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Historical estimates of curvina (*Cynoscion acoupa*) growth and mortality parameters in Lake Maracaibo, Venezuela

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Abstract

This paper addressed the historical trend in growth and mortality parameters of curvina (*Cynoscion acoupa*) in Lake Maracaibo based on data from artisanal commercial fisheries collected in 1969-1970, 1985-1986 and 2009. Mean total length ($\overline{TL}$) of captures of curvina diminished 31 per cent in 25 years ($\overline{TL} \pm sd_{1969-1970} = 49.0 \pm 3.9$ cm TL; $\overline{TL} \pm sd_{1985-1986} = 48.7 \pm 4.1$ cm TL; $\overline{TL} \pm sd_{2009} = 33.7 \pm 7.57$ cm TL), indicating that the fishery was sustained by juveniles and preadults (length of first maturity = 40 cm TL). Although natural mortality (M) remained constant between 1985-1986 and 2009 ($M_{1985-1986} = 0.53$ year^{-1}; $M_{2009} = 0.56$ year^{-1}), the significant increasing of fishing mortality (F) ($F_{1985-1986} = 0.58$ year^{-1}; $F_{2009} = 3.76$ year^{-1}) corroborated that the fishing intensity exerted in the zone was high. Mesh size lesser than 8.89 cm should be banned from the curvina fishery to ensure that fish have spawned at least once before being caught. This would avoid curvina recruitment overfishing.

Keywords: curvina, growth, mortality, Lake Maracaibo, Venezuela.

Estimados históricos de parámetros de crecimiento y mortalidad de la curvina (C*ynoscion acoupa*) en el Lago de Maracaibo, Venezuela

Resumen

Este trabajo evaluó la tendencia histórica de parámetros de crecimiento y mortalidad de la curvina (*Cynoscion acoupa*) en el Lago de Maracaibo a través de datos obtenidos de las pesquerías artesanales comerciales en 1969-1970, 1985-1986 y 2009. La longitud total promedio ($\overline{LT}$) de las capturas de curvina disminuyó 31 por ciento en 25 años ($\overline{LT} \pm de_{1969-1970} = 49{,}0 \pm 3{,}9$ cm LT; $\overline{LT} \pm de_{1985-1986} = 48{,}7 \pm 4{,}1$ cm LT; $\overline{LT} \pm de_{2009} = 33{,}7 \pm 7{,}57$ cm LT), indicando que la pesquería era sostenida por juveniles y pre-adultos (longitud de primera madurez sexual = 40 cm LT). Aunque la mortalidad natural (M) permaneció constante entre 1985-1986 y 2009 ($M_{1985-1986} = 0{,}53$ año^{-1}; $M_{2009} = 0{,}56$ año^{-1}), el aumento significativo de la mortalidad por pesca (F) ($F_{1985-1986} = 0{,}58$ año^{-1}; $F_{2009} = 3{,}76$ año^{-1}) corroboró que la intensidad de pesca ejercida en la zona fue alta. Deberían prohibirse los tamaños de malla menores que 8,89 cm para la pesca de la curvina para asegurar

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que los peces hayan desovado al menos una vez antes de ser capturados. Esto evitaría la sobrepesca por reclutamiento de la curvina.

Palabras clave: curvina, crecimiento, mortalidad, Lago de Maracaibo, Venezuela.

Introduction

The commercial artisanal fishery for curvina (*Cynoscion acoupa*) has been operating in Lake Maracaibo, Venezuela for many years. Annual landing for this fishery may have reached 18,000 metric tons in the 1960s and 1970s, but it has shown a sharp declining trend since then, in part due to heavy fishing by small mesh gillnets (1). Nevertheless, this species is still one of the most important fishery resources in Lake Maracaibo, with annual catches of approximately 4000 metric tons. Commercial artisanal fishers in Lake Maracaibo catch curvina primarily with gillnets of 6.35 to 12.7 cm stretched mesh size as well as with hook-and-line (2), although the hook-and-line fishery has almost disappeared.

