Aspects of the population dynamics of *Clarias agboyiensis* (Osteichthyes, Clariidae) from a West African river basin

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Aspects of the population dynamics of Clarias agboyiensis *(Osteichthyes, Clariidae) from a West African river basin.*– The parameters of population dynamics of the West African catfish, *Clarias agboyiensis*, were estimated for the first time based on the length-frequency data of samples from the Anambra River basin, Nigeria. Length-weight relationship with a b-value of 2.9502 showed no significant difference from isometric growth. Maximum size (l_{max}) and longevity (t_{max}) were 29 cm TL and 4 yr respectively. Estimated Von Bertalanffy growth parameters were: L_4 = 39.1 cm TL, W_4 = 403.4 g, K = 0.8 yr^{1} and t_0 = - 0.19 yr. The length growth performance index (N' = 3.09) indicated high growth impetus, showing that the catfish has a high aquacultural potential. Sexual maturity occurred at between 22.2 and 24.1 cm TL as the fish attained 1.2 yr. Mortality estimates were: Z = 10.79 yr^{-1}, M = 1.50 yr^{-1} and F = 9.29 yr^{-1}. The high fishing mortality coefficient (F) and exploitation ratio (E = 0.86) indicated over-exploitation of *C. agboyiensis*. Management and conservation strategies have been designed and established to avoid a possible collapse of the fishery.

Key words: *Clarias agboyiensis*, Growth, Mortality, Exploitation, Management, Nigeria.

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Introduction

Several *Clarias* species are endemic (Teugels, 1982) and of commercial importance in the freshwater artisanal fisheries of the forest zone of West Africa, from Ghana to Nigeria. One of these is *Clarias agboyiensis* Sydenham, 1980 which occurs in both the Guinean and Sudanean regions of Nigeria (Sydenham, 1980; Ezenwaji, 1986). This species is widely distributed and abundant in the Anambra River basin (Ezenwaji, 1993).

In recent years, the fishing pressure on *Clarias* species in the basin has intensified and *C. agboyiensis* appears to have declined in size (pers. obs.) indicating overexploitation. The present study is primarily aimed at investigating this hypothesis. Parameters of population dynamics are provided and strategies for the management of the species in the Anambra River basin are formulated.

Material and methods

Study Area

The study was carried out in the Anambra River basin, Nigeria (fig. 1). The Anambra River, about 207.4 km in length, has many tributaries, the most important being the Ezu/Adada complex. An internal delta occurs around Ogurugu and the extensive floodplain, 40 km wide in the lower reaches, has numerous perennial ponds, lakes and marshes. These floodplain lentic water bodies, especially the small-sized (< 500 m^2) and medium-sized (≤ 5000 m^2) ponds/lakes (Welcomme, 1985), are the most important habitats for *C. agboyiensis* (Ezenwaji, 1993).

The vegetation in the basin is derived from the Guinea savannah but riparian shrubs and forests, described by Ezenwaji (1998), fringe the water bodies.

The two main seasons are the dry season (October/November–March) and the rainy season (April–September/October). Large quantities of *C. agboyiensis* are harvested from floodplain ponds, which are often fished out during the dry season, apparently resulting in a steady reduction in the overall size attained by the species.

Sampling locations and processing of samples

Samples of the catfish were collected from six sampling locations –Nsugbe, Otuocha, Oroma-etiti, Enugwu-otu, Ogurugu and Ugwuoba– in the Anambra River basin, Nigeria (fig. 1) from June, 1983 to September, 1985 and June to September, 1986. Sampling gears include 200 baited hooks (Willoughby & Tweddle, 1977), baskets and traps. Sampling was carried out in four major habitats (forest floodplain pond, grassland floodplain pond, marshy area and river) in each sampling location. Samples for the study period were pooled together.

