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REPRODUCTIVE ASPECTS OF *Girardinichthys multiradiatus*, MEEK 1904 (PISCES: GOODEIDAE)

ASPECTOS REPRODUCTIVOS DE *Girardinichthys multiradiatus*, MEEK 1904 (PISCES: GOODEIDAE)

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ABSTRACT

This paper discusses biology reproductive aspects of the yellow fish *G. multiradiatus* in the reservoir of Villa Victoria located in the State of Mexico, Mexico. Monthly samplings were carried from November, 2005 to October, 2006. 657 organisms were collected using a baitwell net. The sex ratio of females/males was 2.27:1 ($p < 0.05$) and the size at first maturation for the females was 32 mm of standard length. The spawning season occurred between March and November, corresponding to the highest values of the gonadosomatic index. For the fecundity pattern, only the fecundated eggs and embryos were considered, which were adjusted to potential model ($F = 0.0001L^{3.331}$, $p < 0.05$). The basic biology studies on this species are important because *G. multiradiatus* is endemic and literature on the species is insufficient.

Key words: *Girardinichthys multiradiatus,* sex ratio, fecundity, sexual maturity.

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RESUMEN

Este trabajo discute aspectos de la biología reproductiva del pez amarillo *G. multiradiatus* en el embalse de Villa Victoria localizado en el Estado de México, México. Se realizaron muestreos mensuales de noviembre de 2005 a octubre de 2006. Se colectaron 657 organismos usando una red de cuchara. La proporción sexual de hembras/machos fue 2.27:1 ($p < 0.05$) y la talla de primera maduración para las hembras fue 32 mm de longitud. La temporada de desove comprendió de marzo a noviembre, correspondiendo al valor más alto del índice gonadosomático. Para el patrón de fecundidad, solamente se consideraron huevos fecundados y embriones, a cuyos datos se ajustó un modelo potencial ($F = 0.0001L^{3.331}$, $p < 0.05$). Los estudios de biología básica de esta especie son importantes debido a que *G. multiradiatus* es endémica y la literatura concerniente es insuficiente.

INTRODUCTION

The yellow fish *G. multiradiatus*, also called mexcalpique of Lerma, is a viviparous species with marked sexual dimorphism that is distributed in the basins of the Balsas and Lerma-Santiago rivers in the states of Mexico, Michoacan and Queretaro. It is mainly located in shallow environments with little movement in the waters, as ponds or ditches, and with riparian or submerged vegetation (Miller et al., 2005). Some papers on this species have addressed aspects of their behavior, feeding and biology, but few have addressed the reproduction; among the most notable works are those of Macías-García and Burt de Perera (2002), Burt de Perera and Macías-García (2003), Macías-García and Saborío (2004), Cruz-Gómez et al. (2005), García (2006), Mendoza (2005), Trujillo-Jiménez and Viveros (2006), Flores (2007), Cruz-Gómez et al. (2010) and De la Cruz (2010).

Uribe-Aranzábal et al., (2004) mention that the study of reproduction biology is an essential aspect to attain knowledge of the species, so the objective of this study was to determine some reproductive aspects of the yellow fish in the reservoir of Villa Victoria, State of Mexico.

MATERIALS AND METHODS

Study Area

Villa Victoria is located in the State of Mexico, at the geographical coordinates 19 º 26′ 16″ 'N and 99º 59' 45' O, at an altitude of 2597 masl (meters above sea level) and it has a temperate sub-humid climate with summer rains. *G. multiradiatus* do not present a uniform pattern of distribution in the system, so the sampling site was selected according to the criteria of Miller et al. (2005), who reported that these fish live near the shore and in areas with submerged vegetation where they can find shelter from predators. In order to capture the organisms, 10 monthly trawls were carried out on the submerged vegetation from November 2005 to October 2006, using a baitwell net with a frame of 45 x 25 cm, 30 cm in depth and two mm mesh.

