tion, Stage I zoeae of *C. septemspinosa* can be distinguished from Stage I zoeae of *C. franciscorum angustimana* by the exopodites of the maxillipeds. The exopodites of the maxillipeds are jointed in Stage I zoeae of *C. septemspinosa* and are not jointed in Stage I zoeae of *C. franciscorum angustimana*. Also, the fifth pair of telson spines are distinctly shorter than the fourth or sixth pair in *C. septemspinosa*; whereas, in my Stage I zoeae of *C. franciscorum angustimana*, the fifth pair of telson spines are about equal in length to the fourth and sixth pairs.

The occurrence in later zoeal stages of functional exopodites on the first pair of pereopods but not on pereopodal pairs 2-5 has been used as a criterion for distinguishing larvae of the genus *Crangon* from larvae of other genera of the family Crangonidae (Williamson 1960).

I found buds of exopodites on both the first and second pair of pereopods in Stage I zoeae of *C. franciscorum angustimana*. Assuming zoeae of *C. franciscorum angustimana* undergo typical development for crangonid larvae, these buds will become functional exopodites at Stage III or IV (Needler 1941; Kurata 1964; Makarov 1967). The criterion of the absence of exopodites on the second pair of pereopods for distinguishing larvae of *Crangon* from other genera of the Crangonidae, therefore, is invalid for the North Pacific Ocean. Unfortunately, larvae are described for only a few species of crangonids from the North Pacific Ocean, including the genus *Crangon*, and confirmation of the generic characteristics of the larvae is needed.

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# LENGTH-WEIGHT RELATIONSHIPS OF WESTERN ATLANTIC BLUEFIN TUNA, *THUNNUS THYNNUS*[1]

The Atlantic bluefin tuna, *Thunnus thynnus*, is seasonally distributed over most of the North Atlantic Ocean from Newfoundland to Brazil and from Norway to the Canary Islands (Gibbs and Collette 1967). There has been a great reduction in the Atlantic-wide catch (including Mediterranean) from 38,500 metric tons (t) in 1964 to 12,500 t in 1973 (Miyake et al. 1974). Because of this, a number of studies have been made and are being continued in order to understand the reason for this decline (Parks 1977; Shingu and Hisada 1977).

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Length-weight, length-to-length, and weight-to-weight relationships are necessary in population analyses for converting one measurement to another. In this paper I present the relationships of the following: round weight-straight fork length, round weight-dressed weight, and straight fork length-curved fork length.

During my review of bluefin tuna literature, I found a lack of information on size relationships. Mather and Schuck (1960) used a length-weight curve based on 778 bluefin tuna from Cape Cod to estimate length. They did not indicate, however, when these fish were collected. They did not give a regression formula for the length-weight relationship, but they did present a straight length-curved length relationship based on 185 measurements fitted by inspection. Rodriguez-Roda (1964, 1971) collected 793 bluefin tuna and then determined the length-weight relationship. Of these, 467 bluefin tuna (prespawning) were entering the Mediterranean during May and June and 326 bluefin tuna (postspawning) were leaving the Mediterranean during July and August 1956, 1958, 1959, and 1961. Butler (1971) determined the length-weight relationship by the standard least squares regression method for 237 giant bluefin tuna caught during July through September 1966 from Conception Bay, Newfoundland. Mather et al. (1974) presented regression equations for converting from weight to length for bluefin tuna from Newfoundland, Libya, and the Bahamas from data supplied by the Fisheries Research Board of Canada, the International Council for the Exploration of the Sea, and the Woods Hole Oceanographic Institution. They also presented an equation for converting dressed weight to round weight. The method of determining the equations, the sample sizes, and time period sampled were not presented. Coan (1976) gave a length, weight, and age conversion table for bluefin tuna of both sexes. He converted length to weight based on a length-weight regression given in Sakagawa and Coan (1974), who had in turn, obtained this regression from Frank J. Mather, Woods Hole Oceanographic Institution. Unfortunately, there was no mention of sample size, location, or date.

