Annual Research & Review in Biology

21(4): 1-9, 2017; Article no.ARRB.37307
ISSN: 2347-565X, NLM ID: 101632869

The Fish Population Size of Tepetitlan Reservoir (Mexico) is at a Critical State

Daniel Aguilar-Ramírez[1], Patricia Devezé-Murillo[2*], Juan Acosta-Jimeno[3] and José Alfredo Villagómez-Cortés[2]

[1]Instituto Nacional de Pesca, Pitágoras 1320, Col. Sta. Cruz Atoyac, C.P. 03319, México City, Mexico.
[2]Unidad Veracruzana, Facultad de Medicina Veterinaria y Zootecnia, Universidad Veracruzana, Miguel Ángel de Quevedo y Yañez s/n, Col. 91710, Veracruz, Mexico.
[3]Colegio de Postgraduados-Campus Veracruz, Mexico.

Authors' contributions

This work was carried out in collaboration between all authors. Author DAR wrote the protocol, performed field activities and recorded all data. Author PDM designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Author JAJ prepared drawings and contributed analytical tools. Author JAVC managed the literature search and wrote the English version of the paper. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2017/37307
Editor(s):
(1) Cosmas Nathanailides, Professor, Department of Fisheries and Aquaculture Technology, Technological Educational Institute of West Greece, Messolonghi, Greece.
(2) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
Reviewers:
(1) Tiogué Tekounegning Claudine, The University of Dschang, Cameroon.
(2) Fazıl Şen, Van Yuzuncu Yil University, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/22440

Original Research Article

Received 10th October 2017
Accepted 20th December 2017
Published 26th December 2017

ABSTRACT

Aims: To determine the fish population structure of the Tepetitlan reservoir in the state of Mexico, Mexico, identifying the present species, distribution, age, length and weight.
Study Design: Convenience sampling.
Place and Duration of Study: Tepetitlan reservoir in the state of Mexico, Mexico, from April to September 2011.
Methodology: Each month, at least 200 fish were used for morphological measurements (weight, total length, standard length, max height and perimeter) and reproductive traits such as sex and gonadal maturity stage. Descriptive statistics were used to characterize the population structure,

**Corresponding author: E-mail: pdeveze@uv.mx;*

age and size of first capture. Growth parameters, natural mortality, instantaneous fishing mortality rate, exploitation rate, yield per recruit potential growth model were all 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: The Tepetitlan reservoir has a small population of shortfin silverside (*Chirostoma humboldtianum*) with average catch sizes of 11 cm, and rare presence of axolotls (*Ambystoma mexicanum*) and marbled crayfish (*Procambarus sp*). The fishing effort of 0.53 and exploitation rate of 0.44 indicate that the reservoir is used within its tolerance limits. The compressed size of the populations, potential problems of inbreeding and reduced physical space for the species pushes the habitat to a fragile situation for their permanence.

Conclusion: Tepetitlan reservoir has a dramatically small population of shortfin silverside (*Chirostoma humboldtianum*), and an extremely small population of axolotls (*Ambystoma mexicanum*) and marbled crayfish (*Procambarus sp*).

Keywords: Shortfin silverside; axolots; marbled crayfish; fishing effort; reservoir; exploitation rate.

1. INTRODUCTION

Dams and reservoirs serve several purposes such as to supply drinking water, to generate hydroelectric power, provide a water supply for irrigation, offer recreational opportunities, and flood control [1]. Dams and reservoirs also provide a proper habitat for diverse fish species, but habitat destruction and degradation are great threats to survival of most fish populations. In addition, poverty in many world regions results in over-exploitation of natural resources by local residents, especially by uncontrolled fishing [2]. Exploitation of the resource might influence maintaining the resource itself. Thus, the appropriate management of fisheries requires, among many other things, monitoring the fish population structure in dams and reservoirs [3,4,5]. [6] define a fish population as a group of individuals of the same species or subspecies that are spatially, genetically, or demographically separated from other groups. Size-selective fishing will affect species in different ways. In any habitat, fish communities' composition is expected to change in age and size structure, abundances of fish populations, fecundity and spawning potentials, and sex ratios, among other variables [7]. Therefore, the current study aims to determine population structure, age and size at sexual maturity as well as length-weight relationship of fishes caught at the Tepetitlan reservoir in the state of Mexico, Mexico.

