

Abstract.—The parameters from von Bertalanffy's growth equation were estimated for *Mugil cephalus* and *M. curema* located in Tamiahua coastal lagoon in Veracruz, México. Also differences in growth and longevity between sexes were obtained. The following were growth parameters for *M. cephalus*: $L_{\infty} = 642.4$ mm, $W_{\infty} = 2,352.12$ g, $k = 0.099$, $t_0 = -2.85$, $(A_{0.95}) = 28.3$ years; and for *M. curema*: $L_{\infty} = 461.4$ mm, $W_{\infty} = 844.73$ g, $k = 0.14$ y $t_0 = -3.62$, $(A_{0.95}) = 18.7$ years. Some important differences among growth rates from other areas were found. Significant differences in the growth rate between sexes were observed. The following were growth parameters for *M. cephalus*: females: $L_{\infty} = 622.9$ mm, $k = 0.107$, $t_0 = -2.67$; $A_{0.95} = 26.2$ years; males: $L_{\infty} = 603.9$ mm, $k = 0.105$, $t_0 = -2.98$; $A_{0.95} = 26.5$ years; for *M. curema*: females: $L_{\infty} = 454.6$ mm, $k = 0.135$, $t_0 = -3.94$; $A_{0.95} = 19.2$ years; males: $L_{\infty} = 411.8$ mm, $k = 0.187$, $t_0 = -3.03$; $A_{0.95} = 14.0$ years.

Growth analysis of striped mullet, *Mugil cephalus*, and white mullet, *M. curema* (Pisces: Mugilidae), in the Gulf of Mexico

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The striped mullet, *Mugil cephalus* (Linnaeus, 1758), has a worldwide distribution, between 42°N and 42°S (de Silva, 1980), whereas the white mullet, *Mugil curema* (Valenciennes, 1836), is basically an American species found from Cape Cod, USA, to Brazil in the Atlantic and from Bahia Magdalena, Mexico, to Chile in the Pacific (Jordan and Everman, 1896). However, Alvarez (1976) has recorded *M. curema* off the western coast of Africa.

In Mexico, 99% of the commercial catch of these mullets takes place in the states of Tamaulipas, mainly in Laguna Madre and in Veracruz, and mainly in the Pueblo Viejo and Tamiahua. The mullet fishery constitutes one of the ten most important fisheries in Mexico as a result of its catch volume, which surpasses 10,000 metric tons (t) annually (Polanco et al., 1987).

These species provide both the meat and the roe, locally called "hueva," which commands a greater commercial price than the meat. Whereas striped mullet meat has a value of one US\$ per kg, the roe is valued at seven US\$ per kg. The female gonad has a widespread

market because it is eaten regionally as well as nationally and internationally. In 1995 alone, 43 t of roe with a value of US\$ 150,000 (at the present time US\$ 800,000) were exported to the United States (Polanco et al., 1987).

Although these species of mullets represent an important source of food in many countries, studies on their ecology and population dynamics are insufficient. In Mexico some population parameters of *M. cephalus* in Tamiahua lagoon, Veracruz, have been analyzed by Marquez (1974) and Garcia (1980). Similarly, Diaz and Hernandez (1980) and Romero and Castro (1983) studied *M. cephalus* in the San Andres lagoon in Tamaulipas and in the Mar Muerto in Chiapas, respectively. Yañez-Arancibia (1976) analyzed some aspects of feeding habits, growth, and maturity of *M. curema* in the coastal lagoon system of Guerrero. Comparative studies on *M. curema* and *M. cephalus* in Tamiahua lagoon, Veracruz, were carried out by the following authors: Perez-Garcia and Ibañez-Aguirre (1992) and Ibañez-Aguirre and Leonart (1996) on relative growth

and comparative morphometrics; Ibañez-Aguirre and Gallardo-Cabello (1996a) on total and natural mortality and Sanchez-Rueda et al. (1997) on the analysis of sediments in stomach contents. On the international scene, the studies on *M. cephalus* by de Silva (1980), Perera and de Silva (1978), de Silva and Silva (1979) in a coastal lagoon in Sri Lanka, Drake et al. (1984) in the coastal lagoon of San Fernando Cadiz, Cech and Wohlschlag (1975) along the coast of Texas, Broadhead (1958) along the coast of Florida, and Thompson (1963) in Australia, are worthy of mention, as well as those carried out by Alvarez (1976, 1979 and 1981), Richards and Castagna (1976), and Phillips et al. (1987) on *M. curema*.

In view of the above studies, the purpose of this study was to carry out an in-depth analysis of the growth characteristics of *M. cephalus* and *M. curema* with respect to length, sex, weight, and longevity in Tamiahua lagoon, Veracruz, Mexico.

Material and methods

Specimens were obtained from the commercial catch landed near Tamiahua lagoon, Veracruz, Mexico (Fig. 1). The most commonly employed fishing nets were gill nets of 35-mm mesh size (knot-to-knot) for *M.*

cephalus and 30-mm mesh size (knot-to-knot) for *M. curema*. Sampling was carried out monthly during the first 8 days of each month for a year, from April 1991 to March 1992.

Total length (TL) was recorded from 2628 specimens of *M. cephalus* and 3354 of *M. curema*. For the study of growth, two independent readers examined scales, and otoliths (right sagitta) from 232 specimens of *M. cephalus* (122 females and 110 males) ranging from 200 to 400 mm and 292 specimens of *M. curema* (148 females and 144 males) ranging from 180 to 330 mm. The scales were cleaned, placed between two glass slides, and observed with transmitted light. The otoliths were submerged in a petri plate in xylol as a clarifying liquid and observed through a stereoscopic microscope with transmitted light. The analysis of the annual frequency variation of the fast growth rings (opaque) and slow growth rings (hyaline) of the margin of the otoliths showed that each year, one fast growth band and one slow growth band are deposited in the otoliths of both species of mullets (Ibañez-Aguirre and Gallardo-Cabello, 1996b). It was reported earlier that otoliths give better results than do scales for the age determination of both species and make possible a definition of five age groups for *M. cephalus* and six for *M. curema* (Ibañez-Aguirre and Gallardo-Cabello, 1996b). These average lengths were used to obtain the constants for the von Bertalanffy equation (Table 1).