## Methods

Bluefin tuna length and weight measurements were collected during 1974 through 1977 from various landing points and processing plants along the east coast of the United States from Florida to Maine and from the Bahamas. These fish had been caught by purse seine, rod and reel, handline, and harpoon. Straight fork length (centimeters) was measured by caliper, and curved fork length (centimeters) was measured along the body contour by tape. Round weight (total weight of fish when caught) and dressed weight (head, viscera, and tail removed) were recorded in pounds and later converted to kilograms.

Ricker (1973) showed that the geometric mean (GM) regression can be used for a majority of biological situations as a reasonable and consistent estimate of the functional slope because most of the variability is natural.

The functional (GM) regression was calculated for the logarithmic transformation of the length-weight relationship for 3,578 bluefin tuna taken from May through October. The GM regression was also calculated for the relationship between round weight and dressed weight for 685 bluefin tuna taken from July through September, and for the straight fork length to curved fork length relationship for 606 bluefin tuna taken from July through October.

The general equation for the GM regression as given by Ricker is: $Y = u + vX$, with variables $X$ and $Y$, and $u$ is the $y$-axis intercept, where $u = \bar{Y} - v\bar{X}$, $v$ is the slope, and $v = [\Sigma y^2/\Sigma x^2]^{1/2}$, where $y_i = Y_i - \bar{Y}$ and $x_i = X_i - \bar{X}$. The limits on all $\Sigma$ are $i = 1, \ldots, n$.

The standard error of the slope was computed for each regression equation using the following equation from Ricker (1973): $S_v = [S_{yx}^2/\Sigma x^2]^{1/2}$, where $S_v$ is the standard error of the slope and $S_{yx}^2$ is the mean square or variance of the observations from the regression line in the vertical direction.

## Results and Discussion

Based on the classification system of Rivas and Mather (in press), the fish sampled mainly consisted of two size categories, giant bluefin tuna (>180 cm straight fork length and 130 kg round weight) and small bluefin tuna (<130 cm straight fork length or <45 kg round weight). Based on previous growth studies by Mather and Schuck (1960), the giant fish are probably age 9 and older and the small bluefin tuna are most likely age 4 or younger. Very few medium bluefin tuna (130-180 cm straight fork length and 45-130 kg round weight) probably ages 5 through 8 were sampled.

The functional (GM) regressions for straight fork length-round weight (log transformation), round weight-dressed weight, and straight fork length-curved fork length are presented in Table 1. All of these relationships were characterized by high correlation coefficients. The data points are plotted with regression lines in Figures 1-3. The data points show that the GM regression model fits the data reasonably well for the size ranges studied. Extrapolation beyond the size range of observations may yield erroneous predictions. Regression statistics for each relationship are presented in Table 2.

The use of logarithmic transformations may lead to bias in data estimates (Pienaar and Thomson 1969; Beauchamp and Olson 1973; Lenarz 1974). However, since the mean square error for the round weight-straight fork length logarithmic transformation is low (Table 2), the bias in the data estimate was found to be minimal (1%).

Previous publications have not included standard errors or confidence limits or statistics necessary for their estimation. Therefore, comparisons with my data could not be made. To compare results from my study with studies by other authors, I compared estimates of $Y$ using both their regression equations and mine. Whenever possible, I selected $X$ values at each end of their range of values that corresponded with my range of values. I also compared estimates of $Y$ for an $X$ value taken at the middle of their size range.

TABLE 1.—Functional (GM) regression equation and correlation coefficient for the relationships between round weight ($Y$) and straight fork length ($X$), round weight ($Y$) and dressed weight ($X$), and straight fork length ($Y$) and curved fork length ($X$) for western Atlantic bluefin tuna. Weights in kilograms and lengths in centimeters.

| Geometric mean regression equation | $r$ |
|---|---|
| $\text{Log}_{10}$ round weight – $\log_{10}$ straight fork length: | |
| $\log_{10} Y = -4.52307 + 2.91920 \log_{10} X$ | 0.997 |
| Round weight – dressed weight: | |
| $Y = -7.92240 + 1.29607X$ | 0.935 |
| Straight fork length – curved fork length: | |
| $Y = -2.06971 + 0.963300X$ | 0.892 |