Standard and total lengths (cm) and body weight (g) of each catfish were measured and the sex of fish determined. The total length-standard length, and length-weight relationships were determined using the power curve:

$$W = aTL^b \qquad (1)$$

The length-frequency data were grouped into 2 cm TL intervals. The length-based Powell-Wetherall method, especially suitable for situations where little or nothing is known about the fish stock (Sparre & Venema, 1992) as in this case, was employed in estimating the asymptotic length (L_∞) of the Von Bertalanffy growth function and the ratio of total mortality to growth coefficient (Z/K) from the linear relationship:

$$\bar{L} - L' = a + bL' \qquad (2)$$

Plotting $\bar{L} - L'$ against L' gave a linear regression from which a and b were estimated. From equation (2):

$$L_\infty = - (a / b) \qquad (3)$$

$$Z / K = - (1 + b) / b \qquad (4)$$

The growth coefficient (K) was estimated from Ursin (1984):

$$K = 0.27 \exp^{0.038T} \qquad (5)$$

where T = 27.5 °C (Ezenwaji, 1982).

The age-at-length zero (t_0) was derived from the empirical relationship of Pauly (1979):

$$Log(- t_0) = - 0.3922 - 0.2752 \, LogL_\infty - 1.038 \, LogK \qquad (6)$$

Length-at-age zero (l_0) was estimated according to Sparre & Venema (1992) as:

$$l_0 = L_\infty[1 - \exp^{(kt_0)}] \qquad (7)$$

The individual maximum size encountered was designated as l_{max}. Longevity (t_{max}) (Pauly, 1983) was computed as:

$$t_{max} = 3 / K \qquad (8)$$

The length (ϕ') (Pauly & Munro, 1984) and weight (P) (Pauly, 1979) growth performance

