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# SEX COMPOSITION, LENGTH-WEIGHT RELATIONSHIP, AND REPRODUCTION OF THE WHITE MARLIN, *TETRAPTURUS ALBIDUS*, IN THE WESTERN NORTH ATLANTIC OCEAN[1]

In the Atlantic, white marlin, *Tetrapturus albidus*, range from lat. 35°S to 45°N with concentrations in the western Atlantic, including the Gulf of Mexico, and the Caribbean Sea (Mather et al. 1975). Tag returns show that some white marlin migrate seasonally from the U.S. Middle Atlantic Bight (the coastal area between Cape Cod and Cape Hatteras) in the summer to the southeastern Caribbean Sea in the winter (Mather et al. 1972). Commercial catches by Japanese longline vessels support the tagging results, but the catches also indicate that a second group of white marlin moves from a wintering area in the southeastern Caribbean to summer grounds in the Gulf of Mexico (Ueyanagi et al. 1970; Mather et al. 1972; Wise and Davis 1973).

A substantial sport fishery exists for white marlin in the Atlantic off North and South America. In the United States, the major sport fisheries occur along the Middle Atlantic States, from New Jersey to North Carolina, off southeast Florida, and along the Gulf Coast States. Important sport fisheries also occur in the Bahamas, off Havana, Cuba, and along the coast of Venezuela (Mather et al. 1972). Another important sport fishery recently developed off eastern Brazil (Anonymous 1976).

The white marlin is also an incidental catch of commercial longline vessels fishing for tuna in the Atlantic and Gulf of Mexico (Mather et al. 1975). The marlin is highly prized as a food item in some countries (Kume and Joseph 1969).

My review of the literature on white marlin shows that there is a need for additional information on sex composition and length-weight relationships. Until recently, no information was available regarding its reproductive potential (Baglin[2]). In this paper I update reproductive and sex ratio data presented by Baglin (see footnote 2) and include length-weight relationships.

## Materials and Methods

White marlin from the northern Gulf of Mexico (hereafter referred to as the gulf), the Florida Straits, the western Bahamas, and the Middle Atlantic Bight of the western North Atlantic (hereafter referred to as the Atlantic) were sampled from anglers' catches at sport fishing tournaments and at Pflueger Marine Taxidermy, Inc., Hallandale, Fla. One marlin was collected by longline in the Windward Passage between Cuba and Hispaniola during RV *Oregon* Cruise 66.

Sex data were obtained from 1,128 white marlin captured by anglers in the gulf (1971-77) and from 720 white marlin caught by anglers from the Atlantic (1972-77).

Lengths and weights were obtained from 904 white marlin captured in the gulf (1971-76) and from 489 white marlin captured in the Atlantic (1972-76). Body lengths (straight distance from tip of lower jaw to tips of midcaudal rays) were measured in centimeters (Rivas 1956); weights were recorded to the nearest pound and converted to kilograms.

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[2]Baglin, R. E., Jr. 1977. Maturity, fecundity and sex composition of white marlin (*Tetrapturus albidus*). Collective Volume of Scientific Papers 6(79):408-416. International Commission for the Conservation of Atlantic Tunas, Madrid, Spain.

Ovaries from 186 females caught from 1972 through 1976 were examined. Fresh ovaries were either blotted dry and weighed in grams or stored in 10% Formalin[3] and weighed later. No significant difference was found between the mean weight of fresh and preserved ovaries ($F = 0.0001$; df = 1, 16; $P > 0.75$). The gonosomatic index (GSI), ovary weight as a percentage of total body weight, was used as an indicator of maturity.

Preserved eggs 0.56 mm in diameter and larger were counted when estimating fecundity. Eggs <0.56 mm were less spherical in shape and in an earlier stage of development. The 0.56-mm size was determined by measuring the diameters of 3,912 eggs from mature, partly spent, and spent fish. Small transparent ova were stained with aceto-carmine to facilitate measuring. Egg diameters were measured with an ocular micrometer at 30× magnification and the orientation of egg diameters was assumed to be random. Thin cross sections were taken from the anterior, middle, and posterior parts of one ovary of a mature fish and subdivided into three subsamples, representing the center, midregion, and periphery of the ovary (Otsu and Uchida 1959).