Ages "0" and "1" were not collected for *M. cephalus*, as a result of the mesh size of the nets; instead they were obtained by using the back-calculation method of Lea (1910, in Francis, 1990) and Bagenal and Tesch (1978, in Francis, 1990).

The constants for the von Bertalanffy equation (1938), L_{∞} , k , and t_0 , were obtained by using the combined method of Ford (1933) and Walford (1946), and the methods of Gulland (1964), Tomlinson and Abramson (1961), Allen (1966), Beverton¹, Prager (1987), and Bayley (1977). Growth was also measured for each sex of both species. Growth curves for both species were obtained from the constants of the equation calculated by the above mentioned methods. The sum of the squared differences ($\sum e_i^2$) was used to compare the differences between calculated and observed values.

Hotelling's T^2 test (Bernard, 1981) was used to compare growth curves of the two sexes of both species. This test assumes that estimations of L_{∞} , k , and t_0 for both groups were obtained from two normal

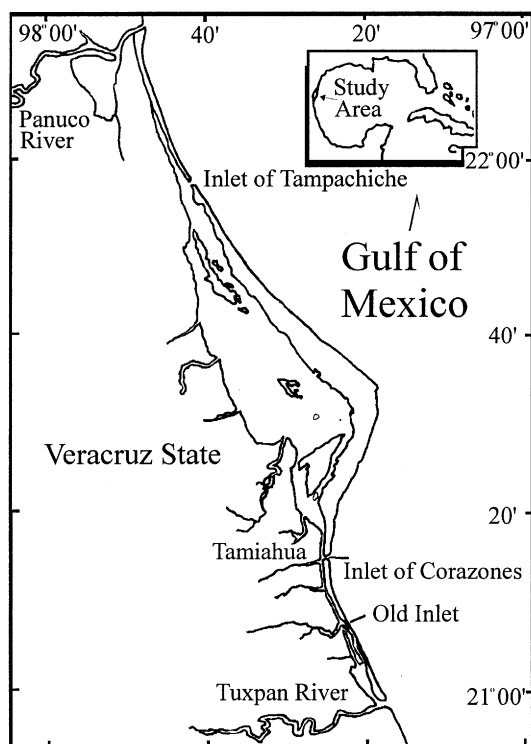


Figure 1

Map of the Tamiahua Lagoon, Veracruz, Mexico.

¹ Beverton, R. J. H. 1954. Notes on the use of theoretical models in the study of the dynamics of exploited fish populations. U.S. Fish Wildl. Serv., Fisheries Laboratory, Beaufort, Misc. Contrib. Rep., 181 p.

Table 1
Mean length (mm) employed for obtaining the growth parameters.

| Age | <i>Mugil cephalus</i> | | | | <i>Mugil curema</i> | | | | | |
|-----|------------------------|-------------------------|-------------------------|----------|----------------------------|------------------|----------------|------------------|----------|----------------------------|
| | Females (±SD) | Males (±SD) | Species (±SD) | <i>n</i> | Calculated values (±SD) | Females (±SD) | Males (±SD) | Species (±SD) | <i>n</i> | Calculated values (±SD) |
| "0" | 156 ^l (± 9) | 160 ^l (± 13) | 158 ^a (± 11) | 0 | 158.34 (± 9) | 187 (± 10) | 176 (± 11) | 183 (± 4) | 4 | 184.20 (±9) |
| "1" | 203 ^l (± 7) | 207 ^l (± 9) | 204 ^a (± 7) | 0 | 204.09 (± 9) | 224 (± 8) | 221 (± 9) | 223 (± 7) | 60 | 220.56 (± 11) |
| "2" | 246 (± 5) | 247 (± 19) | 246 (± 14) | 45 | 245.53 (±13) | 251 (± 6) | 250 (± 8) | 252 (± 9) | 71 | 252.15 (± 6) |
| "3" | 283 (± 3) | 281 (± 10) | 282 (± 11) | 59 | 283.04 (± 11) | 276 (± 7) | 276 (± 7) | 278 (± 8) | 66 | 279.60 (± 4) |
| "4" | 319 (± 7) | 315 (± 10) | 317 (± 9) | 44 | 317.01 (±11) | 299 (± 6) | 300 (± 4) | 303 (± 7) | 54 | 303.44 (± 3) |
| "5" | 350 (± 9) | 344 (± 8) | 349 (± 12) | 51 | 347.77 (± 8) | 320 (± 4) | 321 (± 4) | 325 (± 8) | 37 | 324.16 (± 4) |
| "6" | 377 (± 8) | 369 (± 6) | 375 (± 12) | 33 | 375.62 (± 11) | — | — | — | | |

^l Average lengths obtained by back calculation.

