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SEXUAL DIMORPHISM IN SIZE AND VERTEBRAL NUMBER IN THE WESTERN ATLANTIC EEL *MORINGUA EDWARDSI* (ANGUILLIFORMES, MORINGUIDAE)

P. H. J. Castle and James E. Böhlke

ABSTRACT—Mature males of *M. edwardsi* (Jordan and Bollman) are 115-155 mm TL and have 109-117 vertebrae ($\bar{x} = 112.6$). Females with clearly recognizable ova are conspicuously larger, 245-360 mm TL, and have 116-124 vertebrae ($\bar{x} = 119.4$). A matching bimodality in myomere numbers occurs in leptocephali with frequency peaks at 113-114 and 119-120 indicating males and females respectively. Sex is probably therefore determined by karyotypic features. Type specimens, where still available, of the other nominal species of western Atlantic *Moringua* examined conform with either male or female counts and it is concluded that there is but the single species, *M. edwardsi*, in the Atlantic. Similar bimodality in vertebral numbers occurs in at least one Indo-Pacific species and may be typical for *Moringua*.

The moringuids have been the center of some long-standing and as yet unsolved problems in eel taxonomy and reproductive biology. The nature of these problems has been pointed out by Gordon (1954), Gosline and Strasburg (1956), Castle (1968) and Böhlke and Chaplin (1968), and essentially concerns the gross morphological changes which occur during maturation of both sexes. These changes have been the basis for the complex nomenclatural history of *Moringua*, involving four family names and some nine generic names to which about 40 species have been referred. The species structure of *Moringua* in the Indo-Pacific is undoubtedly complex but it has become accepted that there is only a single species, *M. edwardsi* (Jordan and Bollman, 1889),

in the Atlantic. However, this has not yet been conclusively demonstrated.

In the course of studying the biology of leptocephali of *Moringua edwardsi* in the western North Atlantic from the large DANA collections, one of us (P.H.J.C.) observed that the number of myomeres in the larvae was bimodal with frequency peaks at 113-114 and 119-120. While separately collecting specimens and data for a review of the species in this area the other of us (J.E.B.) noted that bimodality was also suggested for juveniles and adults. The vertebral bimodality was less apparent because fewer vertebral counts were made than counts of myomeres from larvae. These two separate observations are expressed in the frequency histogram (Fig. 1) from which it is clear that the frequency modes of vertebrae (adults) and myomeres (larvae) coincide almost exactly.

While the ranges in number of vertebrae and myomeres are closely similar, there is a difference, significant at the .01 level, in the means (vertebrae $\bar{x} = 117.98$, $SD = 2.75$, $n = 175$; myomeres $\bar{x} = 116.65$, $SD = 3.24$, $n = 588$). The difference occurs because the frequency distribution of vertebral number is skewed toward the group of adults with the higher number of vertebrae (Fig. 1).

Various reasons were initially proposed to explain this bimodality but only three were seriously considered: (a) that it indicated the presence of two distinct species or subspecies of *Moringua* in collections of both larvae and adults from the area; (b) that it resulted from different environmental factors influencing segmental numbers during embryonic development; or (c) that it indicated males and females of a single species. In respect of (a) and (b) no correlation could be found between myomere-vertebral number and season, locality, or depth. In other words, any specific collection of larvae contained about equal numbers of individuals with both low and high myomere numbers. Collections of adults, while tending to contain individuals with