Curvina has not received enough attention from the Venezuelan scientific community. Only Ferrer Montaño (1), de Espinosa (2-3), Lorenzo and de Lorenzo (4), and Goncalves (5) have been reported on the biology and fishery of curvina. Age, growth and mortality have been studied by de Espinosa (2), who estimated the parameters of the von Bertalanffy growth function (VBGF) from lengths-at-age backcalculated from scales. Estimates of growth parameters and rates of mortality are not only necessary for implementing most fishery management strategies, but for testing life history hypotheses as well (6) and for empirical estimation of parameters of biological and fishery interest such as length at first maturity and maximum yield-per-recruit (7).

The objective of this study was to address the historical trend in growth and mortality parameters of curvina in Lake Maracaibo based mostly on fishery-dependent data from artisanal commercial fisheries surveys. This time series comprised information published by de Espinosa (2) (from now on DE), unpublished data collected between 1985 and 1986 by the senior author (from now on OJFM), and data collected between February and July 2009 by the junior author (from now on ICM). The goal of addressing trends in growth and mortality parameters is to look for evidence of mid- and long-term changes in key fishery parameters needed for implementing future management plans. Results of time series fishery parameters for the same area may be useful, since population parameters vary according to differences in environmental conditions and fishing intensity (8, 9).

Materials and methods

Study site

Lake Maracaibo (figure 1) is a coupled ocean-lake system connected through a partially mixed estuary, located on the Caribbean coast of Venezuela (10). The whole Lake Maracaibo system is a complex of several interacting bodies of water: Gulf of Venezuela, El Tablazo Bay, the Strait of Maracaibo, the Lake itself and many streams and rivers. A navigational channel that reaches depths of 18 m crosses the system from the Gulf to the Lake. There is an extensive mangrove system in the northern part of the Lake and a substantial fluvial input in the southern part. The rain regime has a pronounced peak during the second half of the year. At that time most of the Lake exhibits freshwater conditions caused by rain runoff. The surface water salinity throughout the Lake fluctuates strongly.

Samplings were conducted in El Tablazo Bay. This bay is influenced by tides, and near the sampling area salinity generally ranges from 10 to 28 PSU and temperature ranges from 26 to 30 °C. The study area

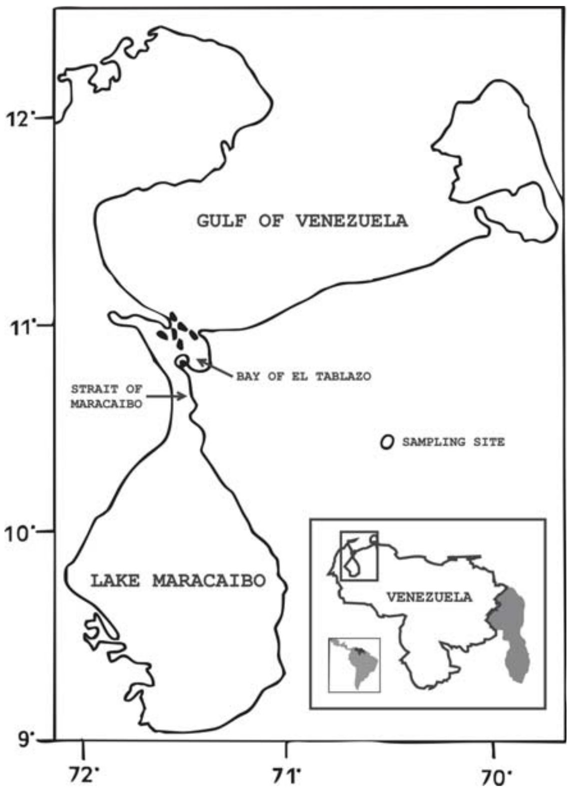

Figure 1. Sampling area and its relative position on the Venezuelan coast. Circle represents the sampling sites.

has a maximum depth of 12 m at mean low water and its substrates are primarily fine sand and mud.