Fecundity was defined as the potential number of mature eggs (yolked ova in the most advanced size mode) that could be spawned during one reproductive season and was estimated using a dry weight method. For six fish in which entire ovaries were saved for fecundity analysis, subsamples consisted of a thin cross section taken from the anterior, middle, and posterior parts of each ovary. The eggs in these subsamples were separated from the ovarian tissue, enumerated, dried, and weighed according to the procedure described by Baglin (see footnote 2). For six other fish, only the ovary weight and a single cross section from the middle of the ovary were taken; these cross sections comprised the subsamples. The eggs were separated, counted, dried, and weighed. A dry/wet weight regression was used to estimate the total dry weight of the eggs in these ovaries, which were not saved. Before the eggs in the subsample were counted, 25 eggs 0.30 mm and larger from the two most advanced modes were randomly selected and measured. Eggs in this second most advanced mode were included to give an indication of the percentage of eggs in both modes because future histological studies may indicate that these smaller eggs undergo further development and are also spawned. Fecundity estimates, rounded to the nearest 0.1 million eggs, were calculated from the relationship: $C = (AD/B) + A$, where $A$ is the number of mature ova in the subsample, $B$ is the weight of the ova in the subsample, $C$ is the number of mature ova, and $D$ is the weight of ova from both ovaries.

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

## Results and Discussion

### Sex Composition

From 1971 through 1977, sex was determined from 1,128 white marlin from the gulf (Table 1). The deviation from an expected 1:1 sex ratio was significant from May through October. Sampling was inadequate for the remaining months. Females were more prevalent than males for each month studied.

From 1972 through 1977, sex was determined for 720 white marlin from the Atlantic (Table 1). There were 323 sex determinations from the Florida Straits (March through May) and 397 from the Middle Atlantic Bight (June through September). Sampling was inadequate from October through February. No significant difference from an expected 1:1 sex ratio was found for March, May, July, August, and September, but a significant difference was found for April and June. For the months in which the sex ratio was significantly different from the expected 1:1 ratio, females were more prevalent.

deSylva and Davis (1963) found a significant difference from an expected 1:1 sex ratio (60% females) when they combined their data from the Middle Atlantic Bight for the summers of 1959 and 1960. They presented monthly sex composi-

TABLE 1.—Monthly sex ratios for white marlin from the northern Gulf of Mexico (1971-77), Florida Straits and Middle Atlantic Bight (1972-77).

| Location | Month | Number of white marlin | Sex ratio (females/males) |
|---|---|---|---|
| Gulf of Mexico | May | 21 | 4.25* |
| | June | 85 | 4.00* |
| | July | 374 | 3.16* |
| | August | 444 | 1.63* |
| | September | 150 | 1.50* |
| | October | 54 | 1.84* |
| Florida Straits | March | 103 | 0.87 |
| | April | 172 | 1.96* |
| | May | 48 | 1.40 |
| Middle Atlantic Bight | June | 55 | 3.23* |
| | July | 56 | 1.67 |
| | August | 219 | 0.80 |
| | September | 67 | 0.97 |

*Significant departure from null hypothesis at 0.05 level (chi-square).

tion data for 1960 only. My analysis of their data shows a significant difference for June and July but no significant difference for August and September. Their findings for June, August, and September agree with those in this study. The extreme difference in sex ratios found in the present study for the gulf (May through October) and for the Florida Straits in April has not been reported previously. The above findings suggest that some white marlin segregate into distinct areal groups according to the predominating sex and that sex ratios may change with season. A similar occurrence has been noted for the blue marlin, *Makaira nigricans* (Kume and Joseph 1969).

### Length-Weight Relationship

The average length of females is greater than that of males from both the gulf and the Atlantic (Figure 1). It is also apparent (Figures 2, 3) that the average length of females is greater than that of males from each area for each month studied. This difference may be due to faster growth of females or higher mortality of males and should be considered in future growth studies of the white marlin.

The length-weight relationship by sex was determined for white marlin taken in the gulf from 1971 through 1976 (Figure 4) and in the Atlantic from 1972 through 1976 (Figure 5). Analysis of covariance (Table 2) indicated that length-weight regression coefficients were significantly different between gulf females and males ($F$ = 16.0; df = 1, 900; $P$<0.001), gulf males and Atlantic males ($F$ = 19.2; df = 1, 514; $P$<0.001), and gulf females and Atlantic females ($F$ = 10.8; df = 1, 871; $P$<0.001). The adjusted means were also significantly different between Atlantic females and males ($F$ = 13.4; df = 1, 486; $P$<0.001). These findings agree with those of Lenarz and Nakamura (1974), who found a significant difference between sexes in the relationship between weight and eye-fork length for white marlin from the gulf during 1971.