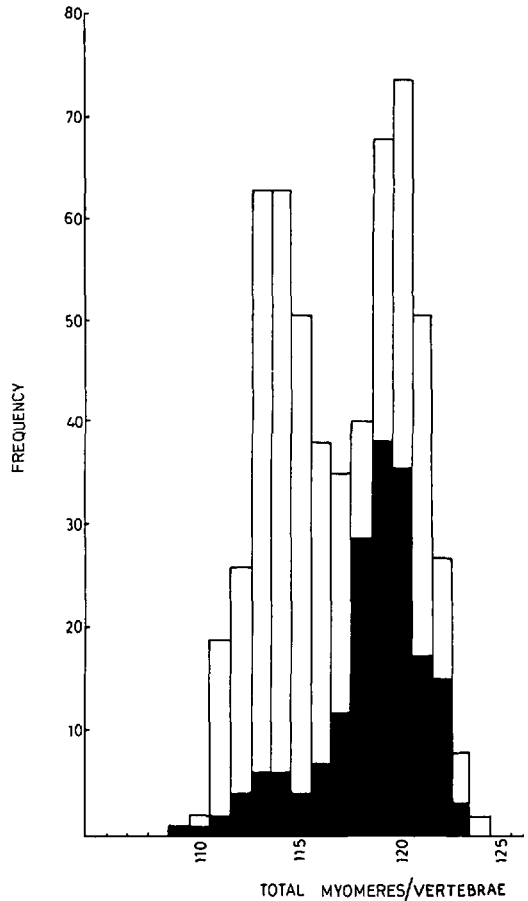


Figure 1. Frequency distribution of number of myomeres (larvae) and vertebrae (juveniles and adults) in *Moringua edwardsi*. White: 588 leptocephali from the DANA collections, Universitets Zoologiske Museum, København; black: 175 juveniles and adults from the collections of the Academy of Natural Sciences of Philadelphia.

higher numbers of vertebrae had similar frequency distributions, sample to sample.

Most collections of juveniles and adults of *M. edwardsi* lack fully mature specimens, probably because maturing individuals are pelagic rather than fossorial and are thus collected less readily with ichthyocides. However, among U.S. collections there were known to be a few mature males and females and these were examined in respect of possibility (c) above.

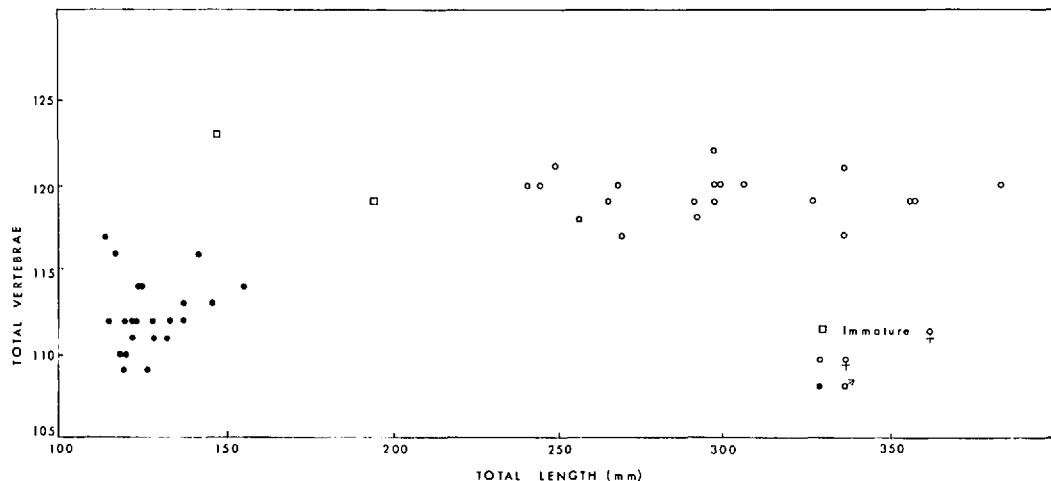


Figure 2. Length and number of vertebrae of mature males and females of *Moringua edwardsi*. Specimens listed in Material Examined.

Radiographs of these specimens, as listed in Material Examined, clearly show that mature males and females have different numbers of vertebrae (males: range 109-117, $\bar{x} = 112.6$, $n = 22$; females: range 116-123, $\bar{x} = 119.4$, $n = 20$). Furthermore, mature males are only about 115-155 mm total length while females with discrete ova are conspicuously larger at 245-360 mm total length. These data are expressed in Figure 2.

A number of other moringuid species have been described from the western North Atlantic but that they are referable to *M. edwardsi* is now quite apparent from the determination of sex and vertebral numbers in the type specimens, as follows (this also serves as a primary synonymy for the species):

Silbiscus edwardsi Jordan and Bollman, 1889. Holotype, USNM 41735, 337 mm TL, vertebrae 116, female.

Apthalmichthys caribeus Gill and Smith, 1900. Holotype, USNM 49720, 265 mm, vertebrae 117, female.

Mayerina mayeri Silvester, 1916. Holotype, Princeton University 3037, lost, 310 mm, vertebrae unknown, female? Paratype, Princeton Univ. 3126, lost, 280 mm, verte-

brae unknown, female? While the number of vertebrae are unknown for these two specimens, their sizes suggest females.

