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AGE AND GROWTH OF *Poeciliopsis gracilis* IN THE AMATE AMARILLO MICRORESERVOIR, MORELOS

José Luis Gómez-Márquez
Limnology Laboratory, FES Zaragoza, UNAM, Mexico City, Mexico

Aida Victoria Muñoz-Ruiz
Limnology Laboratory, FES Zaragoza, UNAM, Mexico City, Mexico

José Luis Guzmán-Santiago
Limnology Laboratory, FES Zaragoza, UNAM, Mexico City, Mexico

Roberto Trejo-Albarrán
Hydrobiology Laboratory, Biological Research Center. UAEM Cuernavaca, Morelos, Mexico

María del Carmen Alejo-Plata
Universidad del Mar, Campus: Puerto Ángel, Ciudad Universitaria, Puerto Ángel, San Pedro Pochutla, Oaxaca, Mexico

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Abstract: The age and growth of *Poeciliopsis gracilis* were obtained in Amate amarillo microreservoir, Morelos, which is an artificial, shallow, productive system, in which rainwater is collected for later use for irrigation, watering and aquaculture purposes among others. The work was carried out from September 2018 to August 2019, during which 639 organisms were collected. The sex ratio favored females over males throughout the study (M:M; 4.2:1). The length-weight relationship for the population, females and males, showed positive allometric growth, that is, greater growth in weight than in length. Le Cren's relative condition factor (Kr) presented values above 1 throughout the study, indicating that the organisms are in good condition. The age of 365 organisms was determined by reading the *circullis* of 1090 scales, of which the maximum age recorded was 4 months and the minimum age was 12 days. It was observed that growth marks were deposited every 3 days and the species has a longevity of approximately two years. The values of the asymptotic length (L∞) of the von Bertalanffy growth model for the population, females and males were overestimated. For the Gompertz model, the value of L∞ for the population, females and males was 10.07, 8.48 and 3.89 cm respectively and this better represented the observed data. The aquatic system has warm waters (average 24°C), slightly alkaline (pH > 7.2), well oxygenated (greater than 5 mg L^{-1}), hard waters and highly productive for the growth of organisms.

INTRODUCTION

Fish are an important source of food, aimed at satisfying the dietary needs of man and have become a very important resource, since 70% of global fish production is destined for direct human consumption; the rest goes to flour production and other purposes.

Total fisheries and aquaculture production reached a record 214 million tons in 2020, of which 178 million tons were aquatic animals, largely due to the growth of aquaculture, especially in Asia. The amount destined for human consumption is 20.2 kg per capita. However, due to the increase in the world's population, demand for this resource has continued to grow and aquatic food production is even expected to continue increasing by 13% by 2030. It is essential that this growth is accompanied by the safeguarding of ecosystems, reducing pollution, protecting biodiversity and guaranteeing social equality (FAO, 2022).

In 2021, national fishing production in Mexico was recorded at 1,928,947 tons. In the case of the fishing activity carried out in the country's continental waters, in 2021 a volume of 110,698 tons was reached, which represented 0.15% of the national fishing production (CONAPESCA, 2021).

In Mexico, more than 101,698 million freshwater ornamental fish are sold annually, representing 222 tons, which generates an income of approximately 1,102 million pesos. The main states producing ornamental fish are: Tabasco, Campeche, Veracruz, Yucatán, State of Mexico, Morelos and Jalisco (CONAPESCA, 2021).

The introduction of fish from one region to another is a result of intense global trade related to sporting activities, aquaculture, biological control purposes and ornamental use. The increase in the ornamental fish trade has grown to become an activity that represents around 30 billion dollars annually worldwide (Chang *et al*. 2009).

The cultivation of fish in Mexico for ornamental use, sports activities and consumption as food has led to the mobilization of more than 115 species, many of them now established in a significant number of natural ecosystems in the country (Contreras-Balderas 1999; Mendoza and Koleff 2014)

The state of Morelos has become one of the main centers for the cultivation and trade of ornamental fish and this activity causes an enormous possibility of bringing a greater number of non-native species to the environments and becoming a serious risk for the areas of ecological care (Mejía-Mojica *et al*., 2012, 2018).

Members of the order Cyprinodontiformes are cosmopolitan and live in tropical, subtropical and temperate latitudes. The order is divided into seven families, of which four (Poeciliidae, Anablepidae, Jenynsiidae and Goodeidae) are endemic to the American continent. The Poeciliidae family includes 37 genera and 304 species (Nelson *et al*., 2016) and in Mexico it is possible to find 22 genera and 180 species. Poecilids are small fish, none exceed 20 cm in length and most are less than half of this measurement. They have internal fertilization through the gonopodium of males that functions in the transfer of sperm packets (spermatozoa) to the genital pore of females and give birth to their live young (except *Tomeurus*) (Miller *et al*., 2009).

