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Population Structure of *Oreochromis* sp. at El Rodeo Dam, Morelos State, Mexico

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To determine the population structure of *Oreochromis* sp. and the current fishing effort at the El Rodeo dam in the state of Morelos, Mexico.
Study Design: Convenience sampling.
Place and Duration of Study: El Rodeo dam, state of Morelos, Mexico, between April and September 2010.
Methodology: Each month, a sample of organisms was caught with the help of local fishermen, and morphometric measurements of a minimum of 200 organisms were done. Morphological measurements of each organism included weight, total length, standard length, height at the beginning of the dorsal fin and maximum perimeter, as well as reproductive traits such as sex and gonadal maturity phase. Descriptive statistics were calculated to characterize the population structure. Size of first capture and recruitment size, age, and growth parameters. Natural mortality, instantaneous fishing mortality rate, exploitation rate, yield per recruit potential growth model were

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calculated by empirical equations and formulas. Differences between height and weight by sex, were explored by one-way analysis of variance defining weight as a covariate.
Results: A total of 1,344 organisms were measured. There were 7.5 males per female. About 73% of organisms correspond to sizes between 15 and 17 cm in total length. Average catch size is smaller than those reported in the literature for this species, which may be due to the season and sampling area, problems of inbreeding, early reproduction and selectivity of fishing gear used. The current fishing effort of 1.2 and the exploitation level of 0.56 indicate that the reservoir is within adequate limits of exploitation. However, the small size of the fish organisms causes to be commercialized at a very low price.
Conclusion: The dam is dominated by *Oreochromis sp*. The current fishing effort of 1.2 and the exploitation level of 0.56 indicate that the reservoir is within adequate limits of exploitation.

Keywords: Bass; fishing effort; reservoir; exploitation rate; ANOVA.

1. INTRODUCTION

The growing demand for food has led to a greater emphasis on inland fisheries, not only for obtaining high protein food but also for the creation of employment sources for rural communities as a result of the introduction of exotic species such as tilapia (*Oreochromis* sp.) [1]. In such fisheries, studies on age and growth are necessary for a proper management and breeding of fishery resources. This studies are required to describe and quantify the estimated mortality, population size, recruitment, selectivity of fishing gear, age of first maturity, and maximum sustainable yield, among other population variables that influence survival, sexual maturation and fish fecundity [2,3].

In spite of the large amount of water bodies present in Morelos state, Mexico little information is available on the the limnological (morphometry, bathymetry and water quality), biological and production characteristics of the aquatic resource [4]. Therefore, to gain knowledge about this, it is necessary to carry out hydrobiological studies in order to obtain the necessary data for a better management and use of the aquatic resource. The present work details the activities, results and conclusions of a research carried out at the El Rodeo dam of the State of Morelos, Mexico with the objective of determining the population structure of *Oreochromis* sp. and the current fishing effort at the El Rodeo dam in the state of Morelos, Mexico.

2. MATERIALS AND METHODS

2.1 Location

The study was conduct between April and September 2010 at the state of Morelos is located in central Mexico. This zone is characterized by a rugged topography, considerable bodies of water, great diversity of climates, diverse types of vegetation and fauna, and high agricultural productivity. Despite being of small size, this state has seven rivers that cover much of its territory, six lakes and 124 reservoirs both dams and weirs, as well as around 50 water springs. The El Rodeo dam is located in the municipality of Miacatlán, in the state of Morelos (Fig. 1). It is placed in the Western part of the state at a height of 1105 meters above sea level. Originally, the dam had a capacity of 28 million m^3, but in 2009 after several repairs of water leaks in the subsoil, where a percentage of the stored liquid was lost, it was agreed not to fill the dam to its maximum capacity, so currently it is only up to with 18 million m^3.