Analysis of covariance was conducted for the length-weight relationship, on a monthly basis, for which sufficient samples were available: gulf females versus Atlantic females in May, June, August, and September, and gulf males versus Atlantic males for June, August, and September. A significant difference in the regression coefficients was found only for the August males ($F$ = 13.7; df = 1, 211; $P$<0.001). A significant difference in adjusted means was found for females dur-

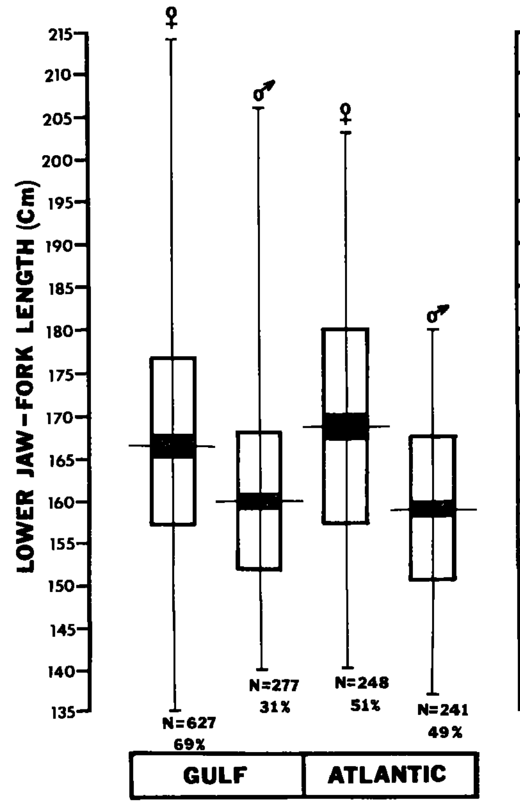


FIGURE 1.—Comparison of length between female and male white marlin collected in the northern Gulf of Mexico (1971 through 1976) and in the Atlantic (1972 through 1976). The number, percent, mean (horizontal line), range (vertical line), 1 SD on each side of the mean (open box), and 2 SE on each side of the mean (shaded box) are shown.

ing June ($F$ = 9.3; df = 1, 74; $P$<0.005) and August ($F$ = 12.0 df = 1, 286; $P$<0.001), and for males during September ($P$ = 7.6; df = 1, 73; $P$<0.01).

Differences between length-weight relationships of white marlin from the gulf and the Atlantic suggest the possibility of separate groups inhabiting the two areas. Tag returns, however, showed there is at least some migratory movement from the Middle Atlantic Bight to the gulf. To date, tag return data have not shown white marlin migrations in the reverse direction, although one fish tagged in the gulf was recaptured off Cuba, giving some support to the likelihood that they do migrate in the opposite direction (Chester C. Buchanan, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149, pers. commun.)

