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LENGTH-WEIGHT INTERRELATIONSHIPS FOR SWORDFISH, *Xiphias gladius* L., CAUGHT IN THE CENTRAL NORTH PACIFIC

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

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ABSTRACT

The interrelationships among commonly used length and weight metrics are described for swordfish (*Xiphias gladius*) from the central North Pacific Ocean. Swordfish were sampled by National Marine Fisheries Service (NMFS), Southwest Region (SWR) observers aboard commercial vessels of the Hawaii-based longline fishery during 1994-97 and caught on research cruises of the NOAA ship *Townsend Cromwell* during 1991-97.

Our attempt has been to provide complementary data for different users. First and foremost, the described length-weight relationships provide previously unavailable information required for pending stock assessments and life-history studies of swordfish in the North Pacific Ocean. Findings further allow researchers and managers to convert length and weight metrics for comparison with swordfish landings on the U.S. Atlantic seaboard and elsewhere where different metrics are used. Information on monthly fluctuations in condition (weight at length) also should interest Hawaii-based commercial fishermen and buyers.

INTRODUCTION

The broadbill swordfish, *Xiphias gladius*, is widely distributed throughout tropical, subtropical, and temperate waters worldwide, with a range that extends from latitudes 50˚N to 35-45˚S in the Pacific Ocean (Nakamura, 1985). Throughout its wide distribution, the swordfish has been sought by recreational and especially commercial fishermen (Nakamura, 1985). Size has been recorded throughout time and across the species' extensive distribution, but the types of measurement have varied. Comprehensive definitions of length and weight measurements have been provided for swordfish and other billfishes by Rivas (1956), and more recently by Nakamura (1985) and Prager et al. (1995). Thorough analyses of length and weight interrelationships have been conducted for billfishes other than swordfish (e.g., Prager et al., 1995).

Most studies of swordfish length and weight interrelationships have been problematic for one or more reasons. Typically, studies have related only one type of length measure with a single weight measure (e.g., Caddy, 1976; Garcés and Rey, 1984; Rodriguez et al., 1989) or at most two of the many possible weight measures (Arfelli and de Amorin, 1982). Sometimes the identity of one of the variables being examined is uncertain (weight: Garcés and Rey, 1984) or the terminology being used is obscure (operculum-fork length: Beardsley et al., 1979). Even if a larger number of variables were examined, sample sizes relating weight to length were often inadequate (Beardsley et al., 1979) or segments of the size distribution were undersampled.[1] Relatively few length-weight data exist for swordfish in the Pacific, and these appear in only two documents. Kume and Joseph (1969) related total or round weight (RW; n = 5) and dressed weight (with bill, head, and entrails removed, n = 15) to eye to fork length for eastern Pacific swordfish. Skillman and Yong (1974) related RW on fork length (n = 7) for central Pacific swordfish. Clearly, larger sample sizes and more comprehensive interrelationship conversions are needed for lengths and weights of Pacific swordfish. Swordfish length-weight data have become especially important now that the Hawaii-based longline fishery's

[1]Turner, S. 1986. Length to weight and weight to length conversions for swordfish in the western North Atlantic and Gulf of Mexico. Swordfish Workshop Working Paper 86/11. NMFS, NOAA, SEFC, Miami Laboratory, April 1986.

catch of swordfish has expanded to estimated annual landings of 1,900-5,954 t/yr (1991-96).[2]

In this report, we provide a comprehensive description of length and weight interrelationships for swordfish from the central North Pacific Ocean. Our primary objectives are to provide formulas enabling straightforward conversion of input parameters for (1) stock assessment and (2) life history studies of swordfish at the National Marine Fisheries Service (NMFS), Honolulu Laboratory (HL). Secondarily, the formulas provided should facilitate comparisons of size measures between swordfish in the Pacific and elsewhere and be useful to researchers in other institutions as well as at HL. Length-weight interrelationships should also interest members of the local Hawaii-based pelagic longline fishery.

MATERIALS AND METHODS

Sources and Types of Data

Swordfish length and weight data were provided by fish obtained from two sources: *Townsend Cromwell* research cruises and commercial catches of the Hawaii-based pelagic longline fishery. The latter data were obtained in part by NMFS SWR observers aboard vessels at sea and in part by Honolulu Laboratory personnel at the United Fishing Agency (UFA, Honolulu fish auction).

Research cruises provided the opportunity to take different types of measurements on individual fish, thereby allowing the description of detailed length conversions. Round weight that was unavailable from commercial swordfish was obtained on research cruises. Commercial catches provided extensive data needed to describe and evaluate sex and seasonal effects on fundamental length-weight interrelationships and one specific pair of linear measures (EFL-CKL, see below; these and all other terms used are defined when first used in the text and are also in a glossary). Although research data were limited to specific cruise dates, commercial catch data were generally available throughout the year.

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[2]Ito, R. Y., and W. A. Machado. 1997. Annual report of the Hawaii-based longline fishery for 1996. Honolulu Lab., Southwest Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Cent. Admin. Rep. H-97-12. 48 p.

Research Fish

Swordfish were caught using standard commercial longline gear and methods (He et al., 1997) at the swordfish fishing grounds north of the Hawaiian Islands from 1991 through 1997 (Appendix Table 1). Fishing operations were conducted in the vicinity of the southern Musician Seamounts up to latitude 27°N on cruises TC-91-01 (January 4-February 2, 1991) and TC-92-03 (April 13-May 7, 1992). In 1993, fishing was conducted farther north at about latitude 29°N, longitudes 160-162°W on cruise TC-93-03, Leg I (March 12-April 8, 1993). Cruises dedicated to swordfish research after 1993 expanded the fishing grounds up to latitude 40°N, longitudes 150-178°W. Research emphasized aspects other than catch, distribution, and environment on cruises after 1993, however, and the number of specimens available for morphometrics decreased. In this report, we utilize various elements of all cruise data but restrict our statistical comparisons of research cruises to 1991-93 for length interrelationships because of limited sample sizes on other cruises. Evaluation of length-weight interrelationships was further limited to the April-May cruises of 1992-93 because fish were not dressed (description follows) on the 1991 cruise.

Fish were processed in a standard manner on all cruises, except for the instruments used to weigh them (Appendix Table 2). Analyses described herein include interrelationships among fork length (FL), lower jaw to fork length (LJFL), eye to fork length (EFL), round weight, and several types of dressed weights. When a swordfish was first brought on deck, it was measured for FL (straight line from tip of bill to fork of tail), LJFL (straight line from tip of lower jaw with mouth closed to fork of tail), and EFL (straight line from caudad margin of orbit to fork of tail) to the nearest millimeter. RW (total weight including bill, head, and all entrails) was taken immediately after measuring FL, LJFL, and EFL and before dressing the fish. Usually, large fish (>20 kg) were weighed using a hanging crane scale and small fish (<20 kg) were weighed in the ship's wet laboratory using a platform scale (Appendix Table 2). Bills of large swordfish were cut off at the tip of the lower jaw and weighed separately. After obtaining RW, the fish was processed by removing the extremities of the caudal fin and the dorsal, anal, and pectoral fins at their bases. Approximately 5-8 cm of the caudal rays were left attached to the hypural plate. The head was sawed off at the caudal end of the skull, with the cut usually passing through the 2nd vertebra. The abdomen was slit from the anal fin to the gill cavity exposing the coelom. The viscera, gonads, and gas bladder were removed. Next, the internal abdominal walls were scraped to remove the mesenteries and the kidneys beneath the vertebrae. The dressed carcass was then weighed with the caudal peduncle attached (DPW for "dressed with peduncle weight"). The caudal peduncle was cut off by inserting a knife perpendicular to the spine at the anterior end (insertion) of the keel and cutting between the vertebrae. This resulted in a cut between the 22nd and 23rd vertebrae. For small fish, dressed weight (DW) was obtained by cutting off the caudal peduncle and reweighing the fish. DW for large fish was obtained by weighing the caudal peduncle and subtracting this weight from the previously obtained DPW. Prince and Miyake (1989) and Prager et al. (1995) provide comprehensive schematic diagrams that illustrate the progressive stages used when dressing billfishes.

Extenuating circumstances sometimes precluded certain measurements. When the tip of the bill was broken, FL was not measured. Weights of shark damaged fish were not used. When the sea was rough, weights were not taken.

It is important here to note that our usage of LJFL (= LBFL) is synonymous with "body length" as defined by Rivas (1956) and Nakamura (1985).

Commercial Fish

NMFS SWR observers were trained at HL before collecting data at sea. Observers measured EFL and cleithrum to keel length (CKL, straight line from posterior edge of cleithrum to insertion of caudal keel) in centimeters before further processing the fish aboard ship. A subset of these measured fish (selected based on month and body length) was labeled so that HL personnel could identify the specimen when it was later weighed at the UFA fish auction. Either DPW or DW was ascertained; DW was mostly available for large fish (>22.7 kg). DPW was largely limited to small fish (<22.7 kg) because swordfish of these two size groups are dressed and priced differently in Honolulu. (Swordfish of different sizes are also priced differently in the Atlantic: see Caddy, 1976). Weights were initially recorded in pounds and later converted to kilograms. An unbiased sample of the labeled and unlabeled fish were sexed based on gross visual appearance of their gonads; gonad specimens were collected for a subset of these fish, for which sex was later verified histologically.[3] Commercial (observer) data used in this report span from March 1994 to November 1996 (length-weight interrelationships) and from March 1994 to June 1997 (EFL-CKL relationship).

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[3]DeMartini, E. E., J. H. Uchiyama, and H. A. Williams. Unpubl. ms. Sexual maturity, sex ratio, and size composition of swordfish caught by the Hawaii-based pelagic longline fishery.

Partway through the sampling period, it became necessary to amend the DW variable to reflect a change in dressing procedure adopted by the UFA. In order to conserve muscle tissue handled by buyers during pre-auction inspection of fish, in August 1994 the auction crew began cutting between the 23rd-24th, rather than between the 22nd-23rd caudal vertebrae when removing the caudal peduncle. Starting in August 1994, DW values thus were slightly greater because a portion of the keel was included. Hereafter in this report, we shall refer to DW data collected from commercial fish prior to August 1994 as DW_{old} and data collected starting in August 1994 as DW_{new}.

Data Analyses

Data were first plotted and plots evaluated for agreement with a priori expectations. Unless allometric growth was obvious from the plot, all relations were assumed monotonic, and all length-length and length-weight relations were considered to be linear and nonlinear, respectively. Functional (reduced major axis) regressions were not used because prediction, not description, was our primary interest (Sokal and Rohlf, 1981; p. 549). For relations (like length-weight) in which one or the other variable might interest different users, separate equations were calculated for predicting length from weight and weight from length.

When data were sufficient to evaluate, the potential effects of sex and time of collection (month or cruise-year) were evaluated as class variables in ANCOVA (General Linear Models, GLM) using log-linear, least squares regression procedures. Effects on weight of sex and time of collection were described by least square means (means adjusted by the length covariate). Data were log transformed prior to all ANCOVA comparisons using natural logs. For all ANCOVA comparisons using research cruise data, length distributions were trimmed at both ends to provide exact overlapping ranges. Fish larger than 200 cm EFL (mostly females) were trimmed for ANCOVA evaluations of length-weight interrelationships using commercial data. If sex or time was significant, separate final regressions were then calculated for the different levels using untrimmed data. If sex or time was not significant (or if these data were not collected, were insufficient, or were intractable), the untrimmed data were pooled and a single final regression was calculated to describe a general relationship.

Final predictive models of length on length were fitted using linear least squares regression. Nonlinear regression techniques were used to fit the final nonlinear models most appropriate for describing length-weight relationships and for predicting weight from length and length from weight. For final weight on weight relationships, the best fits were obtained with nonlinear models. Equations for these models are:

Linear model: $Y = a + bX$,

where X = length or weight variable, *a* = Y-intercept, and *b* = slope, and

Nonlinear model: $Y = aX^b$,

where X = length or weight variable, and *a* and *b* are estimated constant and exponent, respectively.

Where warranted, extreme values were deleted before making statistical comparisons or fitting predictive models. For research cruise data, outliers (defined below) were not deleted because the relatively few observations were collected by scientists and outliers were assumed to be extreme but real values. Commercial data were collected by "third party" observers; these data were screened and outliers were deleted because recording errors were more likely and the data were more plentiful. Outliers were defined as observations whose Studentized residuals had absolute values greater than 2.0.

The weights of all commercial fish <22.8 kg (50 lb) were assumed to be DPW even though the dressed state of some small fish was unknown. These latter primarily comprised <10% of the small fish for which DPW was slightly greater than 22.7 kg (DW = 20.9-22.3 kg, 46-49 lb). The approximately 2,590 fish with known sex and dressed weight were separated into three groups, DPW, DW_{old}, and DW_{new}, and analyzed separately. Weights for December 1994 samples used for GLM analyses were originally measured as DPW, and were converted to DW_{new} using the appropriate conversion equation.

Matched (same fish) measurements of DW_{old} and DW_{new} were unavailable for directly developing a conversion equation. Therefore, matched DPW and DW_{new} were measured for the same carcass at the auction and their relationship described. Estimates of DW_{old} and DW_{new} were calculated from predetermined DPW set at 10-cm intervals between 20-180 kg using appropriate formulas. (DW_{old} was estimated using the relationship derived from research cruise data.)

Relationships were calculated and analyzed using Statgraphics Plus for Windows v. 3 (Manugistics, Inc., 1997) and SAS v. 6.03 (SAS, 1988).

RESULTS

Length Relationships

When sex and cruise-year (1991-93) were examined separately by ANCOVA, neither factor significantly influenced the relationship among LJFL, FL, and EFL (Appendix Tables 3 and 4). Data limitations precluded simultaneous evaluation of sex and cruise-year effects. Thus, all data for these three variables were pooled over sexes and cruises. One general regression equation for each relationship is provided in Table 1 and plots of the relationships in Figures 1-3.

The relationship between CKL and EFL was complicated by a statistically significant but minor effect of sex (Appendix Table 5). For males, CKL represented a trivially larger (<1%) fraction of EFL, reflected by a 9-mm difference in least square means of the two sexes. Both sex-specific and sex-pooled regressions of CKL-EFL are provided (Table 1), but plotted (for ease of viewing) as a single regression (with sexes pooled) in Figure 4.

Length-Weight Relationships

Round Weight-Length

Various RW-length relationships were evaluated using ANCOVA for the effects of sex and cruise-year (1991, 1992, and 1993). Sex and cruise-year effects were not significant (Appendix Tables 6 and 7), so single regressions are used to describe both sexes and all cruise-years pooled (Table 2). A representative RW-EFL relation is plotted in Figure 5.

Dressed Weight-Length

ANCOVAs were used to test the potential effects of sex and cruise-year (1992-93) for various DPW-length and DW-length metrics recorded on research cruises. Neither DPW-length nor DW-length relations were significantly influenced by sex or cruise-year, although sex differences were suggestive for DPW-FL and DW-FL relations measured on cruise TC-92-03 (Appendix Tables 6 and 7). A single regression is provided for each weight-length combination (Table 2). Figure 5 illustrates the DPW-EFL, DW-EFL, and RW-EFL relationships.

Because research data suggested that sex might influence weight at length, another evaluation was made using independent data. Sex effects on DPW-length and DW_{old}-length relationships were reevaluated using commercial landings data for swordfish caught between March 1994-June 1996 and March 1994-July 1994, respectively. Neither DPW-EFL (Appendix Table 8) nor DPW-CKL (Appendix Table 9) relations were significantly influenced by sex for these commercial fish. The DPW-EFL and DPW-CKL relationships were therefore calculated for commercial fish with sexes pooled (Table 3; Figs. 6 and 7). Plots of residuals of DPW regressed on EFL (Fig. 8) and CKL (Fig. 9) have nonmonotonic patterns, which suggests that these relationships should be used with caution.

DW_{old}-EFL (Appendix Table 10) and DW_{old}-CKL (Appendix Table 11) relations were significantly influenced by sex. The DW_{old}-EFL relation was influenced by the interaction between sex and length (Appendix Table 10). Both DW_{old}-length relations are provided for males and females pooled and for males and females separately (Table 3). For ease of viewing, the relations are plotted for the sexes pooled in Figures 10 and 11.

Sex and month effects on DW_{new}-EFL relations were also evaluated using ANCOVA for swordfish caught by the commercial fishery during August 1994-June 1996. The month effect was significant, as were most interactions (Appendix Table 12). Males averaged slightly greater body condition (approximately 2-3% greater weight at length) than females overall; and the condition (least squares mean weight at length) of each sex differed among many months of year (Table 4). Condition was generally higher in the first half of the calendar year (December-May; best in February) than the second half of the year (June-November; lowest in August). The maximum difference in condition (between February and August) was about 15-18%. In general, condition appeared to be more strongly influenced by month rather than sex. For purposes of predicting DW_{new} from EFL and EFL from DW_{new}, separate regressions are provided by month with the sexes pooled (Tables 5 and 6), as well as one with both sexes and months pooled (Table 3). Statistical outliers (2.7% of all values) were excluded, but large (>200 cm EFL) fish were included in the calculation of all predictive relationships (Tables 3, 5, and 6). For ease of viewing, relations are plotted for sexes and months pooled in Figure 12.

Sex and month effects on DW_{new}-CKL relations also were evaluated using ANCOVA. Only month and the interaction between length and month were significant (Appendix Table 13). Trends in monthly changes of DW_{new} least squares means adjusted for CKL (sexes pooled) were similar to those from the DW_{new}-EFL ANCOVA (Table 4). For purposes of predicting DW_{new} from CKL and CKL from DW_{new}, separate regressions are provided by month with sexes pooled (Tables 7 and 8). For simplicity, a single equation (Table 3) with sexes and months pooled is plotted in Figure 13.

Weight Relationships

Weight to Weight Relationships

The relationships between RW and DPW, RW and DW, and DPW and DW are described and plotted for research fish in Table 9 and Figures 14-16, respectively. The best fit for these relationships was nonlinear rather than linear, although the difference was sometimes slight (Fig. 16).

DW_{old}-DW_{new} Relationships

The relationship between DW_{old} and DW_{new} was constructed from other relationships using DPW as reference. The relation between DW_{new} and DPW for commercial fish is described in Table 9 and Figure 17. The relation between DW_{old} and DW_{new} (Table 9) is derived from estimates of DW ($\approx DW_{old}$) and DW_{new} using predetermined values of DPW and is described and plotted in Figure 18.

Research Versus Commercial Data

All weight-EFL relationships from research and commercial sources were plotted for comparison (Fig. 19). Where both sources of data are available, estimated length-weight relations are approximately congruent. Overall, relationships fell in the following order, with RW > DW_{new} > DPW > DW_{old} > DW.

DISCUSSION

Allometries

Length interrelationships were fundamentally linear for fish longer than the approximate 60 cm EFL minimum in our samples. However, disproportional growth of the bill (rostrum) or head was apparent for comparisons such as EFL versus FL (Fig. 2) and LJFL versus FL (Fig. 3) that contrasted metrics which included versus excluded the bill and most of the head region. For example, at 150 cm FL the EFL is 56.7% of FL and at 300 cm FL the EFL is 62.3% of FL. In other words, the relative length of the bill and head anterior of the eye was greater for smaller swordfish. Yabe et al. (1959, Fig. 12) observed that the relative length of the bill or snout versus snout plus body declined for western North

Pacific swordfish over the range of 90-200 cm "Body Length" (cf. standard length). Relative proportions of bill or head to "post operculum to tail fork" (cf. CFL) change at about 75 and 126 cm CFL (90 and 147 cm EFL, respectively) for swordfish from the North Atlantic (McGowan, 1988; Fig. 2D, E). Ovchinnikov (1970, p. 34) mentioned allometric growth of the bill of swordfish from the Caribbean and Atlantic, but did not specify its exact nature.

Factors Influencing Length-Weight Relations

Sex

We observed slight but statistically significant effects of sex on some, but not all, length-weight relationships. For the relatively sparse research cruise data on RW and DPW, weight at length was indetectably influenced by sex. However, for the relatively large commercial data set on DW_{new} (a weight metric uninfluenced by variations in gonad development and stomach contents), power was sufficient to detect male somatic weights at length that averaged 2-3% heavier than that of females (Table 4). We speculate that this may reflect the generally greater reproductive burden of females.[4]

Turner[5] examined sexual dimorphism in DW-LJFL relations for western North Atlantic swordfish and observed only "slight differences" in the parameters. Unfortunately, he did not provide the results of the statistical comparisons. To our knowledge, Lee and Scott (1992) provided the only rigorous evaluation of the effects of sex on length-weight relations of swordfish in the Atlantic Ocean (or elsewhere), prior to our report. Lee and Scott (1992) observed slight, but significant effects of sex on weight at length for swordfish in the Northwest Atlantic that were similar to those we observed for swordfish in the central North Pacific Ocean.

Time of Year

Temporal factors can strongly influence the weight at length relationships of central North Pacific swordfish, depending on the time scale. Year (cruise) effects were indetectable, if present, using the relatively small sample sizes provided by research cruise collections. Month effects were apparent and easily detectable, however, using the relatively large commercial data set. These effects were seasonal and likely reflected

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[4]see footnote 3.

[5]see footnote 1.

subannual changes in condition related to spawning. For each sex, the greatest condition occurred in February, immediately prior to the start of spawning, and the poorest condition occurred in August, right after the completion of spawning. This spawning related subannual effect had a sixfold greater influence on condition (17% vs. 2.5%: Table 4) than did sex per se. Sex and month effects were partly confounded by high order interactions. Apparent differences between sexes and among months may partly reflect variations among months in the size and sex composition of the commercial catch (Appendix Figs. 1-4). Sex effects disappeared when May, August, and September data were deleted; sex effects on length composition data for these 3 months differed most greatly from the other months.

Turner[6] compared DW on LJFL relations between fish landed in the Gulf of Mexico and off the eastern Florida coast and found differences in the slopes; temporal differences were noticeable in DW at length for fish >160 cm LJFL. Since samples were collected in various regions during different months and years, observed temporal changes in DW-LJFL were confounded by region of capture.

Comparison of Predictive Curves

The sequence of RW > DPW > DW at EFL in plots of RW-EFL, DPW-EFL, and DW-EFL relations for research fish (Fig. 5) is ordered as expected. The DW_{new}-EFL relation for commercial fish also reliably tracks all of the weight-EFL relationships for research fish (Fig. 19). The DW_{old}-EFL curve for commercial fish above 190 cm EFL lies between the DPW and DW curves for research fish, as expected.