2.2 Research Design

The study was carried out by monthly sampling from April to September 2010, for logistical and budgetary reasons. Each month, a sample of organisms was caught with the help of local fishermen, using the fishing gear that is traditionally on site operated [4]. Fishing activities at the El Rodeo dam are mainly carried out by traditional fishermen organized in a Union, using wood boats, locally named *pangas*, from 3 to 5 m in length, built locally and with capacity for one or two fishermen. They roam and use as fishing gear nets with mesh sizes from 2½ to 2¾ in. The cast nets are operated by a single person standing on the boat, so the operational efficiency of these gears depends on the operator's expertise. The sinking time depends on the depth and on the amount of ballast placed on the reel. The equipment is recovered from the hawser, which is attached to the fisherman's wrist.

In the study area the construction of the thread is handmade, starting with a certain number of

meshes from the apex of the cone and with a systematic growth up to a few tens of meshes before its base where the reel is placed. The increment in the number of meshes of each section depends on the fisherman criterion. Fig. 2 shows the scheme of the netting used commercially as well as in the collection of organisms during the sampling in the present investigation:

Fishing begins in the early hours of the morning and ends at 10:00 a.m. to 11:00 a.m. Most of the catch consists of tilapia (*Oreochromis* sp). This species can be kept alive out of water for relatively long periods and this particularity makes it available a good market; however, fish organisms with reduced sizes and weights have a low price (less than € 1.00 kg.).

At each sampling, morphometric measurements of a minimum of 200 organisms taken by fishermen and randomly selected for their study were done. Morphological measurements of each organism included weight, total length, standard length, height at the beginning of the dorsal fin and maximum perimeter, as well as reproductive traits such as sex and gonadal maturity phase.

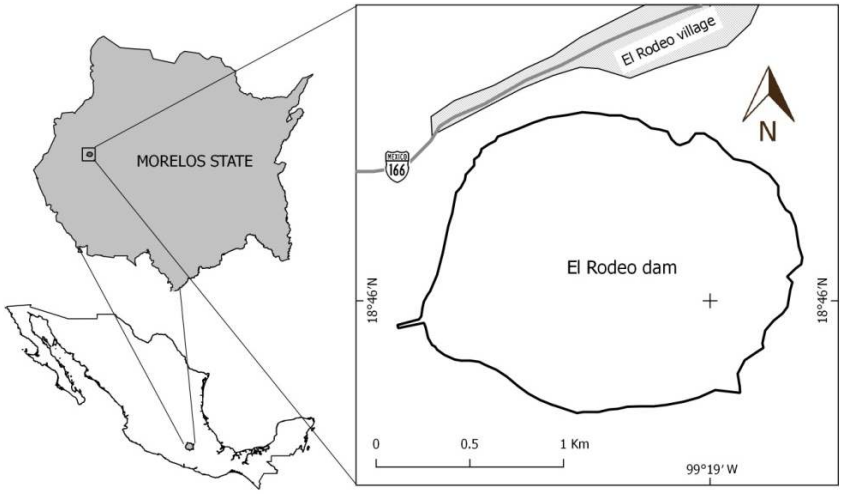
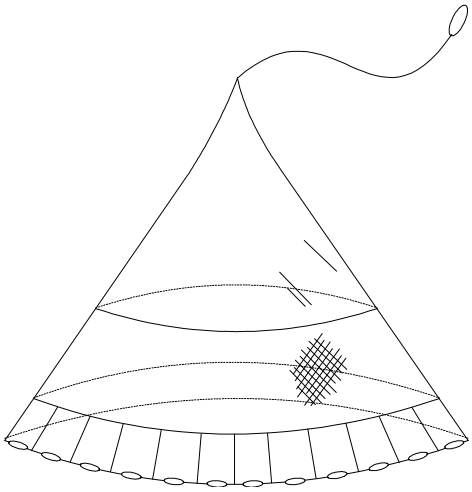


Fig. 1. Location of the El Rodeo Dam in Morelos, Mexico



Material = monofilament yarn 0.3 mm in diameter
Mesh size = 2 ¾ inch
147 mesh of fall
124 barrel leads of 7.15 by 6.0 mm
Diameter = 9-12 m

Fig. 2. Schematic of the netting used by fishermen during the research

2.3 Analysis of Data

Field data was captured into Microsoft Excel spreadsheets. Descriptive statistics, i.e. mean, median, minimum value, maximum value, quartiles and standard deviation were calculated to characterize the population structure. To calculate the size of first capture and recruitment size, size distribution was adjusted to a normal cumulative distribution, thus selecting values L_{50} and L_{25}. The empirical equation for the estimation of natural mortality was used to calculate age t_0 [5].