Table 2
Estimates of the constants of the von Bertalanffy equation for *M. cephalus*, according to the different methods used.

| Method | Species | | | | Females | | | | Males | | | |
|---------------------------|-------------------|----------|---------|--------------------|-------------------|----------|---------|--------------------|-------------------|----------|---------|--------------------|
| | L_{∞} (mm) | <i>k</i> | t_0 | SD ² | L_{∞} (mm) | <i>k</i> | t_0 | SD ² | L_{∞} (mm) | <i>k</i> | t_0 | SD ² |
| Walford-Gulland | 637.97 | 0.0998 | -2.8838 | 4.049 | 627.54 | 0.1052 | -2.7342 | 2.186 | 609.05 | 0.1028 | -3.0651 | 3.339 |
| Beverton regression | 637.97 | 0.1000 | -2.8723 | 3.827 | 627.54 | 0.1053 | -2.7281 | 2.110 | 609.05 | 0.1029 | -3.0575 | 3.237 |
| Tomlinson and Abramson | 640.64 | 0.0998 | -2.8418 | 3.211 | 627.24 | 0.1054 | -2.7280 | 2.115 | 604.93 | 0.1043 | -3.0376 | 3.341 |
| Beverton regression | 640.64 | 0.0998 | -2.8400 | 3.211 | 627.24 | 0.1059 | -2.6958 | 1.793 | 604.93 | 0.1050 | -2.9860 | 2.725 |
| Allen | 642.00 | 0.0993 | -2.8483 | 3.421 | 622.87 | 0.1074 | -2.6709 | 1.794 | 603.52 | 0.1054 | -2.9772 | 2.919 |
| Beverton regression | 642.00 | 0.0994 | -2.8476 | 3.210 | 622.87 | 0.1074 | -2.6697 | 1.783 | 603.52 | 0.1055 | -2.9765 | 2.723 |
| Prager | 642.40 | 0.0993 | -2.8480 | 3.210 | 622.90 | 0.1074 | -2.6690 | 1.790 | 603.90 | 0.1054 | -2.9770 | 2.722 |
| Beverton regression | 642.40 | 0.0993 | -2.8499 | 3.209 ^l | 622.90 | 0.1074 | -2.6699 | 1.782 ^l | 603.90 | 0.1054 | -2.9791 | 2.722 ^l |
| Bayley | 640.00 | 0.1003 | -2.8210 | 3.408 | 615.89 | 0.1094 | -2.6620 | 2.382 | 608.34 | 0.1055 | -2.8988 | 8.592 |

^l The best fit.

distributions of joint probability, with three variables and one common variance.

The complete and eviscerated weights of 473 and 329 specimens of *M. cephalus* and *M. curema*, respectively, were recorded for the study of growth by weight. Weight data were recorded for each 20-mm length interval and the average weight for each size class was calculated.

The function $W = aL^b$ was used to obtain the weight-length relationship. Data for growth by length and the weight-length relationship were used to obtain the weight for each age. Growth by weight was obtained by substituting L_t and L_{∞} by W_t and W_{∞} , respectively, obtained from the weight-length relation-

ship in the von Bertalanffy equation. Taylor's equation (1958, 1960) was used to calculate age limit or longevity (95% of L_{∞}).

Results

Growth in length

Mugil cephalus The values for L_{∞} and *k* were very similar (Table 2). The method that provided the greatest differences was that of Ford (1933) and Walford (1946). This similarity was due to the obtention of these constants; the t_0 value determined by Gulland

(1964) was also employed. Gulland recommends using just the age groups that are best represented and thus avoids errors due to a low representation of some poorly sampled age groups. Some calculations were repeated and the following t_0 values were obtained for the 3–5 years age groups: -2.74 (females), -3.07 (males), -2.89 (both species, sexes combined); and for the 3–6 age groups: -2.67 (females), -2.98 (males), -2.85 (both species, sexes combined).

The best fit was found with the t_0 result calculated for 3–6 years age groups. Thus, these values were used to obtain the average t_0 (Table 2). Use of the Beverton¹ equation improved the calculated values in comparison with the values observed by Ford (1933) Walford (1946), Tomlinson and Abramson (1961), Allen (1966), Bayley (1977), and Prager (1987) methods.

The calculated curve that best fitted values observed through otoliths corresponded to the parameters that were calculated with the Prager (1987) method and fitted with the Beverton¹ equation (Table 2). The calculated values of the lengths for different ages as well as their standard deviation (SD) were obtained by using these parameters for the two species (Table 1) which are consistent and, in general, show improved calculated values. Figure 2 presents the theoretical growth curve for *M. cephalus* ages 0–6 years.

During the first two years of life, striped mullet grew rapidly in length, with average increases of 45.8 mm during the first year and 41.4 mm during the second. From the third year on, growth decreased to annual increases in total length of 37.5 mm. Increases

between the third and fifth years varied from 34.0 to 30.8 mm. Between the fifth and sixth years the increase was even smaller, with an average increase of 27.8 mm. In general, growth was high during the first two years of life and then decreased. This decrease is probably related to the time of first sexual maturity, which for this species occurs from 280 to 299 mm TL (males and females, respectively), which corresponds to an age of 3 years in both cases (Ibañez-Aguirre and Gallardo-Cabello, 1996b). L_∞ and k have a negative correlation, whereas L_∞ is high, the growth rate is low (Table 2).

Mugil curema As can be seen in Table 3, L_∞ and k values obtained with the Ford (1933) and Walford (1946) method show the greatest difference with respect to the values calculated by the Tomlinson and Abramson (1961), Allen (1966), Prager (1987), Beverton,¹ and Bayley (1977) methods.

As with *M. cephalus*, new calculations for the t_0 value were made by using the Gulland (1964) method for the 1–4, 3–5, and 2–4 years age groups; the following t_0 values were obtained: for the 1–4 years age groups -3.94 (females), -3.03 (males), -3.62 (both species, sexes combined), for the 3–5 years age groups: -3.73 (females), -2.77 (males), -3.41 (both species, sexes combined) and for the 2–4 years age groups -3.72 (females), -2.75 (males), -3.39 (both species, sexes combined).

The von Bertalanffy curves showed the best fit for the calculated values of the 1–4 yr age groups. These values were used to obtain average t_0 . The Beverton¹ equation with the above methods improved calculated values only in the case of the Ford (1933) and Walford (1946) method. The calculated curve that best fitted observed values through otoliths corresponded to the parameters calculated with the Prager (1987) method, as can be seen in Table 3.

