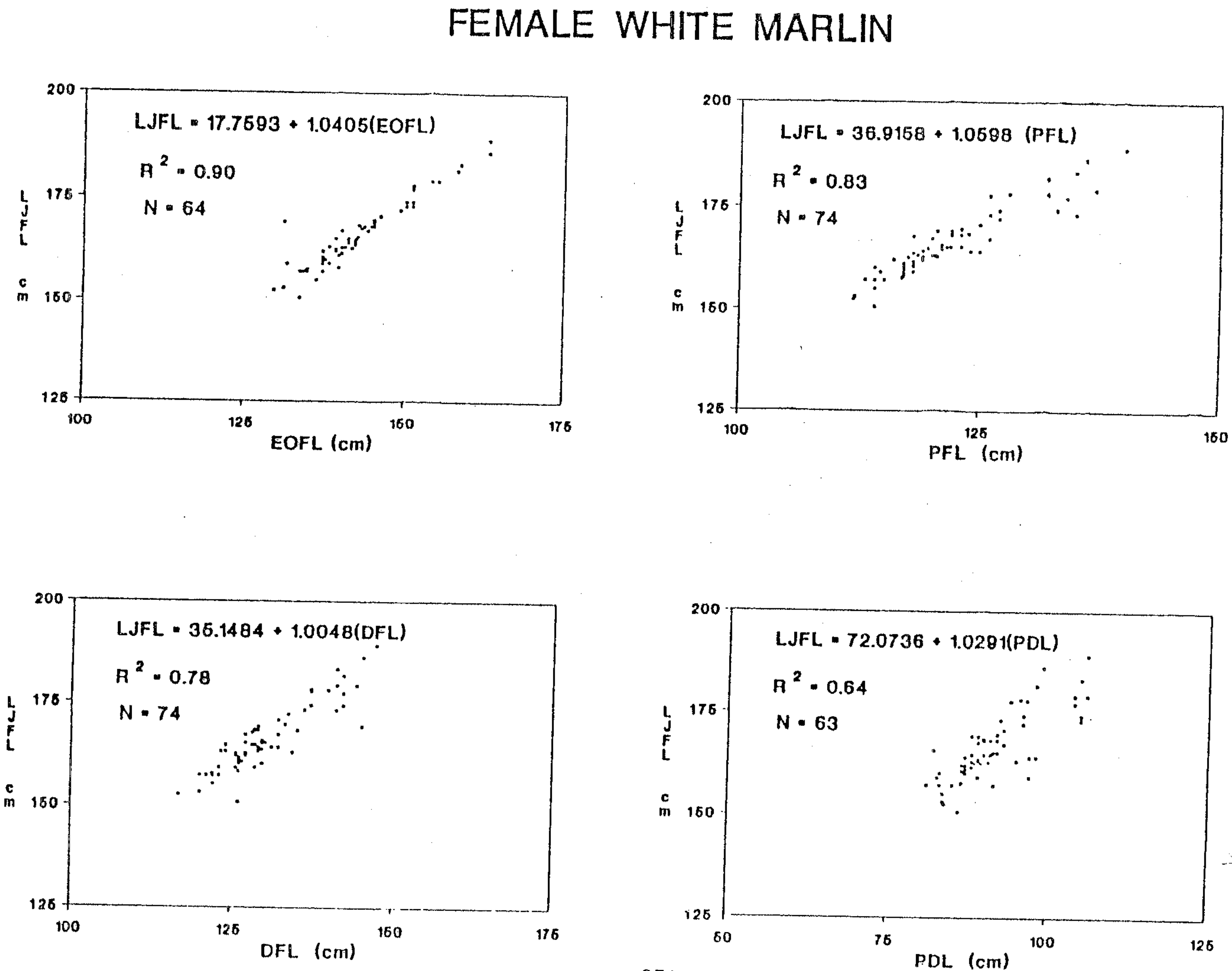

Figure 4. Length regressions for male white marlin. Dependent variable is lower jaw fork length (LJFL) and independent variables are eye orbit fork length (EOFL), pectoral fork length (PFL), dorsal fork length (DFL), and pectoral second dorsal length (PDL). Regression equation, coefficient of determination (R^2), and sample size (N) are given for each relationship.