Comparisons using commercial data (Fig. 19) have several complications, however. Below 190 cm EFL, the DW_{old}-EFL curve begins to cross above the DPW curve and eventually crosses above the DW_{new}-EFL curve below 150 cm EFL. This results in a maximum 2% overestimate of DW_{old} (vs. DW_{new}) below 150 cm EFL. This may have been caused by the seasonally incomplete collection of DW_{old} data (mainly April and May), reflecting subannual differences in condition.

The DPW of both commercial and research swordfish is 6.35 kg at 77 EFL. As length increases, the DPW predicted from EFL for commercial fish decreases relative to that predicted for research fish, and produces a maximum 12% underestimate of weight for a commercial fish corresponding to a research fish estimated as

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[6]see footnote 1.

weighing 22.7 kg at 116 cm EFL (Fig. 19). This likely results from size stratification (the practice of marketing fish based on weight strata), which allots heavier fish to the "pup" category (biased high) and lighter fish to the "rat" category (biased low). Most of the commercial DPW data came from the rat category.

The DW_{new}-EFL curve for commercial fish consistently lies above the DPW-EFL curve of research fish, but this can be readily explained. The lighter weight at length for research cruise fish is probably due to slight differences in dressing methods. When heads were removed from the commercial fish the cut usually passed through the brain case, whereas on research fish, the cut was made through the 2nd vertebra. The other difference occurred when fin rays were removed. On commercial fish, the fin rays were cut above the condyles; on research fish, the cuts were made a little deeper to extract the condyles with the fin rays. The two differences in dressing carcasses could account for these slight differences in weight at length between research and commercial fish.

Research and commercial data on swordfish weight at length each have their own applications. For variables for which both research and commercial data exist, like DPW and DW_{old}, predictive relationships should be based on commercial data for several reasons. First, sample sizes for both DPW and DW_{old} in the commercial data are at least double those in the research data set. More importantly, commercial data, which incorporate the correct details of dressing (exact method of head and fin ray removal) and possible effect of cold storage on weight at length, represent the relationships of interest to most users. Length-weight relationships developed from research data, though, may be more suitable for biological studies (e.g., energetics) where fish of a continuous range of body sizes are of interest.

Implications for Stock Assessments

Sex and Time Stratification

Stratifying by sex and subannual period could substantially improve the accuracy of length-weight interconversions. Sex might not have practical value in analyses (unless sex ratios are predicted by length class[7]), because sex cannot be routinely determined for dressed swordfish. The influence of sex on weight at length or condition, however, is relatively minor (2-3%) compared to the effect of subannual period (17%); and date of

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[7]See footnote 3.

collection will always be known within a week or so. For this reason we strongly recommend that conversions be stratified by month (Tables 5-8) even if sex of sample fish is unknown.

Historical Weight Records

Another consideration when converting length to weight or vice versa in stock assessments is the importance of information specifying the type of weight metric recorded. This is crucial both when analyzing contemporary data records and evaluating historical market data. Prior to the major start-up of the Hawaii-based longline fishery in 1989, swordfish were marketed as entire fish minus bill only. From about 1989 through the present, most weight data for rats[8] (swordfish <50 pounds or <22.7 kg) have been dressed with peduncle (DPW). Almost all larger swordfish have been sold dressed. Prior to August of 1994, these larger fish, including pups (between 50 and 100 pounds or 22.7-45 kg) and markers (>100 pounds or 45 kg), were marketed as what we have called DW_{old}, with the caudal peduncle severed between the 22nd and 23rd caudal vertebrae. Since August of 1994, larger fish have been dressed with the peduncle severed between the 23rd and 24th vertebrae (DW_{new}). The difference between these two types of dressed weights (on average, 2% of DW_{old}) is a potentially important detail that needs explicit consideration by NMFS personnel, both when recording contemporary landing weights on the auction floor and when analyzing historical catch records that bridge August 1994. On average, dressed with peduncle weight (DPW), post-August 1994 dressed weight(DW_{new}), and pre-August 1994 dressed weight (DW_{old}) vary within 1-3% of one another. Depending on the specific application, it may or may not be important to distinguish between the two DW metrics or between the DW and DPW metrics when recording and analyzing landings data.

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[8]www.ralboray.com/swordfis.htm (see website for a summary of swordfish marketing practices).

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TABLES

Table 1.--Linear length-length relationships for central North Pacific swordfish, *Xiphias gladius*. *N* = number of fish.

Relation◆		Model: Y = *a* + *b*X								Range (cm)			
										Y		X	
Y on X	Sex	Corr. coef.	r^2	SE	*N*	*b*	SE*	*a*	SE	min.	max.	min.	max.
CKL on EFL	F	0.9933	0.986	2.6033	3387	0.68945	1.3724E-3	-3.65943	0.2094	41	179	63	260
CKL on EFL	M	0.9918	0.983	2.4508	2986	0.69460	1.6355E-3	-4.085	0.2287	33	157	50	229
CKL on EFL	both	0.9929	0.986	2.5381	6373	0.69047	1.0301E-3	-3.67494	0.1512	33	179	50	260
EFL on CKL	F	0.9933	0.986	3.7509	3387	1.43123	2.8490E-3	7.21113	0.2897	63	260	41	179
EFL on CKL	M	0.9918	0.983	3.4995	2986	1.41624	3.3348E-3	8.01739	0.3107	50	229	33	157
EFL on CKL	both	0.9929	0.986	3.6502	6373	1.42802	2.1304E-3	7.25441	0.2083	50	260	33	179
LJFL on EFL	both	0.9963	0.992	3.2904	179	1.07064	6.9351E-3	8.00884	0.8653	74.9	228.8	87.5	252.0
EFL on LJFL	both	0.9963	0.992	3.0619	179	0.92713	6.0056E-3	-6.54341	0.8487	87.5	252.0	74.9	228.8
FL on EFL	both	0.9881	0.976	7.9335	167	1.4847	1.7989E-2	20.8207	2.2209	116.5	350.3	69.9	228.8
EFL on FL	both	0.9881	0.976	5.2799	167	0.65760	7.9680E-3	-10.8856	1.6218	69.9	228.8	116.5	350.3
FL on LJFL	both	0.9877	0.975	8.0629	167	1.37303	1.6914E-2	11.4496	2.3692	116.5	350.3	82.2	252.0
LJFL on FL	both	0.9877	0.975	5.8002	167	0.71052	8.7531E-3	-4.83424	1.7816	82.2	252.0	116.5	350.3

◆CKL = cleithrum-keel length, EFL = eye fork length, LJFL = lower jaw fork length, and FL = fork length.

*E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2}).

Table 2.--Nonlinear weight-length relationships for central North Pacific swordfish, *Xiphias gladius*, based on measurements taken aboard the NOAA ship *Townsend Cromwell*. All analyses are for female and male sexes pooled. *N* = number of fish.

Relation◆	Model: $Y=aX^b$			Exponent		Constant		Range			
								Weight (kg)		Length (cm)	
Y on X	r^2	SE	*N*	*b*	SE*	*a**	SE*	Min.	Max.	Min.	Max.
RW on EFL	0.967	7.9396	166	3.0738	4.1144E-2	1.2988E-5	3.0096E-6	5.1	220.3	69.9	228.8
EFL on RW	0.979	5.2015	166	0.3111	3.4552E-3	41.206	0.5614				
DPW on EFL	0.966	8.3714	64	3.0995	7.7592E-2	9.0319E-6	4.0014E-6	4.1	180.2	75.0	228.8
EFL on DPW	0.981	5.5733	64	0.2987	5.3584E-3	46.9602	1.0224				
DW on EFL	0.965	7.5857	73	3.0721	6.9556E-2	9.8701E-6	3.9106E-6	3.8	173.2	75.0	228.8
EFL on DW	0.979	5.5370	73	0.2998	5.1833E-3	47.4036	0.9737				
RW on LJFL	0.968	7.8191	166	3.2968	4.2767E-2	2.8872E-6	7.1616E-7	5.1	220.3	82.2	252.0
LJFL on RW	0.977	5.7156	166	0.2928	3.2634E-3	49.9409	0.6471				
DPW on LJFL	0.966	8.3568	64	3.3485	8.3096E-2	1.7473E-6	8.5077E-7	4.1	180.2	87.5	252.0
LJFL on DPW	0.981	5.7988	64	0.2812	4.9275E-3	56.4537	1.1226				
DW on LJFL	0.966	7.5086	73	3.3104	7.2156E-2	2.0320E-6	8.6393E-7	3.8	173.2	87.5	252.0
LJFL on DW	0.980	5.6962	73	0.2803	4.7114E-3	57.3666	1.0632				
RW on FL	0.941	9.7039	156	3.4438	5.9130E-2	3.8076E-7	1.4073E-7	5.1	216.7	116.5	350.3
FL on RW	0.975	8.1263	156	0.2800	3.5276E-3	76.2293	1.0300				
DPW on FL	0.925	12.0717	62	3.4824	0.1252	2.4670E-7	1.9549E-7	4.1	180.2	116.5	350.3
FL on DPW	0.964	10.9035	62	0.2612	6.5702E-3	88.0677	2.3026				
DW on FL	0.928	10.6288	72	3.4741	0.1102	2.4481E-7	1.6937E-7	3.8	173.2	116.5	350.3
FL on DW	0.969	9.6785	72	0.2610	5.6332E-3	89.3247	1.9443				

◆RW = round weight, EFL = eye fork length, DPW = dressed with peduncle weight, DW = dressed weight, LJFL = lower jaw fork length, and FL = fork length.

*E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2}).

Table 3.--Nonlinear weight-length relationships for central North Pacific swordfish, *Xiphias gladius*, based on measurements recorded from fish landed by the Hawaii-based pelagic longline fishery during March 1994-June 1996. *N* = number of fish.

Relation◆	Model: $Y = aX^b$				Exponent		Constant		Range: Weight (kg)		Range: Length (cm)	
Y on X	sex	r^2	SE	*N*	*b*	SE*	*a**	SE*	min.	max.	min.	max.
DPW on EFL	both	0.840	1.544	354	2.80104	6.109E-2	3.30403E-5	1.0228E-5	5.9	22.7	77	125
DPW on CKL	both	0.761	1.891	356	2.44628	6.8362E-2	4.90312E-4	1.5367E-4	5.9	22.7	50	83
DW_{old} on EFL	both	0.930	9.311	358	3.02006	3.6242E-2	1.37192E-5	2.8362E-6	23.1	237.0	113	238
DW_{old} on EFL	F	0.929	11.290	192	3.08275	5.5599E-2	9.83298E-6	3.1440E-6	23.1	237.0	113	238
DW_{old} on EFL	M	0.923	6.250	166	2.92337	5.7334E-2	2.26721E-5	7.2422E-6	23.3	108.4	113	202
DW_{old} on CKL	both	0.937	8.694	352	2.97331	3.5457E-2	5.87721E-5	1.0735E-5	23.1	237.0	73	155
DW_{old} on CKL	F	0.938	10.353	189	3.01681	5.1955E-2	4.75369E-5	1.3024E-5	23.1	237.0	74	155
DW_{old} on CKL	M	0.922	6.225	163	2.8597	5.8048E-2	1.00436E-4	2.9644E-5	23.1	108.4	73	132
DW_{new} on EFL	both	0.931	9.300	1550	3.1307	1.7412E-2	7.96012E-6	7.9042E-7	22.8	262.6	112	249
DW_{new} on CKL	both	0.928	9.076	1510	3.07865	1.8024E-2	3.56565E-5	3.3497E-6	22.8	262.6	73	165

◆DPW = dressed with peduncle weight, EFL = eye fork length, CKL = cleithrum-keel length, and DW_{old} = dressed weight recorded prior to August 1994, and DW_{new} = dressed weight recorded after August 1994.

*E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2}).

Table 3.--(cont.)

Relation◆		Model: $Y = aX^b$			Exponent		Constant		Range			
									Weight (kg)		Length (cm)	
Y on X	sex	r^2	SE	*N*	*b*	SE*	*a*	SE	min.	max.	min.	max.
EFL on DPW	both	0.848	3.227	354	0.28861	6.605E-3	48.341	0.9158	5.9	22.7	77	125
CKL on DPW	both	0.770	2.780	355	0.28947	8.5373E-3	31.6658	0.7755	5.9	22.7	50	83
EFL on DW_{old}	both	0.944	6.186	358	0.30525	3.7330E-3	45.4369	0.7140	23.1	237.0	113	238
EFL on DW_{old}	F	0.949	6.680	192	0.29839	4.8477E-3	47.1355	0.9898	23.1	237.0	113	238
EFL on DW_{old}	M	0.935	5.172	166	0.30821	6.2117E-3	44.4539	1.1144	23.3	108.4	113	202
CKL on DW_{old}	both	0.946	4.169	352	0.31691	3.8597E-3	28.7028	0.4655	23.1	237.0	73	155
CKL on DW_{old}	F	0.951	4.482	189	0.31270	4.9995E-3	29.3684	0.6349	23.1	237.0	74	155
CKL on DW_{old}	M	0.929	3.683	163	0.31794	6.7664E-3	28.3933	0.7741	23.1	108.4	73	132
EFL on DW_{new}	both	0.940	6.010	1550	0.29451	1.8010E-3	47.2751	0.3617	22.8	262.6	112	249
CKL on DW_{new}	both	0.929	4.433	1510	0.30581	2.0718E-3	30.1231	0.2638	22.8	262.6	73	165

◆DPW = dressed with peduncle weight, EFL = eye fork length, CKL = cleithrum-keel length, DW_{old} = dressed weight recorded prior to August 1994, and DW_{new} = dressed weight recorded after August 1994.

*E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2}).

Table 4.--Table of least squares means for log dressed weight ($ln\mathrm{DW}_{new}$) from the ANCOVA on eye fork length: sexes pooled by month, males, and females. *N* = number of fish.

Month	Sexes pooled by month			Males by month			Females by month		
	N	$ln\mathrm{DW}_{new}$	DW_{new}	*N*	$ln\mathrm{DW}_{new}$	DW_{new}	*N*	$ln\mathrm{DW}_{new}$	DW_{new}
January	139	3.99996	54.595	65	4.00305	54.764	74	3.99688	54.426
February	132	4.03711	56.662	76	4.05018	57.408	56	4.02405	55.925
March	226	3.99412	54.278	94	3.99608	54.385	132	3.99216	54.171
April	233	3.95810	52.357	110	3.96921	52.943	123	3.94698	51.778
May	109	3.96146	52.533	48	3.99198	54.164	61	3.93091	50.952
June	114	3.92365	50.584	71	3.93129	50.892	43	3.91647	50.279
July	87	3.91394	50.095	65	3.9288	50.846	22	3.89915	49.356
August	44	3.86163	47.542	27	3.8537	47.170	17	3.86959	47.917
September	17	3.90681	49.740	8	3.87796	48.375	9	3.93554	51.143
October	180	3.97939	53.484	97	3.97583	53.294	83	3.98295	53.674
November	33	3.94985	51.927	16	3.89341	49.082	17	4.00628	54.937
December◆	106	4.03999	55.970	52	4.03958	56.802	54	4.01007	55.150

◆weights were converted to dressed weight (DW_{new}) from dressed with peduncle weight.

Table 5.--Monthly nonlinear dressed $weight_{new}$-eye fork length relationships (with sexes pooled) for central North Pacific swordfish, *Xiphias gladius*, based on measurements recorded for fish landed by the Hawaii-based pelagic longline fishery from August 1994-June 1996. *N* = number of fish.

	Model: $Y = aX^b$			Exponent		Constant		Range			
								Weight (kg)		Length (cm)	
Month	r^2	SE	*N*	*b*	SE*	*a**	SE*	Min.	Max.	Min.	Max.
January	0.939	10.0432	155	3.02335	5.10796E-2	1.42278E-5	4.1740E-6	22.8	219.1	116	249
February	0.941	9.2216	140	3.17513	6.0322E-2	6.86465E-6	2.36342E-6	24.5	183.7	118	219
March	0.948	8.0722	357	3.1423	3.24471E-2	7.67947E-6	1.41846E-6	23.1	200.5	114	236
April	0.956	9.0184	254	3.27579	3.54572E-2	3.81019E-6	7.78313E-7	23.6	262.6	116	246
May	0.915	8.4533	113	3.22306	7.29197E-2	4.90067E-6	2.015E-6	23.1	158.7	114	212
June	0.948	5.9938	137	2.77658	4.34009E-2	4.49718E-5	1.10439E-5	23.1	173.7	115	240
July	0.909	7.5926	104	2.72467	7.41975E-2	5.74347E-5	2.40802E-5	23.6	129.7	114	217
August	0.931	4.8362	48	2.98218	0.100486	1.48796E-5	8.32474E-6	23.6	105.7	118	198
September	0.804	4.0033	17	2.65569	0.270936	7.82173E-5	1.13651E-4	23.6	50.8	120	157
October	0.925	7.8762	185	2.87944	4.87812E-2	2.82976E-5	7.79552E-6	23.1	185.0	112	230
November	0.969	7.3919	40	3.13415	7.70351E-2	7.58801E-6	3.37168E-6	24.9	182.3	112	230
December◆			118							123	236

*E indicates scientific notation (e.g., 3E-2 = 3×10^{-2}).

◆all swordfish carcasses were weighed with peduncles attached for all sizes in December.

Table 6.--Monthly nonlinear eye fork length on dressed $weight_{new}$ relationships (with sexes pooled) for central North Pacific swordfish, *Xiphias gladius*, based on measurements recorded for fish landed by the Hawaii-based pelagic longline fishery from August 1994-June 1996. *N* = number of fish.

	Model: $Y = aX^b$			Exponent		Constant		Range			
								Weight (kg)		Length (cm)	
Month	r^2	SE	*N*	*b*	SE*	*a*	SE	Min.	Max.	Min.	Max.
January	0.948	6.1083	155	0.300517	5.46338E-3	45.8036	1.09495	22.8	219.0	116	249
February	0.952	5.2937	140	0.288831	5.41439E-3	47.4747	1.13731	24.5	183.7	118	219
March	0.952	5.3628	357	0.291834	3.33649E-3	47.5076	0.674707	23.1	200.5	114	236
April	0.958	5.4495	254	0.287392	3.5762E-3	48.7634	0.756522	23.6	262.6	116	246
May	0.923	5.8393	113	0.289413	7.46579E-3	48.3251	1.4838	23.1	158.7	114	212
June	0.950	5.1178	137	0.320866	6.14125E-3	43.2762	1.09787	23.1	173.7	115	240
July	0.929	6.2605	104	0.32814	8.80025E-3	42.2362	1.53264	23.6	129.7	114	217
August	0.926	4.9318	48	0.315919	1.28273E-2	44.8441	2.28882	23.6	105.7	118	198
September	0.822	4.6462	17	0.294398	3.41137E-2	47.0486	5.72084	23.6	50.8	120	157
October	0.930	6.1906	185	0.313748	6.09966E-3	43.6251	1.10349	23.1	185.0	112	230
November	0.959	5.9741	40	0.312404	9.96354E-3	44.2203	1.91842	24.9	182.3	112	230
December◆											

*E indicates scientific notation (e.g., 3E-2 = 3×10^{-2}).

◆all swordfish carcasses were weighed with the "peduncles on" in December.

Table 7.--Monthly nonlinear dressed weight$_{new}$-cleithrum to keel length relationships (with sexes pooled) for central North Pacific swordfish, *Xiphias gladius*, caught by the Hawaii-based pelagic longline fishery from March 1994-June 1996. *N* = number of fish.

	Model: $Y=aX^b$			Exponent		Constant		Range			
								Weight (kg)		Length (cm)	
Month	r^2	SE	*N*	*b*	SE*	*a**	SE*	Min.	Max.	Min.	Max.
January	0.948	8.4657	148	2.92576	4.58108E-2	7.6024E-5	1.82543E-5	22.8	219.1	77	165
February	0.943	8.2969	134	2.93965	5.62481E-2	7.21501E-5	2.10171E-5	23.1	166.0	74	151
March	0.928	9.2043	349	3.02396	3.84533E-2	4.68145E-5	9.37694E-6	23.1	200.5	74	157
April	0.943	10.3045	251	3.2134	4.14738E-2	1.93026E-5	4.22389E-6	23.6	262.6	75	164
May	0.914	8.0892	110	3.14286	7.38438E-2	2.51551E-5	9.59552E-6	23.1	158.7	74	143
June	0.911	7.1673	134	2.80738	6.57551E-2	1.19043E-4	4.03E-5	23.1	140.6	73	144
July	0.914	7.3152	100	2.84645	7.8865E-2	1.00011E-4	4.05981E-5	23.6	129.7	77	136
August	0.902	5.8731	48	2.75994	0.115119	1.43159E-4	8.40475E-5	23.6	105.7	77	130
September	0.709	4.4487	16	2.52354	0.326647	4.32904E-4	5.61781E-4	23.6	50.8	78	104
October	0.929	7.4678	180	2.89794	5.01019E-2	8.22116E-5	2.12565E-5	23.1	185.1	74	152
November	0.963	7.7684	40	2.99817	7.99223E-2	5.30867E-5	2.23358E-5	24.9	182.3	74	152
December◆			114							83	161

*E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2}).

◆all swordfish carcasses were weighed with the "peduncles on" in December.

Table 8.--Monthly nonlinear cleithrum to keel-dressed weight$_{new}$ relationships (with sexes pooled) for central North Pacific swordfish, *Xiphias gladius*, measured on commercial fish. *N* = number of fish.