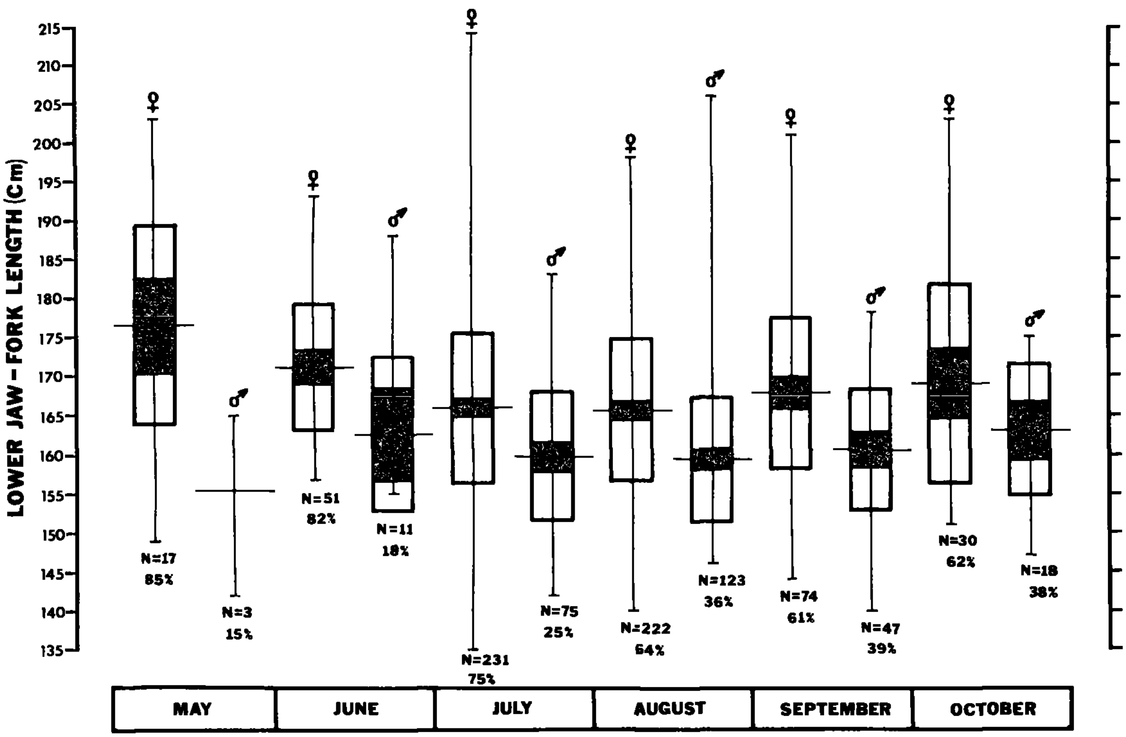


FIGURE 2.—Monthly comparisons of length between female and male white marlin collected in the northern Gulf of Mexico during 1971 through 1976. The number, percent, mean (horizontal line), range (vertical line), 1 SD on each side of the mean (open box), and 2 SE on each side of the mean (shaded box) are shown.

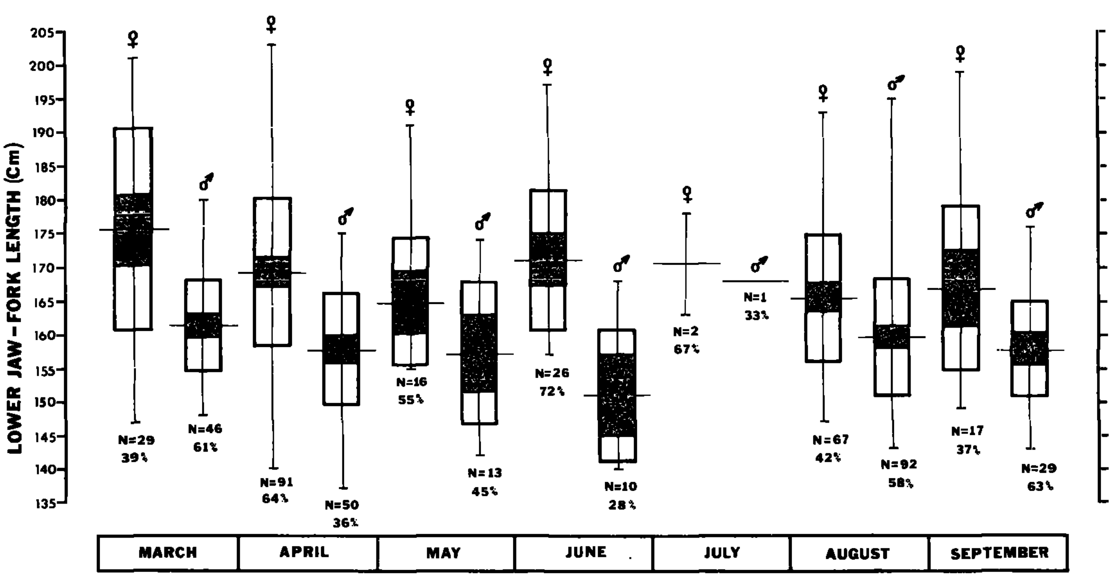


FIGURE 3.—Monthly comparisons of length between female and male white marlin collected in the Atlantic during 1972 through 1976. The number, percent, mean (horizontal line), range (vertical line), 1 SD on each side of the mean (open box), and 2 SE on each side of the mean (shaded box) are shown.