Using these parameters, we calculated values for lengths at different ages, as well as their SD, which, as in the case of *M. cephalus*, are consistent and, in general, show improved calculated values (Table 1). Figure 2 presents the theoretical curve for growth in length of *M. curema*, for the ages of 0–5 years.

A high increase in length was recorded during the first year, after which growth decreased markedly. Size increased by 27.5 mm TL between the second and third years, 23.8 mm between the third and fourth years, and 20.7 mm between the fourth and fifth years. The decrease in growth from the first year on is related to the first sexual maturity, which in this species occurs in small sizes from 181 to 208 mm TL for males and females, respectively, at ages "0" and "1" (Ibañez-Aguirre and Gallardo-Cabello, 1996b).

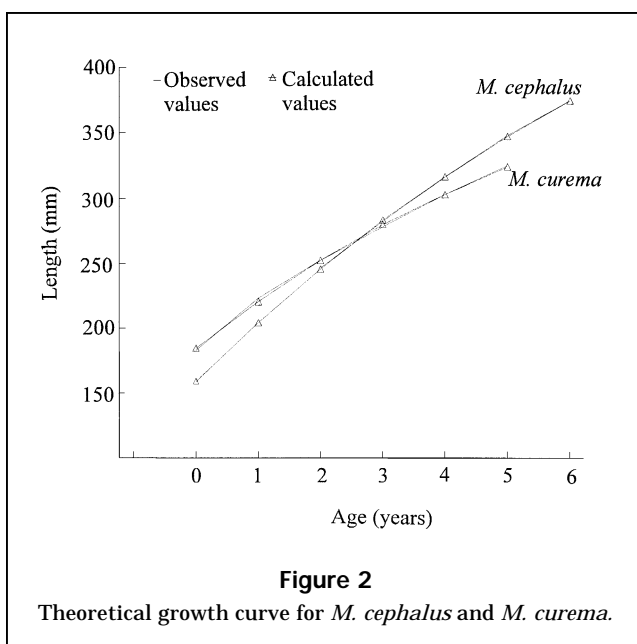


Figure 2

Theoretical growth curve for *M. cephalus* and *M. curema*.

Table 3
Estimates of the constants of the von Bertalanffy equation for *M. curema*, according to the different methods employed.

| Method | Species | | | | Females | | | | Males | | | |
|---------------------------|-------------------|--------|---------|---------------------|-------------------|--------|---------|--------------------|-------------------|--------|---------|---------------------|
| | L_{∞} (mm) | k | t_0 | SD^2 | L_{∞} (mm) | k | t_0 | SD^2 | L_{∞} (mm) | k | t_0 | SD^2 |
| Walford-Gulland | 450.35 | 0.1511 | -3.4372 | 14.921 | 444.98 | 0.1446 | -3.7568 | 11.144 | 402.75 | 0.2026 | -2.8121 | 30.593 |
| Beverton regression | 450.35 | 0.1494 | -3.5039 | 11.547 | 444.98 | 0.1430 | -3.8259 | 8.479 | 402.75 | 0.2000 | -2.8816 | 23.712 |
| Tomlinson and Abramson | 458.44 | 0.1427 | -3.5976 | 10.895 | 454.13 | 0.1358 | -3.9352 | 8.041 | 411.99 | 0.1863 | -3.0272 | 21.688 |
| Beverton regression | 458.44 | 0.1430 | -3.5875 | 10.944 | 454.13 | 0.1360 | -3.9283 | 8.057 | 411.99 | 0.1869 | -3.0116 | 21.825 |
| Allen | 461.37 | 0.1406 | -3.6238 | 10.866 | 454.58 | 0.1354 | -3.9413 | 8.054 | 411.85 | 0.1865 | -3.0256 | 21.688 |
| Beverton regression | 461.37 | 0.1408 | -3.6167 | 10.885 | 454.58 | 0.1356 | -3.9332 | 8.053 | 411.85 | 0.1871 | -3.0097 | 21.830 |
| Prager | 461.40 | 0.1406 | -3.6240 | 10.864 ¹ | 454.60 | 0.1355 | -3.9400 | 8.040 ^a | 411.80 | 0.1865 | -3.0260 | 21.682 ¹ |
| Beverton regression | 461.40 | 0.1408 | -3.6170 | 10.885 | 454.60 | 0.1356 | -3.9334 | 8.053 | 411.80 | 0.1872 | -3.0090 | 21.833 |
| Bayley | 455.79 | 0.1451 | -3.5559 | 11.134 | 449.60 | 0.1390 | -3.8953 | 8.127 | 406.54 | 0.1931 | -2.9721 | 22.057 |

¹ The best fit.

Growth between sexes

For *M. cephalus*, the growth curves that best fitted observed data were obtained with the Prager method (1987) and Beverton¹ equation (Table 2). In *M. cephalus* females the value of L_{∞} is higher than in males, though the differences between k values are small.

In *M. curema* the growth curves that best fitted observed values were obtained with the Prager (1987) method, as shown in Table 3. The k value in *M. curema* males is higher than in females; therefore males will reach L_{∞} faster than females and the growth curve will be slightly more convex. Conversely, the females, showed a slighter growth curve and therefore greater longevity. However, in the case of *M. cephalus*, the k value was observed to be the opposite of that of *M. curema*.

Table 4 contains the values of the parameters and their variances calculated with the Prager method (1987) for both species. The results from the multivariate analysis show that females and males of *M. cephalus* and *M. curema* grow differently (Table 5). The calculated value of T^2 (8928.135) is considerably higher than the tabulated value (11.796, $P < 0.01$) for *M. cephalus* and the same happens for *M. curema*, with a calculated T^2 (1843.808) and tabulated value (11.777, $P < 0.01$).

Growth in weight

Length-weight relationship The relationships between length and weight stretch to be isometrical (Figs. 3 and 4). In length-weight relationships, dis-

person is higher in *M. cephalus* because of the weight of gonads and viscera.

