

Original Research Paper

Ecophysiology of *Chirostoma Jordani* Pisces: Atherinopsidae. Habitat Characterization and Population Dynamics in a Periurban Lake (Xochimilco, México)

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Article history

Received: 24-09-2020

Revised: 07-01-2021

Accepted: 23-01-2021

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Abstract: *Chirostoma Jordani* is an endemic species of the Mexican plateau, whose population, due to anthropogenic causes, has experienced a notable decrease from 2000 to the present, putting its permanence in its natural habitat at risk. Therefore, the objectives of this research were focused on evaluating the population dynamics of *C. Jordani* through its size and weight distributions and growth rate during an annual cycle and on determining if there is a relationship of these processes with water quality in the study site. Monthly samplings were carried out from August to November 2014 and from February to May 2015, in the Cuemanco canal, in Xochimilco México. A total of 435 specimens were collected, the smallest sizes and weights were recorded during the months of February and April (indicating a spawning period during this time) and the largest in November. A higher growth rate was recorded in the March-May months, compared to that of August-November (0.19 ± 0.05 and 0.04 ± 0.03 mm/day, respectively). The water quality indicators: Temperature, oxygen dissolved, pH and nitrite, were highly significant in the spatio-temporal variation of the *C. Jordani* habitat and influenced the abundance and growth of the population. These results lay the foundations to explain the life and performance strategies of the *C. Jordani* population in Xochimilco, México and are fundamental to the future management of the species in the study area and under controlled conditions.

Keywords: Evaluation, *Chirostoma Jordani*, Management, Population Dynamics, Water Quality, Xochimilco. México

Introduction

The Xochimilco, México lake system has been affected by multiple anthropogenic pressures, such as the introduction of exotic species, the dumping of wastewater and the overexploitation of its water resources, this has altered the abundance and survival of native species at the site, including the charales of the genus *Chirostoma*, this taxon was represented by the species: *Chirostoma humboldtianum* and *Chirostoma Jordani*, (Saldívar, 2007). However, currently only *C. Jordani* remains at this site. Islas *et al.* (1995) attribute their permanence to their gradual adaptation to extreme conditions and to the fact that they can resist poor water quality conditions. Nevertheless, as a result of various ecological pressures and human impact in the area, *C. Jordani* populations have experienced a notable decrease, coming to be considered as a species with the

possibility of disappearing (Olvera, 2004). That is why the objective of this investigation was to update the status of the residual population of *C. Jordani* in Xochimilco, in order to gather information that would allow the implementation of measures for its conservation and management in the study area.

Materials and Methods

Samplings

C. jordani specimens were collected at Cuemanco's canal, in Xochimilco, México. Monthly samplings were carried out from August to November 2014 and from February to May 2015. To capture the organisms, trawls were made with a 0.8 m rectangular net, 1 mm mesh

size, submerged at a depth of approximately 1 m, for 1 min. The captured organisms were transferred to the laboratory, where they were euthanised by immersion in a clove oil solution for 20 min and later fixed in 10% formalin for their subsequent analysis.

Environmental Data

At two points of the Cuemanco canal (near from the intersection with the El Bordo canal and in front of the Real Club España: 19°16'50.37''N, 99°6'7.46''W), surface and bottom measurements were taken in situ: pH, temperature, °C and total solids, ppt with a HANNA HI98129 multi-analyzer, dissolved oxygen (mg O₂/l) with an oximeter (YSI 55). Water samples were also collected from both strata and then all the samples were kept at 4°C for a period of 3h, prior to their chemical analysis, which included measuring the concentrations of: Ammonia (NH₄), Nitrite (NO₂), Nitrate (NO₃) and Phosphates (PO₄), with a HACH DR/870 spectrophotometer (±0.005 mg/L).