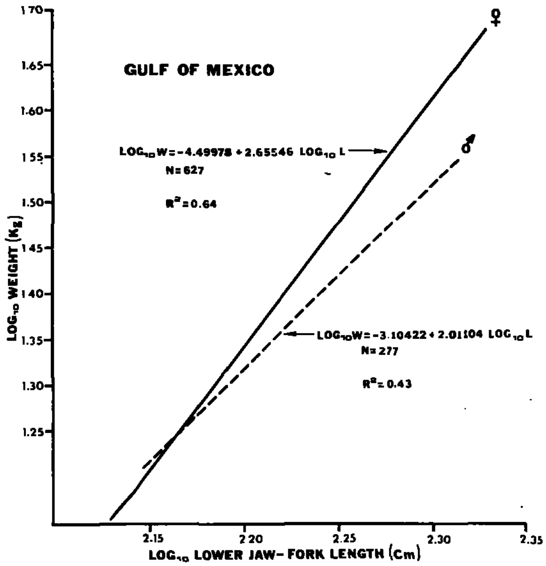


FIGURE 4.—Length-weight relationship (log transformation) for female and male white marlin from the northern Gulf of Mexico.

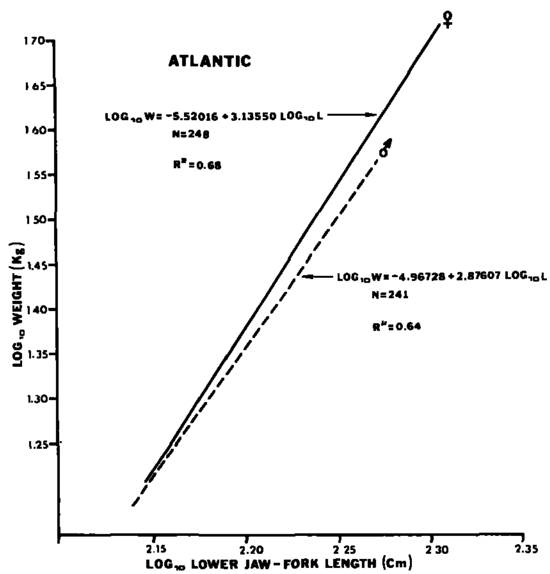


FIGURE 5.—Length-weight relationship (log transformation) for female and male white marlin from the Atlantic.

## Reproduction

A significant difference in egg diameter was found among the anterior, middle, and posterior sections of an ovary from a mature fish ($F$ = 7.7; df = 2, 2,676; $P$<0.001). There was no significant difference in mean diameter among the center, midregion, and periphery within each of the three sections. Because some heterogeneity occurred, estimates of fecundity were based, when possible, on eggs from each section of both ovaries. Heterogeneity of egg size within an ovary has also been shown for albacore, *Thunnus alalunga* (Otsu and Uchida 1959), and swordfish, *Xiphias gladius* (Uchiyama and Shomura 1974).

TABLE 2.—Regression equations, number, sum of squares of $x$, and mean square calculated for the length-weight relationship ($\log_{10}$ transformations) of white marlin from the northern Gulf of Mexico and the Atlantic.

| $Y = \bar{Y} + b(X - \bar{X})$ | $N$ | $\Sigma x^2$ | $\frac{\Sigma y^2 - b\Sigma xy}{N-2}$ |
|---|---|---|---|
| Gulf and Atlantic females: | | | |
| 1.41704 + 2.88186($X$ − 2.22302) | 875 | 0.604832 | 0.00336706 |
| Gulf and Atlantic males: | | | |
| 1.34355 + 2.37655($X$ − 2.20228) | 518 | 0.254956 | 0.00299720 |
| Gulf females: | | | |
| 1.39996 + 2.65546($X$ − 2.22174) | 627 | 0.396458 | 0.00252756 |
| Gulf males: | | | |
| 1.32735 + 2.01104($X$ − 2.20363) | 277 | 0.128593 | 0.00250737 |
| Atlantic females: | | | |
| 1.46021 + 3.13550($X$ − 2.22624) | 248 | 0.204773 | 0.00377638 |
| Atlantic males: | | | |
| 1.36217 + 2.87607($X$ − 2.20073) | 241 | 0.125280 | 0.00244554 |
| May gulf females: | | | |
| 1.48714 + 2.60014($X$ − 2.24572) | 17 | 0.0164014 | 0.00365206 |
| May Atlantic females: | | | |
| 1.44276 + 2.96929($X$ − 2.21669) | 16 | 0.0085322 | 0.00226977 |
| June gulf females: | | | |
| 1.44221 + 3.22066($X$ − 2.23317) | 51 | 0.0210122 | 0.00162473 |
| June Atlantic females: | | | |
| 1.40502 + 2.60180($X$ − 2.23216) | 26 | 0.0163375 | 0.00323226 |
| June gulf males: | | | |
| 1.35686 + 3.55091($X$ − 2.21054) | 11 | 0.00624798 | 0.00085387 |
| June Atlantic males: | | | |
| 1.24868 + 3.01101($X$ − 2.17815) | 10 | 0.00707686 | 0.00165193 |
| August gulf females: | | | |
| 1.38976 + 2.72170($X$ − 2.21631) | 222 | 0.121132 | 0.00226799 |
| August Atlantic females: | | | |
| 1.41118 + 2.81615($X$ − 2.21783) | 67 | 0.0391569 | 0.00206003 |
| August gulf males: | | | |
| 1.32575 + 1.93866($X$ − 2.20207) | 123 | 0.524543 | 0.00179221 |
| August Atlantic males: | | | |
| 1.35384 + 2.91546($X$ − 2.20279) | 92 | 0.0484607 | 0.00169370 |
| September gulf females: | | | |
| 1.40689 + 3.01922($X$ − 2.22399) | 74 | 0.0440863 | 0.00317564 |
| September Atlantic females: | | | |
| 1.42732 + 3.10221($X$ − 2.22137) | 17 | 0.0150308 | 0.00160237 |
| September gulf males: | | | |
| 1.32709 + 1.39787($X$ − 2.20530) | 47 | 0.0199974 | 0.00220416 |
| September Atlantic males: | | | |
| 1.34390 + 2.01746($X$ − 2.19767) | 29 | 0.0105484 | 0.00144724 |