Data collection and analysis

Fish were collected from the commercial artisanal fishery in Sabaneta de Palmas and Punta de Palmas, two small towns located in El Tablazo Bay. These towns have been traditional landing sites for the artisanal fishery fleet and most studies on the fishery of curvina in Lake Maracaibo obtained samples there. The fishery in these sites targets stocks of curvina residing in El Tablazo Bay fishing grounds.

In 1972, DE estimated the VBGF for curvina analyzing growth rings in scales collected between October-December 1969 (N = 111), January-May 1970 (N = 155), July 1970 (N = 6) and September 1970 (N = 30). Scales were obtained from the left side of specimens in the area between the lateral line and the first dorsal fin. Location and time of formation of the growth rings were validated using methodologies proposed by Klima and Tabb (11), Tabb (12) and Larrañeta (13). For determining and interpreting age groups from growth rings, DE used a lineal regression analysis using the least squares method. The Walford method (14) was used for estimating the VBGF parameters: $L_t = L_\infty [1 - e^{-k(t-t0)}]$, where L_t is the length (cm) at time t, L_∞ is the theoretical maximum length (cm) a fish can obtain if it lived indefinitely, k is the growth coefficient (year^{-1}), and t_0 is the hypothetical time (year) when length equals zero. Age frequencies were converted to frequency percentages and plotted against ages to estimate Z (year^{-1}) applying linear regression analysis on points above full recruitment. All fish recorded by DE were caught either with gillnets or with hook-and-line. Gillnets used to fish curvina were made with a 3.5-5.0 inches mesh. The hook-and-line fishery generally used a number eight hook, with fresh bait consisting of *Gobioides broussonetti* and, occasionally, shrimp (2); DE collected most of his samples in landing sites and supplemented it with others obtained directly by experimental fishing.

Between May 1985 and April 1986, OJFM collected data on board fishing boats weekly for assessing stocks of curvina. All fish were measured for total length (cm). Samples were pooled by month and given a single mid-month date. Length frequency data were analyzed with FISAT II. Powell-Wetherall plots (15-16) were first constructed to estimate L_∞; then the Shepherd's (17) method was used to scan k values using the above L_∞ and to conduct a response surface analysis and select the k and L_∞ values resulting in the greatest Rn (goodness-of-fit index). Finally, the generated k and L_∞ values were input into ELEFAN I (18) to generate a VBGF. If the curve generated by the

VBGF did not appear to fit the data, the values of the input parameters were modified and the analysis was rerun. An automated search routine option in ELEFAN I was also used to let the computer find the best combination of parameters (best fit of the curve = greatest Rn).

Among all of the obtained estimates from the different methods, the ELEFAN I values were selected as the most appropriate due to this subroutine offers the most options (i. e., k-scan, response surface, and automatic search) to estimate the VBGF parameters. Bias associated with size selectivity of gill nets was corrected by using mesh selectivity curves developed from length-girth relationships for curvina in Lake Maracaibo by Ferrer Montaño (1).

Natural mortality (year^{-1}) was estimated using Pauly's (19) equation: LnM = –0.0152 – 0.279Ln (L_∞) + 0.6543Ln (k) + 0.463Ln (T), where Ln = natural logarithm, M = natural mortality rate, L_∞ = von Bertalanffy's asymptotic length, k = von Bertalanffy's growth coefficient and T = mean water temperature (°C) for the sampling area. Water temperature was measured during each sampling period with an YSI model 57 oxygen meter. The length converted catch curve (20-21) was used for estimating Z (year^{-1}). Fishing mortality (year^{-1}) was estimated from Z = F + M.