The specimens were fixed in 10% formalin and transported to the laboratory where they were separated by sex and measured in their standard length with a digital caliper with 0.1 mm accuracy and weighed with a digital balance with 0.001g precision. All organisms were grouped in size frequency with three mm intervals. To analyze the sex ratio, it was considered the total catch of females and males per month and the level of significance was established by the Chi-square test (X^2) with $p < 0.05$ (Zar, 1999). For the analysis of maturity, the gonads of all females collected at each sampling were analyzed, separating and counting immature eggs, mature eggs, embryonated eggs and embryos, using Schoenherr's criterion (1977). The Condition Factor (CF) and the Gonadosomatic Index (GSI) were calculated following the methodology proposed by Rodríguez (1992) and Wotton (1992) where the condition factor given by the following equation:

$$CF = W/L^b$$

Were:

CF = Condition factor

W = Weight of the fish

L = Long pattern of the fish

b = resulting slope of the weight/length relationship

The GSI was calculated according to the model:

$$GSI = W_g/W_f$$

Were:

GSI = Gonadosomatic index

W_g = Gonad weight

W_f = Fish weight

Fertility model used was only applied to fertilized eggs and embryos (which were adjusted to potential model) (Holden and Raitt, 1975; Schoenherr, 1977 and Wootton, 1992).

$$F = aL^b$$

Were:

F = fecundity

L= Fish length

a y b = regression constants

The size at first maturity was calculated using a logistic equation (Arancibia et al., 1994; Saborido-Rey, 2008).

$$P=e^{a+bL} / 1 + e^{a + bL}$$

Were:

P = Percentage of maturation

L= Fish length

e = base of natural logarithms

a y b = regression constants

RESULTS

Were collected 657 organisms; 456 were females and 201 males, the overall female/male sex ratio was 2.27:1 ($P < 0.05$) (Table 1).

Table 1. Total organisms collected during the sampling and monthly sex ratio

	Total catch	Total females	Total males	Sex ratio F/M	X^2 values
November	44	31	13	2.38:1*	7.36
December	29	21	8	2.63:1*	5.83
January	92	48	44	1.09:1	0.17
February	59	33	26	1.27:1	0.83
March	89	58	31	1.87:1*	8.19
April	57	54	3	18.00:1*	45.63
May	30	26	4	6.50:1*	16.13
June	50	31	19	1.63:1	2.88
July	51	42	9	4.67:1*	21.35
August	51	36	15	2.40:1*	8.65
September	52	39	13	3.00:1*	13.00
October	53	37	16	2.31:1*	8.32
Total	657	456	201	2.27:1*	99.00

* significant

The size ranges collected during the sampling period can be observed in Figure 1 and the monthly mean are presented in Figure 2. Figures 3 and 4 show the variations in the FC and IGS.

Figure 5 shows the monthly variation in immature eggs (oocytes) fertilized eggs (with embryos) and embryos stages.