	Model: $Y = aX^b$			Exponent		Constant		Range			
								Weight (kg)		Length (cm)	
Month	r^2	SE	*N*	*b*	SE*	*a*	SE	Min.	Max.	Min.	Max.
January	0.938	4.3994	148	0.31564	6.4141E-3	28.6178	0.793663	22.8	219.0	77	165
February	0.945	3.9127	134	0.30920	6.3553E-3	29.3647	0.817093	23.1	166.0	74	151
March	0.933	4.3734	349	0.30363	4.1909E-3	30.2913	0.537913	23.1	200.4	74	157
April	0.945	4.2867	251	0.29608	4.259E-3	31.2647	0.577181	23.5	260.6	75	165
May	0.907	4.4084	110	0.30054	8.7764E-3	31.1776	1.12302	23.1	158.7	74	143
June	0.919	4.2438	134	0.32365	8.2413E-3	28.531	0.966646	23.1	140.6	73	144
July	0.922	4.3199	100	0.32698	9.3815E-3	28.043	1.08069	23.5	129.7	77	136
August	0.899	4.0669	48	0.32987	1.5915E-2	28.0841	1.7911	23.5	105.6	77	130
September	0.730	3.5176	16	0.28356	4.4334E-2	31.8418	4.98385	23.5	50.8	78	104
October	0.923	4.3971	180	0.32300	6.6744E-3	28.0738	0.773449	23.1	185.0	74	152
November	0.952	4.2882	40	0.32415	1.1232E-2	27.7112	1.34712	24.9	182.3	74	152
December◆			114							83	161

*E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2}).

◆all swordfish carcasses were weighed with the "peduncles on" in December.

Table 9.--Nonlinear best-fit weight-on-weight relationships for central North Pacific swordfish, *Xiphias gladius*, measured on both research and commercial fish. *N* = number of fish.

Relation[A]	Model: $Y=aX^b$			Exponent		Constant		Range X (kg)		Range Y(kg)	
	r^2	SE	*N*	*b*	SE*	*a*	SE*	Min.	Max.	Min.	Max.
RW on DW	0.987	5.788	73[B]	0.94968	1.4348E-2	1.65743	0.1120	3.8	173.2	6.3	216.7
DW on RW	0.987	4.5805	73[B]	1.03225	1.5803E-2	0.64585	5.1283E-2	6.3	216.7	3.8	173.2
RW on DPW	0.991	4.956	63[B]	0.94311	1.2968E-2	1.62493	0.1013	4.1	180.2	6.3	216.7
DPW on RW	0.991	4.164	63[B]	1.04667	1.4666E-2	0.63644	4.7293E-2	6.3	216.7	4.1	180.2
DPW on DW	0.998	1.7150	60[B]	1.0086	6.0264E-3	1.01515	2.9302E-2	3.8	173.2	4.1	180.2
DW on DPW	0.998	1.6036	60[B]	0.98887	5.7878E-3	0.99675	2.8074E-2	4.1	180.2	3.8	173.2
DPW on DW_{new}	0.999	0.3314	275[C]	0.99884	5.1505E-4	1.02008	2.4991E-3	20.0	219.5	20.4	222.3
DW_{new} on DPW	0.999	0.3269	275[C]	1.0011	5.1632E-4	0.98058	2.4161E-3	20.4	222.3	20.0	219.5
DW_{new} on DW_{old}	1.000	0.0052	17[D]	1.01238	3.4294E-5	0.98376	1.6737E-4	19.2	169.3	19.3	177.4
DW on DW_{new}	1.000	0.0050	17[D]	0.98780	3.3664E-5	1.0162	1.7119E-4	19.3	177.4	19.2	169.3

[A]RW = round weight, DW = dressed weight recorded on all research cruise, DPW = dressed with peduncle weight, DW_{new} = dressed weight recorded after August 1994 , and DW_{old} = dressed weight recorded prior to August 1994.

[B]from research cruises.

[C]from commercial source.

[D]weights estimated from dressed with pedncle weight using above equations.

*E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2}).

FIGURES

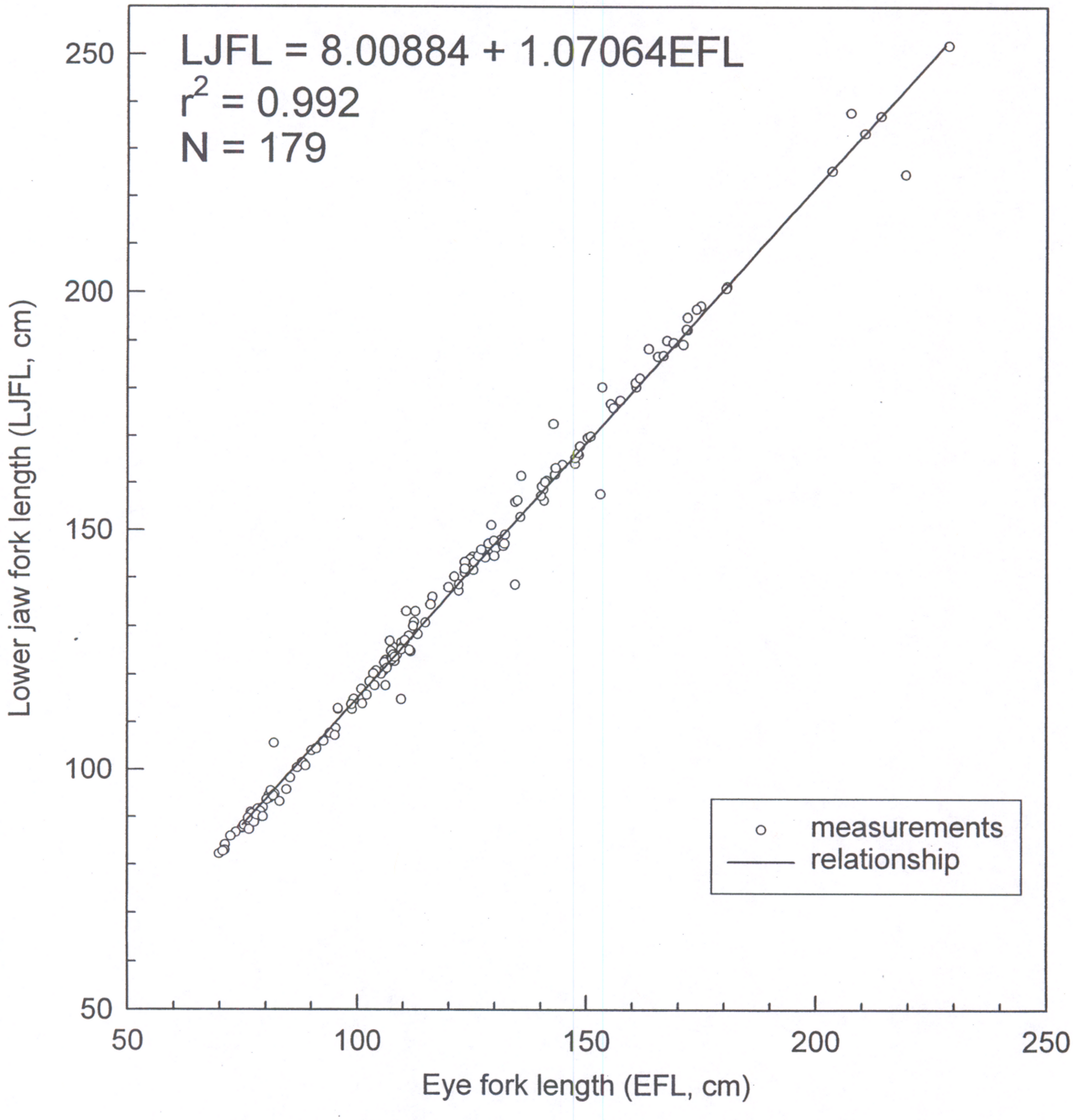


Figure 1.--Linear lower jaw fork length to eye fork length relationship of swordfish, *Xiphias gladius*, from the central North Pacific Ocean.

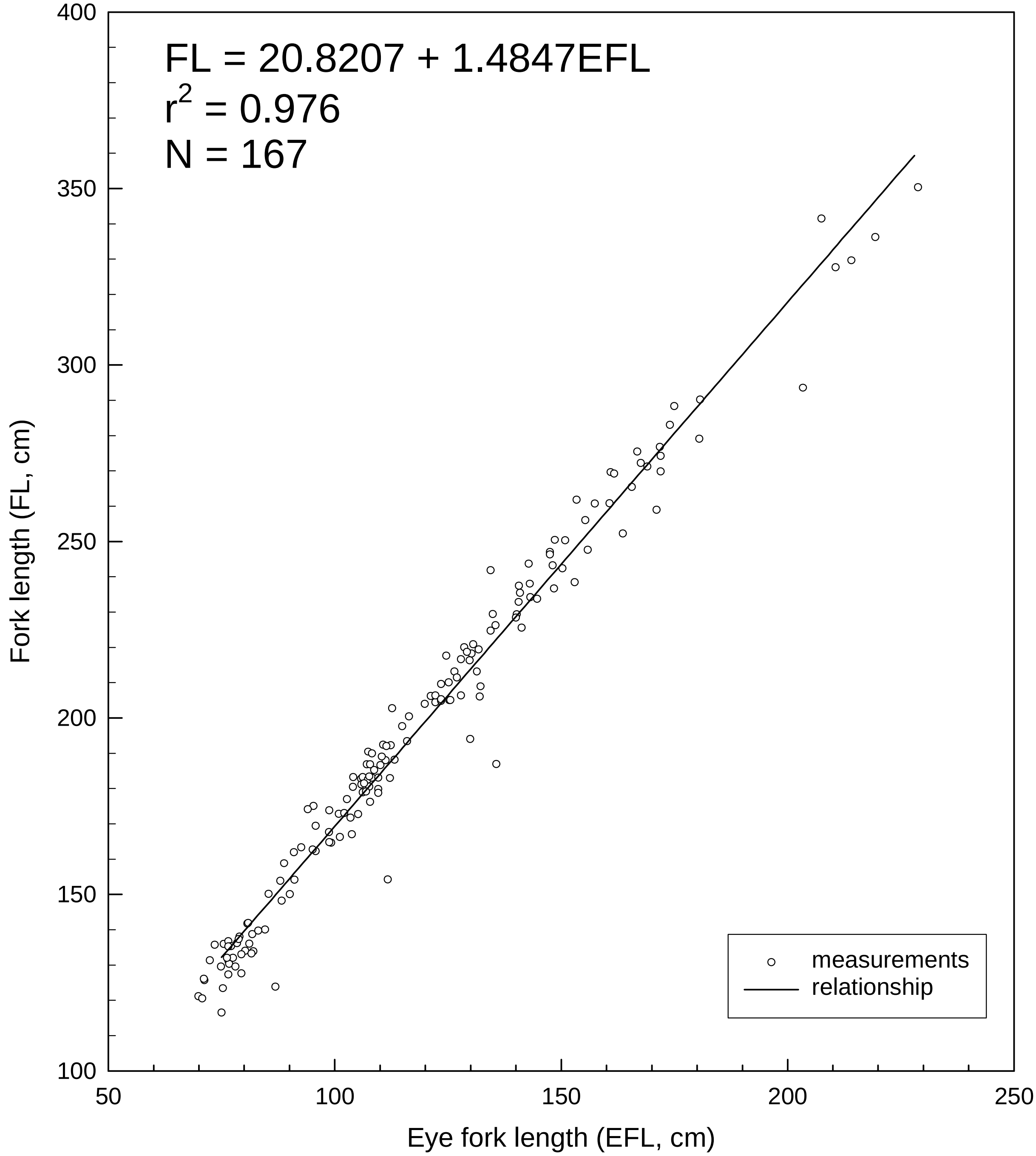


Figure 2.--Linear fork length on eye fork length relationship of swordfish, *Xiphias gladius*, from the central North Pacific Ocean.

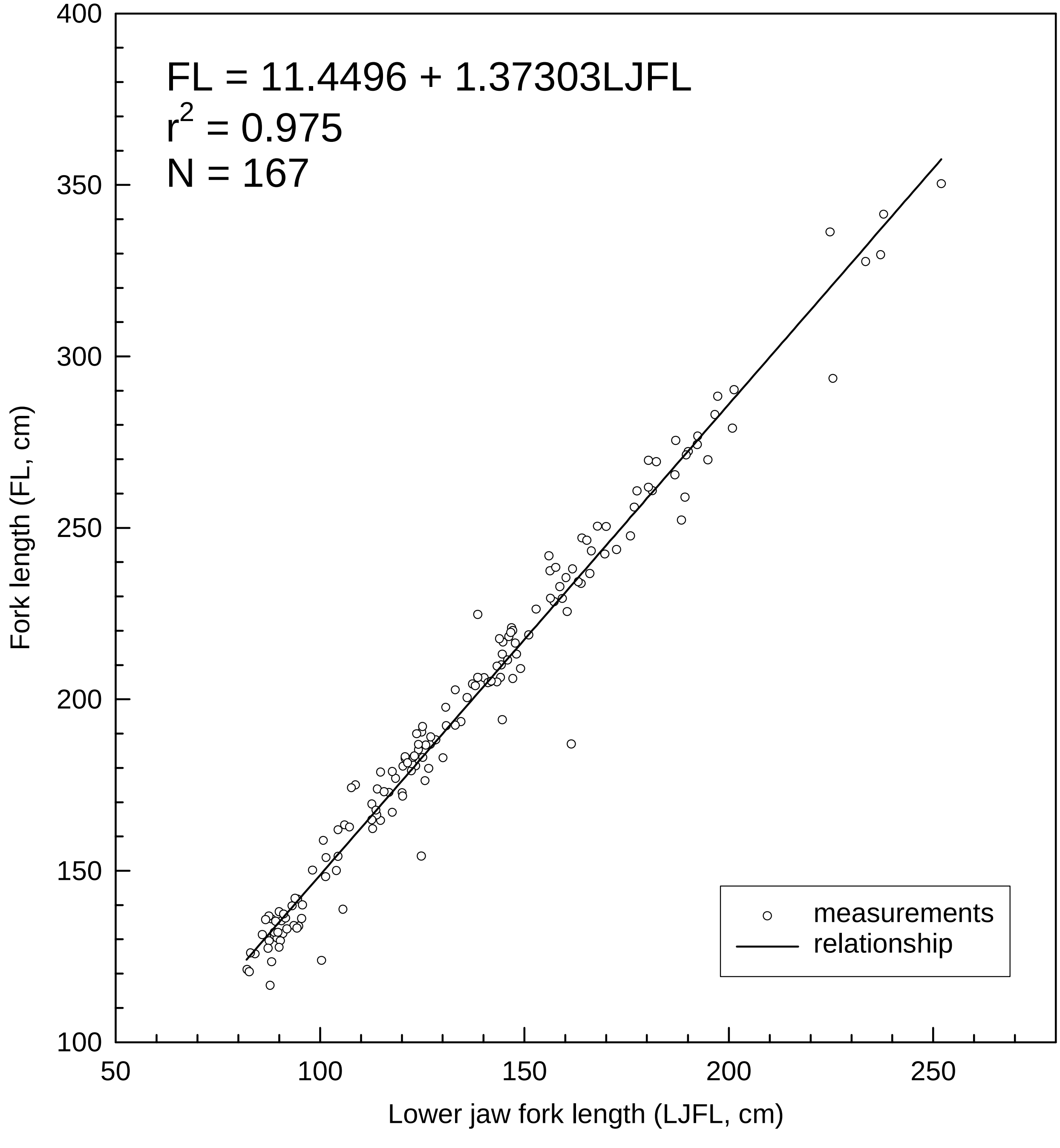


Figure 3.--Linear fork length to eye fork length relationship of swordfish, *Xiphias gladius*, from the central North Pacific Ocean.

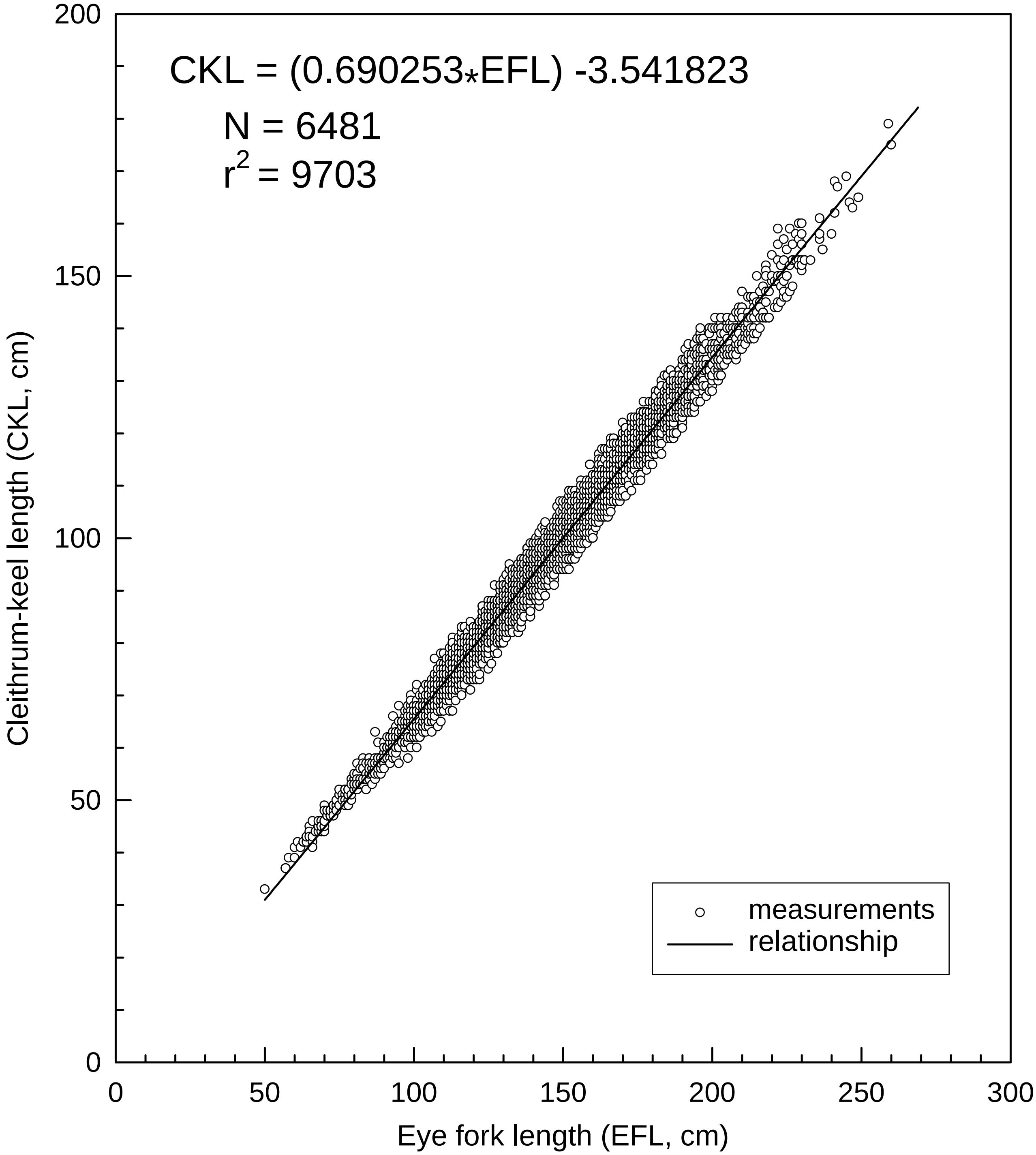


Figure 4.--Linear cleithrum to keel length on eye fork length relationship of swordfish, *Xiphias gladius*, from the central North Pacific Ocean. (commercial fish with sex and months pooled)

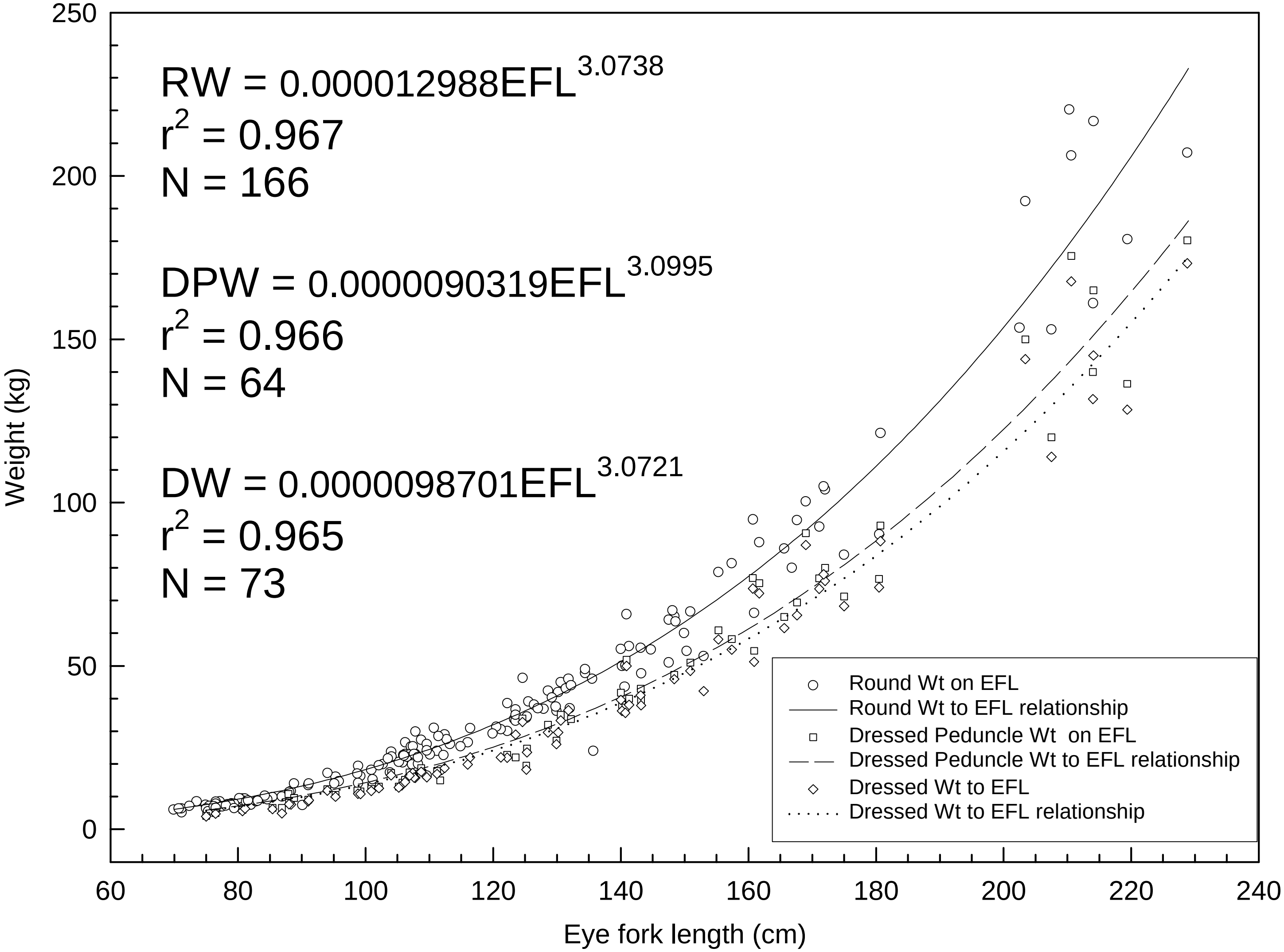


Figure 5.--Nonlinear round, dressed with peduncle, and dressed weights on eye fork length relationships of swordfish, *Xiphias gladius*, from the central North Pacific Ocean based on cruise data.