Theoretical growth in weight The theoretical weight for *M. cephalus* and *M. curema* in relation to each age group was obtained employing the mentioned weight equations (Figs. 5 and 6).

Longevity (Age $A_{0.95}$) Both species reach the 95% of L_{∞} at the following ages:

$$\begin{array}{ll} \textit{Mugil cephalus} & \textit{Mugil curema} \\ A_{0.95} = 28.32 \text{ years} & A_{0.95} = 18.68 \text{ years} \end{array}$$

The 95% of L_{∞} is reached between sexes as follows:

$$\begin{array}{ll} \textit{Mugil cephalus} & \textit{Mugil curema} \\ \text{Females} = 26.24 \text{ years} & \text{Females} = 19.17 \text{ years} \\ \text{Males} = 26.46 \text{ years} & \text{Males} = 14.04 \text{ years} \end{array}$$

Discussion

The parameters of the von Bertalanffy growth equation for *M. cephalus* in different areas of the Gulf of Mexico are shown in the Table 6. In the present paper, the value of k , calculated for *M. cephalus* is smaller than values presented by Marquez (1974) and Diaz and Hernandez (1980). Similarly, the values of L_{∞} given from these authors are smaller than those obtained in our paper. On the other hand, differences of the growth parameters for the Texas coast (Cech and Wohlschlag, 1975) and Florida (Broadhead, 1958) are very pronounced in relationship to those obtained in our paper: the L_{∞} values are smaller.

Table 4

Results of fitting the von Bertalanffy growth equation of females and males of *M. cephalus* and *M. curema*. Entries include parameters estimated and their estimated variance-covariance matrices (S).

| <i>Mugil cephalus</i> | | | | | |
|---|---------------|----------------|---|---------------|----------------|
| Males | | | Females | | |
| $L_{\infty} = 603.9$ | $k = 0.10536$ | $t_0 = -2.979$ | $L_{\infty} = 622.9$ | $k = 0.10736$ | $t_0 = -2.669$ |
| L_{∞} | k | t_0 | L_{∞} | k | t_0 |
| L_{∞} | k | t_0 | L_{∞} | k | t_0 |
| k | t_0 | L_{∞} | k | t_0 | L_{∞} |
| t_0 | L_{∞} | k | t_0 | L_{∞} | k |
| $\begin{bmatrix} 3.1701E+02 & -1.1927E-01 & -1.3055E+00 \\ & 0.4533E-04 & 0.5111E-03 \\ & & 0.6360E-02 \end{bmatrix} = S_m$ | | | $\begin{bmatrix} 1.8417E+02 & -0.5475E-01 & -0.5870E+00 \\ & 0.1642E-04 & 0.1810E-03 \\ & & 0.2221E-02 \end{bmatrix} = S_f$ | | |
| <i>Mugil curema</i> | | | | | |
| Males | | | Females | | |
| $L_{\infty} = 411.8$ | $k = 0.1865$ | $t_0 = -3.026$ | $L_{\infty} = 454.6$ | $k = 0.1355$ | $t_0 = -3.94$ |
| L_{∞} | k | t_0 | L_{∞} | k | t_0 |
| L_{∞} | k | t_0 | L_{∞} | k | t_0 |
| k | t_0 | L_{∞} | k | t_0 | L_{∞} |
| t_0 | L_{∞} | k | t_0 | L_{∞} | k |
| $\begin{bmatrix} 6.8027E+02 & -0.8253E+00 & -7.3708E+00 \\ & 1.0212E-03 & 0.9428E-02 \\ & & 0.9296E-01 \end{bmatrix} = S_m$ | | | $\begin{bmatrix} 8.7866E+02 & -0.6123E+00 & -8.3666E+00 \\ & 0.4310E-03 & 0.6013E-02 \\ & & 0.8794E-01 \end{bmatrix} = S_f$ | | |

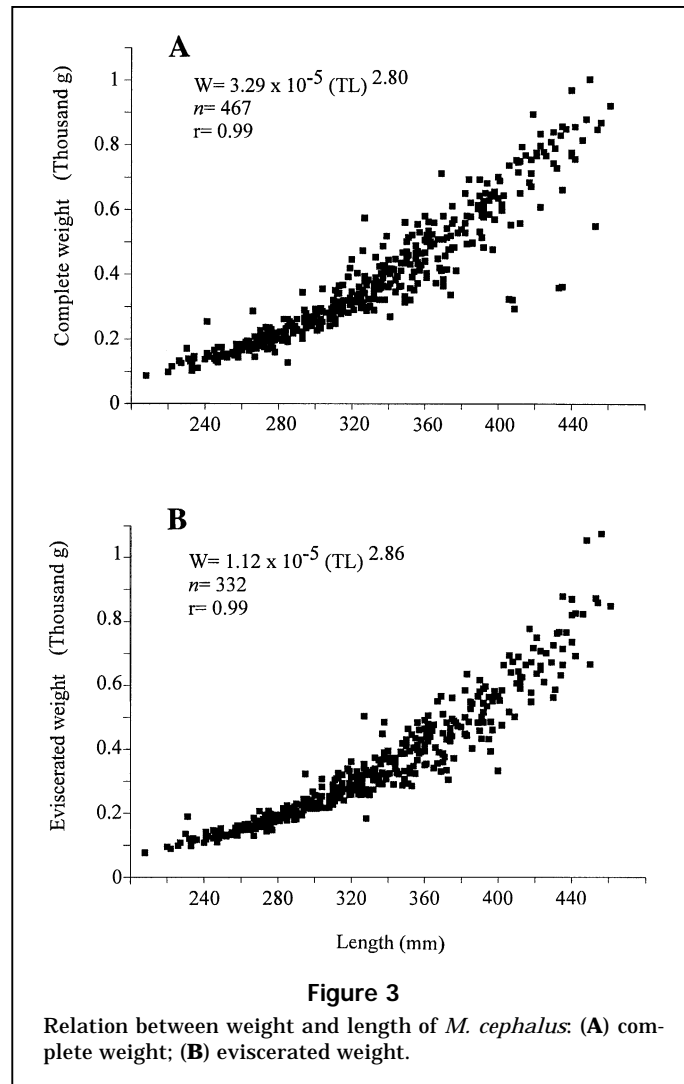
Table 5

Results of the multivariate test between measured growth of males and females from *M. cephalus* and *M. curema*. Entries include the variance-covariance matrix (S) and its inverse (/S), the calculated T^2 statistic, the tabular F and T^2 statistics.