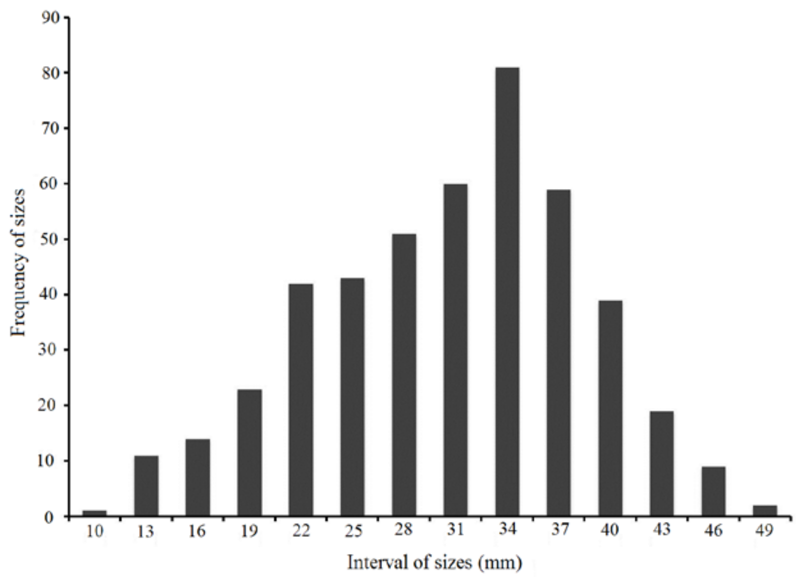

Fig. 1. Frequency of mean sizes caught during the sampling period

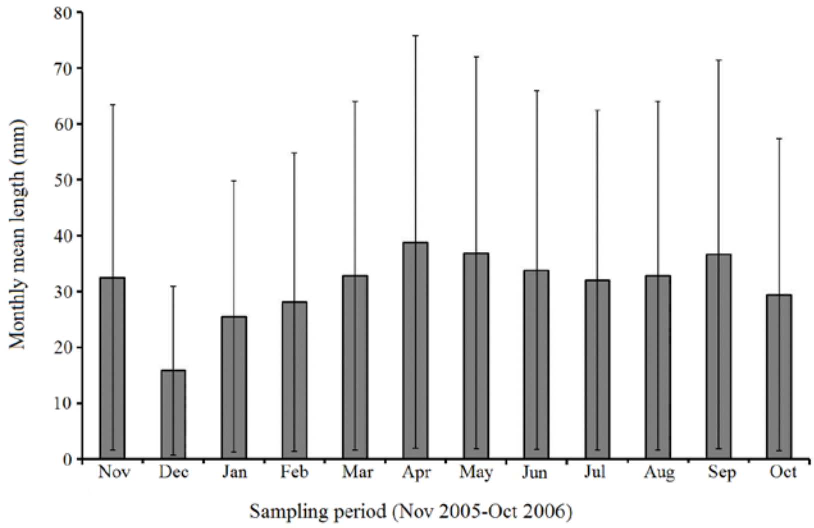

Fig. 2. Mean monthly sizes captured

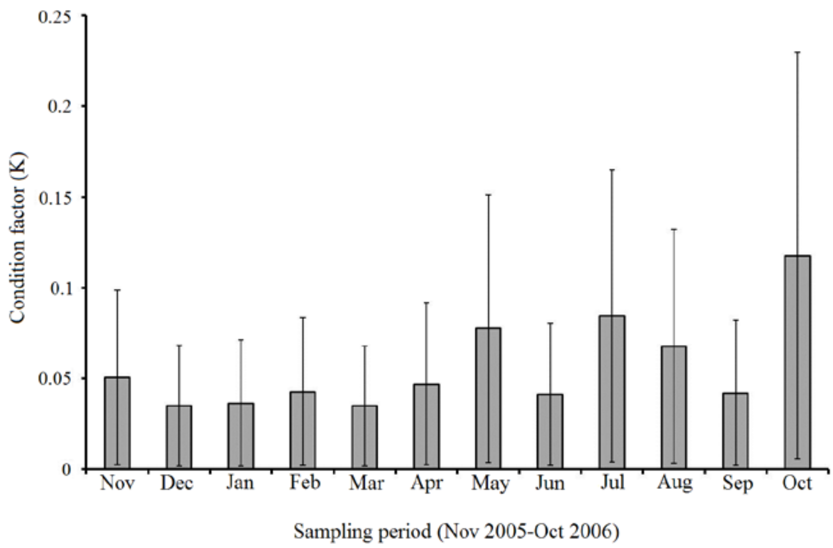

Fig. 3. Monthly values of the CF

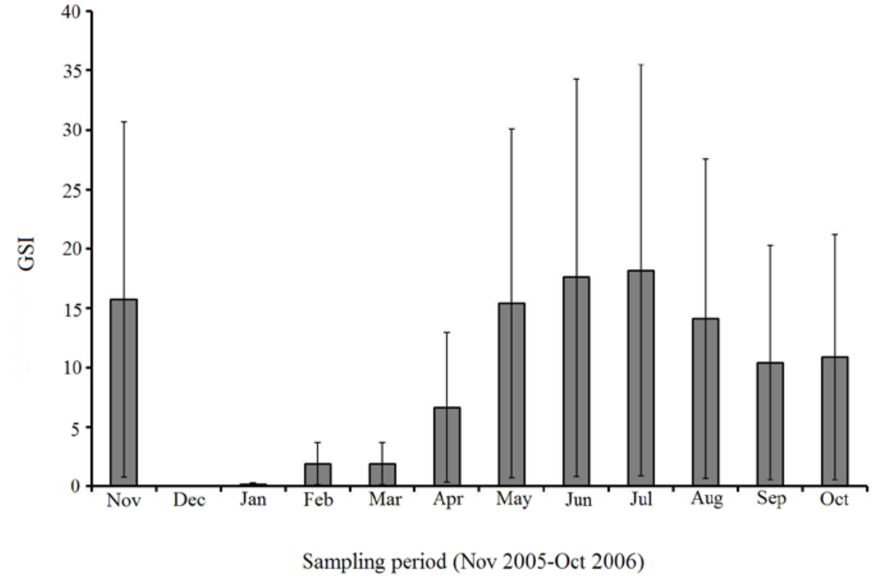

Fig. 4. Monthly values of the GSI

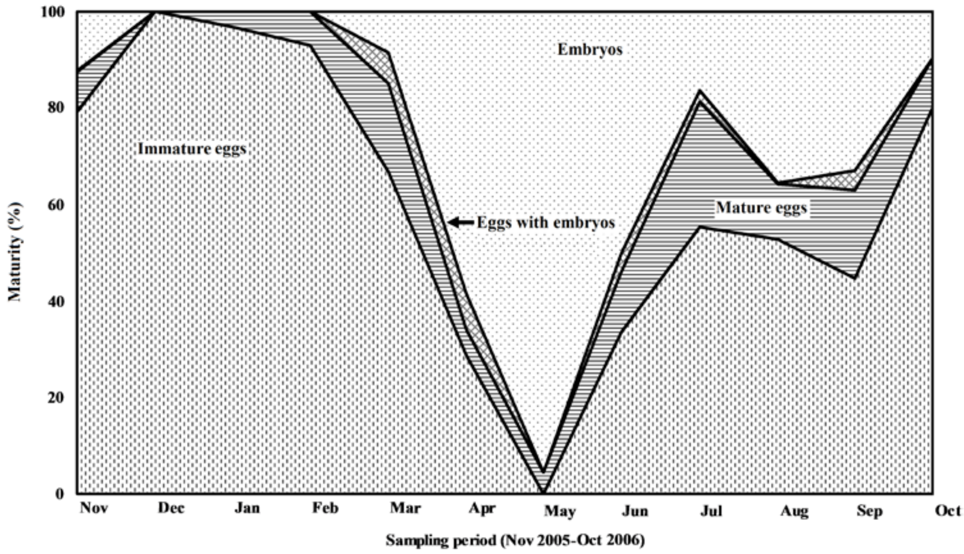

Fig. 5. Monthly variation in immature eggs, mature eggs, fertilized eggs (with embryo) and embryo stages

Table 2 shows the proportion of the maturity stages in the analyzed females; it can be observed that during December, January and February there were only immature eggs in greater proportion. Figure 6 shows the size percentages in immature eggs, mature eggs, fertilized eggs, and embryos stages.

The size at first maturation was 32 mm and is shown in Figure 7; and the fertility model, shown in Figure 8, is adjusted to the potential form $F = 0.0001L^{3.331}$.

Table 2. Females analyzed monthly and percentage of stages observed in the gonads

	Total analyzed females	Immature eggs (%)	Mature eggs (%)	Eggs with embryo (%)	Embryos (%)
November	31	79.12	8.40	0.13	12.35
December	21	100.00	0.00	0.00	0.00
January	48	96.74	3.26	0.00	0.00
February	33	92.93	7.07	0.00	0.00
March	58	66.82	18.39	6.29	8.50
April	54	28.82	5.16	7.61	58.42
May	26	0.00	4.56	0.00	95.44
June	31	33.67	12.50	3.83	50.00
July	42	55.35	26.01	2.21	16.43
August	36	52.78	11.38	0.35	35.49
September	39	44.62	18.29	4.20	32.89
October	37	80.23	10.23	0.00	9.54