Finally, ICM collected data in landing sites weekly between February and July 2009 as part of a broad project intended to assess the fisheries in Lake Maracaibo. These data were analyzed with the same techniques used by OJFM. Analyses of length frequency by OJFM and ICM were applied to data for combined sexes because fish were eviscerated at the moment of recording. All fish recorded by OJFM and ICM were caught with gillnets 2.5-5.0 inches mesh. Given that water temperature was not recorded by ICM, the same temperatures recorded by OJFM were used in this analysis.

Results

Size structure

The curvina size structure reported by DE based on 19,049 (gillnets: N = 11,836; hook-and-line: N = 6,371) recorded specimens ranged between 22.5 and 97.5 cm TL ($\overline{TL}$ ± sd = 49.0 ± 3.9 cm TL; sd = standard deviation). The modal group was 40.0 cm TL. On the other hand, the length range reported by OJFM was between 31.0 and 95.0 cm TL (N = 4,811; $\overline{TL}$ ± sd = 48.7 ± 4.1 cm TL) and the modal group was 45.0 cm TL. Finally, ICM recorded 3,373 specimens with a range of length between 26.3 and 48.8 cm TL ($\overline{TL}$ ± sd = 33.7 ± 7.57 cm TL) and a modal group of 31.0 cm TL.

Age and growth

Total length at the end of each year for data from DE was calculated with the equation TL = -58.5 + 105.5 *R* (where *R* = average distance between the focus and the ring corresponding to each age; R^2 = 0.98; *P* = 0.01). From this equation, DE calculated the length corresponding to each group of age, which in turn was used to obtain the parameters of the VBGF through the Walford method. The VBGF reported by DE was $L_t = 105.5\ [1 - e^{-0.27(t\ -\ 0.21)}]$. This equation predicted that curvina obtained 53 per cent of its asymptotic length by age 3, and may reach age 8 and sizes greater than 95.0 cm TL; however, most fish were less than ages 4-5.

On the other hand, results for OJFM indicated that the automatic search routine generated the greatest Rn (0.265) for estimation of L_∞ and k; L_∞ = 98.1 cm TL and k = 0.26 year^{-1}. From this, the VBGF generated was $L_t = 98.1\ (1 - e^{-0.26t})$. Predicted lengths for this equation for fish between ages 1 and 3 were 22.5 cm TL, 39.8 cm TL and 53.1 cm TL. According to this equation, curvina obtained 54.1 per cent of its asymptotic length at age 3. figure 2 shows the VBGF generated by ELEFAN I. In the case of ICM, the automatic search routine also generated the

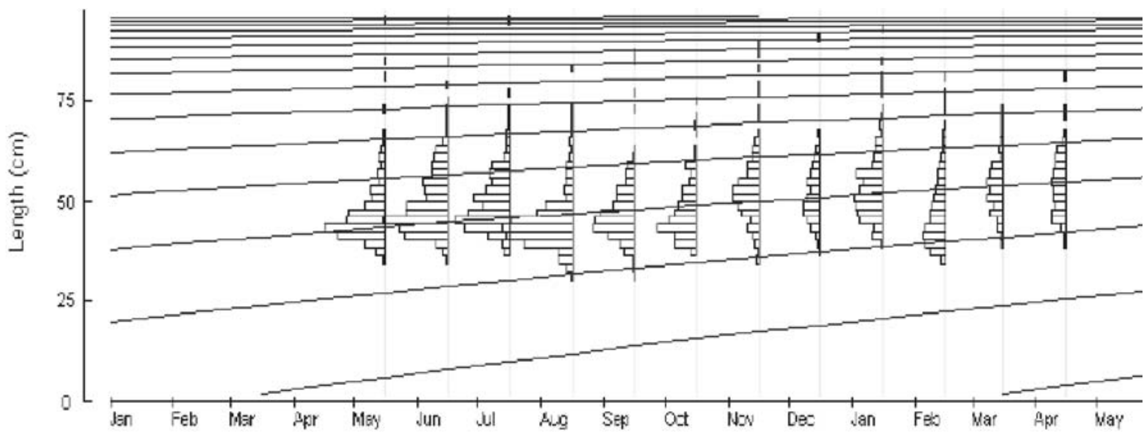

Figure 2. Length frequency distribution and fitted growth curve (parameters: L_∞ = 98.1 cm TL; k = 0.26 year^{-1}; Rn = 0.265) found by the automatic search routine from ELEFAN I for curvina, *Cynoscion acoupa*, from Lake Maracaibo for data from OJFM collected between May 1985 and April 1986.