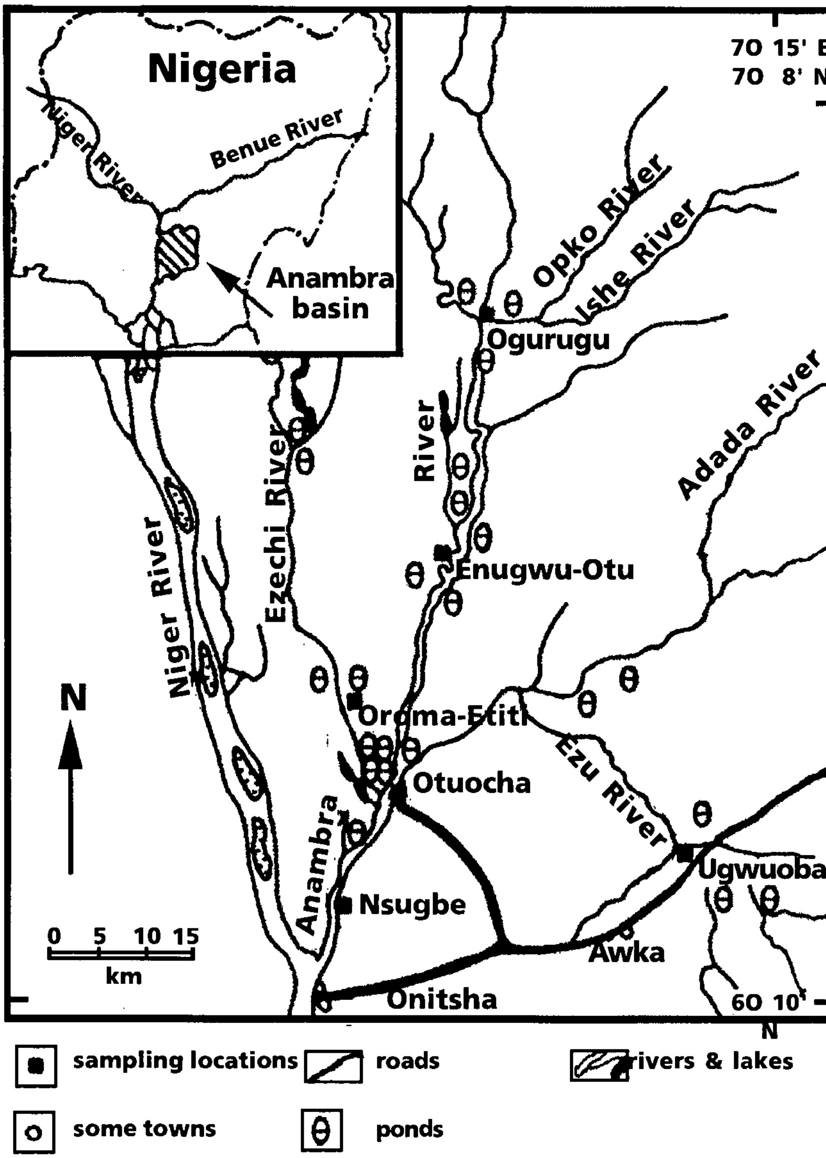

Fig. 1. Map of Anambra River basin showing sampling locations.
Mapa de la cuenca del río Anambra mostrando las localidades de muestreo.

indices were estimated respectively as:

$$\phi' = \log K + 2 \log L_\infty \quad (9)$$

$$P = \log(KW_\infty) \quad (10)$$

The length (l_m) (ROFF, 1986) and age (t_m) (ROFF, 1984) at sexual maturity were computed respectively as:

$$l_m = L_\infty [3K / (3K + M)] \quad (11)$$

$$t_m = (1 / K) \ln (3K + M) / M \quad (12)$$

Gonad maturation was evaluated macroscopically following AWACHIE & EZENWAJI

(1981) who recognized the following maturity stages for *Clarias* species: I–immature; II–developing; III–mature; IV-ripe; V-running and VI-spent. Size at maturity was estimated as the length at which 50% of individuals were in gonad stage III. Total mortality coefficient (Z) was computed from equation (4) by substitution. Natural mortality coefficient (M) (PAULY, 1983) was estimated using the empirical relationship:

$$\text{Log } M = 0.0066 - 0.279 \text{Log } L_\infty + 0.6543 \text{ LogK} + 0.4634 \text{ Log } T \quad (13)$$

where T = 27.5 °C (EZENWAJI, 1982)

The annual natural mortality rate (D) was estimated from ROYCE (1972):

$$D = (I - S)\ M / Z \quad (14)$$

where S = mean survival rate (i.e. e^{-z})

The fishing mortality coefficient (F) was computed as:

$$F = Z - M \quad (15)$$

The fishing mortality rate (E_i) was estimated from ROYCE (1972) as:

$$E_i = (I - S)\ F / Z \quad (16)$$

The exploitation ratio (E) was computed as:

$$E = F / Z \quad (17)$$

The Z test, with H_o: P = 0.5, was used to analyse sex ratio.

Results

Population Structure

The length-frequency distribution (fig. 2) of 1,136 specimens showed that the smallest and largest *C. agboyiensis* were 9 and 29 cm TL respectively (mean 17.8±6 cm TL). The 14 to 18 cm TL size range was dominant in the catches. The weight ranged between 5 and 178 g (mean 48±39.7 g). The ratio of male to female was not significantly different from 1:1 (table 1)(Z = 1.25, P > 0.05).

Morphometric relationships

The relationship between standard and total lengths ($TL = aSL^b$) of 112 *C. agboyiensis* was expressed by the following regression equation:

$$TL = 1.245\ S\ L^{0.965} \quad (18)$$

The correlation coefficient was positive and significant (r = 0.99, P < 0.05). The b-value was not different from 1 (P > 0.05). The length-weight relationship of the catfish ($W = aTL^b$) (fig. 3) was represented by the equation:

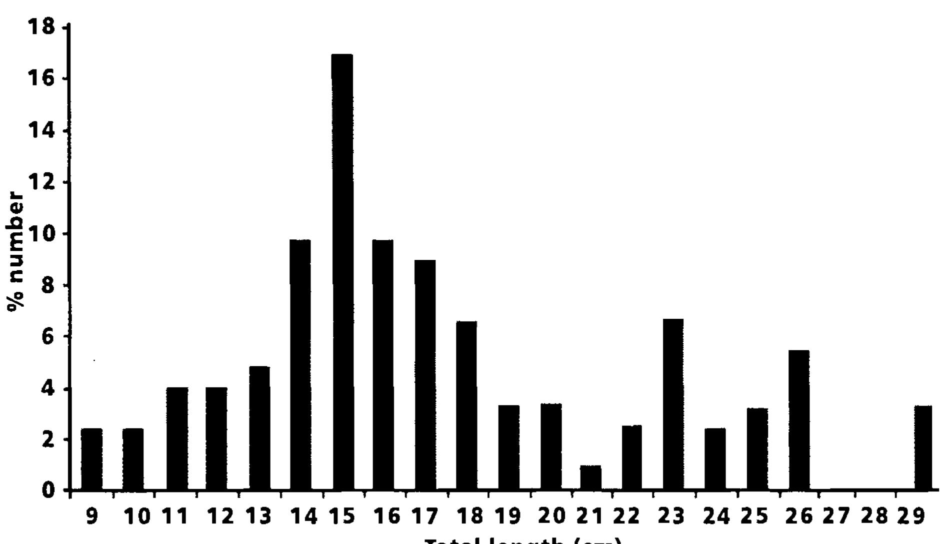

Fig. 2. The length-frequency distribution of *C. agboyiensis* in Anambra River basin.
Distribución de longitud-frecuencia de C. agboyiensis *en la cuenca del río Anambra.*

Table 1. The sex ratio of *C. agboyiensis* in Anambra River basin: N♂. Number of males collected; N♀. Number of females collected; S. sex ratio (♂:♀).

Relación de sexos de C. agboyiensis *en la cuenca del río Anambra: N♂. Número machos recogidos; N♀. Número de hembras recogidas; S. Proporción de sexos (♂:♀).*

Month	N♂	N♀	S
January	70	55	1:0.8
February	49	41	1:0.8
March	27	21	1:0.8
April	32	29	1:0.9
May	30	45	1:1.5
June	81	139	1:1.7
July	61	74	1:1.2
August	44	48	1:1.1
September	29	20	1:0.7
October	29	33	1:1.1
November	37	39	1:1.1
December	58	45	1:0.8
Total	547	589	1:1.1

$W = 8.1 \times 10^{-3}\ TL^{2.9502}$, $r = 0.99$, $P < 0.05$

Thus, about 98% of the variance in total length was explained by changes in weight. The b-value of 2.9502 did not differ significantly from 3 ($P > 0.05$) demonstrating isometric growth.

Population parameters

From the Powell-Wetherall method, $L_\infty = 39.1$ cm TL and by extrapolation from the length-weight regression equation, $W_\infty = 403.4$ g. Estimated K, t_0, t_{max} and l_0 were 0.8 yr^{-1}, -0.19 yr, 3.8 years (4 years) and 5.5 cm TL respectively. From these parameters, Von Bertalanffy length (L_t) and weight (W_t) growth functions were established:

$$L_t = 39.1\ [1 - \exp^{-0.80\ (t + 0.19)}] \quad (19)$$

$$W_t = 403.4\ [1 - \exp^{-0.80\ (t + 0.19)}] \quad (20)$$

Using ages 1 to 4 years as seed values, the mean lengths at age estimates were 24.0, 32.3, 36.1 and 37.7 cm TL. The resulting length growth curve (fig. 4) fitted the data well considering the correlation coefficient ($r = 0.98$). Very rapid growth took place in the first year and then decelerated considerably to a minimum in the fourth year. Length (ϕ') and weight (P) growth performance indices were 3.09 and 2.51 respectively, indicating high growth impetus.