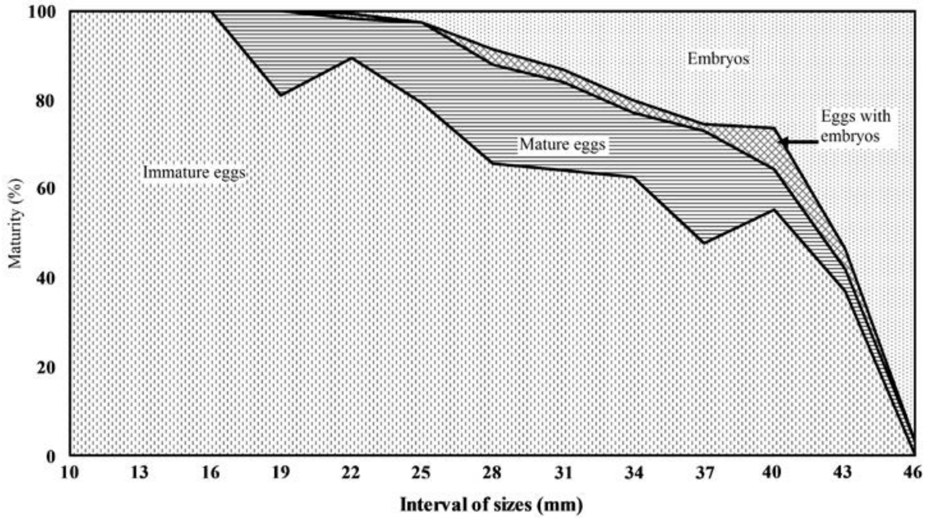

Fig. 6. Percentage of maturity according to size obtained during the sampling period

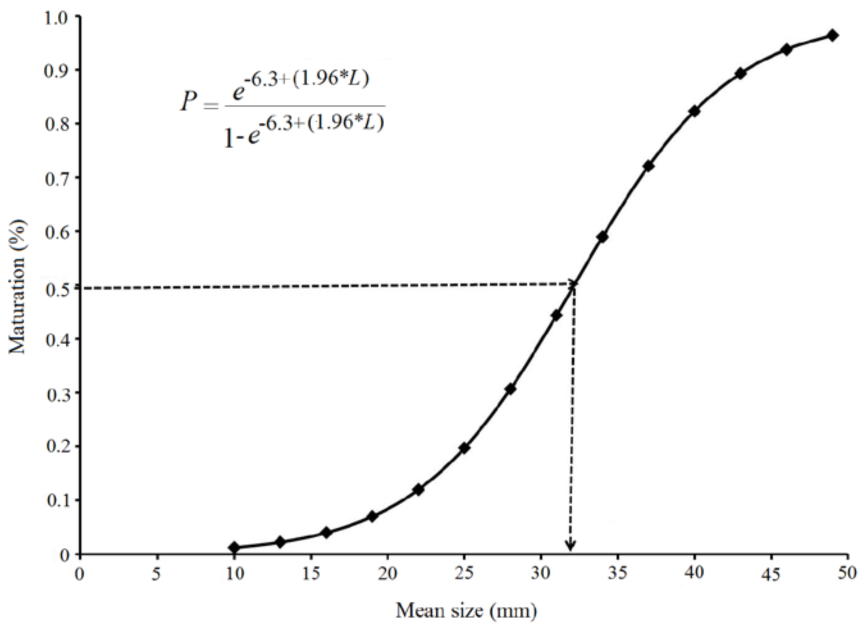

Fig. 7. *G. multiradiatus* first maturation (mean size 32 mm)

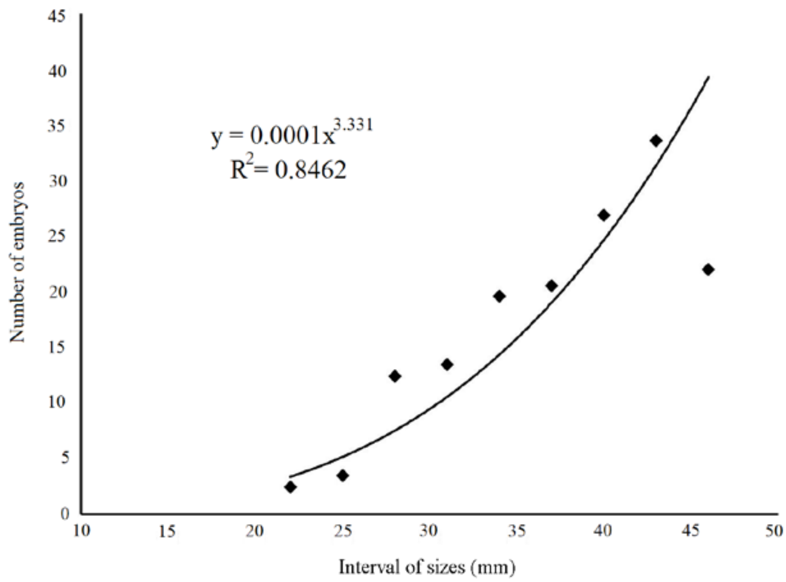

Fig. 8. Fertility model of *G. multiradiatus* obtained from data of embryonated eggs and embryos

DISCUSSION

The sex ratio during the sampling period favored females and only during January, February and June the values were not significant to the theoretical ratio 1:1. In this regard, Snelson (1989) mentions that in viviparous and ovoviviparous species, the overall sex ratio favors females in wild populations; however, some differences are reported for the same species. Cruz-Gómez et al., (2005) reported a sex ratio of 1.7:1 favoring females of *G. multiradiatus* in a reservoir in the San Martín Village in Querétaro State, Mexico while Navarrete-Salgado et al. (2007) reported a sex ratio of 1.3:1 favoring males of the same species in the reservoir of San Miguel Arco, Mexico State, Mexico.