The left ovary ($\bar{X}$ = 25.0 cm, $S_{\bar{X}}$ = 0.732) was significantly longer ($F$ = 35.7; df = 1, 196; $P$<0.001) than the right ovary ($\bar{X}$ = 19.4 cm, $S_{\bar{X}}$ = 0.561). Eldridge and Wares (1974) reported differential growth in the size of ovaries for striped marlin, *Tetrapturus audax*, and for sailfish, *Istiophorus platypterus*. Both were similar to the white marlin in having larger left ovaries.

Well-developed ovaries were present only in 12 white marlin collected during April and May in the Florida Straits. These fish had a GSI of about

6% or greater and were used for estimating fecundity. The mean GSI showed that ovarian weights were lowest during October and increased from November through May (Figure 6). The mean GSI of 2.6 for April and May is lower than the 4.5 mean GSI found by Krumholz (1958) for late April. The GSI of 9.3 (Table 3) agrees with the highest GSI of 9.76 found by Krumholz. The high mean GSI values determined by me for April and May, with the sudden decrease in June, indicated that spawning probably occurred during April and May (Figure 6). Therefore, only one spawning season per year was indicated for the Florida Straits.

White marlin may also spawn in other areas. One fish captured in April 1976 in the Windward Passage had ripe eggs measuring 1.16 mm. Hayasi et al. (1970) found white marlin with mature gonads during April-June in the northern Caribbean. Erdman (1956) found well-developed

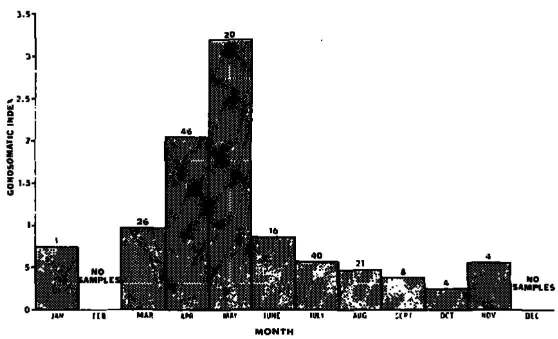


FIGURE 6.—Seasonal variation of mean gonosomatic index in 186 white marlin collected from 1972 to 1976 (number of fish indicated above histograms).