The length (22.2 cm TL) at 50% maturity (fig. 5) was very close to the estimated length ($l_m = 24.1$ cm TL) at sexual maturity. Estimated length (l_m) and age ($t_m = 1.2$ yr) at sexual maturity represent 83.1% and 31.6% of l_{max} and t_{max} respectively. The relative maturity age (t_m/t_{max}) was 0.32.

From equation (4), $Z/K = 13.49$. Thus, $Z = 10.79$ yr^{-1}. Natural mortality coefficient ($M = 1.50$ yr^{-1}) and the annual mortality rate ($D = 0.139$ or 13.9% yr^{-1} of available fish stock) were low. Conversely, fishing mortality coefficient ($F = 9.29$ yr^{-1}) and the annual fishing rate ($E_i = 0.861$ yr^{-1} or 86.1% yr^{-1} of available stock) were high. The ratio of F/M (6.19) was also high.

The exploitation ratio (E) was 0.86.

Discussion

As there is apparently no previous study on the population dynamics of any member of the *Clarias (Clarioides)* complex in this region, the present study on *C. agboyiensis* cannot be accurately contrasted. However considering that the catfish is not a particularly small fish, the ratio, $(l_{max}/0.95)/L_\infty = 0.8$, and the asymptotic length ($L_\infty = 39.1$ cm TL) appear reasonable, especially as previous data obtained in November, 1979 presented an individual maximum size of 37.4 cm TL with a weight of 388.6 g (pers. obs.). The individual maximum size (29 cm TL) recorded in this study indicates that over the years the overall size of *C. agboyiensis* had diminished. However, it is still much larger than that (15.7 cm TL) reported by Sydenham (1980). This is perhaps a reflection of the environmental differences in the geographic locations of the individuals.

The values of the growth coefficient (K) and length growth performance index (ϕ') indicate that *C. agboyiensis* has a high

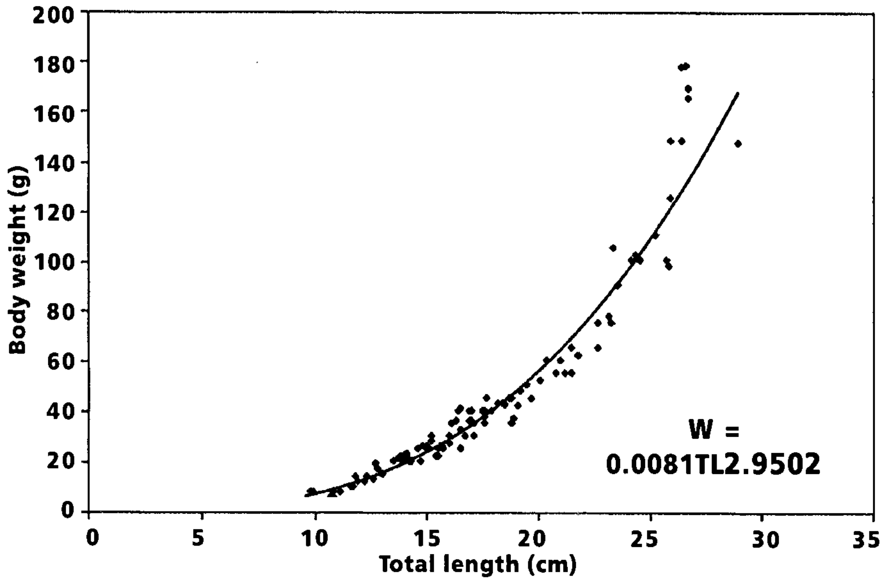

Fig. 3. The length-weight relationship of *C. agboyiensis* in Anambra River basin.
Relación longitud-peso de C. agboyiensis en la cuenca del río Anambra.