Population Dynamic Data

The Total Length (TL) ±0.01 mm and Wet Weight (WW) ±0.001 g of all captured organisms were measured. The growth rates and Specific Growth Rate (SGR) percentages (%) were obtained from the TL and WW size distributions of the organisms from the various samplings, taking into account the average value of the monthly height and weight distribution in consecutive months, according to the (Bhattacharya, 1967) and (Bagenal, 1978) respectively. The relationship between Wet Weight and Total Length ($WW = K * TL^\alpha$) was also calculated to denote the growth pattern of the organisms. Where WW is the total weight of the fish in grams, K is a regression constant equivalent to the condition Factor (F_c), TL is the total length in mm and α is the growth coefficient of regression (Ricker, 1975).

Statistical Analysis

The analysis of the population dynamics was contrasted by means of a unifactorial ANOVA with Tukey's "post hoc" test and p value = 0.05, the contrast factor being the months of sampling. Multivariate analysis in its discriminant modality was used to compare the possible differences in water quality between the months of sampling, the statistical packages: International Business Machine corporation (IBM SPSS Statistics, 20, 2011) Package for the Social Sciences (SPSS), v. 20 (2011) and Statistical Analysis System (SAS) Jump (JMP), v. 10.0, (SAS Institute, 2012) were used for the various routines.

Results, Literature Reviews and Discussions

A high environmental heterogeneity was found in the study site: All the measured factors presented significant

differences among the sampling months ($p < 0.05$), except for ammonia which, given its variability, ranged from undetectable to 2.8 mg/L during August and the period February-March respectively.

The annual thermal range fluctuated between 15.1 and 24.5°C, the pH was always alkaline fluctuating between 7.75 and 8.98, the dissolved oxygen varied from hypoxic conditions in August (1.3±2.8 mg/l) to supersaturation levels in September 2014 (12.1±2.8 mg/l). Nitrite concentrations reached their maximum levels in October-November (1.2-1.45 mg/L). Nitrate and P-orthophosphate levels recorded concentrations from a hypereutrophic habitat with 95% Confidence Intervals (CI_{95%}) of: 27.9-45.1 and 7.9-13.3 mg/L respectively. Two factors (O₂ and temperature) presented significant differences between strata ($p < 0.00$), contributing to the heterogeneity of the column of water, especially in the warm time of the year.

In Fig. 1, the researchers visualize the multivariate (canonical) means resulting from the discriminant analysis, the ellipsoids indicate the different sampling months, except for April that is represented with asterisks.

At the same time, the vectors resulting from the effect of the variables that were highly significant in the temporal discrimination from this interaction (temperature, pH, NO₂ and dissolved O₂, $p < 0.000$) are shown. The resulting model explained 94.9% of the measured environmental heterogeneity.

Table 1, shows the meristic and growth indicators measured in the *C. Jordani* population of Xochimilco, 435 specimens were collected during the various samplings, 145 organisms during the period of August-November 2014 and 290 in February-May 2015.

The month with the highest abundance was April ($n = 127$) and during September and November the catches were of around 30 individuals. The largest specimen was collected during the month of February (60.18 mm TL and 1.53 g WW) and the smallest in February and April (0.003 g WW and 4.56 mm TL), indicating a reproductive peak during the months of January to April.

The comparison of the specific growth rates of TL and WW indicated that the fastest growth of the population occurs in the March-May period of the annual cycle (1.8-2.1% WW/day, which is equivalent to 0.23 mm/day during this period, around 7mm/month).

Moreover, in organisms with a size greater than 35 mm TL, growth is significantly reduced and reaches its lowest values in adults of 42 mm TL and weight of 0.53 g WW (0.2% WW/day), given that these fish channel to a large extent its energy towards the gonads instead of somatic growth, in preparation for the reproductive event, which we detected during the collection in February, where the greatest size dispersions were obtained (Fig. 2 of this study).