2. MATERIALS AND METHODS

2.1 Location

The Tepetitlán reservoir is located across the municipalities of San Felipe del Progreso, Ixtlahuaca and Jocotitlán, in the state of Mexico in Mexico (Fig. 1). It is placed in the Western part of the state at a height of 2600 meters above sea level. The reservoir lies between latitudes 19°38' and 19°66'N orth and longitudes 99°58' and100°17' West. Originally, the reservoir had a capacity of 28 million m³, 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 reservoir to its maximum capacity, so currently it is only filled with 18 million m³. The reservoir is mainly supplied by rainwater and has been classified by the National Institute of Ecology as a Forest Protective Zone. Over 7000 users are estimated to benefit from its presence.

2.2 Research Design

Local fishermen do fishing using small metallic boats of 5 m in length driven by oars, using gillnet of 60 m in length and 4 m of height, made of no. 30 monofilament thread and a mesh size of 76 mm.

During previous sampling campaigns, it was observed that the capture of common carp (*Ciprinus carpio*) was practically null, since less than one specimen/net/day was caught and those captured had weights lesser than 200 g. Inhabitants of the place informed that this situation has been observed for some years and therefore they practically abandoned the fishing activities. Looking for the reason of this resource shortage, it was noted that the reservoir was completely invaded by a rooted submerged hydrophilic plant (*Potamogeton crispus*). This plant grows from the bottom of the reservoir until its surface extending to more than 12 m in length which gives rise to the presence of giant aquatic vegetation practically in the whole extension of the reservoir.

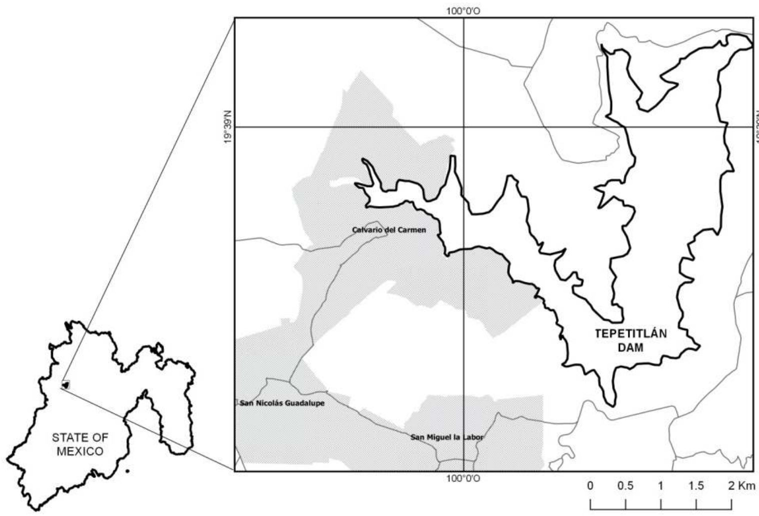

Fig. 1. Location of the Tepetitlán Reservoir in the state of Mexico, Mexico

According to [8], aquatic nuisance plants species possess a number of adaptations, including an ability to rapidly propagate vegetatively, an opportunistic nature for obtaining nutrients, a life cycle that favors cool weather, and a number of mechanisms which enhance photosynthetic efficiency, which allow them to proliferate. Since the plant prevents a proper functioning of the gillnet by becoming entangled and stuck in it, it was proposed to use fish traps (Fig. 2), under the assumption that a devise for fishing exists and that the fault rather lies in the way of fishing. The trap coating material was a 25.4 mm mesh polyamide cloth on a 6.34 mm steel rod base. Local fish caught in the same place was used as bait.

Sampling sites were considered to cover the different areas of the reservoir from the floodgate to its most extreme part, which was where the largest fishing took place, according to native inhabitants fishing daily. Fifteen traps were distributed among several fishermen in the community which were trained in their construction and operation. A sample of organisms was caught with the help of the local fishermen at different points in the reservoir. Six monthly samples were taken. Morphometric variables of a minimum of 200 fish caught by the fishermen and selected for their study were recorded in each sample. From each organism data were taken of weight, total length, standard length, height at the beginning of the dorsal fin and maximum perimeter, as well as reproductive characteristics such as sex and gonadal maturity phase.

2.3 Study Parameters

To calculate the size of first capture and recruitment size, size distribution was adjusted to a normal cumulative distribution, thus selecting L_{50} and L_{25} values. Empirical equation was used to calculate age t_0 [9].