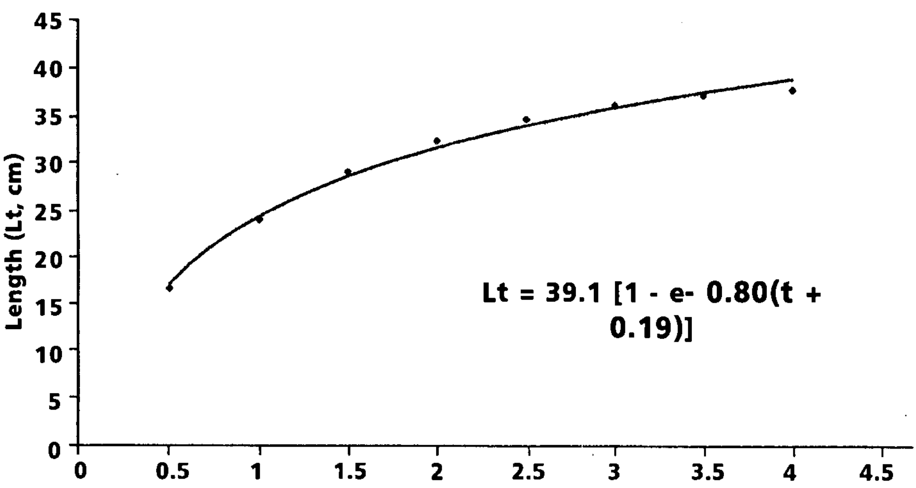

Fig. 4. The length growth curve of *C. agboyiensis* in Anambra River basin.
Curva de crecimiento en longitud de C. agboyiensis *en la cuenca del río Anambra.*

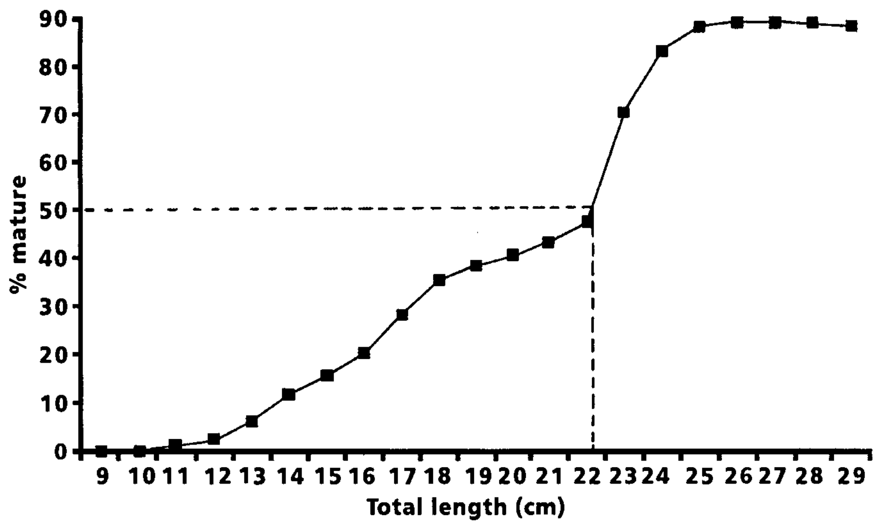

Fig. 5. Percentage of mature *C. agboyiensis* in relation to total length.
Porcentaje de C. agboyiensis *maduros en relación a la longitud total.*

growth performance, which is an index of high aquacultural potential. The ϕ' reported here is within the range reported for other siluriforms particularly schilbeids and bagrids (see KING, 1997 and related references therein).