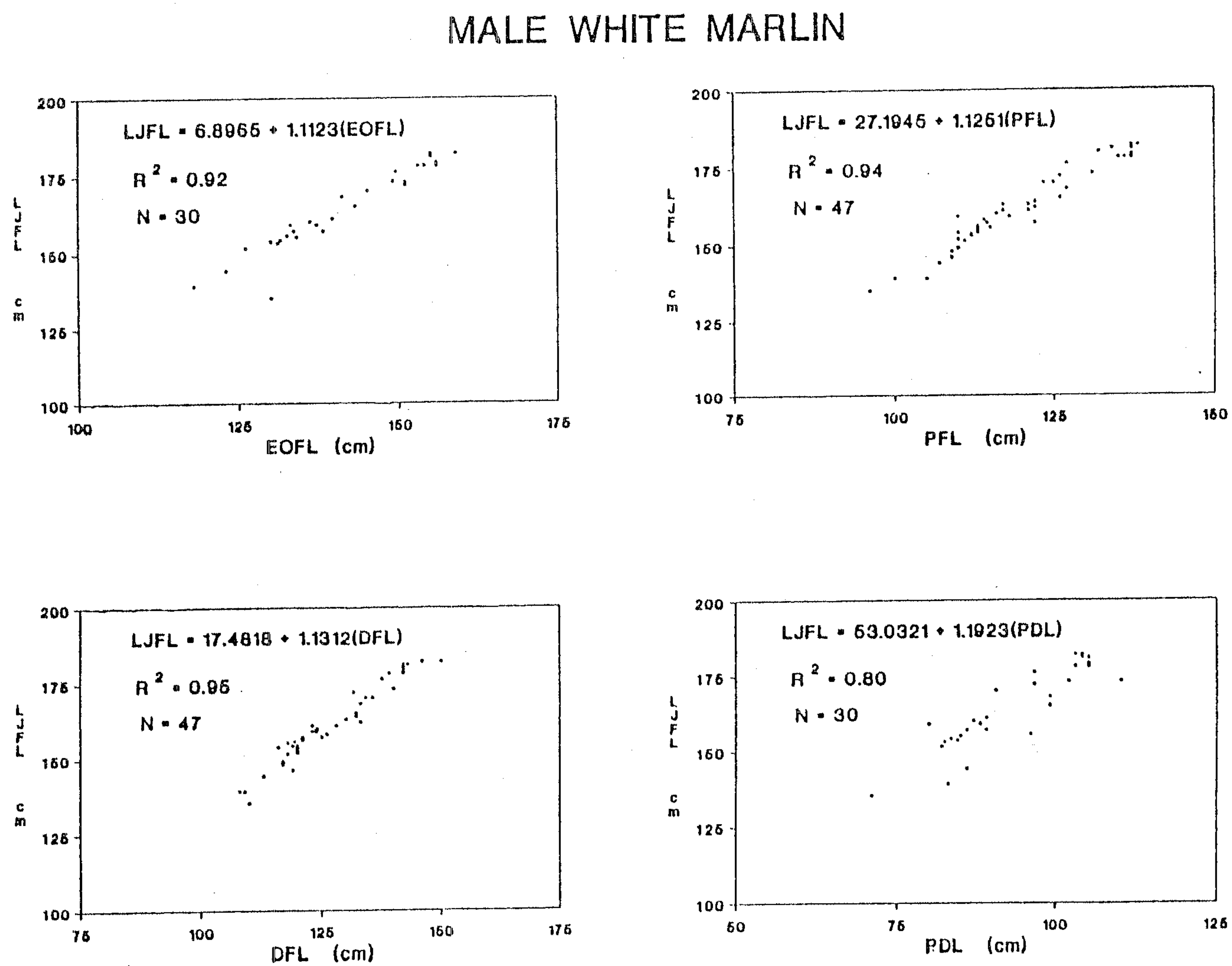

Figure 5. Length regressions for female sailfish. Dependent variable is lower jaw fork length (LJFL) and independent variables are eye orbit fork length (EOFL), pectoral fork length (PFL), dorsal fork length (DFL), and pectoral second dorsal length (PDL). Regression equation, coefficient of determination (R^2), and sample size are given for each relationship.