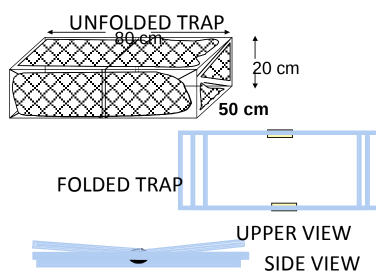

Fig. 2. Schematic of folding traps used for the research in the Tepetitlán Reservoir, state of Mexico, Mexico

In order to estimate infinite or asymptotic length growth parameters ($L\infty$) and growth coefficient (K), the ELEFAN I (Electronic Length Frequency Analysis) method, contained in the FISAT program [10] was used to adjust by the classic von Bertalanffy growth formula. Estimated growth data were used to calculate different mortality rates, namely: the instantaneous total mortality rate (Z), which results from the sum of the natural mortality plus the fishing mortality, so Z = M + F. This was estimated by the relative age catch curve, included in the FISAT package [10]. Natural mortality (M) was estimated by the empirical equation of [9].

Other parameters, such as 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, respectively. The first estimates the number of survivors who die from fishing and the second relates the number of individuals captured and the number of individuals who die within a certain period [11,12]. The yield per recruit (grams provided annually by the fishery) was estimated by the performance/recruitment model or Y/R model [13]. The potential growth model W ∞ was estimated by the formula: $W = aLp^b$. Finally, to determine differences between height and weight by sex, one-way analysis of variance was used defining weight as a covariate.

2.4 Analysis of Data

All field data was input into Microsoft Excel spreadsheets. Population structure was characterized by descriptive statistics, i.e. mean, median, minimum value, maximum value, quartiles and standard deviation.

3. RESULTS AND DISCUSSION

3.1 Species Found

During April, several individuals of shortfin silverside (*Chirostoma humboldtianum*) with average catch sizes of 11 cm, axolotls (*Ambystoma mexicanum*) and marbled crayfish (*Procambarus sp*) were captured; however, in the following five months only a small number of axolotls - with the help of traps and trawls-, and marbled crayfish were captured. The *Chirostoma "humboldtianum*" group includes seven silverside species of great economical and cultural interest for local human populations [14].

The fishing activities in the Tepetitlán reservoir are carried out exclusively by local farmers of the Mazahua ethnic group. This indigenous people are the most numerous in the state of Mexico and they have historically occupied an area integrated by mountains, hills and valleys in which a cold climate prevails. The community that surrounds the reservoir is made up of approximately 54 families. Peasants fish sporadically due to the reduced fish production in the reservoir and to the fact that they are not professional fishermen.

3.2 Descriptive Statistics of Silverside Fish

Most sampling places in the reservoir resulted negative. The setting locally known as Agüita at the community of Estotempa was the most efficient for capturing axolotls. This place is shallow (less than 2 m depth from April to September) and the fishermen there uses hammocks type fishing nets with 30 m wings per side and a 6 m length bag in the middle, mesh size of 8 to 4 mm (mosquito net), and rustic weights and floats (i.e. stones and plastic bottles). Attention has been drawn to the alarming decline of *Ambyostoma mexicanum* population observed in Central Mexico as a result of habitat loss due to urban growth and strong competition with other species [15,16,17]. For that purpose, the presence of *A. mexicanum* has been promoted at Lake Xochimilco, Mexico, as a flagship species for conservation [18,19].

Table 1 shows a slight gender dominance in the population of Mexican axolotl, with a proportion of 0.73 males per female. A total of 1593 organisms were analyzed showing the following average morphometric characteristics. There is also a difference in size and weight in favor of females. Length and weight in current study were greater than those found in the San Miguel Arco reservoir, located at the Northern part of the state of Mexico [20].

Analysis of variance with weight as covariate did not find significant statistical difference in weight and average size for both sexes (F = 1.169 P = 0.68). Since no difference was found by sex, weight and size of the organisms, regression analysis was performed by mixing females and males and adjusting to a potential model. Fishes of indeterminate sex were excluded from the length vs. weight analysis. Although the slope parameter (b) is slightly lesser than 3, the occurrence of an isometric growth similar for both sexes could be considered (Fig. 3).