| | | | | | |
|---|---|------------------------------|--|--|--|
| <i>Mugil cephalus</i> | | | | | |
| $\begin{bmatrix} 249.7833 & -0.08662 & -0.94189 \\ & 0.000031 & 0.000344 \\ & & 0.004265 \end{bmatrix} = S$ | $\begin{bmatrix} 0.29749 & 1074.014 & -20.9378 \\ & 4216597 & -102946 \\ & & 3914.545 \end{bmatrix} = /S$ | | | | |
| $[-50 \quad 0.0097 \quad -0.12] = [P_m - P_f]'$ | | | | | |
| $T^2 = 8928.135^{**}$ | $T^2_{0.01; 3, 245} \cong 11.79551$ | $F_{0.01; 3, 245} \cong 3.9$ | | | |
| <i>Mugil curema</i> | | | | | |
| $\begin{bmatrix} 795.2974 & -0.7018 & -7.94817 \\ & 0.000293 & 0.007448 \\ & & 0.090049 \end{bmatrix} = S$ | $\begin{bmatrix} 0.010014 & -1.37597 & 0.99771 \\ & -2904.87 & 118.8114 \\ & & 89.34055 \end{bmatrix} = /S$ | | | | |
| $[-42.8 \quad 0.052 \quad 0.914] = [P_m - P_f]'$ | | | | | |
| $T^2 = 1843.808^{**}$ | $T^2_{0.01; 3, 305} \cong 11.77672$ | $F_{0.01; 3, 305} \cong 3.9$ | | | |

The values of the parameters of the von Bertalanffy growth equation for *M. cephalus* in different areas are also shown in Table 6. The values of k are higher for the coastal lagoons, whereas the L_{∞} values are lower in relation to those obtained for the marine areas; all these differences are important even in areas that are very close (Kesteven, 1942; Thomson, 1951, 1963). Thomson (1951) and Broadhead (1953) found impor-

tant variations in *M. cephalus* populations in adjacent estuaries; these differences can be explained because of the populational density and abundance of food. On the other hand, Oren (1981) showed that mugilids, because of the accessibility of the lagoons to the sea, can emigrate to the sea at least once per year and mix with other nearby populations. This exodus decreases the amount of local variation in local growth rates.

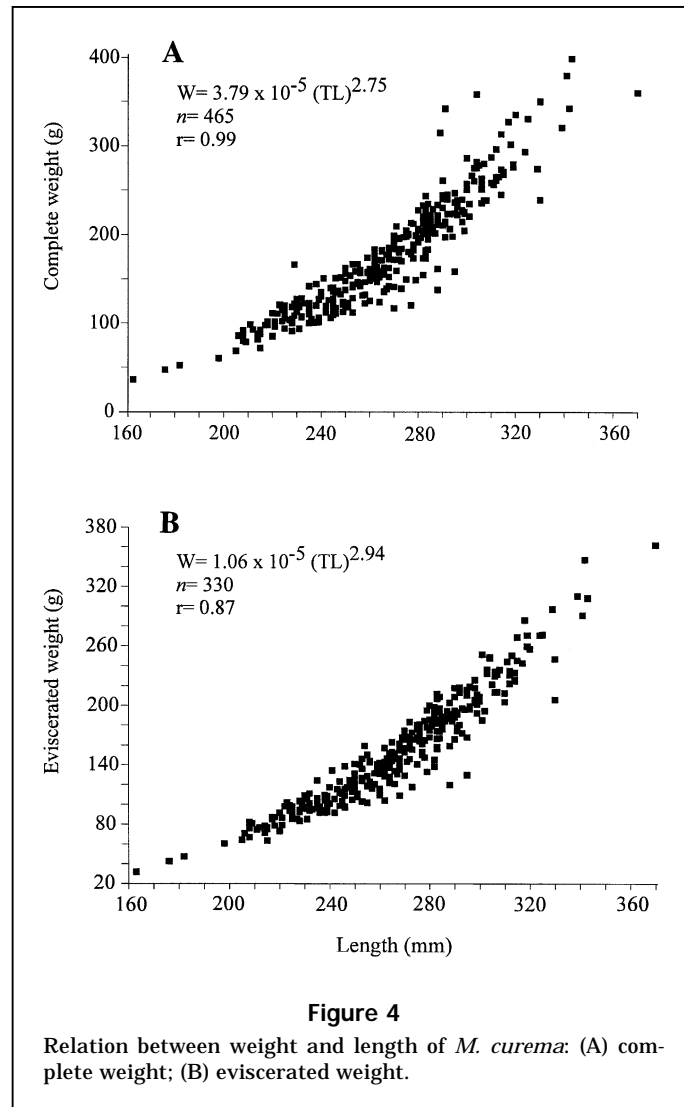


Finally, it is important to take into account that differences between growth rates are important even in areas that are very close; these differences could be explained by the different methods applied for age determination (Oren, 1981); however, these differences could be also explained by the world-wide distribution of this species and its different survival strategies. On the other hand, the differences between growth rates can also occur because of commercial exploitation, for when fishing is very intense, the commercial size of fish decreases and the variations of the k coefficient increase.