These differences may be the result of some factors like the type of fishing equipment used, size and characteristics of the reservoir and male sexual behavior during courtship, which together can promote such differences in the sex ratio during the sampling periods (Table 1).

The size ranges during the sampling period showed a fluctuation between 10 and 49 mm, which showed reproductive activity throughout the year (Navarrete-Salgado et al. 2007, Cruz-Gómez et al., 2010) and the presence of young organisms with mean sizes of 10 to 12 mm, mean size at birth, (Rivas, 2004) are a good indication of this process. In this regard, Figure 2 shows that the monthly mean length of 23 mm and above which is the smallest size in the presence of embryos occurs throughout the year, except during December.

On the other hand, in order to quantify gonadal development in a simple way, we performed the GSI calculation. Figure 3 shows the increase in this index from February on, lasting until November. These values match the stages of advanced maturity observed in Figure 5. It is important to stand out that it is from February on when mature eggs are observed and, from March on, when embryos are noticed. The same trend is detected in Figure 6 since, by a gross examination of the gonads, the fish of 10-19 mm captured from December to February are immature, so their GSI values are low; from 22 mm on, mature eggs are observed and from 23 to 46 mm, the presence of embryos is perceived, and their length correspond to parental organisms that are beginning to reproduce.

While some authors do not agree with the fact that GSI is an indicator of maturity, in this case and for this species in particular, it can be taken into account. Saborído-Rey (2008) mentions that in species showing seasonality in their reproductive cycles, this index can be a good indicative of maturity and, in this case, both the GSI and the CF match with the highest values of gonad maturity, as well as with the largest sizes of gravid females.

According to these data, it can be established that the spawning season of the yellow fish in this reservoir takes place from March to November. From December to February, when low temperatures in the area occur, there is a decrease in reproductive activity; authors like Mendoza (2005), Navarrete-Salgado et al. (2007), and Cruz-Gómez et al. (2010) report this for the same species in other systems. Authors like Díaz-Pardo and Ortíz-Jiménez (1986), Gómez-Márquez et al., (1999) and Blanco (2000) relate the maximum period of viviparous fish reproduction to the increase in water level and temperature. The same authors also mention an interruption in the life cycle of these fish from November to February due to environmental effects, as the collection site.

In the case of other godeids, reproduction also occurs throughout the year or at the end of the dry season (Orbe-Mendoza et al., 2002).

The size or age at first maturity, defined as the size or age in which 50% of the organisms in a population are mature (Saborido-Rey, 2008), was observed in organisms of 32 mm and with average broods of 18 embryos (Fig. 7). In other systems Rivas (2004), Mendoza (2005) and Cruz-Gómez et al., (2010) reported first maturity sizes of 25 and 30 mm, with average broods of 18 embryos, while Macías-García et al. (1998) report an age of first reproduction in females of 23 mm, and mean broods of 15 embryos for *G. multiradiatus;* Díaz-Pardo and Ortíz-Jiménez (1986) indicate that *Girardinichthys viviparous*, Bustamante 1837 are sexually mature after reaching sizes greater than 30 mm, and showing average broods of 27 organisms, that is, maturation in sizes above 20 mm can be perceived.

Figure 6 shows the stages of development by size and the fact that from 23 mm on, the presence of embryos can be observed and, from 32 mm on, the number of embryos increases. Orbe-Mendoza et al., (2002) reported on Lake Patzcuaro, in Michoacán State, Mexico a mean of 19 to 39 embryos in females with lengths between 50 and 150 mm respectively, for three species of godeids. It is clear that not all organisms of a species reproduce for the first time when reaching the same size or age and that this depends on several factors related to the environment, such as temperature variations, water levels and food availability, competition and extent of each system, which indicates the particularities of the environments in which *G. multiradiatus* develops.