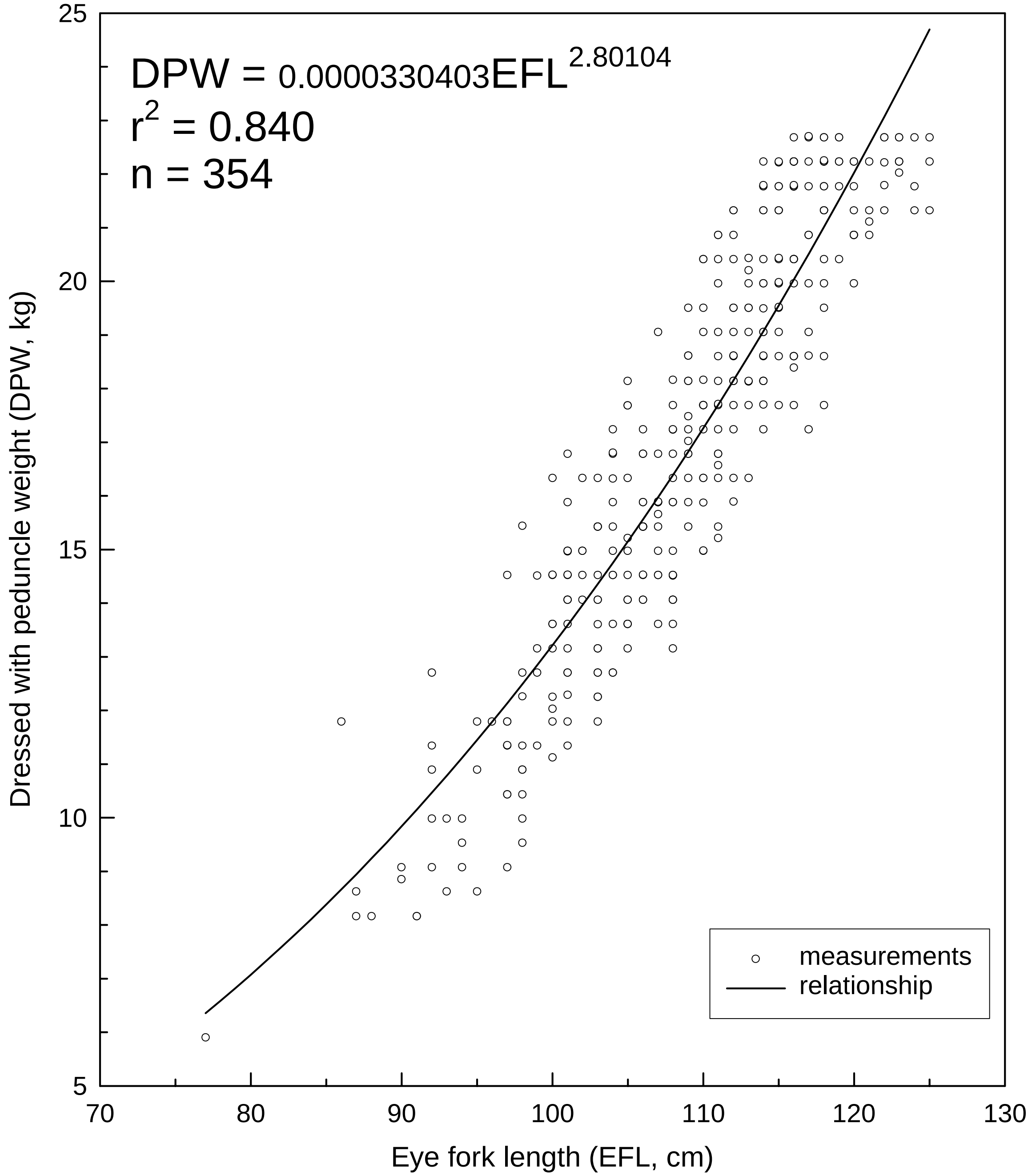


Figure 6.--Nonlinear dressed with peduncle weight on eye fork length relationship of swordfish, *Xiphias gladius*, from the central North Pacific Ocean. (commercial fish with sex and months pooled)

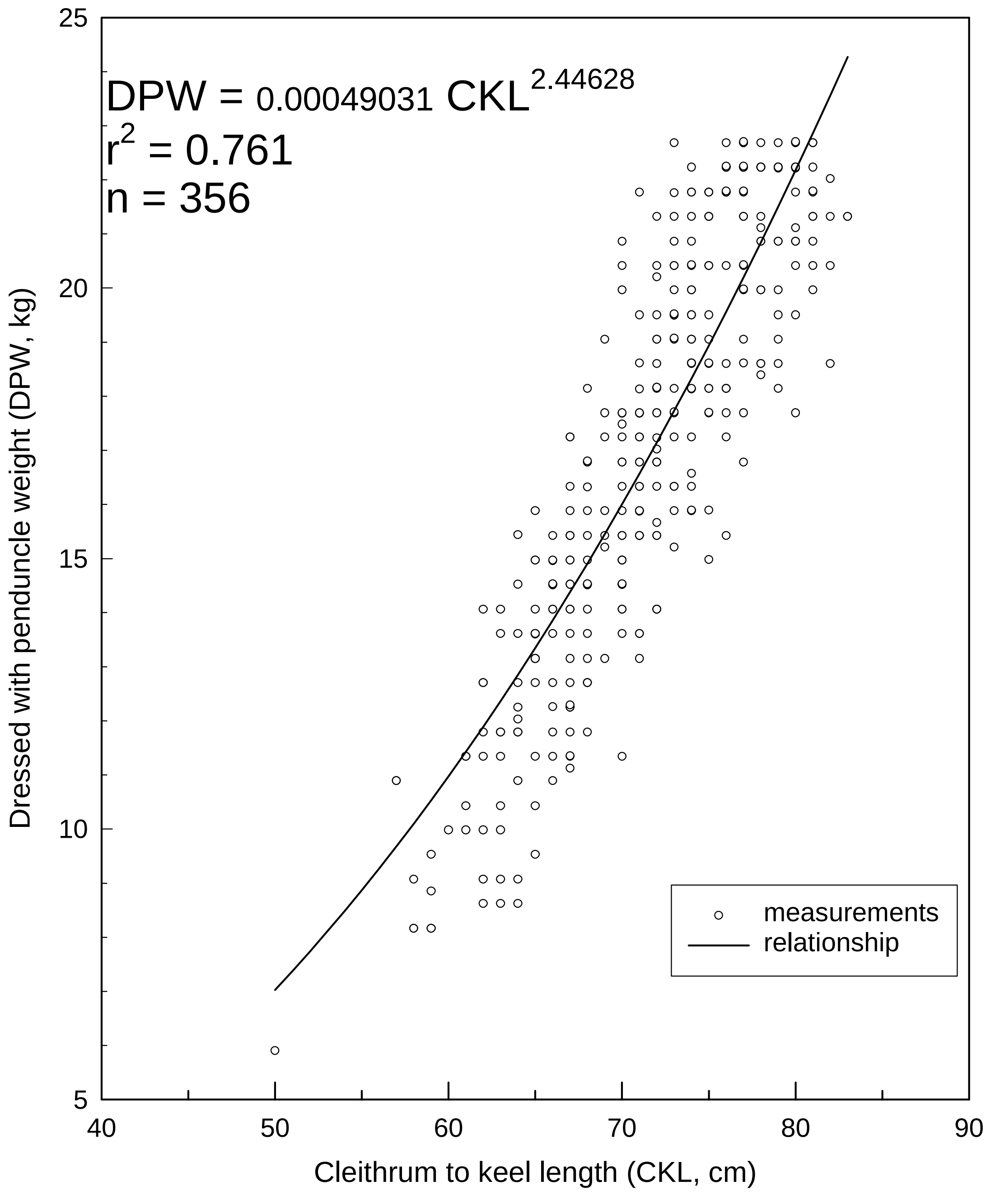


Figure 7.--Nonlinear dressed with peduncle weight on cleithrum to keel length relationship of swordfish, *Xiphias gladius*, from the central North Pacific Ocean. (commercial fish with sex and months pooled)

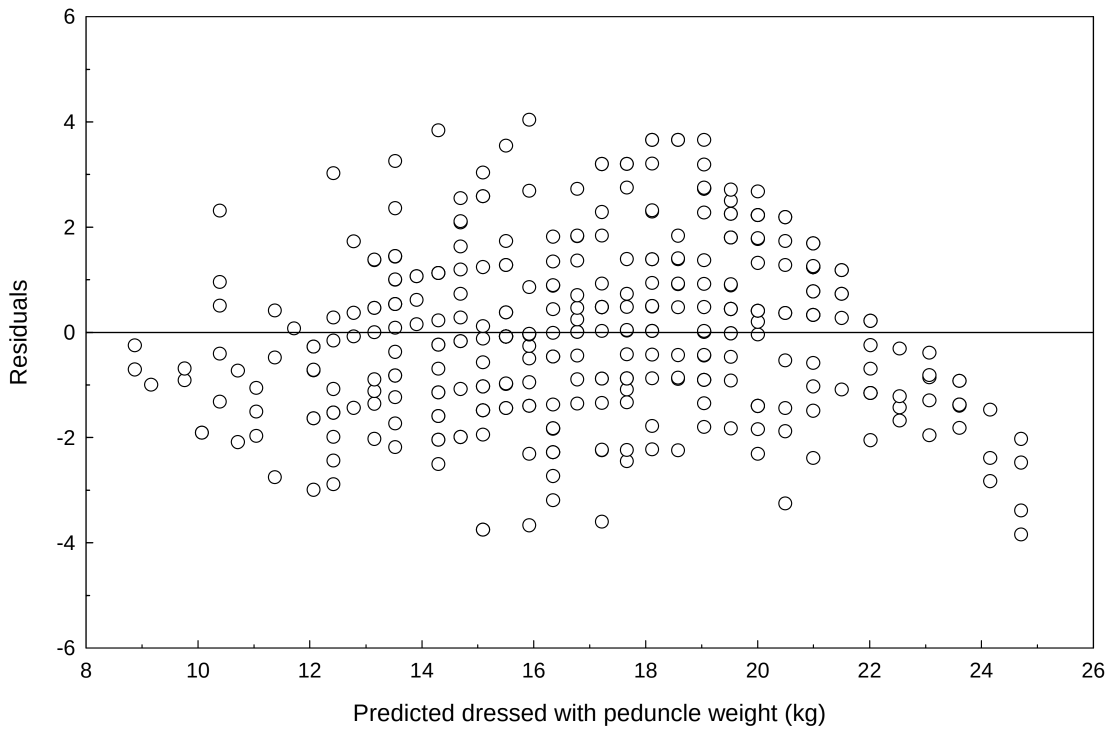


Figure 8.--Plot of residuals on predicted dressed with peduncle weights from dressed with peduncle weight-eye fork length relationship.

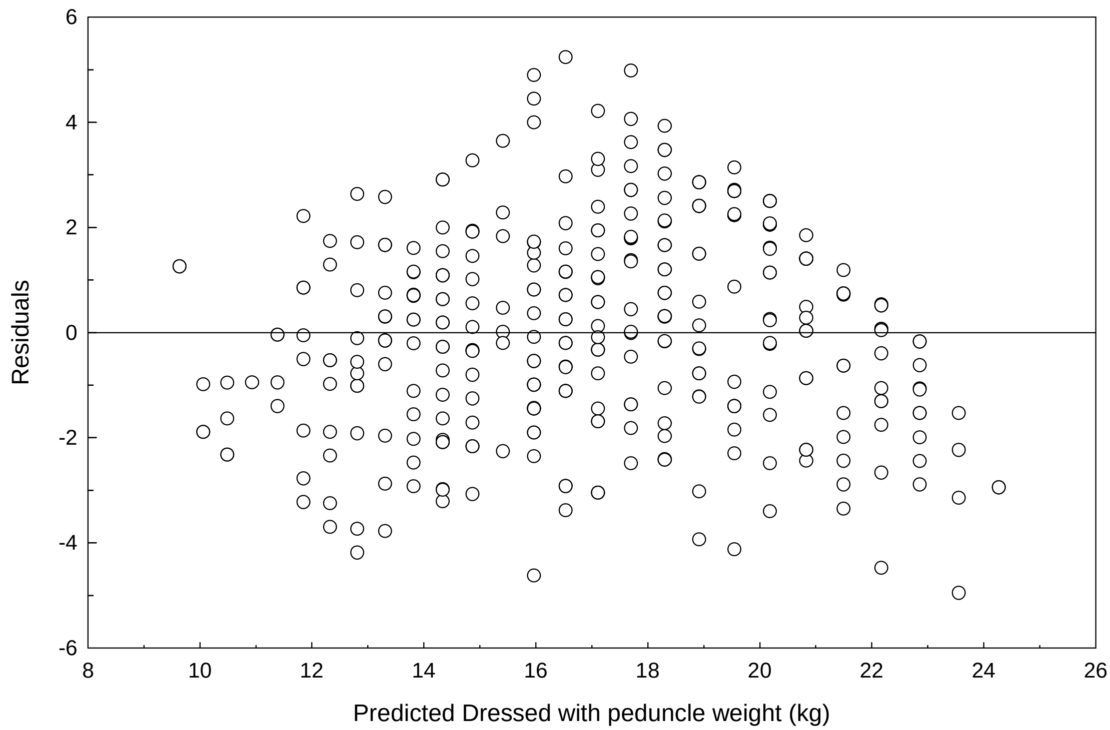


Figure 9.--Plot of residuals on predicted dressed with peduncle weights from dressed with peduncle weight-cleithum to keel length relationship.

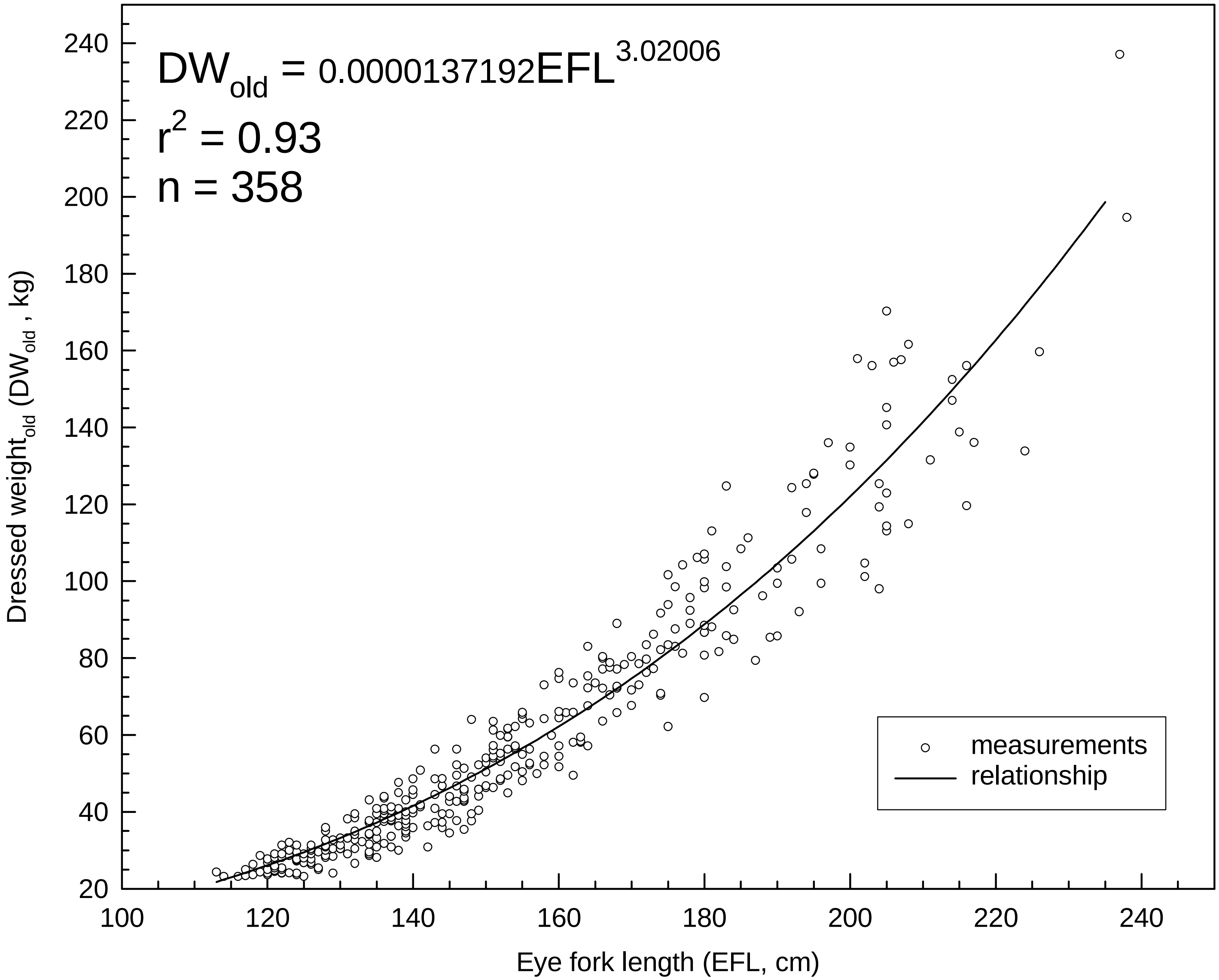


Figure 10.--Nonlinear dressed weight$_{old}$ on eye fork length relationship of swordfish, *Xiphias gladius*, from the central North Pacific Ocean. (commercial fish with sex and months pooled)

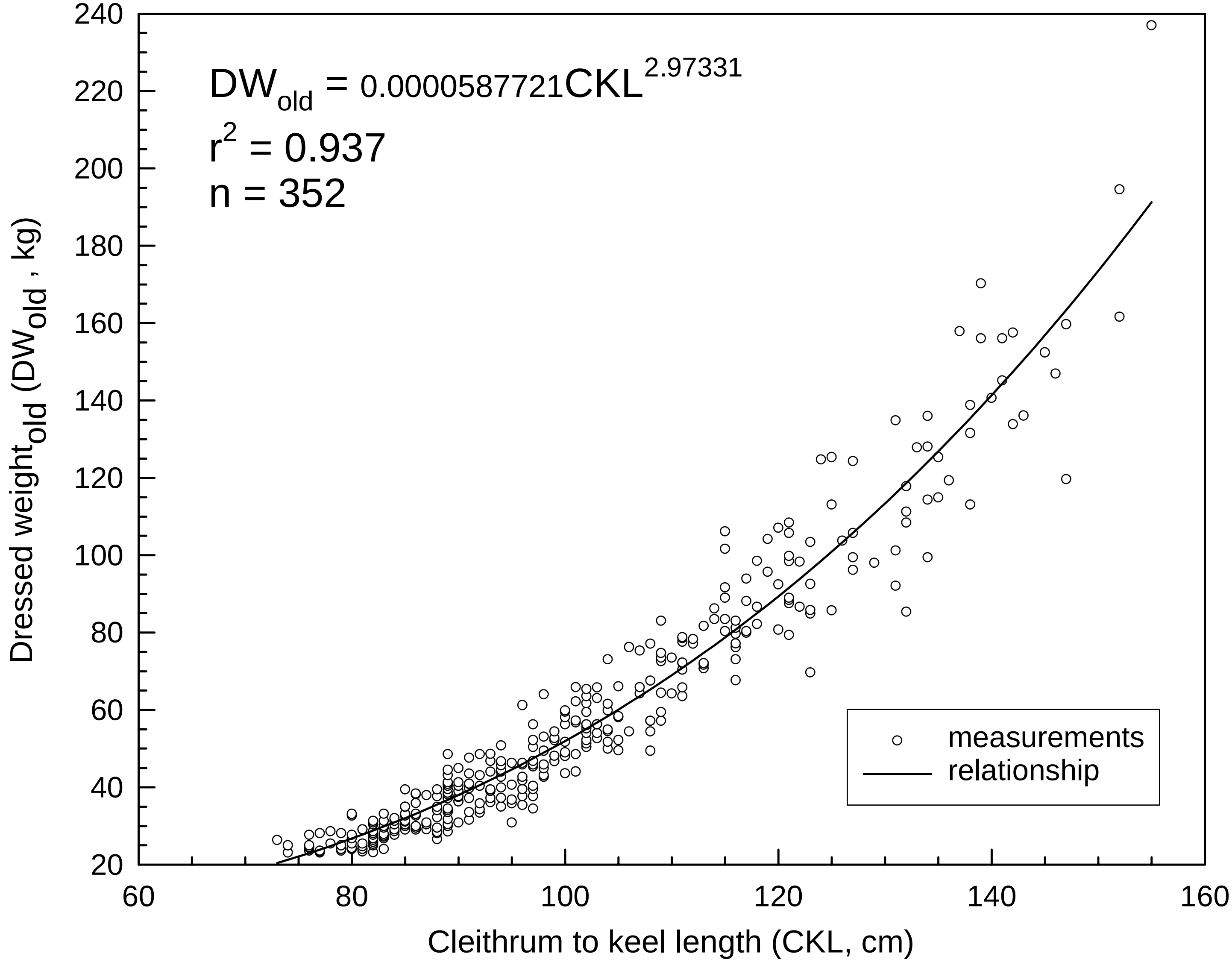


Figure 11.--Nonlinear dressed weight$_{old}$ on cleithrum to keel length relationship of swordfish, *Xiphias gladius*, from the central North Pacific Ocean. (commercial fish with sex and months pooled)