TABLE 3.—Weight, length, and gonadal data for 12 female white marlin from the Florida Straits collected during 1972, 1974, and 1975. The mean and standard error of the mean are given at the bottom of the columns.

| Body weight (kg) | Body length (cm) | Ovary wet weight (g) | Gono-somatic index | Estimated number of eggs >0.55 mm in diameter (millions) | Estimated number of eggs >0.29 mm in diameter[1] (millions) |
|---|---|---|---|---|---|
| 26.8 | 160 | [2]1,600 | 6.0 | 5.4 | 10.4 |
| 26.8 | 169 | [2]2,050 | 7.6 | 4.8 | 8.0 |
| 30.4 | 168 | [2]2,324 | 7.6 | 7.0 | 11.7 |
| 30.4 | 176 | [2]1,700 | 5.6 | 3.8 | 7.3 |
| 31.3 | 168 | 2,908 | 9.3 | 10.4 | 18.6 |
| 32.7 | 166 | 2,150 | 6.6 | 7.1 | 11.8 |
| 32.7 | 166 | 2,693 | 8.2 | 10.1 | 16.8 |
| 33.6 | 167 | 2,161 | 6.4 | 7.6 | 11.9 |
| 35.0 | 169 | [2]2,250 | 6.4 | 6.5 | 10.2 |
| 35.4 | 170 | [2]2,320 | 6.6 | 7.5 | 14.4 |
| 36.3 | 171 | 2,488 | 6.8 | 10.5 | 20.2 |
| 37.2 | 179 | [2]2,050 | 5.5 | 8.1 | 14.5 |
| 32.4 | 169 | 2,224 | 6.9 | 7.4 | 13.0 |
| 0.98 | 1.4 | 107 | 0.32 | 0.62 | 1.16 |

[1]Estimated using actual percent from 0.30 to 0.55 mm in diameter from 25 eggs measured for each fish.
[2]Entire ovaries available.

ovaries in white marlin caught off Puerto Rico in April and found well-formed eggs in a fish taken in June from the same locality.

The smallest fish approaching a ripe condition with large ovaries weighed 26.8 kg (Table 3). Ueyanagi et al. (1970) reported that white marlin reach sexual maturity at 130 cm eye-fork length. Using the conversion equation of Lenarz and Nakamura (1974), 130 cm eye-fork length would be equal to about 20.3 kg.

Frequency distributions of white marlin ovum diameters were made from measurements on 3,912 ova from spent, partly spent, and mature fish (Figure 7). Spent fish caught during May and June contained mostly eggs 0.15 mm in diameter and smaller. Eggs from a partly spent fish caught during June had a frequency mode of about 0.35 mm, with few eggs larger than 0.60 mm. Some of the larger eggs appeared to be undergoing absorption. Jolley (1977), in his histological examination of spent sailfish, found degeneration and absorption of advanced unovulated eggs common. Merrett (1970), studying several species of billfish from the Indian Ocean, suggested that there also may be at least a partial resorption of resting

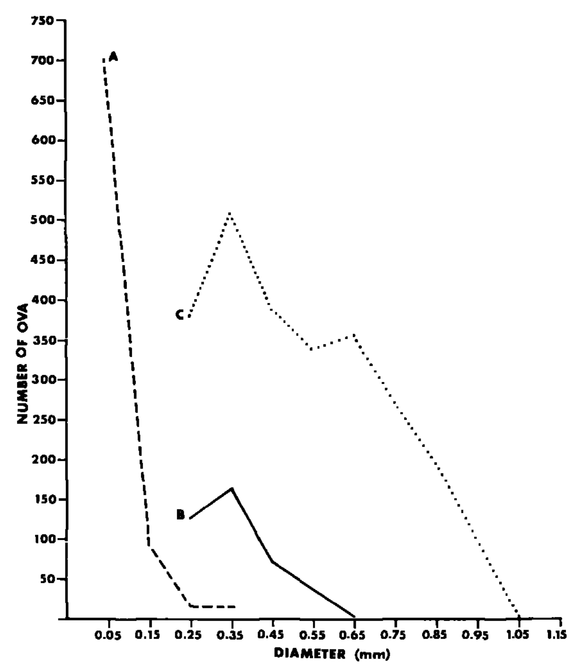


FIGURE 7.—Frequency distribution of white marlin ovum diameters for: A, four spent fish (827 ova) in May and June; B, one partially spent fish (406 ova) in June; C, one mature fish (2,679 ova) in April.

oocytes. I found frequency modes of about 0.35 mm and 0.65 mm in a mature fish caught in April. Only eggs measuring 0.56 mm and larger were included when estimating fecundity. Because there were two frequency modes present in mature fish, an estimate of the number of eggs 0.30 mm in diameter and larger is also presented (Table 3).