Table1. Descriptive statistics for shortfin silverside (*Chirostoma humboldtianum*) in the Tepetitlán Reservoir, State of Mexico, Mexico

	n	Average	Median (L_{50})	Minimum	Maximum	First quartile (L_{25})	Third quartile (L_{75})	Interquartile range	Standard deviation
Total male length (cm)	620	11.31	11.40	7.20	19.00	10.30	12.40	2.10	1.76
Male weight (g)	619	10.78	10.60	0.50	41.00	7.70	13.00	5.30	4.50
Female total length (cm)	846	11.69	11.50	6.50	23.50	10.60	12.50	1.90	1.77
Female weight (g)	843	12.08	10.90	0.50	86.60	8.90	13.80	4.90	6.01
Undetermined total length (cm)	127	6.03	5.50	2.40	16.00	4.30	6.90	2.60	2.31
Undetermined weight (g)	125	2.30	1.10	0.20	24.50	0.60	2.10	1.50	3.63

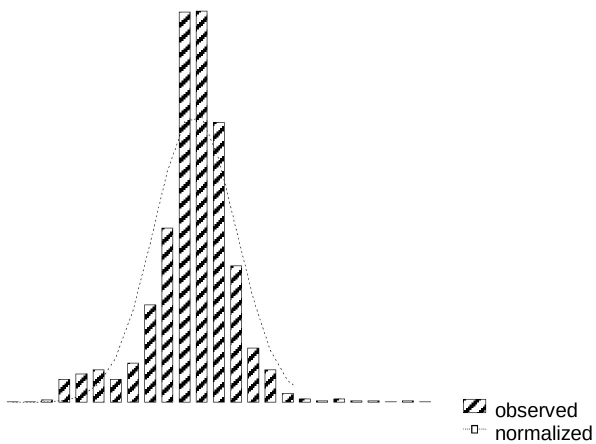

Fig 3. **Distribution of frequencies for the size structure in Tepetitlán Reservoir, state of Mexico, Mexico**

3.3 Silverside Fish Sizes Structure

The structure of sizes for the population and its adjustment to a normal distribution is presented in Fig. 3. Over 70% of organisms had a total length between 10 and 14 cm. A better approximation of the catch selection can be observed by the accumulated frequency distribution, in which the value of L_{50} was 11.1 cm, likewise, L_{25} value was 9.5 cm and corresponded to first mature organisms in the sample. Therefore, the total length of 8.5 cm can be considered as the size at first maturity, the size of 9.5 cm as recruitment size and the length of 11.1 cm as the average capture size. This finding is in contrast with that of [21] who detected genetic and morphometric variation in samples of *Chirostoma grandocule* populations from Lake Patzcuaro, Mexico and attributed them to differences in physio-geographical and intra-lacustrine conditions. It is noteworthy that the extreme genetic divergence of *Chirostoma humboldtianum* has been described by [22].

3.4 Silverside Fish Instantaneous Total Mortality Rate

The growth curve by age and size of shortfin silverside (*C. humboldtianum*) is showed in Fig. 4.

3.5 Silverside Fish Parameters

Six clearly defined age groups were observed in which the growth after 14 cm in length became very slow. A coefficient of 0.27 was estimated as the annual growth rate for the analyzed data, and the asymptotic growth point for infinite total length was 21 cm. The estimation was carried out using relative ages from 1.5 to 6 months (r^2 = 0.877, *P* = .05), so sizes from 10 to 19 cm are supporting the fishery. The parameters of natural and fishing mortality, as well as the degree of exploitation of the resource indicate an adequate use: instantaneous mortality rate = 1.21; natural mortality rate = 0.68 (at 17.8℃); fishing mortalit y rate = 0.53, and exploitation rate = 0.44.

3.6 Performance/Recruitment Analysis

According to population dynamics results, the performance/recruitment analysis was performed at different capture ages. For the current level of exploitation, if one-month-old organisms (8.23 cm) are caught, the yield would drop by half a unit. In addition, some organisms that did not reproduce yet would be affected. At the current level and utilization of 1.92 g/annual recruit, it could be inferred that a threefold increase in fishing effort may increase yield up to 0.36 units, but in detriment of available biomass. However, if two-month organisms (11.65 cm in total length) are caught at the same fishing intensity, the yield would be 0.5 units, greater than quadrupling fishing effort.