greatest Rn (0.443). The VBGF generated was $L_t = 80.0\ (1 - e^{-0.26t})$. According to this equation, curvina obtained 54.1 per cent of its asymptotic length at age 3. figure 3 shows the VBGF generated by ELEFAN I.

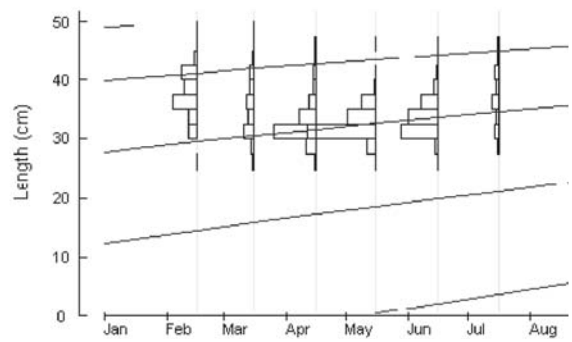

Figure 3. Length frequency distribution and fitted growth curve (parameters: L_∞ = 80.0 cm TL; k = 0.26 year^{-1}; Rn = 0.443) found by the automatic search routine from ELEFAN I for curvina, *Cynoscion acoupa*, from Lake Maracaibo for data from ICM collected between February and July 2009.

Mortality

Total mortality reported by DE, Z = 1.17 year^{-1}, did not differ from that reported by OJFM (Z = 1.23 year^{-1}; figure 4). In contrast with these results, however, results of ICM indicated that Z has increased significantly (Z = 3.76 year^{-1}; figure 5) in the last years. Natural mortality for OJFM, M = 0.53 year^{-1}, did not differ from the result of ICM (M = 0.56 year^{-1}); in both cases, calculus assumed a mean water temperature of 28 °C. Fishing mortality for OJFM was F = 0.58 year^{-1}, whereas ICM obtained a greater value of F = 3.20 year^{-1}; DE did not report any F value.

Discussion

All analyses performed in this investigation confirm that growth and mortality parameters of curvina from Lake Maracaibo have changed over time; L_∞ has decreased and Z and F have increased dramatically. This decreasing of L_∞ is not just a result of differences between methods of analysis applied, but it has occurred simultaneously with a diminishing in the length frequencies of captures, which in turn implies that most individuals have not spawned at least once. This decreasing is not new, however, because de Espinosa (2) already indicated… *the length of the fish caught is decreasing, or*

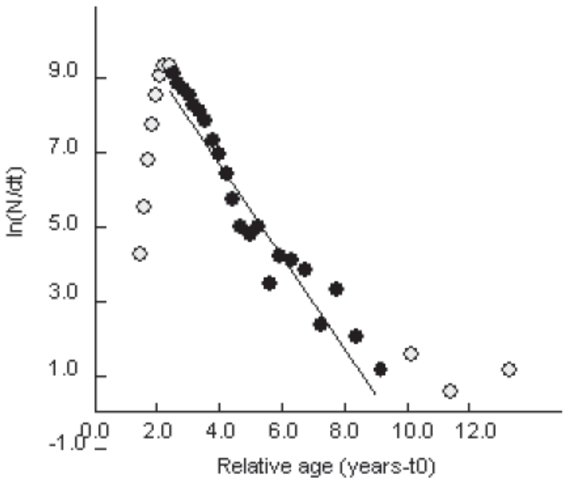

Figure 4. Catch curve analysis applied to data from OJFM collected between May 1985 and April 1986. Using the von Bertalanffy growth parameters L_∞ = 98.1 cm TL and k = 0.26 year^{-1} for fixed values of zero for C and WP yields an estimate of Z = 1.23 year^{-1}, CI: [(–1.08) – (–1.4)], R^2 = 0.936. Clear circles were not used in the analysis. CI = 95% confidence interval.