Fecundity, based on the number of ova in the most advanced size mode, ranged from 3.8 to 10.5 million eggs ($\bar{X}$ = 7.4, $S_{\bar{X}}$ = 0.62) for white marlin weighing 26.8 to 37.2 kg (Table 3). The number of mature ova per gram of body weight ranged from 125 to 332 ($\bar{X}$ = 227, $S_{\bar{X}}$ = 16.76). The average number of eggs measuring 0.30 mm in diameter and larger was estimated as 13 million ($S_{\bar{X}}$ = 1.16).

Fecundity was based on the number of fully yolked eggs, forming a group distinct from another group of developing eggs. Fecundity would vary depending on whether smaller eggs develop further or are absorbed. If fractional spawning occurs, as reported for sailfish by Jolley (1977), the eggs in the next distinct group should be included in seasonal fecundity estimates.


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## RECORDS OF PISCIVORUS LEECHES (HIRUDINEA) FROM THE CENTRAL COLUMBIA RIVER, WASHINGTON STATE

No records of leech infestations on fish of the Columbia River exist in the published literature. As a whole, the freshwater hirudinean fauna of the Pacific Northwest remains a relatively unsurveyed, little known, and neglected biotic group. This is due, in part, to problems in leech identification as well as in obtaining representative collections.

We obtained leeches from the external surface, oral cavity, and gill chambers of fish during a continuing environmental assessment program on the central Columbia River above Richland, Wash. (Benton and Franklin Counties), from 1975 through 1977. This paper identifies four piscivorous species, provides new host and distribution records, and reviews some recent taxonomic changes for the species encountered. Ecological observations are included.

The leeches recorded herein are *Myzobdella lugubris* Leidy 1851, *Piscicola salmositica* Meyer 1946, *Placobdella montifera* Moore 1906, and *Actinobdella inequiannulata* Moore 1901.

### Methods and Site Description

Fish were collected at monthly or bimonthly intervals by a variety of gear (gill nets, trammel nets, hoop nets, beach seines, and electroshocker) from January 1975 to December 1977. Over 20,000 fish, representing nearly 40 species, were examined during this period (Gray and Dauble 1977). Leech specimens were preserved in 10% Formalin[1] solution, either when captured or after being examined alive in the laboratory.

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

Our leech collections were more qualitative than quantitative because leech-fish associations in nature are normally periodic and facultative despite the nutritional requirement of piscivorous leeches for fish blood. Also, piscivorous leeches can readily detach from fish captured by most types of fishing gear, particularly from fish recovered when moribund or dead.

Occurrence of many freshwater leech species can be correlated with characteristic aquatic habitats. Water quality parameters vary seasonally in the central Columbia River, as follows: dissolved oxygen, 8.0-12.0 mg/l; pH, 7.4-8.6; phosphate (as $PO_4$), 0.03-0.04 mg/l; ammonia-nitrogen, 0.01-0.2 mg/l; hardness (Ca, Mg), 55-75 mg/l; and alkalinity ($CaCO_3$), 50-67 mg/l. Water temperatures range from 1° to 3°C in midwinter to about 21°C in late August and early September. There are no significant quantities of organic and inorganic pollutants (our data). The water carries minimal silt loads.

The central Columbia River in the Hanford Reach where our collections were made (river km 550-629) survives as the last free-flowing section of the main channel above Bonneville Dam. Decades of hydroelectric development have transformed other sections into a consecutive series of river-run reservoirs. River flows in the study area usually range from about 2,000 $m^3/s$ over much of the year to over 12,000 $m^3/s$ during the annual spring spate, when surplus runoff is passed downriver over spillways from reservoirs (Nees and Corley[2]).

Additionally, Hanford flows are now regulated at Priest Rapids Dam in response to daily and weekly power demand peaks, causing water levels in the river to fluctuate widely. This periodically exposes and inundates a rocky or muddy shoreline zone, apparently restricting development of a diverse leech fauna along the river margins. Water levels in Wanapum Reservoir behind Priest Rapids Dam (river km 639) and in Umatilla Reservoir behind McNary Dam (river km 470) are relatively stable, although subject to controlled summer drawdowns. Substantial populations of such common omnivorous leeches as *Erpobdella punctata* (Leidy 1870), *Helobdella stagnalis* (Linnaeus 1758), and *Theromyzon* spp. occur along the

[2]Nees, W. L., and J. P. Corley. 1974. Environmental surveillance at Hanford for CY-1973. Unpubl. manuscr., 56 p. R&D Rep., BNWL-1881, Battelle, Pacific Northwest Laboratories, Richland, WA 99352.