3.7 Silverside Fish Reproductive Status

Silverside fish reproductive status during the study period was analyzed, and reproductive pulses were observed mainly in July and August. A study of *Chirostoma humboldtianum* in San Felipe Tiacaque dam in the state of Mexico, Mexico determined the following growth

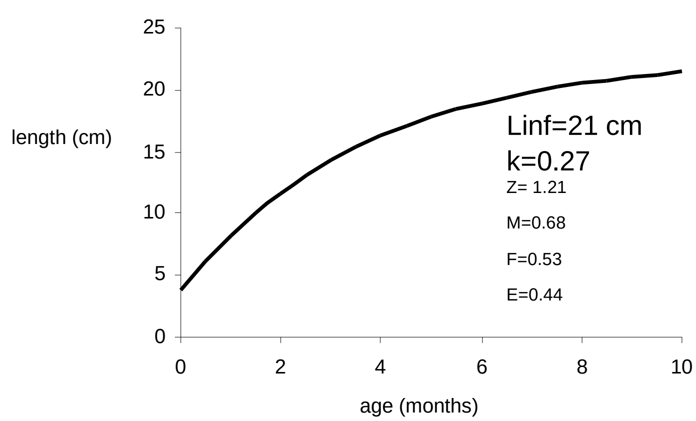

Fig. 4. Growth curve by age and size of shortfin silverside (*Chirostoma humboldtianum*) in Tepetitlán Reservoir, State of Mexico, Mexico

rates: spring 0.1778, summer 0.3364, fall 0.2032 and winter 0.2869. Spring was the time of the highest condition factor and food abundance (the sliverside is planktivorous) but also of lowest growth because resources are allocated to reproduction. In contrast, growth is concentrated in the summer [23].

3.8 Fishing Effort and Exploitation Index

Results indicate an acceptable fishing effort and exploitation index. However, during the sampling it was observed an almost null applied effort. In fact, local fishermen only worked on sampling days to assist in the collection, but this is not a regular activity for them because marbled crayfish is not of their liking. This simple fact has been determinant so prevent that the small population collapses. The performance/ recruitment analysis considered that the current harvest level is 23.8% of the initial biomass percentage. On the other hand, a dozen individuals with scoliosis and lordosis (deformities of the spine) problems were recorded.

Silverside fish maximum size observed as well as the estimation of the infinite length corresponds to the largest organisms reported in the literature for *C. humboldtianum*. This piece of information together with the isolation of this ecosystem suggest that this species is endemic. A species is considered endemic when a taxon is unique and its distribution is confined to a sub-basin or river watershed, meaning that its distribution is restricted to a given area [24].

According to the performance/recruitment analysis, it is considered that the utilization of reservoir resources is at an adequate level; however, an increase in the effort level would not reflect a better utilization but an increase in the exploited biomass. When this yield is compared to what could be achieved by capturing organisms of an average size of 11.65 (at a relative age of 2 months) at the current effort level, it is possible to appreciate a substantial increase in yield and to remain below the $BV_{50\,\%}$ extracted biomass.

3.9 Marbled Crayfish (*Procambarus* sp) and Axolotls (*Ambystoma mexicanum*)

Regarding the presence of marbled crayfish (*Procambarus sp*), [25] pointed out that Mexico is one of the most crayfish-diverse countries worldwide, with over 50 described species. It is also noted that poverty in many regions of México results in over-exploitation of natural resources by local residents, especially by uncontrolled crayfishing and that fishermen sell their produce at local markets at very low prices. In a long-term study on the abundance and habitat distribution of *P. rocambarus clarkii* at Lake Naivasha, Kenya, it was found that its growth and morphometrics were similar to other locations in the world and that adults and juveniles forage on the lake bed at night [26]. In a study on the population dynamics of the red swamp crayfish (*P. clarkii* Girard, 1852) done in two marshes in Portugal, [27] identified faster growth and larger maximum sizes at the site with the more stressed environment and lowest relative crayfish densities pointing to the relevance of consider hydroperiod management and maximum crayfish densities. [28] reported that *Procambarus clarkii* catch per unit effort harvested from the Atchafalaya River Basin, Louisiana increased nearly 600% between two consecutive years despite similar hydrologic regimes, physicochemical conditions, and littoral macrophyte densities, even though reduced size in the latter year indicated density-dependent growth. In fact, *P. clarkii* exhibited trends of lower CPUE and reduced carapace length in habitats subject to chronic sub-optimal water quality. However, other than annual flooding influences, it is difficult to elucidate inter-annual harvest differences and intra-annual population variability among habitats. A cannibalism behavior was also observed finding up to five small fish in the mouth and stomach of a bigger fish. This is probably a result of limited food availability in the ecosystem [29].