My estimates of round weight from straight fork length using the functional (GM) regression agreed most closely with my estimates obtained using the regression equation of Sakagawa and Coan (1974), with the greatest difference in estimates of only 2% occurring for a 270 cm fork length (FL) bluefin tuna. My calculated functional regression estimates next most closely agreed with estimates obtained using the length-weight relationship of Butler (1971), with the largest difference of 6% occurring at 250 cm FL. My esti-

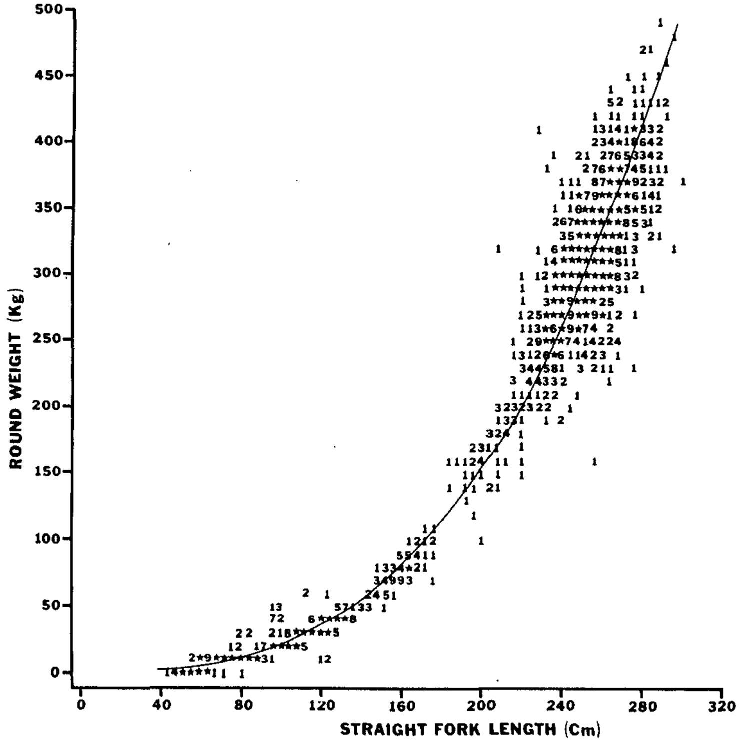

FIGURE 1.—Functional (GM) regression of round weight on straight fork length for 3,578 western Atlantic bluefin tuna 1974-77. (Number of fish indicated, star signifies number >9.)