The values of the parameters of the von Bertalanffy growth equation for *M. curema* in different areas are shown in Table 7. In our paper, the value of k calculated for *M. curema* shows a higher position in relation to the value proposed by Alvarez (1979) and the value of L_{∞} is higher in Cuba. On the other hand, the

values of k obtained by Richards and Castagna (1976) in Virginia and by Phillips et al. (1987) in the Nicoya Gulf of Costa Rica show a higher position in relation to the k value obtained in our paper.

For the relation of growth between sexes, some authors have shown that there are no differences between sexes: for *M. cephalus*, Dannevig (1902); Kesteven (1942); Thomson (1951); Morovic (1957); Erman (1959); Thakur (1967); Cech and Wohlschlage (1975); Grant and Spain (1975); for *M. curema*, Alvarez (1979) and Angell (1973). On the other hand, Ezzat (1965), Brulhet (1974; 1975), and Farrugio (1975) have stated that there are differences in the growth between sexes. However, these latter authors did not infer whether these differences in the growth between sexes are significant or not from a statistical point of view. For this reason, a statistical test to compare the growth curves between sexes was



applied in our study (Tables 4 and 5); the results show that there are significant differences in growth between males and females for *M. cephalus* and *M. curema*. Oren (1981) mentioned: "sometimes the females grow slightly faster (Thomson, 1951; Hickling, 1970); Cech and Wohlschlag, 1975), live longer than the males (Thomson, 1951) or at least are predominant among older fish (Hickling, 1970)."

In general, the values of the relationship between length and weight obtained in our study are very similar to those expressed by other authors for coastal lagoons and marine areas. The results obtained for *M. cephalus* are similar to those shown by Kesteven (1942), Morovic (1954), Marquez (1974), Serbetis (1939), and Ezzat (1965). In the same way, the results obtained for *M. curema* are similar to those shown by Angell (1973) and Richards and Castagna (1976).

The longevity values for *M. cephalus* in different localities are given in Table 6. The highest values, 57.6 and 49.9 years, were found in the marine zones by Ilin (1949) in the Black Sea and Kesteven (1942) in Australia, respectively. The lowest values were obtained by Broadhead (1958), 3.7 for males and 4.5 years for females of this species in the marine zones, and by Heldt (1948), 4.6 years in coastal lagoons.

The values of longevity for *M. curema* in different areas are shown in the Table 7. The highest value was obtained by Alvarez (1979), 30 years in Cuba, and the lowest by Richards and Castagna (1976), 3.8 years in Virginia.

The longevity values obtained in the study, 28.3 and 18.7 years for *M. cephalus* and *M. curema*, respectively, showed an intermediate position in relation to the values found by other authors. In all cases, as Taylor (1958) has shown, the longevity and

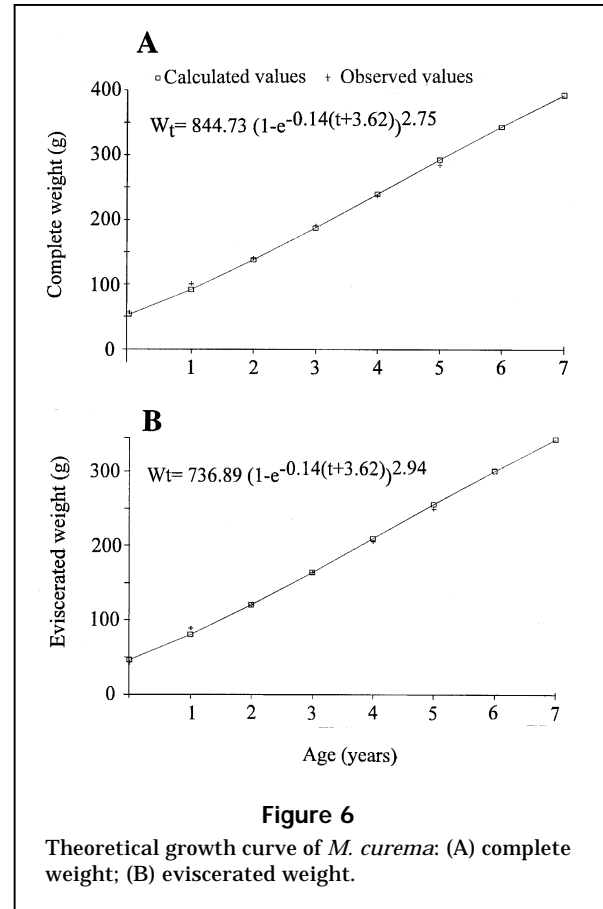
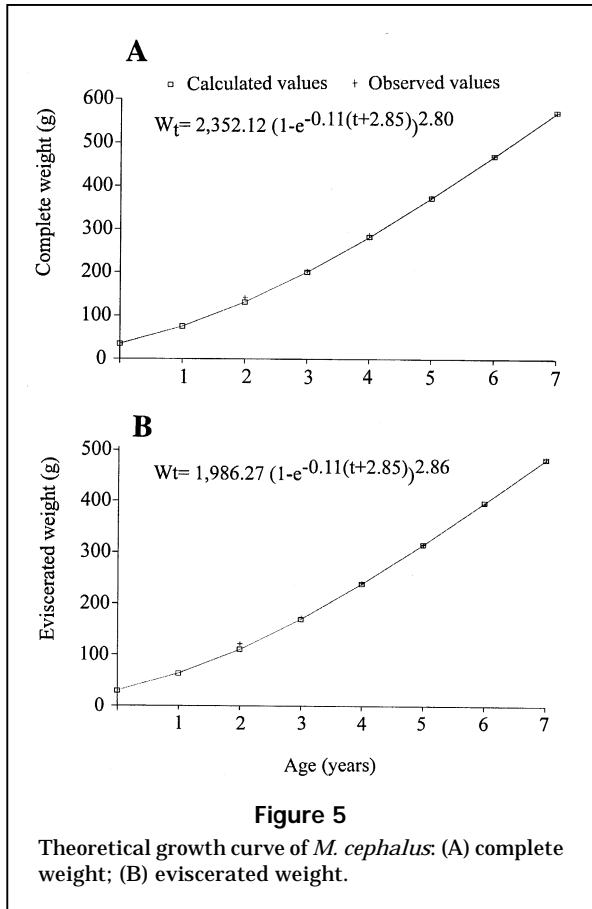