Table 1: Wet Weight (WW), Total Length (TL), Mean \pm SD, specific growth rate (%/day) and $\alpha \pm$ SE = exponent of the allometric relationship $WW = k \cdot TL^\alpha$, in monthly samples of *Chirostoma Jordani* population of Xochimilco. N = sample size, r^2 = determination coefficient of allometric relationship, *p value ($p < 0.000$). Means with different letters are statistically different ($p < 0.05$)

Sampling	N	WW (g)	SGR %/day	TL (mm)	%/day SGR	$\alpha \pm$ SE	r^2
^A Aug.2014	82	0.37 ^B \pm 0.19		36.91 ^A \pm 6.02		2.82 \pm 0.165	0.785*
^S Sep.2014	32	0.47 ^A \pm 0.32	0.8 ^{A-S}	38.06 ^A \pm 10.62	0.1 ^{A-S}	3.05 \pm 0.095	0.971*
^N Nov.2014	31	0.53 ^A \pm 0.28	0.2 ^{S-N}	41.91 ^A \pm 9.86	0.16 ^{S-N}	3.12 \pm 0.102	0.970*
Aug. - Nov	145	0.43 \pm 0.25		38.23 \pm 8.29		3.01 \pm 0.076	0.916*
Febr.2015	48	0.17 ^{CD} \pm 0.30		22.89 ^{BC} \pm 14.79		2.19 \pm 0.146	0.774*
^{Ma} Mar.2015	59	0.07 ^D \pm 0.11		19.11 ^C \pm 6.42		3.12 \pm 0.079	0.965*
^A Apr.2015	127	0.13 ^{CD} \pm 0.09	2.1 ^{Ma-A}	25.41 ^{BC} \pm 6.32	1.0 ^{Ma-A}	2.99 \pm 0.062	0.949*
^{My} May.2015	36	0.22 ^C \pm 0.19	1.8 ^{A-My}	29.77 ^B \pm 9.47	0.5 ^{A-My}	2.92 \pm 0.053	0.989*
Febr – May	290	0.14 \pm 0.18		24.08 \pm 8.89		2.66 \pm 0.057	0.882*