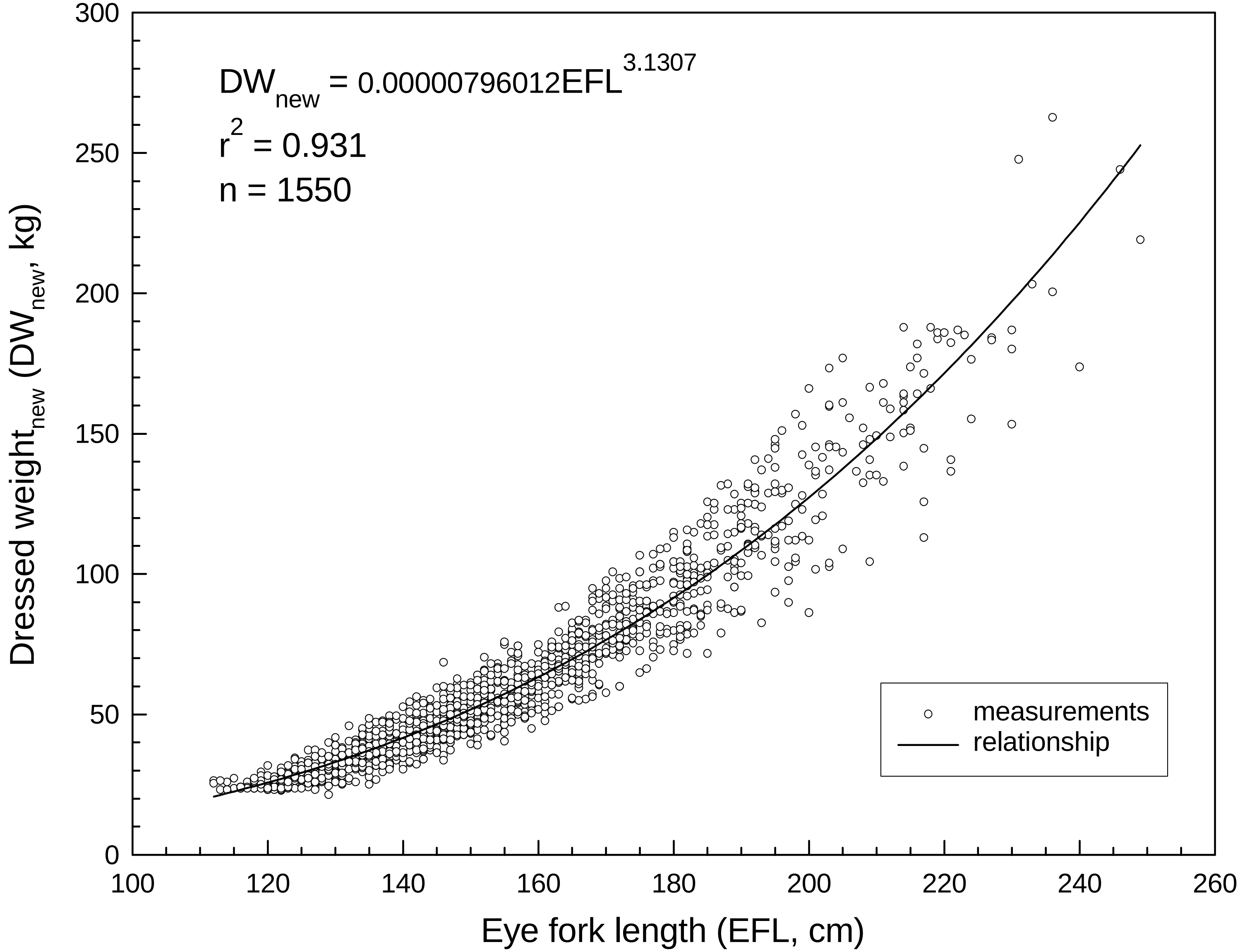


Figure 12.--Nonlinear dressed weight$_{new}$ on eye fork length relationship of swordfish, *Xiphias gladius*, from the central North Pacific Ocean. (commercial fish with sex and months pooled)

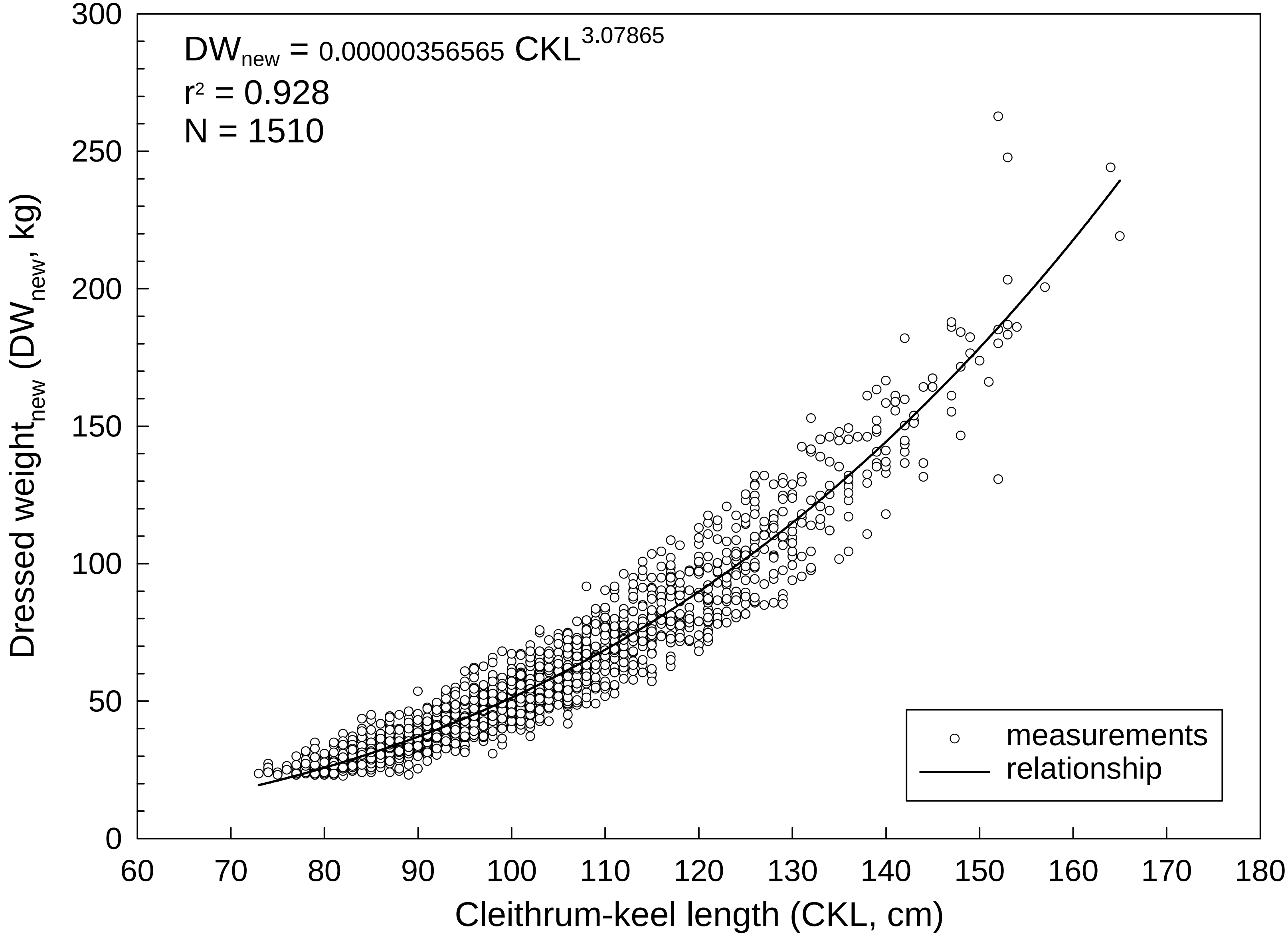


Figure 13.--Nonlinear dressed weight$_{new}$ on cleithrum to keel length relationship of swordfish, *Xiphias gladius*, from the central North Pacific Ocean. (commercial fish with sex and months pooled)

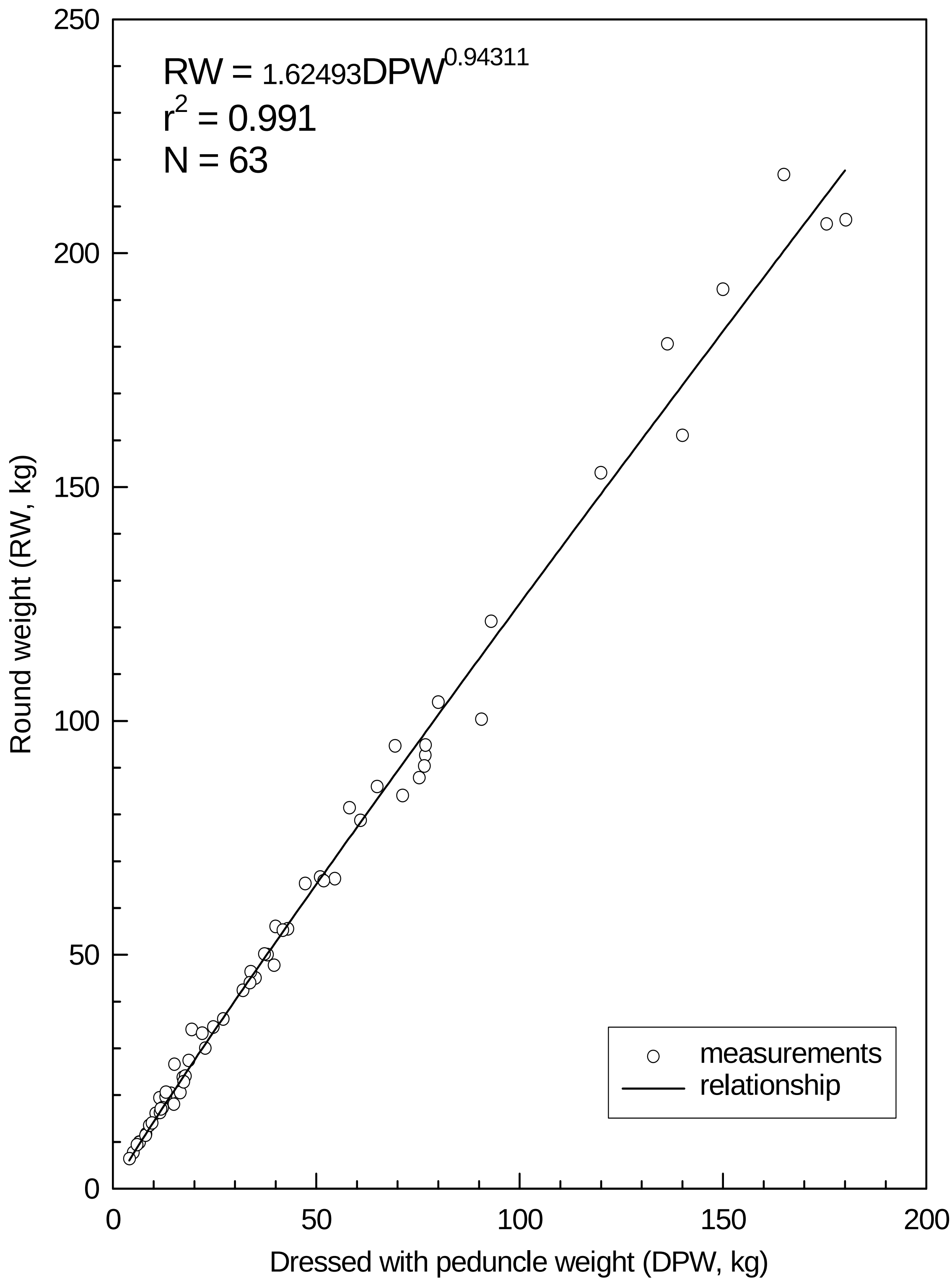


Figure 14.--Nonlinear round weight on dressed with peduncle weight relationship of swordfish, *Xiphias gladius*, from the central North Pacific Ocean.

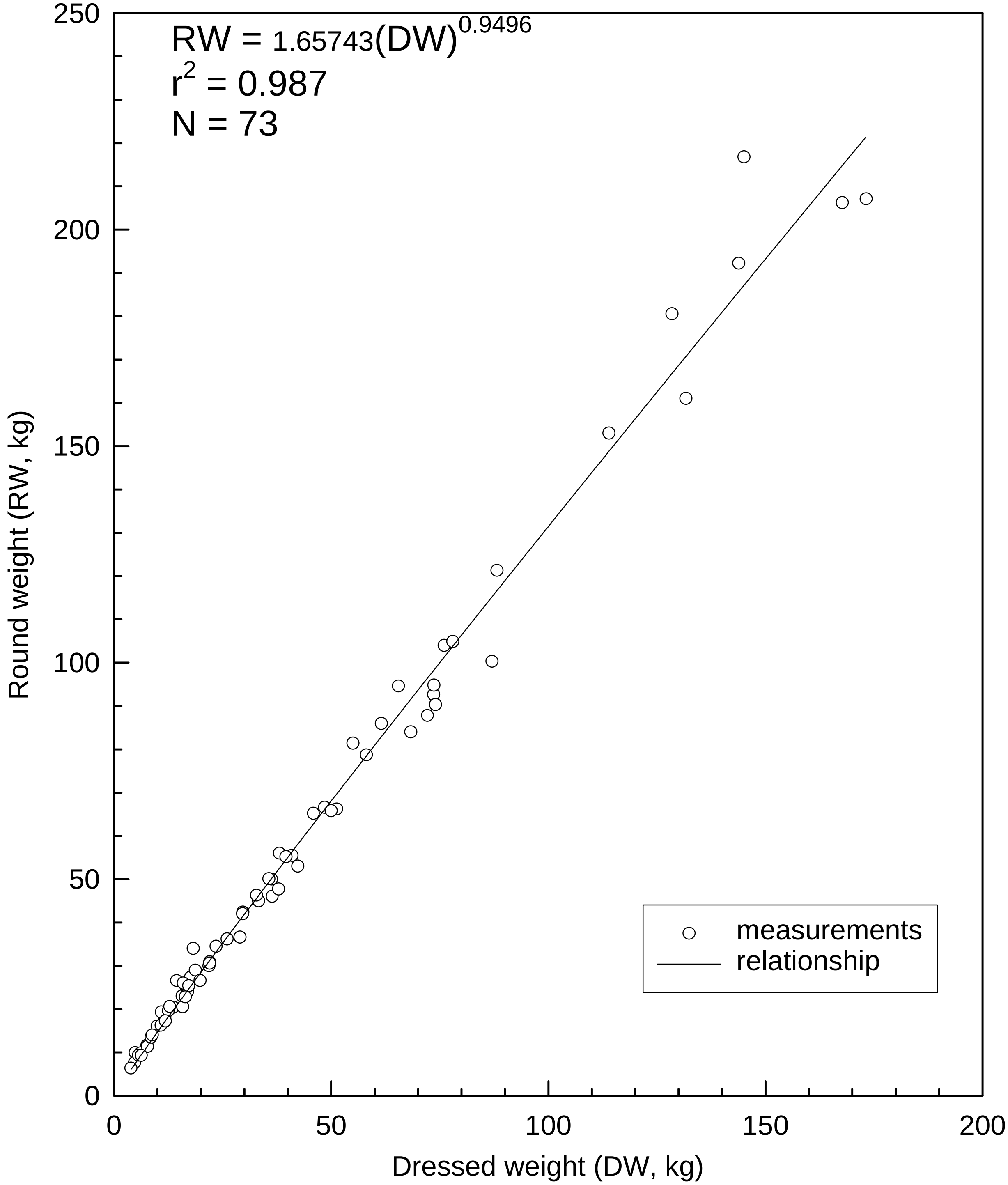


Figure 15.--Nonlinear round weight on dressed weight relationship of swordfish, *Xiphias gladius*, from the central North Pacific Ocean.

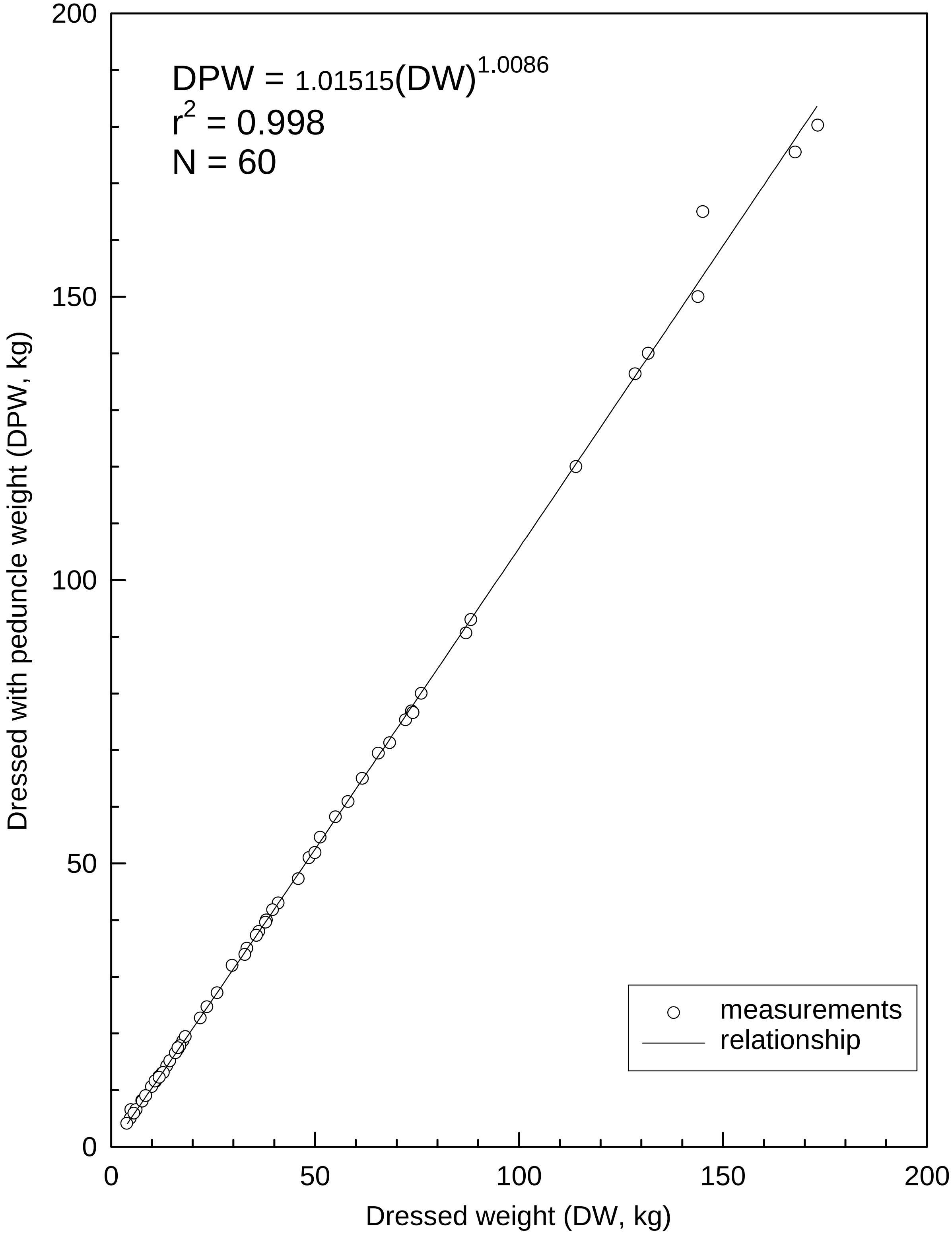


Figure 16.--Nonlinear dressed with peduncle weight on dressed weight relationship of research swordfish, *Xiphias gladius*, from the central North Pacific Ocean.

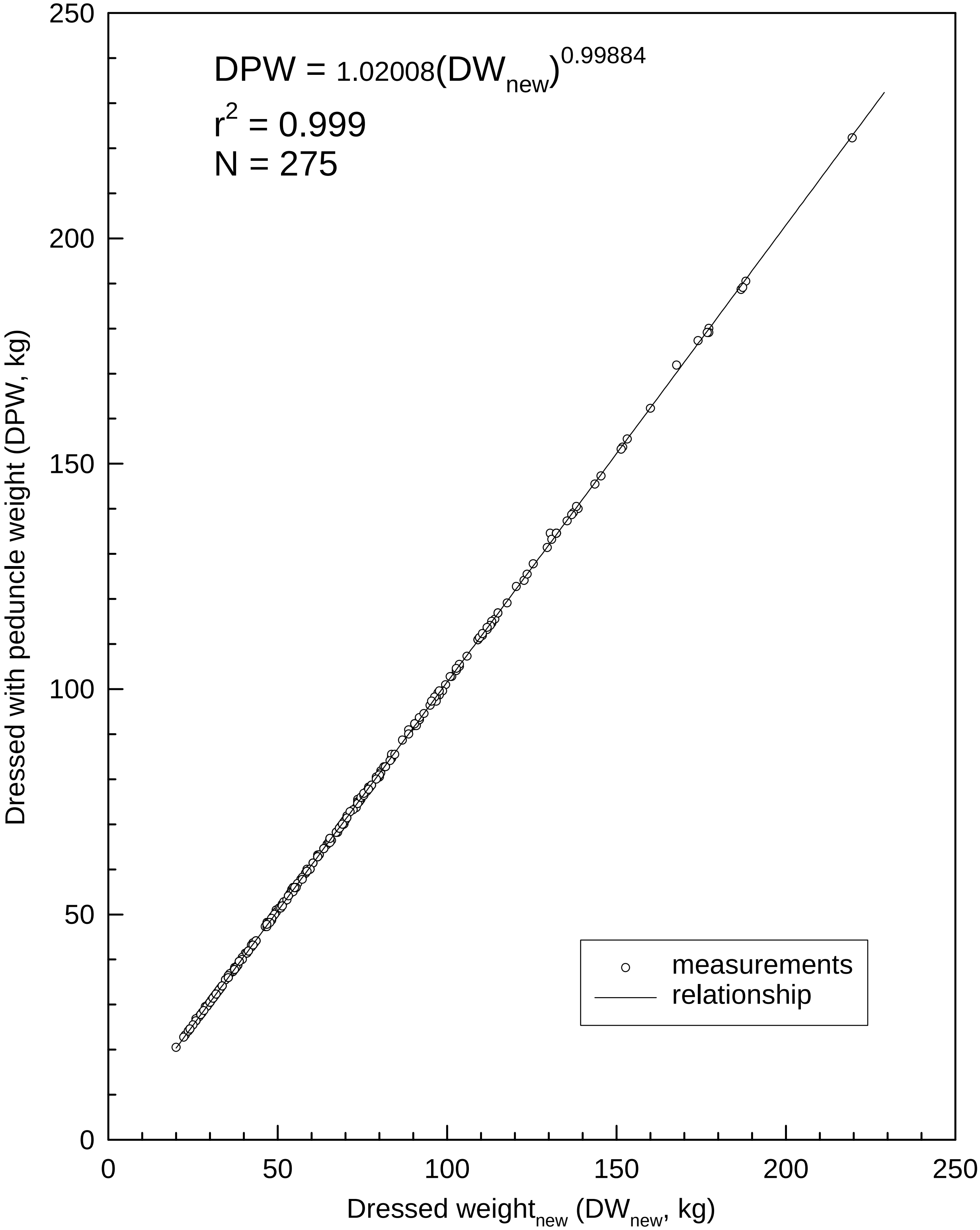


Figure 17.--Nonlinear dressed with peduncle weight on dressed weight$_{new}$ relationship of commercial swordfish, *Xiphias gladius*, from the central North Pacific Ocean.