Table 6

Growth parameters of *M. cephalus* for the Gulf of Mexico and other localities. TL = total length, F = female, M = males, Sp. = species. This table was modified from Tables 5.4 and 5.5 in Oren (1981).

| Authority | Locality | Method | Length | Sex | L_{∞} | k | t_0 | $A_{0.95}^t$ |
|---------------------------|--------------------|----------------|--------|-----|--------------|------|--------|--------------|
| Gulf of Mexico | | | | | | | | |
| Coastal lagoons | | | | | | | | |
| This study | Tamiahua, Mexico | Otoliths | TL | F | 622.9 | 0.11 | -2.670 | 26.2 |
| | | Otoliths | TL | M | 603.9 | 0.11 | -2.979 | 26.5 |
| | | Otoliths | TL | Sp. | 642.4 | 0.10 | -2.850 | 28.3 |
| Marquez, 1974 | Tamiahua, Mexico | Scales | TL | Sp. | 510.0 | 0.34 | -0.114 | 8.8 |
| Diaz and Hernandez, 1980 | Tamaulipas, Mexico | Scales | TL | Sp. | 588.0 | 0.19 | -0.213 | 15.4 |
| Marine zones | | | | | | | | |
| Cech and Wohlschlag, 1975 | Texas, USA | Scales | TL | F | 407.0 | 0.32 | -0.710 | 9.4 |
| | | Scales | TL | Sp. | 450.0 | 0.24 | -0.900 | 12.5 |
| Broadhead, 1958 | N & NW Florida USA | Scales and tag | TL | F | 374.0 | 0.82 | -0.160 | 3.7 |
| | | Scales and tag | TL | M | 379.0 | 0.66 | -0.036 | 4.5 |
| Other localities | | | | | | | | |
| Marine zones | | | | | | | | |
| Ilin, 1949 | Black Sea | Scales | TL | Sp. | 1089.0 | 0.05 | -1.620 | 57.6 |
| Kesteven, 1942 | Australia | Scales | TL | Sp. | 1729.0 | 0.06 | -0.510 | 49.9 |
| Thompson, 1951 | West Australia | Scales | TL | Sp. | 609.0 | 0.30 | -0.143 | 10.0 |
| Thompson, 1963 | Australia | Scales | TL | Sp. | 727.0 | 0.23 | 0.006 | 13.1 |

continued

Table 6 (continued)

| Authority | Locality | Method | Length | Sex | L_{∞} | k | t_0 | $A_{0.95}^1$ |
|-------------------------|---------------------|----------|-----------------|-----|--------------|------|--------|--------------|
| Coastal lagoons | | | | | | | | |
| Romero and Castro, 1983 | Chiapas, Mexico | Scales | TL ² | Sp. | 458.5 | 0.21 | -1.770 | 14.4 |
| Ezzat, 1964 | France | Otoliths | TL | Sp. | 417.7 | 0.47 | -0.169 | 6.4 |
| Serbetis, 1939 | Rome, Italy | Scales | TL | Sp. | 563.0 | 0.56 | 0.083 | 5.3 |
| Morovic, 1954 | Venice, Italy | Scales | TL | Sp. | 611.0 | 0.21 | -0.465 | 14.3 |
| Alessio, 1976 | Orbetello, Italy | Scales | TL | Sp. | 615.0 | 0.40 | -0.044 | 7.5 |
| Morovic, 1957 | Vransko, Yugoslavia | Scales | TL | Sp. | 590.0 | 0.23 | -0.083 | 12.8 |
| Heldt, 1948 | Tunisia | Scales | TL | Sp. | 620.4 | 0.65 | -0.048 | 4.6 |
| Farrugio, 1975 | Tunisia | Scales | TL | Sp. | 693.0 | 0.19 | -0.630 | 15.8 |

¹ These values of longevity were obtained in our study by the application of the Taylor method (1958) to the growth parameters given by the authors mentioned in this table.

² For the conversion from standard length to TL, the equation given by Thompson et al. (1991) was used.

Table 7

Growth parameters of *M. curema* for other localities.

| Authority | Locality | Method | Length | Sex | L_{∞} | k | t_0 | $A_{0.95}^1$ |
|-----------------------------|------------------|--------------|-----------------|-----|--------------|------|--------|--------------|
| This study | Tamiahua, Mexico | Otoliths | TL | F | 454.6 | 0.14 | -3.900 | 19.2 |
| | | Otoliths | TL | M | 411.8 | 0.19 | -3.000 | 14.0 |
| | | Otoliths | TL | Sp. | 461.4 | 0.14 | -3.600 | 18.7 |
| Richards and Castagna, 1976 | Virginia, USA | ² | TL ³ | Sp. | 403.4 | 0.78 | -0.060 | 3.8 |
| Alvarez, 1979 | La Habana, Cuba | Spine | TL | Sp. | 532.0 | 0.10 | -5.900 | 30.0 |
| Phillips et al., 1987 | Costa Rica | ² | TL | Sp. | 432.0 | 0.60 | -0.244 | 5.0 |

¹ These values of longevity were obtained in our study by the application of the Taylor method (1958) to the growth parameters given by the authors mentioned in this table.

² = method not indicated.

³ For the conversion from fork length to TL, the equation given by Thompson et al. (1991) was used.

L_{∞} show an inversely proportional relation to the k coefficient.

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