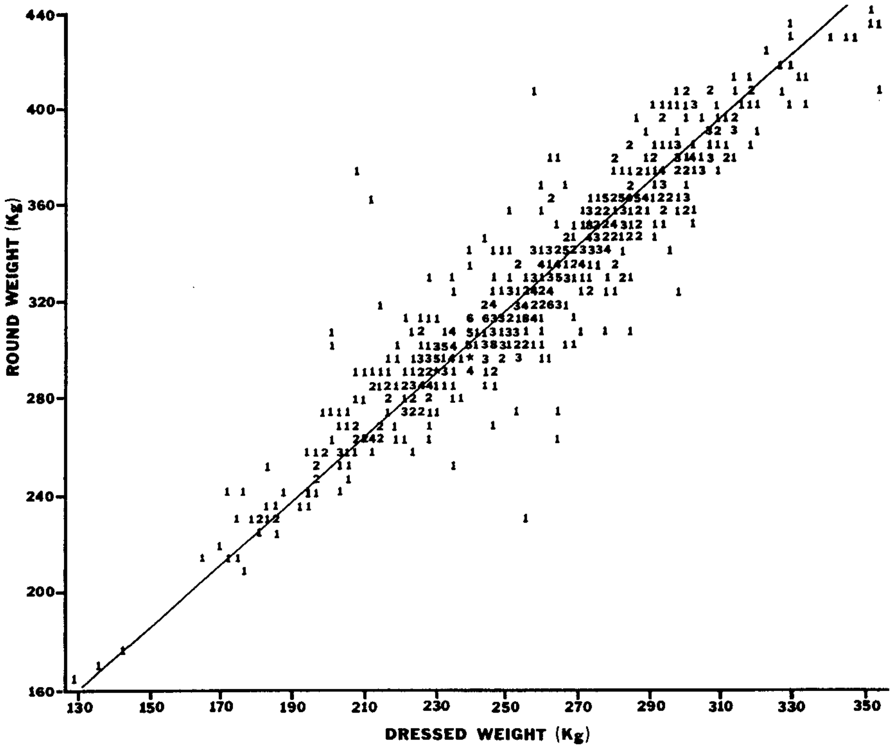

FIGURE 2.—Functional (GM) regression of round weight on dressed weight for 685 western Atlantic bluefin tuna 1974-77. (Number of fish indicated, star signifies number >9.)

TABLE 2.—Regression statistics for $\log_{10}$ round weight *(Y)* – $\log_{10}$ straight fork length *(X)*, round weight *(Y)* – dressed weight *(X)*, and straight fork length *(Y)* – curved fork length *(X)* of western Atlantic bluefin tuna. Weights in kilograms and lengths in centimeters.

| $n$ | $\overline{X}$ | $\overline{Y}$ | $\sum x^2$ | $\sum y^2$ | $\sum xy$ | $Syx^2$ | $S_V$ |
|---|---|---|---|---|---|---|---|
| | | | $\text{Log}_{10}$ round weight – $\log_{10}$ straight fork length | | | | |
| 3,578 | 2.19254 | 1.87739 | 222.745 | 1,898.17 | 648.054 | 0.00356051 | 0.00399809 |
| | | | Round weight – dressed weight | | | | |
| 685 | 256.993 | 325.158 | 832,635 | 1,398,650 | 1,009,090 | 257.261 | 0.0175776 |
| | | | Straight fork length – curved fork length | | | | |
| 606 | 271.477 | 259.444 | 120,979 | 112,262 | 103,959 | 37.9615 | 0.0177140 |

mates of weight from length differed most from estimates which I calculated using equations of Rodriguez-Roda (1964, 1971). The largest variation (12%) was found for a prespawning fish measuring 48 cm.

No size range was reported by Mather et al. (1974) for estimating length from weight. However, estimated length corresponding to the extremes and middle of the size range in weight I studied agree closely to values I calculated using their regression equation for Newfoundland, with the greatest difference being only 3% for a 5 kg fish. A greater difference (13%) was noted when comparing estimates from my functional (GM) regression with estimates obtained using their regression equation for the Bahamas for a 5 kg fish. This large difference may have resulted from their not including fish in this size range when calculating their equation because differences at the middle and upper end of my size range were small, 4% or less. There appears to be a typographical error in the equation these authors gave for bluefin tuna from Libya, so no comparison was made.

My functional (GM) regression estimates of round weight from dressed weight agree well with the estimates I obtained using the regression equation of Mather et al. (1974). The largest dif-