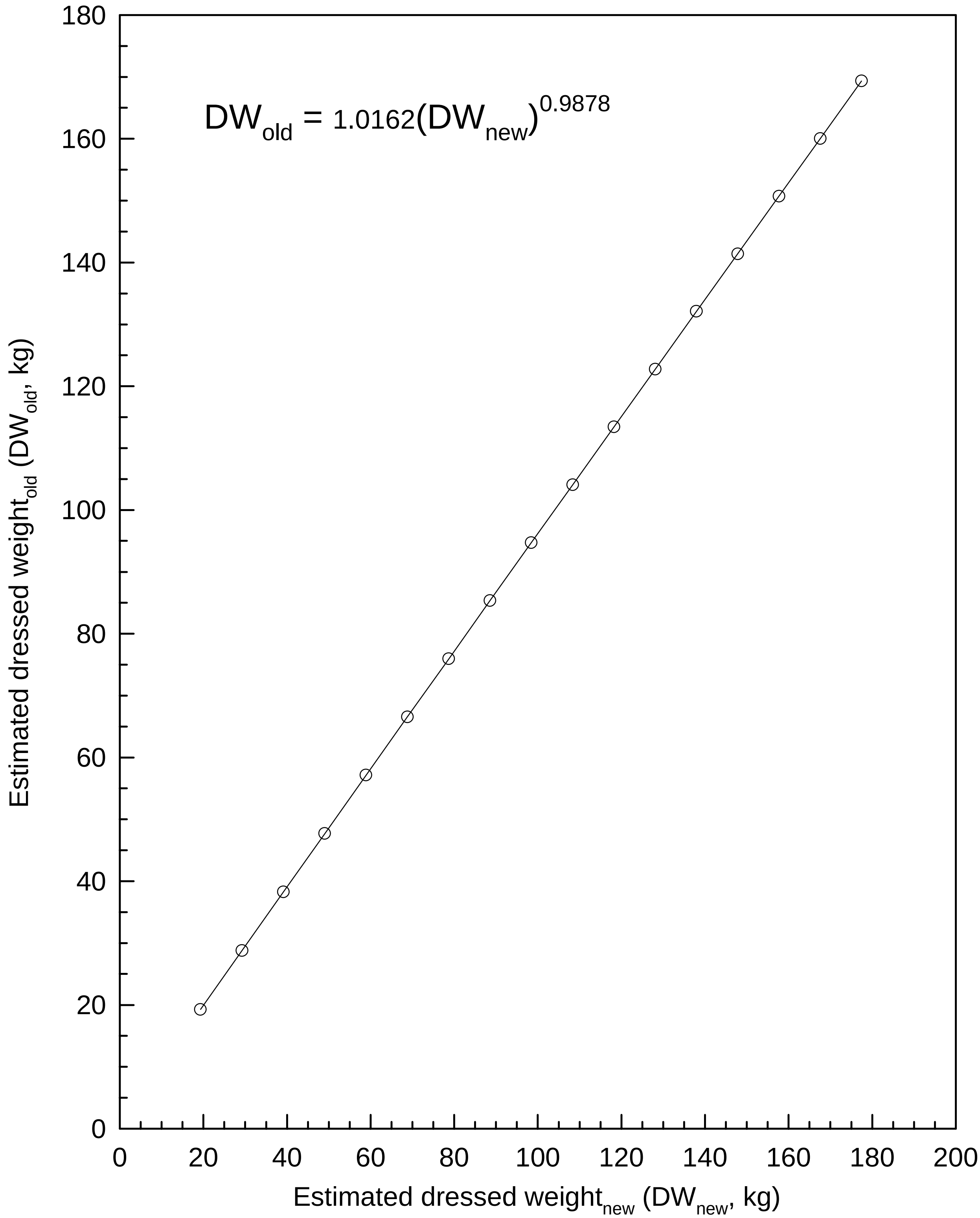


Figure 18.--Nonlinear estimated dressed weight$_{old}$ on estimated dressed weight$_{new}$ relationship of swordfish, *Xiphias gladius*, from the central North Pacific Ocean.

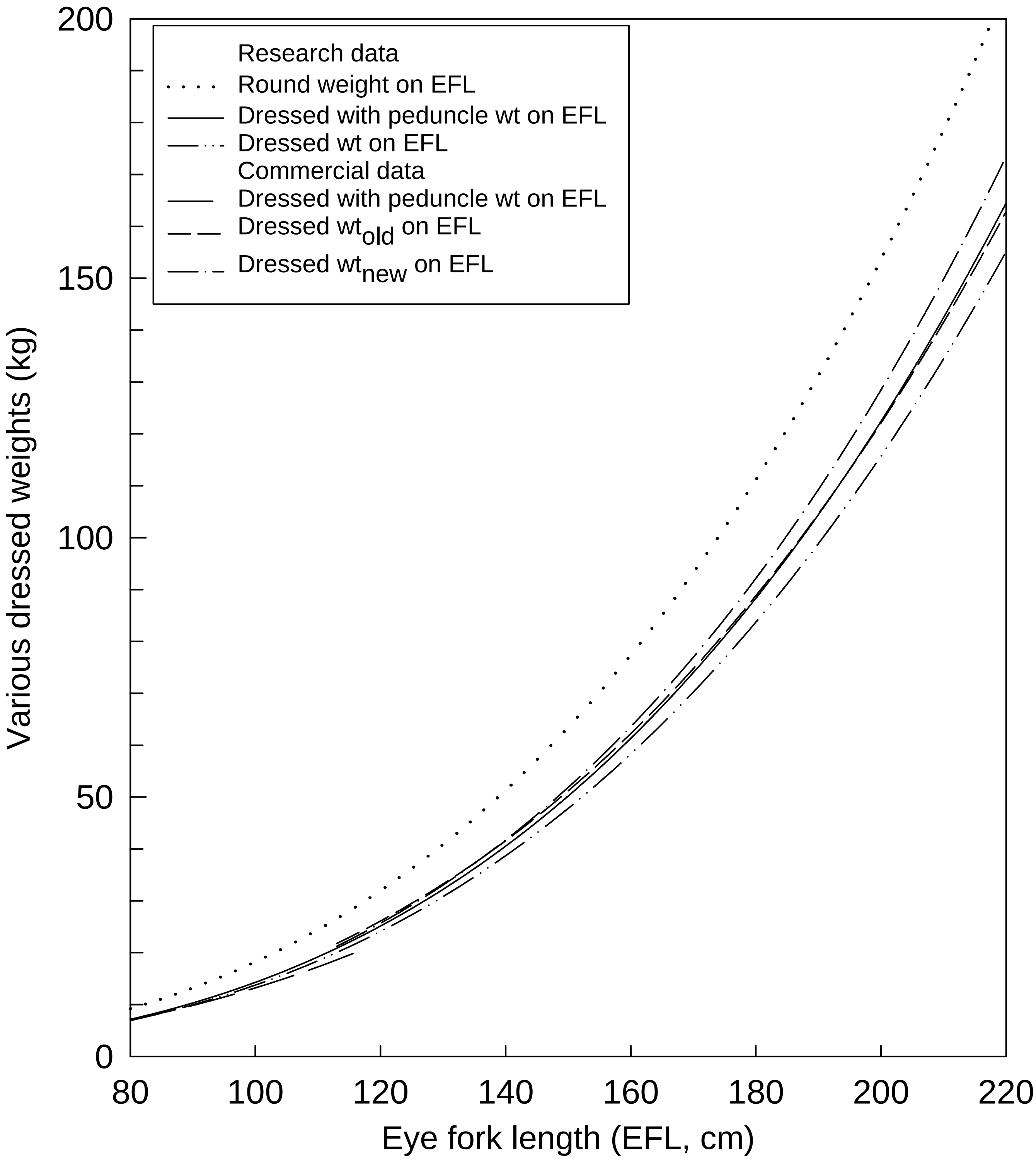


Figure 19.--Comparison of various weights on eye fork length relationships of swordfish, *Xiphias gladius*, from the central North Pacific Ocean.

APPENDIX TABLES

Appendix Table 1.--Summary data for research cruises.

		Area of operation		
Cruise	Month	Latitude	Longitude	Number caught
91-01	1-2	25-27°N	156-164°W	60
92-03	3-4	25-27°N	156-164°W	44
93-03	3-4	25-30°N	156-162°W	44
96-02	2	27-32°N	153-162°W	11
96-03	4	27-31°N	165-178°W	3
96-10	9	28-39°N	159-172°W	10
97-03	3-4	29-31°N	150-154°W	12

Appendix Table 2.--Weighing instruments used on research cruises.

Instrument[1]	Capacity	Accuracy	Cruises
Steelyard	90 Kg		91-01
Maco model 25 beam scale	25 Kg	0.01 Kg	91-01, 92-03, 96-03
Challenger MSI-3260 crane scale	225 Kg	2.25 Kg	92-03, 93-03, 96-02, 96-03, 96-10, 97-03
Micro Weighing System model SGS-240 seagoing scale	40 Kg	0.04 Kg	93-03, 96-02
platform spring scale	15 Kg	0.1 Kg	97-03

[1]The NMFS does not approve, recommend or endorse any proprietary product or proprietary material mentioned in this publication.

Appendix Table 3.--ANCOVA results evaluating the effects of sex on various linear length◆-length relationships for central North Pacific swordfish, *Xiphias gladius*, caught on research cruises.

Cruise	Overlapping EFL Range *cm*	Sex	N	Parameter estimates	Standard error	*t*	*P*
				LJFL = $\boldsymbol{a}_1$ + $\boldsymbol{b}_1$**EFL** for males, and **LJFL** = ($\boldsymbol{a}_1$ + $\boldsymbol{a}_2$) + ($\boldsymbol{b}_1$ + $\boldsymbol{b}_2$)**EFL** for females.			
91-01	71-135	M	20	a_1= 5.268	3.343	1.575	0.122
				b_1= 1.091	0.034	31.954	0.000
		F	29	a_2= 5.593	4.300	1.300	0.199
				b_2=-0.056	0.043	-1.306	0.197
92-03	88-203	M	19	a_1= 7.726	1.457	5.300	0.000
				b_1= 1.072	0.010	101.929	0.000
		F	13	a_2=-0.496	1.927	-0.257	0.798
				b_2= 0.001	0.014	0.098	0.922
93-03	106-161	M	11	a_1=18.800	7.183	2.617	0.015
				b_1= 0.985	0.054	18.156	0.000
		F	27	a_2=-5.551	9.173	-0.605	0.550
				b_2= 0.049	0.070	0.704	0.487
All	71-214	M	72	a_1= 8.582	1.467	5.848	0.000
				b_1= 0.025	0.014	1.685	0.000
		F	90	a_2=-2.312	1.874	-1.233	0.219
				b_2= 1.064	0.011	91.853	0.093
				FL = $\boldsymbol{a}_1$ **+** $\boldsymbol{b}_1$**EFL** for males, and **FL** = ($\boldsymbol{a}_1$ + $\boldsymbol{a}_2$) + ($\boldsymbol{b}_1$ + $\boldsymbol{b}_2$)**EFL** for females.			
91-01	71-135	M	18	a_1= 8.207	5.089	1.612	0.114
				b_1= 1.590	0.052	30.046	0.000
		F	26	a_2= 5.007	6.372	0.785	0.436
				b_2= -0.034	0.064	-0.526	0.601
92-03	88-150	M	15	a_1= 31.339	7.620	4.112	0.000
				b_1= 1.417	0.060	23.406	0.000
		F	9	a_2= -4.249	11.638	-0.365	0.718
				b_2= 0.035	0.101	0.347	0.732
93-03	106-161	M	11	a_1= 16.902	14.492	1.166	0.254
				b_1= 1.532	0.109	13.993	0.000
		F	17	a_2= 9.039	18.506	0.488	0.629
				b_2= -0.072	0.141	-0.512	0.613

Appendix Table 3.--(Continued)

Cruise	OverlappingLJ FL range *cm*	Sex	N	Parameter estimates	Standard error	*t*	*P*
				FL = a_1 + b_1EFL for males, and **FL** = (a_1 + a_2) + (b_1 + b_2)**EFL** for females.			
All	71-171	M	65	a_1= 12.214	4.293	2.844	0.005
				b_1= 1.554	0.035	44.092	0.000
		F	75	a_2= 8.433	5.829	1.446	0.150
				b_2= -0.054	0.049	-1.115	0.266
				FL = a_1 + b_1**LJFL** for males, and **FL** = (a_1 + a_2) **+** (b_2 **+** b_2)**LJFL** for females.			
91-01	83-148	M	18	a_1=-0.522	7.908	-0.066	0.947
				b_1= 1.467	0.071	20.423	0.000
		F	25	a_2= 2.533	10.209	0.248	0.805
				b_2=-0.009	0.091	-0.098	0.921
92-03	101-189	M	17	a_1=20.747	7.530	2.755	0.011
				b_1= 1.326	0.050	26.097	0.000
		F	10	a_2=11.528	10.645	1.082	0.290
				b_2=-0.102	0.076	-1.346	0.191
93-03	122-200	M	14	a_1=15.998	10.486	1.525	0.137
				b_1= 1.355	0.065	20.646	0.000
		F	19	a_2=-3.705	13.815	-0.268	0.790
				b_2= 0.017	0.088	0.198	0.843
All	87-200	M	65	a_1= 4.327	4.836	0.894	0.372
				b_1= 1.424	0.034	40.932	0.000
		F	78	a_2=10.190	6.334	1.608	0.110
				b_2=-0.067	0.045	-1.470	0.143

◆EFL = length: eye fork length: FL = fork length; and LJFL = lower jaw fork length.

Appendix Table 4.--ANCOVA results evaluating the effects of cruise on various linear length◆-length relationships for central North Pacific swordfish, *Xiphias gladius*, caught on research cruises.

Between cruises	Overlapping EFL range *cm*	N	Parameter estimates	Standard error	*t*	*P*
			LJFL = $\boldsymbol{a}_1 + \boldsymbol{b}_1$**EFL** for cruise 92-03, and **LJFL** = $(\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)$**EFL** for cruise 91-01.			
92-03	75-148	29	a_1= 5.093	2.250	2.263	0.026
to			b_1= 1.095	0.020	53.047	0.000
91-01		52	a_2= 3.234	2.779	1.163	0.248
			b_2= -0.035	0.026	-1.354	0.179
			LJFL = $\boldsymbol{a}_1 + \boldsymbol{b}_1$**EFL** for cruise 93-03, and **LJFL** = $(\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)$**EFL** for cruise 91-01.			
93-03	77-147	29	a_1= 11.050	3.176	3.478	0.000
to			b_1= 1.050	0.027	38.525	0.000
91-01		51	a_2= -2.731	3.629	-0.752	0.454
			b_2= 0.009	0.032	0.300	0.764
			LJFL = $\boldsymbol{a}_1 + \boldsymbol{b}_1$**EFL** for cruise 92-03, and **LJFL** = $(\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)$**EFL** for cruise 93-03.			
92-03	76-214	39	a_1= 9.311	1.889	4.926	0.000
to			b_1= 1.064	0.013	76.180	0.000
93-03		41	a_2= -1.384	2.438	-0.567	0.571
			b_2= 0.004	0.017	0.229	0.819
			FL = $\boldsymbol{a}_1 + \boldsymbol{b}_1$**EFL** for cruise 92-03, and **FL** = $(\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)$**EFL** for cruise 91-01.			
92-03	75-130	22	a_1= 8.997	7.000	1.285	0.203
to			b_1= 1.622	0.068	23.630	0.000
91-01		42	a_2= -1.776	8.274	-0.214	0.830
			b_2= -0.014	0.082	-0.176	0.860
			FL = $\boldsymbol{a}_1 + \boldsymbol{b}_1$**EFL** for cruise 93-03, and **FL** = $(\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)$**EFL** for cruise 91-01.			
93-03	76-131	24	a_1= 25.310	8.160	3.101	0.002
to			b_1= 1.461	0.073	19.802	0.000
91-01		42	a_2=-16.047	9.272	-1.730	0.088
			b_2= 0.125	0.086	1.453	0.151

Appendix Table 4.--(Continued)

Between cruises	Overlapping LJFL range cm	N	Parameter estimates	Standard error	t	P
			FL = $\boldsymbol{a}_1 + \boldsymbol{b}_1$**EFL** for cruise 92-03, and **FL** = $(\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)$**EFL** for cruise 93-03.			
92-03	76-214	36	a_1= 27.396	5.471	5.007	0.000
to			b_1= 1.445	0.041	35.080	0.000
93-03		39	a_2= 0.674	7.144	0.094	0.925
			b_2= -0.016	0.053	-0.304	0.761
			FL = $\boldsymbol{a}_1 + \boldsymbol{b}_1$**LJFL** for cruise 92-03 and **FL** = $(\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)$**LJFL** for cruise 91-01.			
92-03	87-166	29	a_1= 9.143	5.858	1.560	0.123
to			b_1= 1.400	0.047	29.632	0.000
91-01		47	a_2=-13.025	7.536	-1.728	0.088
			b_2= 0.104	0.062	1.681	0.097
			FL = $\boldsymbol{a}_1 + \boldsymbol{b}_1$**LJFL** for cruise 93-03 and **FL** = $(\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)$**LJFL** for cruise 91-01.			
93-03	90-165	30	a_1= 4.104	7.811	0.525	0.601
to			b_1= 1.440	0.058	24.748	0.000
91-01		40	a_2= -8.640	9.456	-0.913	0.364
			b_2= 0.069	0.072	0.949	0.346
			FL = $\boldsymbol{a}_1 + \boldsymbol{b}_1$**LJFL** for cruise 92-03 and **FL** = $(\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)$**LJFL** for cruise 93-03.			
92-03	94-237	35	a_1= 20.754	4.651	4.461	0.000
to			b_1= 1.311	0.030	43.068	0.000
93-03		39	a_2= -4.549	7.382	-0.616	0.539
			b_2= 0.038	0.048	0.802	0.424

◆EFL = length: eye fork length; FL = fork length; and LJFL = lower jaw fork length.

Appendix Table 6.--ANCOVA results evaluating effect of sex on various log-linear length◆-weight◆◆ relationships for central North Pacific swordfish, *Xiphias gladius*, caught on research cruises.

Cruise	EFL range *cm*	Sex	N	Parameter estimates	Standard error	*t*	*P*
$ln\mathbf{RW} = \boldsymbol{a}_1$▼ $+ \boldsymbol{b}_1(ln\mathbf{EFL})$ for males, and $ln\mathbf{RW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2$▼▼$) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{EFL})$ for females.							
91-01	71-135	M	19	$\boldsymbol{a}_1$= -12.210	0.769	-15.859	0.000
				$\boldsymbol{b}_1$= 3.255	0.170	19.141	0.000
		F	29	$\boldsymbol{a}_2$= 0.144	0.941	0.153	0.878
				$\boldsymbol{b}_2$= -0.017	0.207	-0.086	0.931
92-03	87-214	M	19	$\boldsymbol{a}_1$= -10.507	0.483	-21.722	0.000
				$\boldsymbol{b}_1$= 2.922	0.098	29.718	0.000
		F	13	$\boldsymbol{a}_2$= -1.042	0.649	-1.605	0.119
				$\boldsymbol{b}_2$= 0.214	0.132	1.626	0.115
93-03	106-161	M	11	$\boldsymbol{a}_1$= -11.869	1.307	-9.077	0.000
				$\boldsymbol{b}_1$= 3.205	0.268	11.934	0.000
		F	17	$\boldsymbol{a}_2$= 0.530	1.670	0.317	0.753
				$\boldsymbol{b}_2$= -0.109	0.344	-0.317	0.753
All	71-214	M	68	$\boldsymbol{a}_1$= -12.057	0.304	-39.552	0.000
				$\boldsymbol{b}_1$= 3.232	0.063	50.670	0.000
		F	81	$\boldsymbol{a}_2$= 0.281	0.399	0.704	0.482
				$\boldsymbol{b}_2$= -0.052	0.083	-0.626	0.531
$ln\mathbf{DPW} = \boldsymbol{a}_1 + \boldsymbol{b}_1(ln\mathbf{EFL})$ for males, and $ln\mathbf{DPW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{EFL})$ for females.							
92-03	87-214	M	15	$\boldsymbol{a}_1$= -12.217	0.647	-18.853	0.000
				$\boldsymbol{b}_1$= 3.207	0.132	24.284	0.000
		F	13	$\boldsymbol{a}_2$= -0.484	0.806	-0.600	0.553
				$\boldsymbol{b}_2$= 0.103	0.164	0.626	0.536
93-03	106-161	M	6	$\boldsymbol{a}_1$= -13.884	1.520	-9.132	0.000
				$\boldsymbol{b}_1$= 3.580	0.310	11.537	0.000
		F	10	$\boldsymbol{a}_2$= -0.377	2.028	-0.186	0.855
				$\boldsymbol{b}_2$= 0.049	0.413	0.119	0.906
All	71-214	M	29	$\boldsymbol{a}_1$= -13.154	0.493	-26.681	0.000
				$\boldsymbol{b}_1$= 3.403	0.100	33.710	0.000
		F	30	$\boldsymbol{a}_2$= 0.355	0.623	0.570	0.570
				$\boldsymbol{b}_2$= -0.072	0.127	-0.564	0.574

Appendix Table 6.--(cont.)