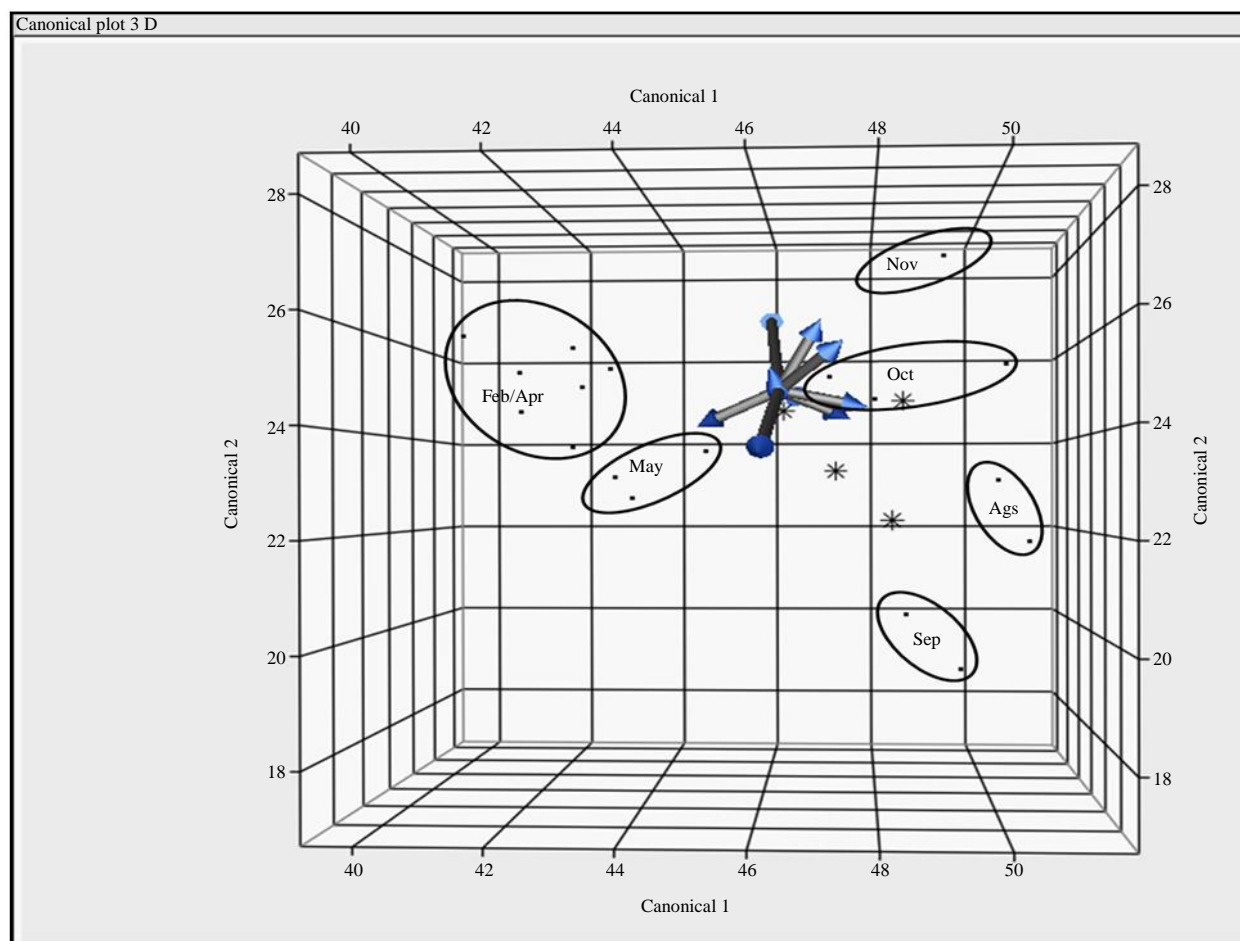


Fig 1: Canonical plot of water quality factors in the habitat of *Chirostoma Jordani* from Xochimilco during the period Aug. 2014-May, 2015

Likewise, the analysis of the WW-TL relationship supports this inference since the exponent (α) during the month of February was the lowest in the annual cycle ($\alpha = 2.19$), indicating a mixture of a large proportion of recruits with adult specimens in spawning period, which

began to incorporate reserves for the reproduction of the stock from September and continued in this process until March of the following year. During this period, the organisms had a positive allometric growth pattern ($\alpha > 3$, denoting a greater growth in weight than in height).