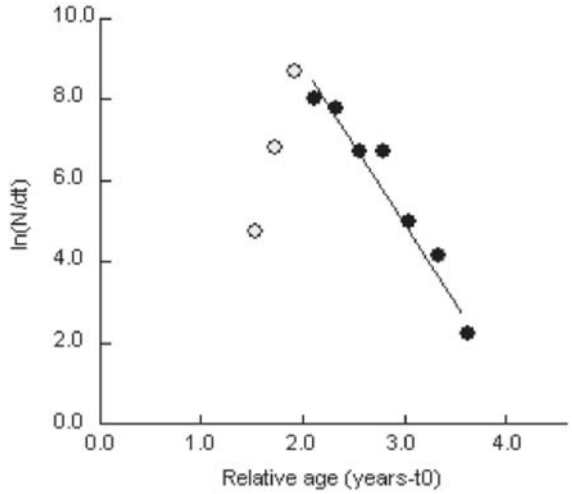

Figure 5. Catch curve analysis applied to data from ICM collected between February and July 2009. Using the von Bertalanffy growth parameters L_∞ = 80.0 cm TL and k = 0.26 year^{-1} for fixed values of zero for C and WP yields an estimate of Z = 3.76 year^{-1}, CI: [(–4.72) – (–2.81)], R^2 = 0.953. Clear circles were not used in the analysis. CI = 95% confidence interval.

at least it is so claimed by the fisherman interviewed by the author, which would be an indication of an over-exploitation, or rather, an inefficient exploitation of that resource, since it would show that the volume of the catches is being increased at the expense of the number of specimens caught…

On the other hand, Z increased significantly in the last few years, indicating that the fishing intensity in the study area was high. Even though M remained constant between 1985-1986 (OJFM) and 2009 (ICM), the significant increase in Z is a product of the increasing in the fishing mortality; corroborating, once again, that the fishing intensity exerted in the study area was high.

Despite reports of large fish before (2, 4), curvina larger than 60 cm TL (about age 3) appear to be uncommon in Lake Maracaibo currently. Therefore, the greater proportions of younger curvina support major commercial fisheries in the study area. Now, the question that arises is: how to manage curvina stocks in a way that it will increase the number of available fish to fishers in the short- or middle-term? Furthermore, what regulatory measures are required to maintain a certain length- or age-frequency distribution? Two strategies can be suggested: 1) to regulate the current fishing gears (indirectly stating a minimum length of catch) or 2) to reduce the fishing effort. While we found it difficult to reduce the fishing effort under the current social conditions of fishers of the Lake Maracaibo basin, regulation of fishing gears seems to be most appropriate. We propose banning fishing gears with mesh size lesser than 8.89 cm (3.5 inches) from the curvina fishery to ensure that fish have spawned at least once before being caught (2).

We consider appropriate to establish the length of first maturity for both sexes (40 cm TL) (1-2) as a size limit for the fishery of curvina in Lake Maracaibo. A gillnet mesh size that would be most effective in capturing this size of curvina is 10.06 cm (4 inches). This net is moderately efficient compared to other nets and has a selective length range between 41 and 52 cm TL (1). The curvina management strategy proposed here is based on protecting the sexually mature animals while making the most efficient use of the remaining population. This strategy will allow continued replacement of the population through natural reproductive processes.

The long-term effects of this approach would be to slowly increase the number of young and ultimately the number of harvestable fish. An important consideration is that curvina is a single species fishery, so an increase in mesh size to harvest this species will not affect other fisheries. This management approach can be monitored by analyses of harvest data.

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