In addition to the above observations and considering the reproductive processes of viviparous species, Schoenherr (1977) mentioned that traditional definitions of fertility could not be applied to the viviparous fish because the maturation of oocytes, eggs and embryos does not appear simultaneously, and the fertility of these organisms should be related to the complex formed by eggs and embryos at different development stages at the time of their capture and preservation.

Therefore, several authors have adopted the term fertility to refer to viviparous and ovoviviparous species, such as *Poecilopsis occidentalis,* Baird and Girard 1853, *Heterandria bimaculata,* Heckel 1848, *Poecilia reticulate,* Peters 1859 and *G. multiraditus* (Gómez-Márquez et al. 1999; Urriola et al., 2004; Cruz-Gómez et al. 2010). In this sense, the fertility model of *G. multiradiatus* was adjusted to the equation $F = 0.0001L^{3.331}$, $p < 0.05$, which showed a direct relationship with the number of embryos with respect to size (Fig. 8). Similar data were observed by Cruz-Gómez et al., (2010) in the Ignacio Ramirez reservoir and by Gómez-Márquez et al., (1999) for poeciliid *H. bimaculata.*

The results show that the yellow fish population in the reservoir of Villa Victoria, is not yet affected in its reproductive process, and this can be proved by the presence of both young and mature females throughout the year. The basic biology studies on this species are important because *G. multiradiatus* is endemic and literature on the species is insufficient.

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REFERENCES

Arancibia, H., L. Cubillos, J. Remmaggi and R. Alarcón, 1994. Determinación de la talla de primera madurez sexual y fecundidad parcial en la sardina común, *Strangomera bentincki* (Norman, 1936), del área de Talcahuano, Chile. Biología Pesquera, 23: 11-17

Blanco, J. L., 2000. *Characodon audax.* Ciclidos-sp artículos. www.ciclidos.org (accessed in October 2010).

Burt de Perera, T. and C. Macías-Garcia, 2003. Use of visual landmarks to orient in space: a comparison between genders and populations of the Amarillo fish *(Girardinichthys multiradiatus)*. Ethology, 109(4): 341-350.

Cruz-Gómez, A., A. Rodríguez-Varela, and D. García-Martínez, 2005. Las larvas de insectos en la dieta de *Girardinichthys multiradiatus* (Pisces: Goodeidae) en el embalse Ignacio Ramírez, Estado de México. Entomología Mexicana, l(4): 1002-1006.

Cruz-Gómez, A. C. Rodríguez-Varela, and H. Vázquez-López, 2010. Madurez sexual y reproducción de Girardinichthys multiradiatus (Mekk, 1904) en un embalse del poblado de san Martín, Querétaro, México. BIOCYT, 3(9): 94-106.

De la Cruz, R. G., 2010. Características tróficas de *Girardinichthys multiradiatus* (Pisces: Goodeidae) del embalse Ignacio Ramírez, Estado de México. 195 p. (Tesis profesional, FESI, Universidad Nacional Autónoma de México, México).

Díaz-Pardo, E. and D. Ortíz-Jiménez, 1986. Reproducción y ontogenia de *Girardinichthys viviparus* (Pisces: Goodeidae*).* Revista de la Escuela Nacional de Ciencias Biológicas, 30: 45-66.

Flores, M. I., 2007. Aspectos tróficos de *Girardinichthys* multiradiatus (Pisces: Goodeidae) pez endémico del altiplano mexicano en el embalse Villa Victoria, Estado de México. 103 p. (Tesis profesional, FESI, Universidad Nacional Autónoma de México, México).

García, M. F. D., 2006. Características tróficas de *Girardinichthys multiradiatus* (Pisces: Goodeidae) en el embalse Ignacio Ramírez, Estado de México durante otoño e invierno. 69 p. (Tesis profesional, FESI, Universidad Nacional Autónoma de México, México).

Gómez-Marquez, J. L., J. L. Guzmán-Santiago, and A. Olvera-Soto, 1999. Reproducción y crecimiento de *Heterandria bimaculata* en la laguna "El Rodeo", Morelos, México. Revista de Biología Tropical, 47(3): 581-592.

Holden, M. J. and D. F. S. Raitt, 1975. Manual de ciencia pesquera Parte 2. Métodos para investigar los recursos y su aplicación. FAO Doc. Tec. Pesca (115) Rev. 1: 211 p.