In order to estimate the growth parameters of infinite or asymptotic length ($L\infty$) and growth coefficient (K), the ELEFAN I (Electronic Length Frequency Analysis) method, contained in the FISAT program [6] adjusting the classic von Bertalanffy growth formula. Estimated growth data were used to calculated different mortality rates, namely: the instantaneous total mortality rate (Z); which is the result of the sum of the natural mortality plus the fishing mortality, Z = M + F. This was estimated by the relative age catch curve, included in the FISAT package. Natural mortality (M) was estimated from the empirical equation for the estimation of natural mortality.

The instantaneous fishing mortality rate (F) and the exploitation rate (E) per year were calculated using the formulas: F = Z M and E = F/Z. The first determines the number of survivors who die from fishing and the second was used to relate the number of individuals captured and the number of individuals who die within a certain period of time [7,8]. To estimate the yield per recruit (grams provided annually by the fishery), the performance/recruitment model or Y/R model [9], was used. For the estimation of $W\infty$, the potential growth model defined by the formula: $W = aLp^b$ was utilized. Finally, to determine differences between height and weight by sex, one-way analysis of variance was used defining weight as a covariate.

3. RESULTS AND DISCUSSION

A total of 1,344 organisms were measured. Table 1 summarizes the morphometric characteristics. There were a proportion of 7.5 males per female. The analysis of variance with weight as a covariate marks significant statistical difference in weight and average size for both sexes, with males being larger and heavier than females (F = 0.122 *P* = 0.001). In the sample size structure, it was estimated that about 73% of organisms correspond to sizes between 15 and 17 cm in total length.

Due to the difference by sex in weight and size of the organisms, regression analysis by sex adjusted to a potential model was performed. The models determined for each sex were subjected to a parallelism test, confirming that the growth is slightly higher for males, however, although the slope parameter (b) is slightly lower than 3, it can be considered as an isometric growth and similar for both sexes (Fig. 3).

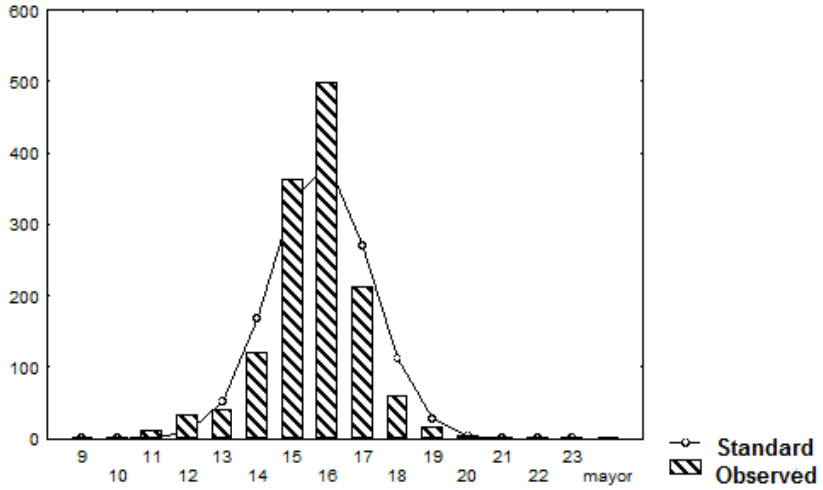


Fig. 3. Size structure of *Oreochromis sp* captured at El Rodeo Dam, Morelos State, Mexico