Cruise	EFL range *cm*	Sex	N	Parameter estimates		Standard error	*t*	*P*
				$lnDW = a_1 + b_1(lnEFL)$ for males, and				
				$lnDW = (a_1 + a_2) + (b_1 + b_2)(lnEFL)$ for females.				
92-03	87-214	M	15	a_1=	-12.216	0.583	-20.928	0.000
				b_1=	3.197	0.118	26.869	0.000
		F	12	a_2=	-0.871	0.744	-1.170	0.253
				b_2=	0.176	0.151	1.163	0.256
93-03	106-161	M	11	a_1=	-13.619	1.229	-11.081	0.000
				b_1=	3.505	0.252	13.882	0.000
		F	16	a_2=	0.688	1.600	0.429	0.671
				b_2=	-0.152	0.329	-0.461	0.648
All	71-214	M	32	a_1=	-13.290	0.502	-26.439	0.000
				b_1=	3.422	0.102	33.267	0.000
		F	35	a_2=	0.292	0.632	0.463	0.644
				b_2=	-0.059	0.129	-0.457	0.648

Cruise	LJFL range *cm*	Sex	N	Parameter estimates		Standard error	*t*	*P*
				$lnRW = a_1 + b_1(lnLJFL)$ for males, and				
				$lnRW = (a_1 + a_2) + (b_1 + b_2)(lnLJFL)$ for females.				
91-01	83-154	M	19	a_1=	-13.600	0.950	-14.311	0.000
				b_1=	3.456	0.203	16.969	0.000
		F	28	a_2=	-0.118	1.190	-0.099	0.921
				b_2=	0.037	0.254	0.145	0.884
92-03	101-225	M	19	a_1=	11.887	0.556	-21.365	0.000
				b_1=	3.126	0.110	28.314	0.000
		F	12	a_2=	-1.117	0.774	-1.442	0.160
				b_2=	0.226	0.154	1.464	0.154
93-03	122-200	M	14	a_1=	-12.725	0.973	-13.065	0.000
				b_1=	3.294	0.192	17.085	0.000
		F	18	a_2=	0.465	1.350	0.344	0.732
				b_2=	-0.097	0.269	-0.362	0.719
All	87-224	M	67	a_1=	-13.313	0.356	-37.312	0.000
				b_1=	3.404	0.072	46.876	0.000
		F	75	a_2=	0.397	0.500	0.793	0.428
				b_2=	-0.079	0.102	-0.772	0.441

Appendix Table 6.--(cont.)

Cruise	LJFL range *cm*	Sex	N	Parameter estimates		Standard error	*t*	*P*
				$ln\mathbf{DPW} = \boldsymbol{a}_1 + \boldsymbol{b}_1(ln\mathbf{LJFL})$ for males, and				
				$ln\mathbf{DPW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{LJFL})$ for females.				
92-03	101-225	M	15	$\boldsymbol{a}_1$=	-13.741	0.727	-18.882	0.000
				$\boldsymbol{b}_1$=	3.425	0.144	23.716	0.000
		F	12	$\boldsymbol{a}_2$=	-0.590	0.936	-0.631	0.534
				$\boldsymbol{b}_2$=	0.123	0.187	0.660	0.515
93-03	122-200	M	9	$\boldsymbol{a}_1$=	-13.009	1.299	-10.007	0.000
				$\boldsymbol{b}_1$=	3.308	0.254	13.003	0.000
		F	11	$\boldsymbol{a}_2$=	-1.139	1.888	-0.603	0.554
				$\boldsymbol{b}_2$=	0.206	0.371	0.555	0.586
All	100-224	M	29	$\boldsymbol{a}_1$=	-14.379	0.565	-25.429	0.000
				$\boldsymbol{b}_1$=	3.565	0.112	31.651	0.000
		F	24	$\boldsymbol{a}_2$=	0.734	0.788	0.931	0.356
				$\boldsymbol{b}_2$=	-0.148	0.158	-0.937	0.352
				$ln\mathbf{DW} = \boldsymbol{a}_1 + \boldsymbol{b}_1(ln\mathbf{LJFL})$ for males, and				
				$ln\mathbf{DW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{LJFL})$ for females.				
92-03	101-225	M	15	$\boldsymbol{a}_1$=	-13.736	0.659	-20.843	0.000
				$\boldsymbol{b}_1$=	3.423	0.131	26.102	0.000
		F	11	$\boldsymbol{a}_2$=	-1.171	0.869	-1.347	0.191
				$\boldsymbol{b}_2$=	0.235	0.173	1.357	0.188
93-03	122-200	M	14	$\boldsymbol{a}_1$=	-14.302	0.996	-14.357	0.000
				$\boldsymbol{b}_1$=	3.551	0.197	18.005	0.000
		F	17	$\boldsymbol{a}_2$=	0.102	1.412	0.072	0.942
				$\boldsymbol{b}_2$=	-0.033	0.281	-0.120	0.904
All	101-224	M	30	$\boldsymbol{a}_1$=	-13.932	0.561	-24.793	0.000
				$\boldsymbol{b}_1$=	3.471	0.111	31.095	0.000
		F	30	$\boldsymbol{a}_2$=	-0.379	0.747	-0.508	0.613
				$\boldsymbol{b}_2$=	-0.070	0.149	-0.469	0.640

Appendix Table 6.--(cont.)

Cruise	FL range *cm*	Sex	N	Parameter estimates		Standard error	*t*	*P*
				$lnRW = a_1 + b_1(lnFL)$ for males, and $lnRW = (a_1 + a_2) + (b_1 + b_2)(lnFL)$ for females.				
91-01	123-213	M	17	a_1=	-14.839	0.950	-15.607	0.000
				b_1=	3.441	0.188	18.216	0.000
		F	24	a_2=	-0.428	1.187	-0.361	0.720
				b_2=	0.089	0.235	0.379	0.706
92-03	148-293	M	18	a_1=	-15.013	0.985	-15.235	0.000
				b_1=	3.482	0.183	18.931	0.000
		F	11	a_2=	-2.124	1.439	-1.475	0.152
				b_2=	0.410	0.269	1.522	0.140
93-03	174-269	M	11	a_1=	-14.879	1.366	-10.888	0.000
				b_1=	3.462	0.254	13.622	0.000
		F	18	a_2=	-0.299	1.745	-0.171	0.865
				b_2=	0.055	0.325	0.169	0.867
All	123-293	M	64	a_1=	-14.651	0.387	-37.845	0.000
				b_1=	3.415	0.073	46.496	0.000
		F	72	a_2=	-0.550	0.540	-1.018	0.310
				b_2=	0.102	0.102	1.000	0.319
				$lnDPW = a_1 + b_1(lnFL)$ for males, and $lnDPW = (a_1 + a_2) + (b_1 + b_2)(lnFL)$ for females.				
92-03	148-293	M	15	a_1=	-17.001	1.036	-16.405	0.000
				b_1=	3.791	0.193	19.600	0.000
		F	10	a_2=	-2.766	1.501	-1.842	0.079
				b_2=	0.534	0.281	1.898	0.071
93-03	174-269	M	6	a_1=	-16.843	2.134	-7.892	0.000
				b_1=	3.783	0.393	9.604	0.000
		F	11	a_2=	0.131	2.638	0.049	0.960
				b_2=	-0.034	0.488	-0.070	0.944
All	148-293	M	27	a_1=	-16.190	0.889	-18.207	0.000
				b_1=	3.653	0.165	22.100	0.000
		F	24	a_2=	-1.791	1.294	-1.383	0.173
				b_2=	0.329	0.241	1.365	0.178

Appendix Table 6.--(cont.)

Cruise	FL range *cm*	Sex	N	Parameter estimates		Standard error	*t*	*P*
				ln**DW** = $\boldsymbol{a}_1 + \boldsymbol{b}_1(ln\mathbf{FL})$ for males, and				
				ln**DW** = $(\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{FL})$ for females.				
92-03	148-293	M	15	$\boldsymbol{a}_1$=	-17.046	1.072	-15.887	0.000
				$\boldsymbol{b}_1$=	3.790	0.200	18.925	0.000
		F	10	$\boldsymbol{a}_2$=	-2.837	1.554	-1.825	0.082
				$\boldsymbol{b}_2$=	0.548	0.291	1.879	0.074
93-03	174-269	M	11	$\boldsymbol{a}_1$=	-16.776	1.368	-12.256	0.000
				$\boldsymbol{b}_1$=	3.760	0.254	14.770	0.000
		F	17	$\boldsymbol{a}_2$=	0.018	1.768	0.010	0.991
				$\boldsymbol{b}_2$=	-0.013	0.329	-0.039	0.968
All	123-293	M	31	$\boldsymbol{a}_1$=	-16.350	0.690	-23.692	0.000
				$\boldsymbol{b}_1$=	3.673	0.128	28.591	0.000
		F	32	$\boldsymbol{a}_2$=	-1.522	0.947	-1.606	0.113
				$\boldsymbol{b}_2$=	0.282	0.177	1.593	0.116

◆length: EFL = eye fork length; FL = fork length; and LJFL = lower jaw fork length.
◆◆weight: RW = round weight; DPW = dressed with peduncle weight; and DW = dressed weight.
▼log of Y-intercept.
▼▼log of the difference in Y-intercepts of the two relationships.

Appendix Table 7.--ANCOVA results evaluating effect of cruise on various log-linear length◆-weight◆◆ relationships for central North Pacific swordfish, *Xiphias gladius*, caught on research cruises.

Between cruises	EFL range *cm*	N	Parameter estimates		Standard error	*t*	*P*
			$ln\mathbf{RW} = \boldsymbol{a}_1$▼ $+ \boldsymbol{b}_1(ln\mathbf{EFL})$ for cruise 92-03, and				
			$ln\mathbf{RW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2$▼▼$) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{EFL})$ for cruise 91-01.				
92-03	75-148	26	$\boldsymbol{a}_1=$	-11.966	0.527	-22.680	0.000
to			$\boldsymbol{b}_1=$	3.224	0.113	28.462	0.000
91-01		51	$\boldsymbol{a}_2=$	-0.489	0.647	-0.756	0.451
			$\boldsymbol{b}_2=$	0.091	0.139	0.656	0.513
			$ln\mathbf{RW} = \boldsymbol{a}_1 + \boldsymbol{b}_1(ln\mathbf{EFL})$ for cruise 93-03, and				
			$ln\mathbf{RW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{EFL})$ for cruise 91-01.				
93-03	76-147	28	$\boldsymbol{a}_1=$	-11.842	0.691	-17.127	0.000
to			$\boldsymbol{b}_1=$	3.199	0.145	21.948	0.000
91-01		50	$\boldsymbol{a}_2=$	-0.509	0.793	-0.641	0.523
			$\boldsymbol{b}_2=$	0.094	0.168	0.559	0.577
			$ln\mathbf{RW} = \boldsymbol{a}_1 + \boldsymbol{b}_1(ln\mathbf{EFL})$ for cruise 92-03, and				
			$ln\mathbf{RW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{EFL})$ for cruise 93-03.				
92-03	76-214	36	$\boldsymbol{a}_1=$	-11.378	0.308	-36.887	0.000
to			$\boldsymbol{b}_1=$	3.098	0.063	48.840	0.000
93-03		39	$\boldsymbol{a}_2=$	0.004	0.532	0.008	0.993
			$\boldsymbol{b}_2=$	0.001	0.109	0.017	0.986
			$ln\mathbf{DPW} = \boldsymbol{a}_1 + \boldsymbol{b}_1(ln\mathbf{EFL})$ for cruise 93-03, and				
			$ln\mathbf{DPW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{EFL})$ for cruise 92-03.				
93-03	94-214	23	$\boldsymbol{a}_1=$	-12.885	0.625	-20.610	0.000
to			$\boldsymbol{b}_1=$	3.357	0.126	26.527	0.000
92-03		25	$\boldsymbol{a}_2=$	0.132	0.774	0.170	0.865
			$\boldsymbol{b}_2=$	-0.039	0.156	-0.253	0.801
			$ln\mathbf{DW} = \boldsymbol{a}_1 + \boldsymbol{b}_1(ln\mathbf{EFL})$ for cruise 93-03, and				
			$ln\mathbf{DW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{EFL})$ for cruise 92-03.				
93-03	81-214	36	$\boldsymbol{a}_1=$	-12.904	0.473	-27.270	0.000
to			$\boldsymbol{b}_1=$	3.350	0.097	34.445	0.000
92-03		30	$\boldsymbol{a}_2=$	-0.295	0.597	-0.495	0.622
			$\boldsymbol{b}_2=$	0.043	0.122	0.355	0.723

Appendix Table 7.--(cont.).

Between cruises	LJFL range *cm*	N	Parameter estimates		Standard error	*t*	*P*
			ln**RW** = $\boldsymbol{a}_1 + \boldsymbol{b}_1$($ln$**LJFL**) for cruise 92-03, and				
			ln**RW** = ($\boldsymbol{a}_1 + \boldsymbol{a}_2$) + ($\boldsymbol{b}_1 + \boldsymbol{b}_2$)($ln$**LJFL**) for cruise 91-01.				
92-03	87-166	27	$\boldsymbol{a}_1$=	-12.971	0.595	-21.780	0.000
to			$\boldsymbol{b}_1$=	3.343	0.124	26.837	0.000
91-01		51	$\boldsymbol{a}_2$=	-0.974	0.749	-1.300	0.197
			$\boldsymbol{b}_2$=	0.192	0.157	1.222	0.225
			ln**RW** = $\boldsymbol{a}_1 + \boldsymbol{b}_1$($ln$**LJFL**) for cruise 93-03, and				
			ln**RW** = ($\boldsymbol{a}_1 + \boldsymbol{a}_2$) + ($\boldsymbol{b}_1 + \boldsymbol{b}_2$)($ln$**LJFL**) for cruise 91-01.				
91-01	90-165	29	$\boldsymbol{a}_1$=	-13.602	0.805	-16.880	0.000
to			$\boldsymbol{b}_1$=	3.470	0.164	21.044	0.000
93-03		44	$\boldsymbol{a}_2$=	-0.503	0.957	-0.525	0.600
			$\boldsymbol{b}_2$=	0.098	0.197	0.497	0.620
			ln**RW** = $\boldsymbol{a}_1 + \boldsymbol{b}_1$($ln$**LJFL**) for cruise 92-03, and				
			ln**RW** = ($\boldsymbol{a}_1 + \boldsymbol{a}_2$) + ($\boldsymbol{b}_1 + \boldsymbol{b}_2$)($ln$**LJFL**) for cruise 93-03.				
92-03	94-237	36	$\boldsymbol{a}_1$=	-12.614	0.331	-38.044	0.000
to			$\boldsymbol{b}_1$=	3.269	0.066	49.420	0.000
93-03		38	$\boldsymbol{a}_2$=	-0.338	0.547	-0.617	0.538
			$\boldsymbol{b}_2$=	0.069	0.109	0.634	0.527
			ln**DPW** = $\boldsymbol{a}_1 + \boldsymbol{b}_1$($ln$**LJFL**) for cruise 92-03, and				
			ln**DPW** = ($\boldsymbol{a}_1 + \boldsymbol{a}_2$) + ($\boldsymbol{b}_1 + \boldsymbol{b}_2$)($ln$**LJFL**) for cruise 93-03.				
92-03	94-237	32	$\boldsymbol{a}_1$=	-14.114	0.381	-37.025	0.000
to			$\boldsymbol{b}_1$=	3.507	0.076	45.874	0.000
93-03		24	$\boldsymbol{a}_2$=	-0.020	0.738	-0.027	0.977
			$\boldsymbol{b}_2$=	0.014	0.146	0.096	0.923
			ln**DW** = $\boldsymbol{a}_1 + \boldsymbol{b}_1$($ln$**LJFL**) for cruise 92-03, and				
			ln**DW** = ($\boldsymbol{a}_1 + \boldsymbol{a}_2$) + ($\boldsymbol{b}_1 + \boldsymbol{b}_2$)($ln$**LJFL**) for cruise 93-03.				
92-03	94-237	31	$\boldsymbol{a}_1$=	-14.487	0.391	-37.045	0.000
to			$\boldsymbol{b}_1$=	3.567	0.078	45.592	0.000
93-03		36	$\boldsymbol{a}_2$=	-0.022	0.662	-0.034	0.972
			$\boldsymbol{b}_2$=	0.018	0.132	0.136	0.891

Appendix Table 7.--(cont.).

Between cruises	FL range *cm*	N	Parameter estimates		Standard error	*t*	*P*
			$ln\mathbf{RW} = \boldsymbol{a}_1 + \boldsymbol{b}_1(ln\mathbf{FL})$ for cruise 92-03, and				
			$ln\mathbf{RW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{FL})$ for cruise 91-01.				
92-03	123-250	28	$\boldsymbol{a}_1$=	-14.335	0.623	-22.975	0.000
to			$\boldsymbol{b}_1$=	3.354	0.119	27.992	0.000
91-01		51	$\boldsymbol{a}_2$=	-0.597	0.771	-0.774	0.440
			$\boldsymbol{b}_2$=	0.108	0.149	0.724	0.471
			$ln\mathbf{RW} = \boldsymbol{a}_1 + \boldsymbol{b}_1(ln\mathbf{FL})$ for cruise 93-03, and				
			$ln\mathbf{RW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{FL})$ for cruise 91-01.				
93-03	131-228	24	$\boldsymbol{a}_1$=	-15.325	0.936	-16.361	0.000
to			$\boldsymbol{b}_1$=	3.546	0.179	19.798	0.000
91-01		42	$\boldsymbol{a}_2$=	0.136	1.063	0.128	0.898
			$\boldsymbol{b}_2$=	-0.032	0.204	-0.157	0.875
			$ln\mathbf{RW} = \boldsymbol{a}_1 + \boldsymbol{b}_1(ln\mathbf{FL})$ for cruise 92-03, and				
			$ln\mathbf{RW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{FL})$ for cruise 93-03.				
92-03	129-329	34	$\boldsymbol{a}_1$=	-15.947	0.473	-33.677	0.000
to			$\boldsymbol{b}_1$=	3.662	0.089	41.065	0.000
93-03		38	$\boldsymbol{a}_2$=	0.928	0.729	1.271	0.207
			$\boldsymbol{b}_2$=	-0.175	0.136	-1.286	0.202
			$ln\mathbf{DPW} = \boldsymbol{a}_1 + \boldsymbol{b}_1(ln\mathbf{FL})$ for cruise 92-03, and				
			$ln\mathbf{DPW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{FL})$ for cruise 93-03.				
92-03	174-329	20	$\boldsymbol{a}_1$=	-18.818	0.978	-19.224	0.000
to			$\boldsymbol{b}_1$=	4.133	0.180	22.947	0.000
93-03		21	$\boldsymbol{a}_2$=	2.089	1.437	1.453	0.154
			$\boldsymbol{b}_2$=	-0.378	0.263	-1.433	0.159
			$ln\mathbf{DW} = \boldsymbol{a}_1 + \boldsymbol{b}_1(ln\mathbf{FL})$ for cruise 92-03, and				
			$ln\mathbf{DW} = (\boldsymbol{a}_1 + \boldsymbol{a}_2) + (\boldsymbol{b}_1 + \boldsymbol{b}_2)(ln\mathbf{FL})$ for cruise 93-03.				
92-03	174-329	20	$\boldsymbol{a}_1$=	-18.697	0.917	-20.384	0.000
to			$\boldsymbol{b}_1$=	4.101	0.168	24.295	0.000
93-03		33	$\boldsymbol{a}_2$=	1.867	1.230	1.517	0.135
			$\boldsymbol{b}_2$=	-0.336	0.227	-1.483	0.144

◆length: EFL = eye fork length; FL = fork length; and LJFL = lower jaw fork length.
◆◆weight: RW = round weight; DPW = dressed with peduncle weight; and DW = dressed weight.
▼log of Y-intercept.
▼▼log of the difference in Y-intercepts of the two relationships.

Appendix Table 5. --Summary of ANCOVA results evaluating the effects of sex on the log-linear relationship of eye fork length-cleithrum to keel length (CKL) for central North Pacific swordfish.

TYPE I	Initial model					Reduced model				
Source	Sum of squares	Df	Mean square	F-ratio	P-value	Sum of squares	Df	Mean square	F-ratio	P-value
*ln*CKL	6051612.152	1	6051612.152	99999.99	0.0000	6051612.152	1	6051612.1526	99999.99	0.0000
Sex	1135.695	1	1135.695	40.04	0.0001	1135.695	1	1135.6954	40.04	0.0001
*ln*CKL*Sex	48.465	1	48.465	1.71	0.1912					
Residual	178089.146	6279	28.362			178137.611	6280	28.3659		
Total	6230885.459	6282				6230885.459	6282			

TYPE III	Initial model					Reduced model				
Source	Sum of squares	Df	Mean square	F-ratio	P-value	Sum of squares	Df	Mean square	F-ratio	P-value
*ln*CKL	5466701.954	1	5466701.954	99999.99	0.0000	5798820.788	1	5798820.788	99999.99	0.0000
Sex	0.419	1	0.419	40.04	0.9033	1135.695	1	1135.695	40.04	0.0001
*ln*CKL*Sex	48.465	1	48.465	1.71	0.1912					
Residual	178089.146	6279	28.362			178137.611	6280	28.365		
Total	6230885.459	6282				6230885.459	6282			

Appendix Table 8.--Summary of ANCOVA results evaluating the effects of sex on the log-linear relationship of dressed with peduncle weight-eye fork length (EFL) for central North Pacific swordfish caught by the Hawaii-based longline fishery during March-July 1994.