Since few axolots specimens were caught during the study, it was not possible to make inferences about their population dynamics. Some fishermen with a certain economic power have planted carps on the reservoir vicinity with moderately satisfactory results.

4. CONCLUSION

Tepetitlan reservoir has a small population of shortfin silverside (*Chirostoma humboldtianum*), and a very low presence of axolotls (*Ambystoma mexicanum*) and marbled crayfish (*Procambarus sp*).

As part of the reservoir precautionary management, it is recommended not to increase the current fishing effort, as well as to promote and support rearing of carp species in floating cages inside the reservoir, and supply complementary foods to encourage a short-term alternative source of fish [30].

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the authors.

ACKNOWLEDGEMENTS

We wish to acknowledge the fishermen of Tepetitlán reservoir in the state of Mexico, Mexico for their support and cooperation for carrying out the study. We also thank the anonymous reviewers and the editor for their valuable comments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Wildi W. Environmental hazards of dams and reservoirs Terre et Environnement. 2010;88:187–197.
2. Porter-Bolland L, Ruiz-Mallén I, Camacho Benavides C, McCandless SR. (Editors). Community action for conservation; Mexican experiences. Springer Science: New York; 2013.
3. Tito de Morais L. Fish population structure and its relation to fisheries yield in small reservoirs in Côte d'Ivoire. In Management and Ecology of Lake and Reservoir Fisheries. Cowx IG (editor). Oxford: Blackwell Publishing Ltd. 2002;112-122. DOI: 10.1002/9780470995679.ch10
4. Pope K, Lochmann SE, Young MK. Methods for assessing fish populations. In Inland Fisheries Management in North America, Quist M.C., Hubert W.A. (editors). 3rd edition. Bethesda, Maryland: American Fisheries Society. 2010;325-351.
5. Aguilar-Ramírez D, Devezé-Murillo P, Villagómez-Cortés JA, Acosta-Jimeno J. Population structure of *Oreochromis* sp. at El Rodeo Dam, Morelos State, Mexico. J. Appl. Life Sci. Intern. 2017;11(1):1-8. DOI: 10.9734/JALSI/2017/32029
6. Wells JV, Richmond ME. Populations, metapopulations, and species populations: What are they and who should care? Wildl. Soc. Bull. 1995;23:458–462.
7. Delariva RL, Canteri FC, Sanches PV, Gilmar Baumgartner G. Composição e estrutura da ictiofauna de área marginal da Lagoa Xambrê, parque nacional de Ilha Grande, PR, Brasil. Rev. Agroneg. Meio Amb. 2009;2(1):141-153. Portuguese.
8. Nichols SA, Shaw BH. Ecological life histories of the three aquatic nuisance plants, *Myriophyllum spicatum*, *Potamogeton crispus* and *Elodea canadensis*. Hydrobiologia. 1986;131:3-21.
9. Pauly D. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J Cons Int Explor Mer. 1980;39(2):175–192.
10. Gayanilo FC, Pauly D. Food and agriculture organization-international center for living aquatic resources management, stock assessment tools. Reference manual. FISAT Computarized Information Series fisheries 8. Rome: Food and Agriculture Organization of the United Nations; 1996.
11. Brodziak J, Gedamke T, Porch C, Walter J, Courtney D, O´Malley J, Richards B. A Workshop on methods to estimate total and natural mortaliy rates using mean length observations and life history parameters. Technical Memorandum NMFS –PIFSC 32. Honolulu (HI): National Oceanic and Atmospheric Administration; 2012.
12. Ssentongo GW, Larkin PA. Some simple methods of estimating mortality rates of exploited fish populations. J Fish Res Brd Can. 1973;30:695-698. DOI: 10.1139/f73-121
13. Gulland JA. Fish stock assessment. A manual of basic methods. Chichester, John Wiley, Fao/Wiley Ser. Food Agric. 1983;1:223.
14. Barriga-Sosa IA, Ibáñez-Aguirre AL, Arredondo-Figueroa JL. Morphological and genetic variation in seven species of the endangered *Chirostoma “humboldtianum* species group” (*Atheriniformes: Atherinopsidae*). Rev. Biol. Trop. 2002; 50(1):199-216.
15. Contreras V, Martínez-Meyer E, Valiente E, Zambrano L. Recent decline and potential distribution in the last remnant area of the microendemic Mexican axolotl (*Ambyostoma mexicanum*). Biol. Conserv. 2009;142:2881-2885.