EZENWAJI (1992) and EZENWAJI & INYANG (1998) have reported that the abundant and rich variety of fish food organisms enable *C. agboyiensis* and other *Clarias (Clarioides)* species in the Anambra River basin to grow fast and attain sexual maturity in about the first year of life. The close relationship between the length at 50% maturity and the estimated length at sexual maturity indicates that any of these methods could give a reasonable estimate of length at maturity in *C. agboyiensis*. Early sexual maturity is probably also a survival strategy (see NIKOLSKY, 1963) in response to the extremely low mean survival rate (2×10^{-5} yr^{-1}) for the species in the Anambra River basin. The latter is largely a consequence of the high fishing mortality which is clearly a dominant factor in total mortality. This contention is supported by the high ratio of F / M (6.19), annual fishing rate (E_i = 0.861 yr^{-1}) and exploitation ratio (E) of the species. The exploitation ratio of 0.86 is about 72% higher than the expected optimal yield (see GULLAND, 1971; KING, 1996). This shows that the stock of *C. agboyiensis* in the Anambra River basin is extremely over-fished. The high fishing mortality is easily appreciated considering that *C. agboyiensis* and other clariids in the Anambra River basin are concentrated in flood plain ponds and lentic water bodies which are usually fished out during the dry season (EZENWAJI, 1992, 1993; EZENWAJI & INYANG, 1998). As a result, only those in "*Clarias* reservoirs" (EZENWAJI, 1992) in the impenetrable marshes are often left to repopulate the basin. The low natural mortality is expected and perhaps enhances the perpetuation of the species. The prevalence of parasites in clariids in the Anambra River basin is low (EZENWAJI & ILOZUMBA, 1992) and predation by larger piscivores in the preferred habitats of *C. agboyiensis* and other *Clarias (Clarioides)* species is virtually non-existent (EZENWAJI, 1993; EZENWAJI & INYANG, 1998). Under the circumstance, the low natural mortality seems realistic.

Because *C. agboyiensis* is a popular species in the widespread semi-intensive fishing in the floodplain of Anambra River, its management and conservation require serious consideration to avoid a possible collapse of the fishery. In recognition of this, a management paradigm has been outlined (EZENWAJI & INYANG, 1998) and is being locally implemented. In addition, the catfish is conserved in unfished marshes in the potamon reaches of the Anambra River basin.

C. agboyiensis, like some temperate and tropical fish (O'HARA & PENCZAK, 1987; KING, 1991, 1996), exhibits both the r-selected (early reproduction, relatively short life span and rapid growth) and k-selected (low natural mortality rate) attributes in its life history. This type of life history strategy has perhaps evolved to aid survival of the catfish in the unpredictable environment, especially in the murky waters of the small-to medium-sized floodplain ponds, in which it thrives.

Resumen

Aspectos de la dinámica poblacional de Clarias agboyiensis *(Osteichthyes, Clariidae) de la cuenca de un río del oeste africano*

Se analizan por primera vez los parámetros de la dinámica poblacional del pez gato del oeste africano, *Clarias agboyiensis*, basándose en datos de longitud-frecuencia obtenidos en muestras de la cuenca del río Anambra, Nigeria (figs. 1, 2). En la relación longitud-peso el valor de b (b = 2,9502) no es significativamente diferente de 3, demostrándose que el crecimiento es isométrico (fig. 3). La talla máxima (l_{max}) y la longevidad máxima (t_{max}) fueron de 29 cm LT y 4 años respectivamente. Los parámetros para la estima del crecimiento de Von Bertalanffy fueron: L_∞ = 39,1 cm LT, W_∞ = 403,4 g, K = 0,8 años^{-1} y t_0 = - 0,19 años (fig. 4). El índice de crecimiento en longitud (N' = 3,09) muestra un gran ímpetu de crecimiento, indicando que esta especie tiene un alto potencial para la acuicultura. La madurez sexual se da entre los 22,2 y 24,1 cm LT cuando el pez alcanza los 1,2 años (fig. 5). La estimación de la mortalidad fue: Z = 10.79 años^{-1}, M = 1.50 años^{-1} y F = 9.29 años^{-1}. El alto coeficiente de mortalidad en los cultivos (F) y el grado de explotación (E = 0.86) indican una sobreexplotación de *C. agboyiensis*. Se han diseñado y establecido estrategias de dirección y conservación a fin de evitar un posible colapso en la piscifactoria.

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