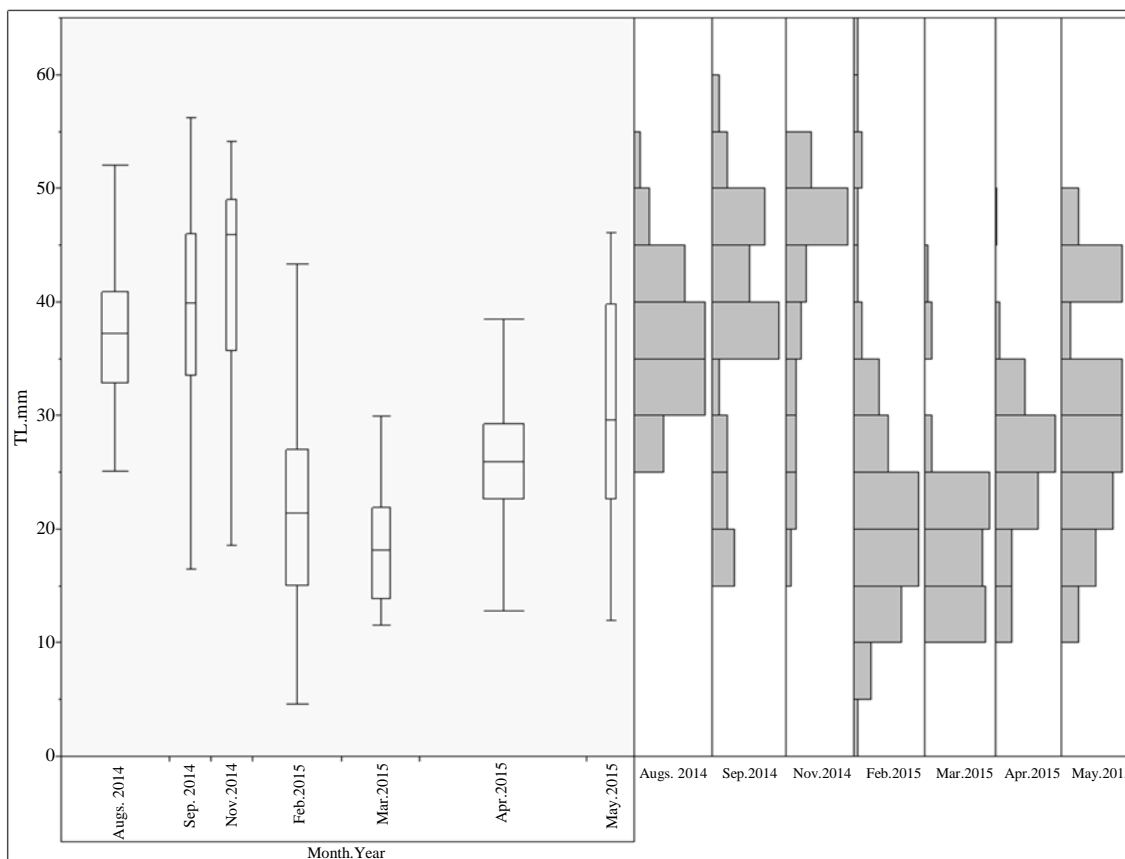


Fig 2: Box plot and frequency distributions of total length of *C. Jordani* population during the period August 2014-May 2015 in Xochimilco, México

The water quality in the Cuemanco canal is a reflection of the prevailing conditions in the Xochimilco, México channel area. This habitat today is the remnant of the lake complex that covered 1150 km² in the study area, upon arrival of the Spanish conquerors and is a reflection of how anthropogenic activities in recent decades have contaminated many freshwater environments throughout the planet. The results obtained in the present study generally agree with previous reports that correlate the environmental variability of physical-chemical factors in the study area, in different months of the year (Nandini *et al.*, 2005; Flores-García, 2009).

The physical-chemical factors measured in this study coexist as complex regimes that vary spatially and temporally in their exposure intensities and in turn interact with each other. Within this continuum of factor intensity, the range of stressors is marked by a manifestation of detrimental effects on organisms or ecosystem processes.

On the other hand, nutrients can be chemical stressors, if their concentrations are excessive, because this circumstance amplifies productivity and distorts other ecological functions, for example,

causing eutrophication of aquatic ecosystems and in even higher concentrations, nutrients can be toxic (González-Delgado *et al.*, 2002).

For two decades, a decrease in abundance and in the captured sizes of *C. Jordani* in the study area has been reported (Olvera, 2004; Saldívar, 2007). The present investigation confirms these results, since the abundance has decreased even more and the largest size captured only reached 60.18 mm of TL with a WW of 1.53 g, previous data reported sizes and weights which are no longer reached.

In the dynamic population analysis of *C. Jordani*, the minimum size of 4.56 mm of TL collected is within the range obtained for newly hatched fry of the species under laboratory conditions, where a value of 4 mm of TL has been reported at spawning (González, 2009). Our data indicates that in February, the quartile 25% of the TL distribution, were organisms of around 1 month of age and during March, approximately 60% of the sample were organisms of 1 to 2 months of age, (Refer to TL distributions: February-March, in Fig. 2 of this study) indicating an accelerated growth of recruits in the

population. According to (Weatherly *et al.*, 1987), the fact that there is a greater growth in the early stages is because evolutionarily, the fry that gain greater weight and length in their early stages of life have a greater chance of surviving in their natural environment and reach the adult stage, since the larger the organism, the greater the difficulty in swallowing it and its escape speed from possible predators increases, in addition to the advantages it gives in its intraspecific interactions, such as cannibalism.