Moringua boekei Metzelaar, 1919. Holotype, ZMA 112. 739, 132 mm, vertebrae 115, male.

Anguillichthys bahamensis Mowbray in Breder, 1927. Holotype, BOC 34, 117 mm, vertebrae 112, male. Paratype, BOC 35, 115 mm, vertebrae 111, male.

Males are apparently much less frequent in collections made with ichthyocides throughout the Caribbean but tend to be taken with dip-nets at lights. In contrast, the frequency histogram of larvae (Fig. 1) shows that male and female larvae (for this is what leptocephali with low and high myomere numbers, respectively, must be) are almost equally represented in the DANA plankton hauls. Whether juvenile and maturing males live in a distinct, but less frequently collected habitat from that of females with a consequent predominance of females in collections, or that there is differential mortality of the sexes during life, remains to be determined.

It now seems certain that there is but the single species of *Moringua* in the western North Atlantic, *M. edwardsi* (Jordan and

Bollman, 1889) in which the vertebrae number overall 109-124 but in which males have 109-117 and females 116-124. Males and females occur in about equal numbers as larvae. After metamorphosis presumably both sexes pass through a wormlike, "degenerate" (so-called apththalmichthys) phase in which the pectoral and dorsal fins are much reduced, the eye is small and the lower jaw projects beyond the upper. As maturity approaches, when males are only about 115 mm in length but when females are substantially larger at about 245 mm, the eye enlarges (especially in males) and the pectoral fin, the anterior portion of the dorsal and anal fins and the caudal fin also enlarge.

These externally visible maturation changes have yet to be examined in relation to the precise stage of development of the gonads but this would be a worthwhile study.

An alternative suggestion to the above is that collections of metamorphosed individuals contain two species, including only males of one and females of the other. However, in further study of these eels we shall adopt what seems to us the most reasonable view: that there is only one species of *Moringua* in the western North Atlantic.

Finally, there are two significant implications of the discovery of sexual dimorphism in vertebral numbers in *M. edwardsi* which are likely to affect future studies in reproductive biology in eels in general and moringuid taxonomy in particular.

Since leptocephali are already distinctly male and female, sex is suggested to be determined syngamically, that is, by karyotypic features and not principally by environmental factors, as has been proposed for *Anguilla anguilla* (Linnaeus). It would be of great interest to discover whether similar vertebral, or indeed any other meristic differences, are to be found between the sexes in other groups of eels as a measure of the occurrence of syngamic sex determination. On the basis of our observations on *M. edwardsi*, which has a relatively wide

range in vertebral number, we would recommend that the possibility of sexual dimorphism in this feature be kept in mind when dealing with species showing similar wide ranges.

The existence of sex-related bimodality in vertebral numbers is apparently not unique to *M. edwardsi*. It is suggested for Hawaiian moringuids (Gosline and Strasburg, 1956) referred by them to *M. macrochir* Bleeker, 1855 and for at least one other Indo-Pacific species (personal observation from as yet unidentified Indonesian material in the United States National Museum of Natural History). If this is typical for *Moringua* it will be virtually impossible to identify Indo-Pacific moringuids on vertebral numbers alone. What are currently recognized as distinct species may well be either different maturation forms of the same sex or alternatively males and females of the same species. A reduction in the number of species recognized from the Indo-Pacific is to be expected.

In a comprehensive review of vertebral numbers at various taxonomic levels in fishes and other vertebrates, including an analysis of over 3000 fish species, Lindsey (1975) noted that "sexual dimorphism in total vertebral count has not been found in the great majority of species in which it has been sought." *M. edwardsi* has not been examined to determine whether abdominal vertebrae in females are relatively longer or more numerous than in males, thus presumably conferring on the female a greater egg-carrying capacity. However, this would usefully extend the present study.