Table 1. Descriptive statistics of *Oreochromis sp* captured at El Rodeo Dam, Morelos State, Mexico

	n	Average	Median (L_{50})	Minimum	Maximum	First quartile (L_{25})	Third quartile (L_{75})	Interquartile range	Standard deviation
Total male length (cm)	914	15.64	15.70	11.60	22.70	15.00	16.20	1.2	1.13
Male weight (g)	911	74.31	73.50	28.00	220.00	63.90	83.20	19.3	17.0
Female total length (cm)	123	14.35	14.20	11.80	18.60	13.60	15.20	1.6	1.04
Female weight (g)	123	56.01	56.00	31.30	122.50	47.20	62.9	15.7	12.86
Undetermined total length (cm)	307	14.91	15.00	10.50	20.50	14.20	15.6	1.4	1.49
Undetermined weight (g)	307	68.35	67.20	22.50	175.60	58.90	76.2	17.3	20.61

The coefficient of correlation between length and total weight of *Oreochromis* sp was high (r^2 = 0.77 P = 0.001) (Fig. 4).

Reproductive pulses were observed mainly in July and August. The values of L_{50} and L_{25} are very similar. Likewise, the value of L_{25} corresponds to organisms larger than 13 cm. This length was the one observed for the first mature organisms in the sample, so it can be considered the total length of 13 cm as the first maturity size, the size of 14.6 as recruitment size and the length of 15.3 as the average size of capture.

There were six age groups in which the growth became very slow starting from 14 cm in length. A coefficient of 0.36 as the annual growth rate and an asymptotic growth in the 24.15 cm for infinite total length were estimated from the analyzed data. The estimation was carried out using the relative ages from three to six years (r^2 = 0.95 *P* = 0.001), so the sizes from 9 to 24 cm are sustaining the fishery effort. The parameters of natural and fishing mortality as well as the degree of exploitation of the resource indicate an adequate exploitation. However, capture of small organisms leads to a low yield of the fishery in economic terms.

Estimated values from the equations were: Z = 2.14; M = 0.94 (at 25.9℃); F = 1.20, E = 0.56 and K= 0.36. Growth parameters obtained are within the range of values described in other *Oreochromis sp.* studies [10-13]. However, it was observed that the asymptotic L for the Rodeo resource is smaller than in other studies. Assuming that a correction in the selectivity can improve the performance, an analysis was made to determine the possible capture sizes resulting from increasing mesh size to 3.0" and 3½ in. It is worth noting that in most Mexican reservoirs where tilapia is caught, mesh sizes are up to $4_{1/2}$ in.

Considering the results of population dynamics and the potential catch sizes with a mesh size of 3 in, a performance analysis per recruit was carried out at different ages of capture. For the current level of exploitation, if one-year-old organisms (9.45 cm) are fished, the yield is 4 units lower than currently recorded. At the current level and utilization of 6.5 g/annual recruit, it could be inferred that increasing twice the fishing effort may increase yield by as much as 1.5 units, but to the detriment of available biomass. However, if 3.37 years-old organisms (17.06 cm in total length with 3.0 in mesh) are caught at the same fishing intensity, the yield would be even greater than if fishing effort is quadrupled.

For the current level of exploitation, it is assumed that 33% of the initial biomass is being used, which could be interpreted as an adequate level of utilization of the reservoir resources; in fact,

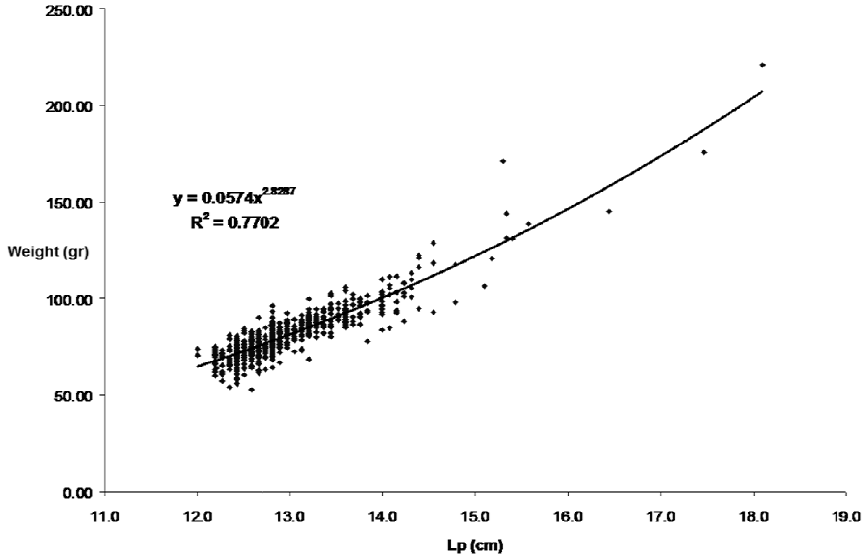


Fig. 4. Length to total weight relationship of *Oreochromis sp* captured at El Rodeo Dam, Morelos State, Mexico