Type I	Initial model					Reduced model				
Source	Sum of squares[▽]	Df	Mean square[▽]	F-ratio	P-value	Sum of squares[▽]	Df	Mean square[▽]	F-ratio	P-value
*ln*EFL	18.959	1	18.959	2020.05	0.0000	18.959	1	18.959	2024.60	0.0000
Sex	2.531E-3	1	2.531E-3	0.27	0.6039	1.634E-3	1	1.634E-3	0.17	0.6764
*ln*EFL*Sex	1.094E-3	1	1.094E-3	0.12	0.7329					
Residual	3.2849	350	0.00938			3.2868	351	9.3643E-3		
Total	22.2476	353				22.2476	353			

Type III	Initial model					Reduced model				
Source	Sum of squares[▽]	Df	Mean square[▽]	F-ratio	P-value	Sum of squares[▽]	Df	Mean square[▽]	F-ratio	P-value
*ln*EFL	18.1992	1	18.1992	1939.58	0.0000	18.9326	1	18.9326	2022.33	0.0000
Sex	6.378E-4	1	6.378E-4	0.07	0.7945	2.5311E-3	1	2.5311E-3	0.27	0.6034
*ln*EFL*Sex	5.877E-3	1	5.877E-3	0.06	0.8025					
Residual	3.2840	350	9.383E-3			3.28599	351	9.3617E-3		
Total	22.2476	353				22.2476	353			

[▽]E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2}).

Appendix Table 9.--Summary of ANCOVA results evaluating the effects of sex on the log-linear relationship of dressed with peduncle weight-cleithrum to keel length (CKL) for central North Pacific swordfish caught by the Hawaii-based pelagic longline fishery during March-July 1994.

Type I	Initial model					Reduced model				
Source	Sum of squares[∇]	Df	Mean square[∇]	F-ratio	P-value	Sum of squares[∇]	Df	Mean square[∇]	F-ratio	P-value
*ln*CKL	17.377	1	17.377	1198.07	0.0000	17.377	1	17.377	1198.82	0.0000
Sex	3.198E-3	1	3.198E-3	0.22	0.6390	2.743E-3	1	2.743E-3	0.19	0.6638
*ln*CKL*Sex	1.086E-2	1	1.086E-2	0.75	0.3874					
Residual	5.10545	352	1.450E-2			5.1167	353	1.4495E-2		
Total	22.4965	355				22.4965	355			

Type III	Initial model					Reduced model				
Source	Sum of squares[∇]	Df	Mean square[∇]	F-ratio	P-value	Sum of squares[∇]	Df	Mean square[∇]	F-ratio	P-value
*ln*CKL	16.9767	1	16.9767	1170.47	0.0000	17.3493	1	17.3493	1196.52	0.0000
Sex	1.108E-2	1	1.108E-2	0.76	0.3825	1.0672E-3	1	1.0672E-3	0.07	0.7863
*ln*CKL*Sex	1.086E-2	1	1.086E-2	0.75	0.3874					
Residual	5.10545	352	1.450E-2			5.11844	353	1.4499E-2		
Total	22.4965	355				22.4965	355			

[∇]E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2}).

Appendix Table 10.--Summary of ANCOVA results evaluating the effects of sex and month on the log-linear relationship of dressed weight $_{old}$-eye fork length (EFL: 116-200 cm) for central North Pacific swordfish caught by the Hawaii-based pelagic longline fishery during March-July 1994.

Type I	Initial model					Reduced model				
Source	Sum of squares	Df	Mean square	F-ratio	P-value	Sum of squares	Df	Mean square	F-ratio	P-value
*ln*EFL	62.9217	1	62.9217	5244.99	0.0000	62.9217	1	62.9217	5307.34	0.0000
Sex	0.23161	1	0.23161	19.31	0.0000	0.231612	1	0.231612	19.54	0.0000
*ln*EFL*Sex	0.08733	1	0.08733	7.28	0.0074	0.087331	1	0.087331	7.37	0.0070
Month	0.35342	4	0.08835	7.37	0.0000	0.353426	4	0.0883564	7.45	0.0000
*ln*EFL*Month	0.09326	4	0.02331	1.94	0.1031	0.093264	4	0.023316	1.97	0.0994
Sex*Month	0.01927	4	0.00481	0.40	0.8074					
*ln*EFL*Sex*Month	0.03230	4	0.00807	0.67	0.6110					
Residual	3.68293	307	0.01199			3.73451	315	0.0118556		
Total	67.4218	326				67.4218	326			

Appendix Table 10.--(Continued)

Type III	Initial model					Reduced model				
Source	Sum of squares[∇]	Df	Mean square[∇]	F-ratio	P-value	Sum of squares[∇]	Df	Mean square[∇]	F-ratio	P-value
*ln*EFL	6.22733	1	6.22733	519.09	0.0000	13.7529	1	13.7529	1160.04	0.0000
Sex	7.286E-3	1	7.286E-3	0.61	0.4364	7.1591E-2	1	7.1591E-2	6.04	0.0145
*ln*EFL*Sex	6.310E-3	1	6.310E-3	0.53	0.4688	6.4861E-2	1	6.4861E-2	5.47	0.0200
Month	4.478E-2	4	1.111E-2	0.93	0.4448	8.6531E-2	4	2.1632E-2	1.82	0.1238
*ln*EFL*Month	4.928E-2	4	1.232E-2	1.03	0.3934	9.3264E-2	4	2.3316E-2	1.97	0.0994
Sex*Month	3.240E-2	4	8.101E-3	0.68	0.6095					
*ln*EFL*Sex*Month	3.230E-2	4	8.075E-3	0.67	0.6110					
Residual	3.68293	307	1.199E-2			3.73451	315	1.8556E-2		
Total	67.4218	326				67.4218	326			

[∇]E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2}).

Appendix Table 11.--Summary of ANCOVA results evaluating the effects of sex and month on the log-linear relationship of dressed weight$_{old}$-cleithrum to keel length (CKL: 76-125 cm) for central North Pacific swordfish caught by the Hawaii-based pelagic longline fishery during March-July 1994.

Type I	Initial model					Reduced model				
Source	Sum of squares	Df	Mean square	F-ratio	P-value	Sum of squares[∇]	Df	Mean square[∇]	F-ratio	P-value
*ln*CKL	50.6445	1	50.6445	3655.71	0.0000	50.6445	1	50.6445	3646.43	0.0000
Sex	0.06824	1	0.06824	4.93	0.0272	6.824E-2	1	6.824E-2	4.91	0.0274
*ln*CKL*Sex	0.03742	1	0.03742	2.70	0.1013					
Month	0.21769	4	0.05442	3.93	0.0040	0.222565	4	5.5641E-2	4.01	0.0035
*ln*CKL*Month	0.10440	4	0.02610	1.88	0.1132					
Sex*Month	0.02134	4	0.00533	0.39	0.8192					
*ln*CKL*Sex*Month	0.03243	4	0.00810	0.59	0.6735					
Residual	4.0036	289	0.01385			4.19442	302	1.38888E-2		
Total	55.1297	308				55.1297	308			

[∇]E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2}).

Appendix Table 11.--(Continued)

Type III	Initial model					Reduced model				
Source	Sum of squares[∇]	Df	Mean square[∇]	F-ratio	P-value	Sum of squares	Df	Mean square[∇]	F-ratio	P-value
*ln*CKL	3.3623	1	3.3623	242.70	0.0000	48.9712	1	48.9712	3525.95	0.0000
Sex	1.0708E-3	1	1.0708E-3	0.08	0.7812	0.051983	1	5.19839E-2	3.74	0.0540
*ln*CKL*Sex	8.7478E-4	1	8.7478E-4	0.06	0.8018					
Month	8.5890E-2	4	2.1472E-2	1.55	0.1878	0.222565	4	5.56412E-2	4.01	0.0035
*ln*CKL*Month	9.1235E-2	4	2.2808E-2	1.65	0.1626					
Sex*Month	3.2755E-2	4	8.1888E-3	0.59	0.6693					
*ln*CKL*Sex*Month	3.2433E-2	4	8.1084E-3	0.59	0.6735					
Residual	4.00367	289	1.1853E-2			4.1944	302	1.38888E-2		
Total	55.1297	308				55.1297	308			

[∇]E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2})

Appendix Table 12.--Summary of ANCOVA results evaluating the effects of sex and month on the log-linear relationship of dressed weight $_{new}$-eye fork length (EFL: 113-200) for central North Pacific swordfish caught by the Hawaii-based pelagic longline fishery during August 1994-June 1996. The initial model was not reduced.

	Type I					Type III				
Source	Sum of squares	Df	Mean square	F-ratio	P-value	Sum of squares	Df	Mean square	F-ratio	P-value
*ln*EFL	275.467	1	275.467	21906.44	0.0000	75.6312	1	75.6312	6014.54	0.0000
Sex	0.03683	1	0.03683	2.93	0.0870	0.01692	1	0.01692	1.35	0.2460
*ln*EFL*Sex	0.05996	1	0.05996	4.77	0.0290	0.01635	1	0.01635	1.30	0.2540
Month	2.82256	11	0.25659	20.41	0.0000	0.80246	11	0.072951	5.80	0.0000
*ln*EFL*Month	0.78589	11	0.07144	5.68	0.0000	0.85233	11	0.077485	6.16	0.0000
Sex*Month	0.27197	11	0.02472	1.97	0.0283	0.29845	11	0.027132	2.16	0.0145
*ln*EFL*Sex*Month	0.29826	11	0.02711	2.16	0.0146	0.29826	11	0.027114	2.16	0.0146
Residual	17.2525	1372	0.01257			17.2525	1372	0.012574		
Total	296.995	1419				296.995	1419			

Appendix Table 13.--Summary of ANCOVA results evaluating the effects of sex and month on the log-linear relationship of dressed weight $_{new}$-cleithrum to keel length (CKL: 73-139 cm) for central North Pacific swordfish caught by the Hawaii-based pelagic longline fishery during August 1994-June 1996.

Type I	Initial model					Reduced model				
Source	Sum of squares[∇]	Df	Mean square[∇]	F-ratio	P-value	Sum of squares	Df	Mean square[∇]	F-ratio	P-value
*ln*CKL	278.664	1	278.664	16898.78	0.0000	278.664	1	278.664	16912.09	0.0000
Sex	2.557E-2	1	2.557E-2	1.55	0.2130					
*ln*CKL*Sex	4.471E-2	1	4.471E-2	2.71	0.0996					
Month	1.90619	11	0.17329	10.51	0.0000	1.86336	11	0.16939	10.28	0.0000
*ln*CKL*Month	0.80266	11	7.296E-2	4.43	0.0000	0.86205	11	7.8369E-2	4.76	0.0000
Sex*Month	0.15426	11	1.402E-2	0.85	0.5893					
*ln*CKL*Sex*Month	0.16965	11	1.542E-2	0.94	0.5051					
Residual	22.6245	1372	1.649E-2			23.0022	1396	1.6477E-2		
Total	304.392	1419				304.392	1419			

[∇]E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2})

Appendix Table 13.--(Continued)

Type III	Initial					Final				
Source	Sum of squares[∇]	Df	Mean square[∇]	F-ratio	P-value	Sum of squares	Df	Mean square[∇]	F-ratio	P-value
*ln*CKL	54.6211	1	54.6211	3312.34	0.0000	67.6898	1	67.6898	4108.09	0.0000
Sex	6.904E-2	1	6.904E-2	4.19	0.0407					
*ln*CKL*Sex	7.057E-2	1	7.057E-2	4.28	0.0386					
Month	0.72851	11	6.622E-2	4.02	0.0000	0.80861	11	7.3510E-2	4.46	0.0000
*ln*CKL*Month	0.77490	11	7.044E-2	4.27	0.0000	0.86205	11	7.8369E-2	4.76	0.0000
Sex*Month	0.17108	11	1.555E-2	0.94	0.4975					
*ln*CKL*Sex*Month	0.16965	11	1.542E-2	0.94	0.5051					
Residual	22.6245	1372	1.649E-2			23.0022	1396	1.6477E-2		
Total	304.392	1419				304.392	1419			

[∇]E indicates scientific notation (e.g., 3E-2 = 3 x 10^{-2}).

Appendix Table 14.--GLOSSARY OF TERMS.

ANCOVA. Analysis of covariance.

cleithrum to keel length. Straight line distance from the cleithrum to anterior edge (insertion) of keel.

CKL. Cleithrum-to-keel length.

dressed weight. Carcass with bill, head, fins, entrails, and caudal peduncle removed.

dressed with peduncle weight. Carcass with bill, head, fins and entrails only removed (caudal peduncle still attached).

DPW. Dressed with peduncle weight.

DW. Dressed weight.

DW_{old}. "Old dressed weight"; produced by original method of dressing fish in which the peduncle was removed at the anterior edge (insertion) of keel by a cut through the joint between the 22nd-23rd vertebrae.

DW_{new}. "New dressed weight"; relevant from August 1994 onwards, in which the peduncle was removed by cutting between the 23rd-24th vertebrae.

eye to fork length. Straight line distance from caudad margin of orbit to fork of tail.

EFL. Eye to fork length.

GLM. General Linear Model.

HL. Honolulu Laboratory.

fork length. Straight line distance from tip of bill to fork of tail.

FL. Fork length. Least square mean. In GLM ANCOVA, the statistical mean adjusted for effect of body length covariate.

lower jaw to fork length. Straight line distance from tip of lower jaw with mouth closed to fork of tail. Synonymous with lower bill to fork length.

LJFL. Lower jaw to fork length (=LBFL).

NMFS. National Marine Fisheries Service, NOAA.

NOAA. National Oceanic and Atmospheric Administration.

outlier. Observation whose Studentized residual was equal to or greater than 2.0 in absolute value.

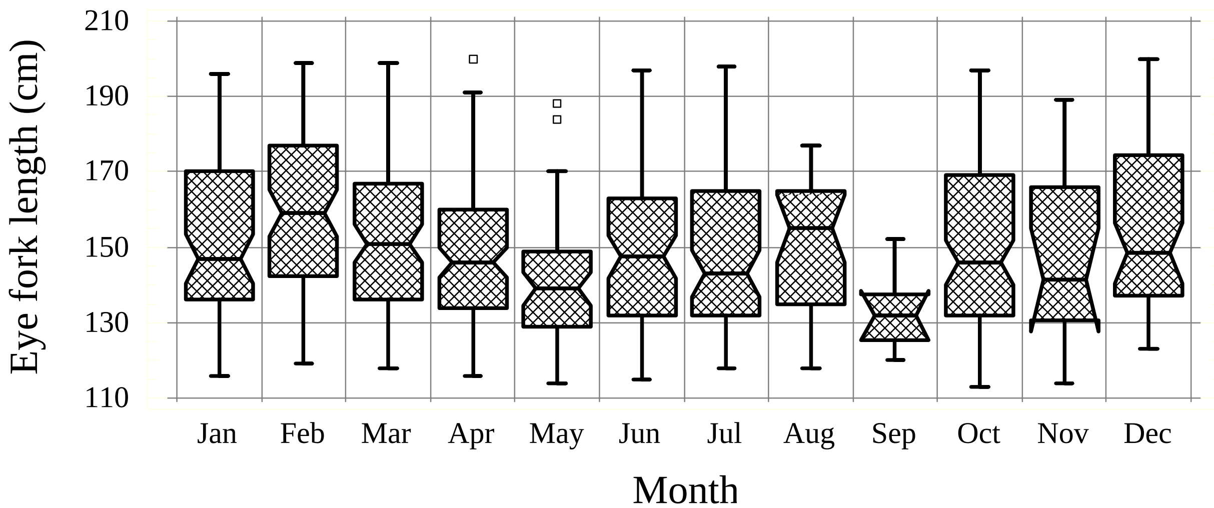
round weight. Total weight including bill, head, fins, and all entrails.

RW. Total or round weight.

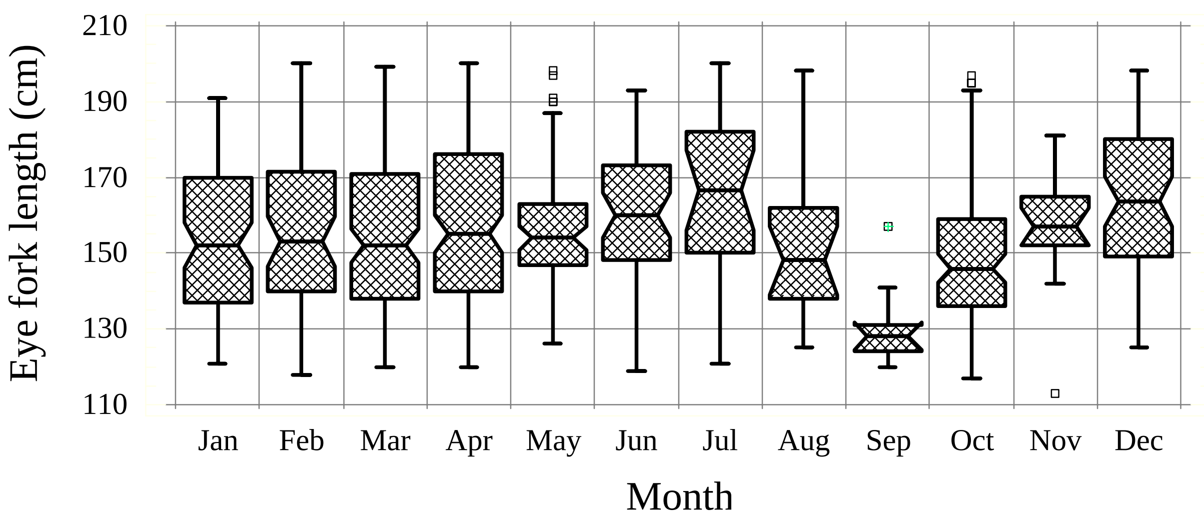
SWR. Southwest Fishery Region, NMFS.

UFA. United Fishing Agency, 117 Ahui St., Honolulu, Hawaii 96813. Honolulu fish auction.

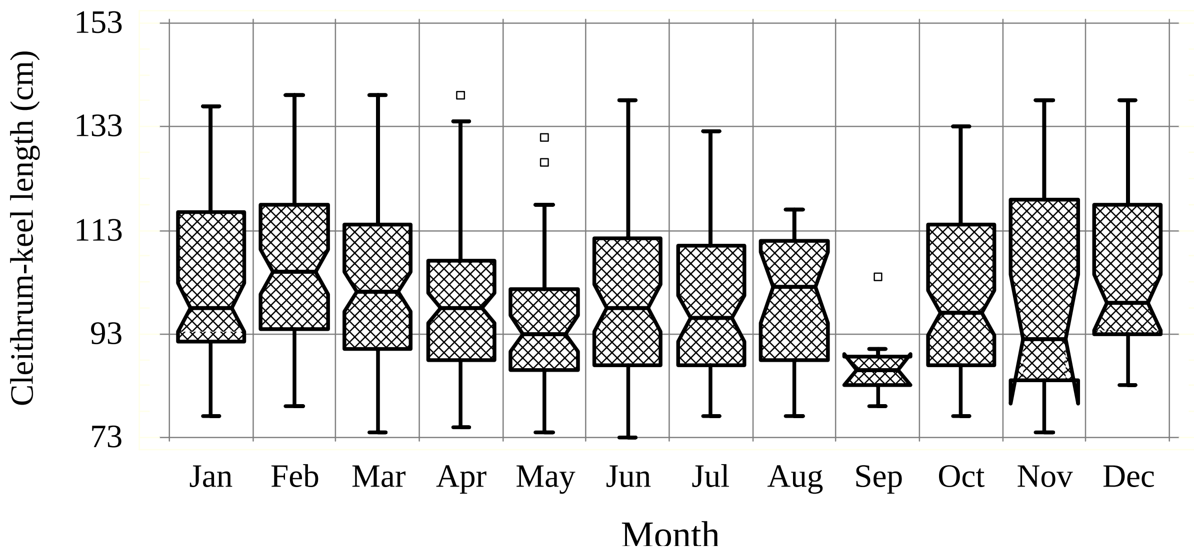
APPENDIX FIGURES



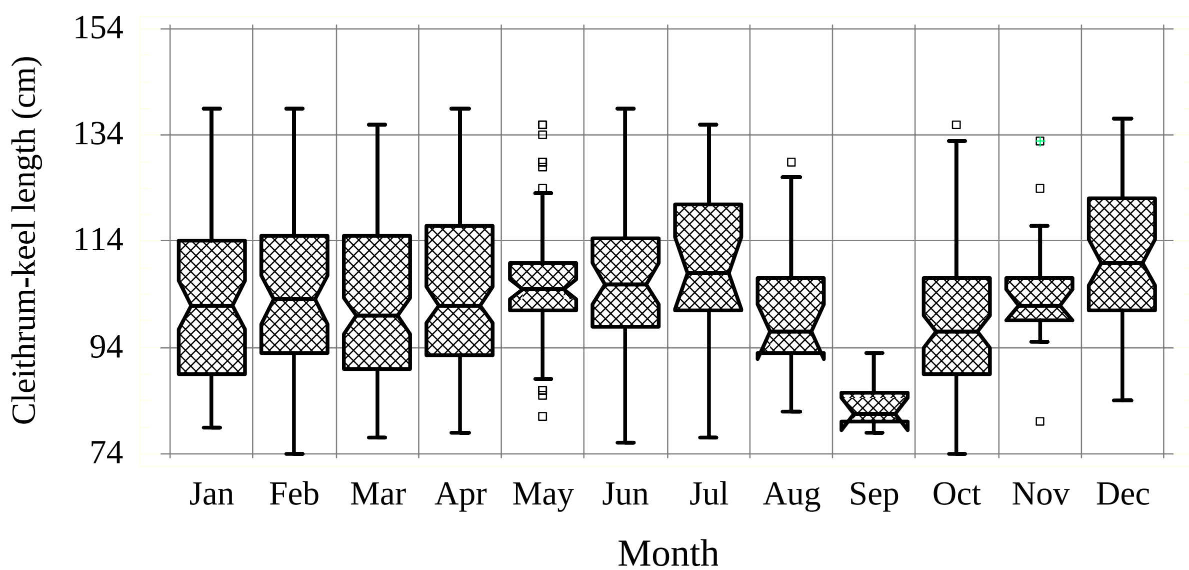
Appendix Figure 1. Monthly notched box-and-whisker plots of male swordfish eye fork length distribution from the general linear model analysis.



Appendix Figure 2. Monthly notched box-and-whisker plots of female swordfish eye fork length distribution from the general linear model analysis.



Appendix Figure 3. Monthly notched box-and-whisker plots of male swordfish cleithrum to keel length distribution from the general linear model analysis.



Appendix Figure 4. Monthly notched box-and-whisker plots of female swordfish cleithrum to keel length distribution from the general linear model analysis.