Material examined. (for Fig. 2)—All but two are mature specimens from the western North Atlantic (lengths of individual specimens in parentheses; italicized lengths are of males). BAHAMAS: AMNH 19869 (1-336), N Bimini I., light from dock; 3 Oct. 1953; C. M. Breder Jr. ANSP 101098 (2-125, 148, out of 34), Andros I., sand spit forming W end of Middle Bight Cay; to ca. 1 m; 10 July 1957; C. C. G. and G. W. Chaplin, H. R. and R. B. Roberts, Capt. Lightbourn, A. Kemp, J. E. Böhlke; sta. 391. ANSP 101540 (1-357), Andros I., tidal creek on S shore of southern bight, near E end; to 4.6 m; 11 July 1957; C. C. G. and G. W. Chaplin, H. R. and R. B. Roberts, J. E. Böhlke; sta. 393. ANSP

101106 (1-195), New Providence I., Malcolm's Creek on S side; 0.3 m; 4 Sept. 1955; C. C. G. Chaplin, H. R. and R. B. Roberts; sta. 258. AMNH 23652 (4-120, 142, 245, 326), ca. 2 mi. W of Great Egg I.; 28 Nov. 1964; C. L. Smith et al. AMNH 22857 (3-128, 268, 269, out of 4), Great Exuma I., Georgetown, February Pt.; 11 July 1964; C. L. Smith et al. AMNH 24063 (6-115, 118, 122, 123, 124, 137), Crooked I., French Wells Cut; 24 Mar. 1965; M. Mazurkiewicz. AMNH 24256 (1-120), Crooked I., Portland Harbour; 29 Mar. 1965; C. L. Smith. AMNH 27746 (1-265), Acklin's I., Salina Pt., edge of dropoff; 9 Mar. 1966; C. L. Smith, J. J. Sohn. AMNH 23979 (2-128, 137), Ragged I., Buena Vista Cay, S end; 21 Mar. 1965; C. L. Smith et al. AMNH 28324 (4-114, 117, 119, 268), Great Inagua, Man-o-War Bay near Northwest Pt.; 13 Mar. 1966; C. L. Smith et al. BMNH 1945.7.9.4 (1-297), "Bahamas." JAMAICA: ANSP 114993 (1-306), Hanover Parish, 2 mi. W of Hopewell; 18 Aug. 1970; M. T. Felix, D. C. Fowler, A. Schwartz; sta. MTF-64. PUERTO RICO: ANSP 115641 (2-249, 299), Puerto Yabucoa, ½ mi. E of Playa de Guyanes, Municipio de Yabucoa; 14-15 July 1969; N. R. Foster, J. J. Loos; sta. 3. ANSP 103422 (1-146), La Parguera, shallow water; June 1965; P. W. Glynn. ST. KITTS: BMNH 1932.5.9.3 (1, 126). ST. LUCIA: BMNH 1932.8.8.25 (1, 155). BMNH 1932.8.8.26 (1, 133). BMNH 1932.8.8.27 (1, 132). GRENADA: BMNH 1932.5.10.2 (1, 122). VENEZUELA: ANSP 110407 (1-356), 12°36'N, 70°04'W; 24 m; 2 Oct. 1965; U.S. Fish and Wildlife Service; OREGON sta. 5652. COLOMBIA: ANSP 117558 (7-241, 256, 291, 292, 297, 297, 336), Island of Baru outside entrance to Cartagena Bay, 10°12'35"N, 75°37'30"W; to 1.2 m; 27 Sept. 1969; L. W. Knapp; sta. LK 69-36.

ACKNOWLEDGMENTS

For the loan of specimens or information about types we thank Han Nijssen of the Zoological Museum of the University of Amsterdam (ZMA), Daniel Merriman of the Bingham Oceanographic Collection at Yale University (BOC), and Victor G. Springer of the United States National Museum of Natural History (USNM); for supplying radiographs we thank Eugenia B. Böhlke of the Academy of Natural Sciences of Philadelphia (ANSP) and M. Norma Feinberg of the American Museum of Natural History (AMNH); and for making available material in his charge we are grateful to Erik Bertelsen of the Universitetets Zoologiske Museum, København. The junior author thanks the U.S. National Science Foundation for its support of his eel studies (NSF-GB-17736).

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SCOMBRID FISHES IN ST. ANDREW BAY, FLORIDA

Eugene L. Nakamura

Except for the Spanish mackerel (*Scomberomorus maculatus*), fishes of the family Scombridae seldom occur in bays and estuaries of the Gulf of Mexico. The occurrence of six species of scombrids in a bay is unusual and worthy of note.

The six species (*Auxis thazard*, *Euthyn-*