the effort may be increased thrice to reach a biomass index of 50%. When comparing this yield to what could be achieved by capturing organisms of average size of 17.06 (relative age of 3.37 years), with the current effort level it is possible to get a substantial yield increase and even a 10% decrease in the impact of available biomass of 10%.

After analyzing the relevance of the sample size on the data collected during six months of observation, it is possible to consider that the analyses applied to them are robust enough to sustain the management measures that emerged from the current investigation. The results obtained on the degree of exploitation and performance of the fishery under the current conditions indicate that although the fishing effort applied is not excessive, the catch of organisms with a size of 15 cm or lesser does not allow a good exploitation of the reservoir. Reduced price of this product in the local market prevents economic gains.

Several events might contribute to generate these small sizes of tilapia. Those considered individually or grouped with greater influence are the following.

3.1 Sampling Season

Traditional fishermen in the place commented that capture of organisms greater than 400 g of weight goes from November to January.

3.2 Sampling Areas

The results obtained could have been biased due to the fishing areas that were chosen by the fishermen, capturing mainly male and small organisms. Largest organisms and females (probably mature) might be make their nests in mud or in places inaccessible to fishing gear, such as shores and weedy areas. Organisms larger than the maximum size of 22.7 cm reported here may be considered as rare.

3.3 Inbreeding and Early Reproduction

The population may have problems of consanguinity due to the fact that for several years there have been no planting of unrelated species and residents may have adopted survival strategies in which they drive their energy resources to reproduction. The results observed in the length/weight ratio indicate that females being smaller than males are addressing their energy resources to reproduction rather than to growth.

3.4 Selectivity

The mesh size used of 2¾ in allows the escape of organisms in carving of first maturity, but the size of captured organisms remains selective to sizes of 15.3 cm in average.

As a precautionary measure, it is important not to increase the fishing effort and, as far as possible, to fully renew existing fishing gear. In fact, depending on the principle of operation, selectivity and efficiency of the cast nets, it is recommended not to allow the use of other catch systems, except line and hook which is used for sport fishing of bass in the same reservoir. Due to the size and depth of the reservoir, it is not recommended to sail boats with outboard engines of more than 25 HP, since they may originate great disturbance and alteration on the bottom and cause physicochemical conditions such as anoxia and generate fish mortalities by asphyxiation.

Some recommendations that may be drawn from this study are the following: considering precautionary management of the dam, it is recommended not to increase the current fishing effort and not use other fishing gear other than the net with a mesh size of not less than $2^{3/4}$ in and preferably change to 3.0 in equipment in a short time. To carry out seeding of non-related organisms of tilapia, if the aim is to boost the fishing of this species, either commercially or for sport. It is important to plan sizes and planting times to avoid predation among them or between resident organisms. It is recommended to encourage and support rustic enclosures built on wooden sticks on the reservoir banks to encourage temporary cultivation of organisms. And finally, to avoid disturbances to the bottom and the habitat degradation by avoiding the use of outboard motors greater than 25 HP.

4. CONCLUSION

The reservoir is dominated by the population of *Oreochromis* sp with average catch sizes of 15.3 cm. The presence of bass is very reduced. The measurements smaller than those reported in the literature for *Oreochromis* sp, suggests problems of inbreeding, early reproduction and selectivity of the fishing gear used. The current fishing effort of 1.2 and the exploitation level of 0.56 indicate

that the reservoir is within adequate limits of exploitation; However, the small size of the fish organisms causes to be commercialized at a very low price (less than €1.00) and consequently the production of the dam is quite reduced in economic terms.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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