16. Parra-Olea G, Zamudio KR, Recuero E, Aguilar-Miguel X, Huacuz D, Zambrano L. Conservation genetics of threatened Mexican axolotls (*Ambystoma*). Anim. Conserv. 2012;15:61–72.
DOI: 10.1111/j.1469-1795.2011.00488.x
17. Recuero E, Cruzado-Cortes J, Parra-Olea G, Zamudio KR. Urban aquatic habitats and conservation of highly endangered species: the case of *Ambystoma mexicanum* (*Caudata*, *Ambystomatidae*). Ann. Zool. Fennici. 2010;47:223–238.
18. Bride IG, Griffiths RA, Melendez-Herrada A, Mckay JE. Flying an amphibian flagship: Conservation of the Axolotl *Ambystoma mexicanum* through nature tourism at Lake Xochimilco, Mexico. Int. Zoo Yb. 2008; 42:116–124.
DOI: 10.1111/j.1748-1090.2008.00044.x
19. Zambrano L, Valiente E, Vander Zanden MJ. Food web overlap among native axolotl (*Ambystoma mexicanum*) and two exotic fishes: Carp (*Cyprinus carpio*) and tilapia (*Oreochromis niloticus*) in Xochimilco, Mexico City. Biol Invasions. 2010;12(9):3061–3069.
DOI: 10.1007/s10530-010-9697-8
20. Sánchez-Merino R, Díaz-Zaragoza M, Navarrete-Salgado NA, García-Martínez ML, Ayala-Niño F, Flores-Aguilar MD. Growth mortality survival rate of silverside fish *Chirostoma humboldtianum* (*Atherinopsedae*) from San Miguel Arco reservoir. Revista Chapingo Serie Ciencias Forestales y del Ambiente. 2006;12(2): 151-154. Spanish.
21. Barriga-Sosa IA, Eguiarte LE, Arredondo-Figueroa JL. Low but Significant Subdivision among Populations of *Chirostoma grandocule* from Lake Patzcuaro, Mexico. Biotropica. 2004;36(1): 85–98.
22. García-Martínez RM, Mejía O, García-De León FJ, Barriga- Sosa IA. Extreme genetic divergence in the endemic fish *Chirostoma humboldtianum*: Implications for its conservation. Hidrobiológica. 2015; 25(1):95-106.
23. Aguilar JF, Navarrete NA. Crecimiento, condición y mortalidad del charal *Chirostoma humboldtianum* (*Atheriniformes: Atherinidae*) en México. Rev Biol Trop. 1996-1997;44/45:573-578. Spanish
24. Park YS, Chang J, Lek S, Cao W, Brosse S. Conservation strategies for endemic fish species threatened by the three gorges dam. Conservation Biology. 2003;17(6): 1748–1758.
DOI: 10.1111/j.1523-1739.2003.00430.x
25. Gutiérrez-Yurrita PJ. The use of the crayfish fauna in Mexico: Past, present and future? Freshwater Crayfish. 2004;14:30-6.
26. Harper DM, Smart AC, Coley S, Schmitz S, de Beauregard ACG, North R, Adams C, Obade P, Kamau M. Distribution and abundance of the Louisiana red swamp crayfish *Procambarus clarkii* Girard at Lake Naivasha, Kenya between 1987 and 1999. Hydrobiologia. 2002;488:143–151.
27. Anastacio PM, Leita AS, Boavida MJ, Correia AM. Population dynamics of the invasive crayfish (*Procambarus clarkii* Girard, 1852) at two marshes with differing hydroperiods. Ann Limnol - Int J Lim. 2009;45:247–256.
DOI: 10.1051/limn/2009025
28. Bonvillain CP, Rutherford DA, Kelso WE, Murphy CE. Biotic and abiotic infuences on population characteristics of *Procambarus clarkii* in the Atchafalaya River Basin, Louisiana. Freshwater Crayfish. 2013; 19(2):125–136.
29. Smith C, Reay P. Cannibalism in teleost fish. Rev. Fish Biol. Fisheries. 1991;1(1):41-64.
30. Tsoumani M, Vrakas E, Anastasiou S, Chatziefstthiou M, Nathanailides C, Tiligadas I. Ecological, economic and social parameters of recreational fishing on the reservoir of Aoos river. Proceeding of the VII International Conference "WATER & FISH" – Belgrade, June 10-12, 2015; 120-124.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/22440