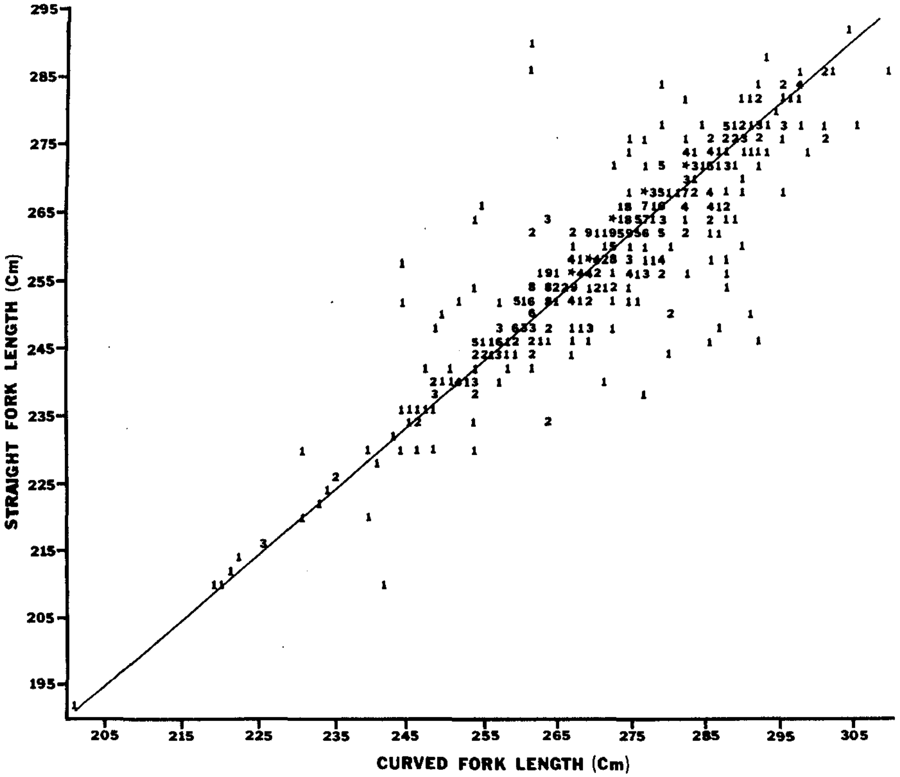

FIGURE 3.—Functional (GM) regression of straight fork length on curved fork length for 606 western Atlantic bluefin tuna 1974-77. (Number of fish indicated, star signifies number >9.)

ference I found was 3% for a 130 cm bluefin tuna. Again I used my range of values for dressed weight since the range was not given by these authors.

My functional (GM) regression estimates of straight fork length from curved fork length agree very closely over my entire size range with estimates I obtained using the regression equation given by Mather and Schuck (1960). The largest difference I found, only 1%, occurred at the lower end of my range of curved fork length values of 200 cm.

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# DEVELOPMENTAL ANATOMY AND INFLATION OF THE GAS BLADDER IN STRIPED BASS, *MORONE SAXATILIS*

In 1974, a percentage of striped bass, *Morone saxatilis*, fingerlings reared at the Cooperative Fishery Research Laboratory, Southern Illinois University, lacked an inflated gas bladder. The purpose of this study was to describe the developmental anatomy of the gas bladder and its associated structures in striped bass so that a better understanding of the inflation mechanism could be obtained.

With regard to gas bladder morphology, bony fishes are classified as physostomes or physoclists. Generally, the more ancient, soft-rayed fishes (Malacopterygii) are physostomous, while the more modern, spiny-rayed fishes (Acanthopterygii) are physoclistic (Lagler et al. 1962). A physotome possesses a hollow connection, the pneumatic duct, between the gut and the gas bladder throughout its entire life. Some physotomes gulp surface air through the pneumatic duct to initiate inflation of the gas bladder (Tait 1960). Fish that are physoclistic do not possess this open connection as adults. Some physoclists, however, do possess a pneumatic duct as larvae, but the duct atrophies prior to adulthood. Günther's (1880) examinations have shown that adult striped bass are physoclistic. Doroshev and Cornacchia (1979) give a partial description of the development of the gas bladder in striped bass.

Several theories have been advanced to explain how the gas bladder is initially inflated in fishes that do not gulp surface air or are physoclistic prior to initial inflation. Some of these theories include: gases produced by the disintegration of organic materials (Powers 1932); production of gasses as a result of digestion (Johnston 1953); vacuolation of the gas bladder epithelia (McEwen 1940); and functioning of a rete mirabile, or gas gland (Schwarz 1971).

## Methods

### Histomorphological Studies

Striped bass larvae were obtained from the Hudson River, N.Y., and Lake Charles, La. Upon arrival, the 1- to 4-day-old larvae were transferred into 200 l aquaria and maintained at 16°-18° C. Brine shrimp, *Artemia salina*, were fed regularly to the larvae. Eighty-three striped bass larvae 4.3-24 days old (from the time of hatching) were removed from the aquaria and prepared for histological study. The larvae were fixed in either 10% Formalin[1] or Bouin's fluid, dehydrated in a series of graded alcohols, cleared in benzene, and embedded in Carbowax. From a representative

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[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.