Meanwhile, the reproductive event is associated with conditions of higher phytoplankton and zooplankton productivity during this period (García *et al.*, 2009). Navarrete-Salgado *et al.* (2010) pointed out that *C. Jordani* varies its diet depending on the size and availability of food in the environment, presenting eating habits zooplanktophagus. Thus, small-sized organisms feed mainly on the genus *Diaptomus* and to a lesser extent on *Daphnia*, *Diaphanosoma* and *Cyclops*. The genus most consumed by intermediate-sized organisms during spring and summer is *Diaptomus* and in autumn and winter they consume *Daphnia*. In large sizes, the main food is *Daphnia* throughout the year. This seasonal variation in the abundance and availability of the zooplankton genders is in agreement with data from previous reports in the study area (Nandini *et al.*, 2005; García *et al.*, 2009). Furthermore, when food is scarce, there is an increase in intraspecific interactions such as cannibalism (Cházaro-Olvera, 1989). In this sense, (Krebs, 1998) has pointed out that the fact that there is a marked difference in the ingested genders with respect to size organism this is related to a strategy to decrease intraspecific competition between organisms in a population, which decreases the mortality in early stages of the life cycle.

In a recent study (Jardinez-Méndez, 2019), reported the comparison of annual cycles of the *C. Jordani* population in Xochimilco, indicating an even greater decrease in abundance in 2017 for this species, with even more heterogeneous conditions of the environmental variability of the water quality in the study area, (for example, excessively alkaline pH values: 9.81 ± 0.58 in the month of February, as well as very high levels of ammonia in the months of March and July and an extreme value in nitrite concentrations in the month of October, 2017. This temporality of stressful effects impacted the survival of brood stock, spawning, as well as the surviving fry during the reproductive peak of the population and still exerted their effect on the juvenile stages of the species, translating into lower reproductive potential and decreasing the rate of growth of organisms. It has also been reported that the

first stages of development of fish are more sensitive to high total solids concentrations, such as those prevailing in the study area and may even decrease hatching of the eggs (CEPA, 1995).

Other results obtained in our laboratory (Vera-Granados, 2019), indicate that the accumulation of metals: Zinc (Zn), Copper (Cu), Lead (Pb) and Cadmium (Cd) in the tissue of *C. Jordani* exceeds the permissible limits of various international laws and the Official Mexican Norm (NOM, 1993), which results in a potential public health problem due to its possible consumption and in turn has an effect on the charal population on site, impacting its reproduction and growth.

Concluding Remarks

In summary, as (Freedman, 2018) has pointed out, the exposure of ecosystems to intense anthropogenic stressors of disturbance and pollution would result in changes that degrade ecological integrity and environmental quality. These threats are particularly severe in regions where the human footprint is more intense, that is, where the human population is greater and the economic infrastructure is more developed, as is the case of Xochimilco, México. A key element for mitigating these effects is the need for monitoring and research programs, to detect or predict stressors that are threats to environmental quality and that contribute to the ecological dimension of avoiding or repairing their effects in order to improve the sustainability of both the human economy and the natural world.

Recommendations

The knowledge generated in this study, should be used to guide decision-making and adjustments to the management plan of the study area (GODF, 2006) by the authorities of the mayor's office, the general direction of protected natural areas and industry, as well as to assist the work of non-governmental organizations and provide material for environmental education.

Acknowledgement

We thank Master of Science, Fernando Carlos Arana Magallón. Former director of the Centro de Investigaciones Biológicas y Acuáticas de Cuernavaca, (CIBAC). UAM-Xochimilco for the facilities granted in the sampling and laboratory infrastructure.

Funding Information

This research was funded by the Faculty of Sciences, UNAM.

Author's Contributions

Latournerié-Cervera José Román: Conceptualization, Methodology, Investigation, Formal analysis, Writing-Reviewing and editing.

Rangel-Nambo María Isabel: Methodology, Investigation, Writing.

Alma Rosa Estrada-Ortega: Software, Validation, Writing-Original draft preparation.

Ethics

The authors declare that they have no known competing financial, ethical or personal relationships that could have influenced the work reported in this manuscript.

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