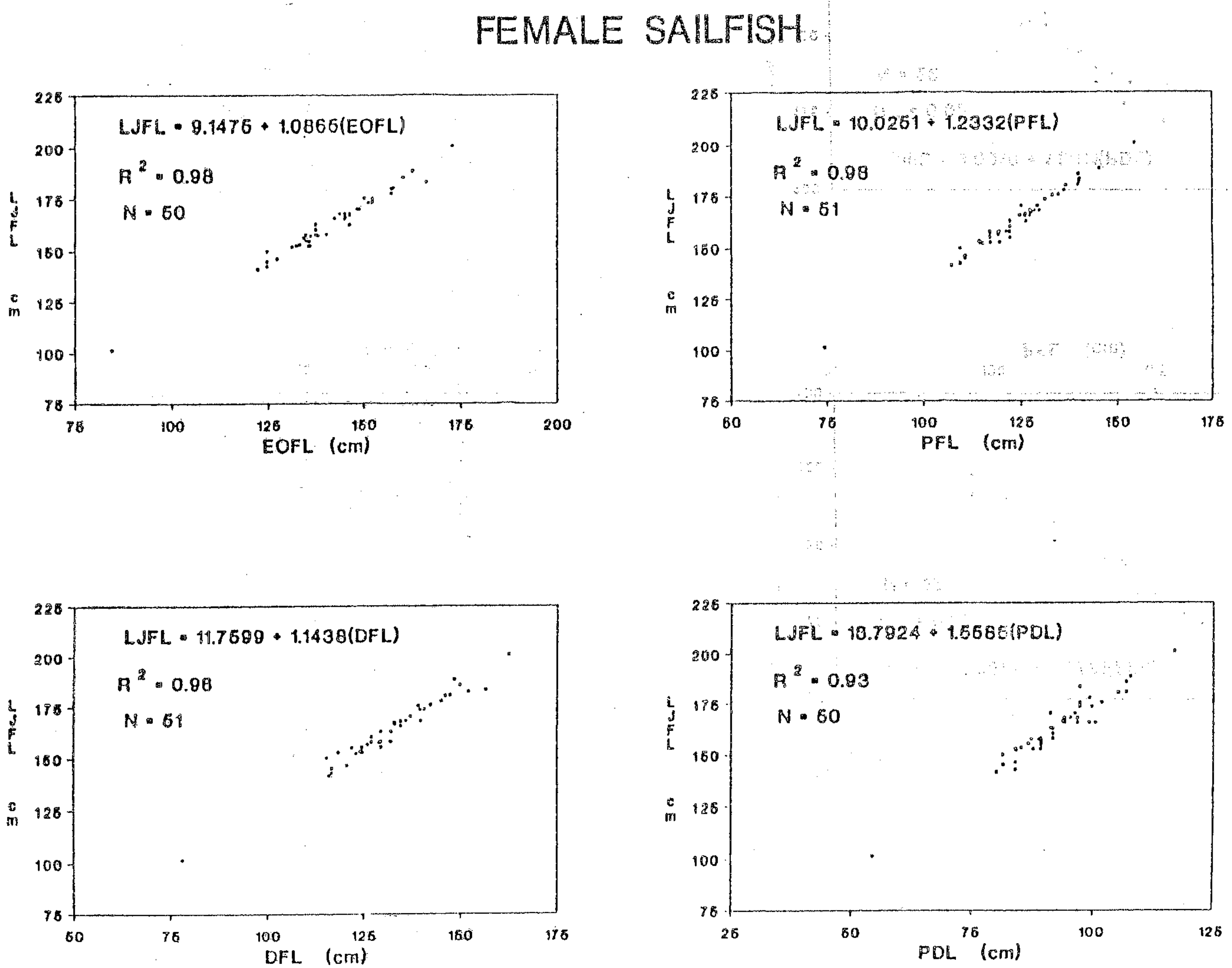

Figure 6. Length regressions for male sailfish. Dependent variable is lower jaw fork length (LJfL) and independent variables are eye orbit fork length (EOFL), pectoral fork length (PFL), dorsal fork length (DFL), and pectoral second dorsal length (PDL). Regression equation, coefficient of determination (R^2), and sample size (N) are given for each relationship.