Macías-García, C., E. Saborío and C. Berea, 1998. Does male-biase predation lead to male scarcity in viviparous fish? Journal of Fish Biology, 53: 104-117.

Macías-García, C. and T. Burt de Perera, 2002. Utraviolet-based female preferences in a viviparous fish. Behavioral Ecology and Sociobiology, 52(1): 1-6.

Macías-García, C. and E. Saborío, 2004. Sperm competition in a viviparous fish. Environmental Biology of Fishes, 70(3): 211-217.

Mendoza, M. J. I., 2005. Madurez sexual y potencial reproductivo del pez amarillo *Girardinichthys multiradiatus* (Pisces: Goodeidae) en un ciclo anual. 56 p. (Tesis profesional, FESI, Universidad Nacional Autónoma de México, México).

Miller, R. R., W. L. Minckley, y S. M. Norris. 2005. Freshwater fishes of México. The University of Chicago Press, Chicago. 490 p.

Navarrete-Salgado, N. A., B. E. Cedillo-Díaz, G. Contreras-Rivero and G. Elías-Fernández, 2007. Crecimiento, reproducción y supervivencia de *Girardinichthys multiradiatus* (Pisces: Goodeidae) en el embalse San Miguel Arco, Estado de México. Revista Chapingo, Serie Ciencias Forestales y del Ambiente, 3(1): 15-21.

Orbe-Mendoza, A., J. Acevedo-García, and J. Lyons, 2002. Lake Patzcuaro fishery management plan. Reviews in Fish Biology and Fisheries, 1: 207-217.

Rivas, L. I. A., 2004. Mantenimiento de *Girardinichthys multiradiatus* (Goodeidae) del embalse La Goleta San José Deguedo, Estado de México en condiciones de laboratorio. 72 p. (Tesis profesional, FESI, Universidad Nacional Autónoma de México, México).

Rodríguez, G. M., 1992. Técnicas de evaluación cuantitativa de la madurez gonádica en peces. AGT Editor, México. 59 p.

Saborido-Rey, F., 2008. Ecología de la reproducción y potencial reproductivo en las poblaciones de peces marinos. Instituto de Investigaciones Marinas (CSIC) Universidad de Vigo, España. http://digital.csic.es/handle/10261/7260 (accessed in October 2010).

Schoenherr, A. A.,1977. Density dependent and density independent regulation of reproduction in the gila topminnow, *Poeciliopsis occidentalis* (Baird and Girard). Ecology, 58: 438-444.

Snelson, F. F. Jr., 1989. Social and Enviromental control of Life History traits in Poeciliid. In: Meffe, G. K. and F. F. Snelson Jr. (Eds), Ecology and evolution of livebearing fishes (Poeciliidae). Prentice-Hall, Englewood Cliffs, New Jersey. Pp. 149-161.

Trujillo-Jiménez, P. and E. E. D. Viveros, 2006. La ecología alimentaria del pez endémico *Girardinichthys multiradiatus* (Cyprinidontiformes: Goodeidae), en el Parque Nacional Lagunas de Zempoala, México. Revista de Biología Tropical, 54: 1247-1255.

Uribe-Aranzábal, M. C., G. De la Rosa-Cruz, S. M. Guerrero-Estévez, A. García-Alarcón, and M. E. Aguilar-Morales, 2004. Estructura del ovario de teleósteos vivíparos. Gestación intraovárica: Intraluminal en *Ilyodon whitei* (Goodeidae), e intrafolicular en *Poeciliopsis gracilis* (Poeciliidae). In Homenaje al Doctor Andrés Reséndez Medina. Un ictiólogo mexicano, V. M. L. Lozano, and A. Contreras-Balderas Eds., Universidad Autónoma de Nuevo León, México.

Urriola, H. M., P. J. Cabrera, and Q. M. Protti, 2004. Fecundidad, fertilidad e índice gonadosomático de Poecilia reticulata *(Pisces: Poeciliidae)* en Heredia, Costa Rica. Revista de Biología Tropical, 52(4): 945-950.

Wootton, R. J., 1992. Fish ecology. Chapman & Hall, Inc. New York, USA. 221 p.

Zar, J. H. 1999. Biostatistical Analysis. Prentice Hall. Upper Saddle River New Jersey. 931 p.