Poeciliopsis gracilis (Heckel. 1948) is distributed on the Atlantic Slope, from a stream 20 km north of Ciudad Cardel, Veracruz, to the south in the Oaxaca-Veracruz basin and has been introduced and established in the Pánuco River, San Luis Potosí and Querétaro and the basins of the Balsas River, Guerrero, Michoacán (Mendoza, 2018: Miller *et al*, 2009). It lives in a typically calm water habitat in streams, flood ponds, banks, microreservoirs, lagoons, backwaters and banks of lowland rivers, in clear to muddy water with a high content of suspended solids; no to moderate current; clay substrate, mud, sand, gravel, rocks; No to sparse vegetation, but green algae are common, up to 0.6 m deep, usually less. In large, low gradient rivers, they are seen in schools along the shore, in very shallow water, although larger adults prefer deeper waters. Juveniles of 7-10 mm total length (Lt) have been captured from late December to early March; Reproduction could take place during much of the year in favorable habitats. The maximum known standard length (Lp) is 73 mm (Miller *et al*., 2009). It is a species that has dark spots along the midline of the sides. It feeds mainly on detritus, although it usually consumes filamentous algae and benthic insects (Rodríguez, 2008). The body is green to iridescent blue, it has 4 to 6 irregular spots on the body that give it the English name "portholelivebearer". Juveniles up to 2 weeks old have these points that differentiate them from other species. All fins are colorless (Pérez, 2005).

P. gracilis has recently been recorded north of its known distribution (Balsas River basin area in Morelos and Puebla, Mexico) (Mejía-Mojica, 1992). Despite the high demand for *P. gracilis* as a forage species in Mexico and as ornamental fish, which is an alternative to improve the family economy of the state (a species that is easy to reproduce, short life cycle, resistant to handling and does not require of large areas of land) and as biological control (pests, weeds, disease vectors) (Gido and Franssen, 2007; Betanzos-Reyes *et al*., 2020). On the "bordos" of the state of Morelos, its commercial value is very low, but from an ecological point of view, there is little research on the impact that this introduced species has on the fauna and habitat of native species in different countries (Gómez -Márquez *et al*., 2008). The fish of this species present secondary sexual dimorphism, although the color is not very different, but in which the females are larger than the males (Miller *et al*, 2009).

Studies on this species were carried out by Contreras-MacBeath and Ramírez-Espinoza (1996), Ayala and Vera (2007), Gutiérrez and Hernández (2007), Gómez-Márquez *et al.* (2008), Miranda *et al.* (2009), Galicia *et* *al.* (2014) and Sánchez (2019), on aspects of growth, age and reproduction of the species. Based on the information collected, it must be noted that there is little information on the determination of the age of this species or similar ones, so in this study the age and growth of *P. gracilis* was determined, to know the relationship that exists between the age and size of the organisms, which will be affected by changes in the biotic and abiotic factors that occur in the aquatic system.

MATERIAL AND METHODS

The Amate amarillo bordo is located in the central-eastern part of the state, in the municipality of Ayala, Morelos; It is located at the coordinates 18°44' north and 98°58' west, at 1267 meters above sea level. (INEGI, 2021). It has an area of 7.84 ha. and a perimeter of 1379 m. The climate of this area is warm subhumid with summer rains $Aw_0''(w)(i')g$, with an average annual temperature of 24°C and precipitation of 894 mm (INEGI, 2021). The type of vegetation that predominates in this state is Low Deciduous Forest (LDF), with 29.52% and grassland, with 6.24% (INEGI, 2010).

Sampling was carried out monthly from September 2018 to August 2019 and a single sampling station was established, that was georeferenced using a GPS, located in the sluice gate of the southwest part of the system, being the deepest part. At the site, parameters were evaluated; environmental temperature water(thermometer), temperature and dissolved oxygen (HANNA oximeter, model H19146); pH and electrical conductivity (HANNA multiparameters, model HI 991300); transparency and depth (Secchi disk). A Van Dorn bottle was used to take water samples and they were collected at five depths (0.30, 1, 2, 3 and 4m). Subsequently, the collected water samples were poured into one-liter polyethylene bottles that were stored in a cooler at 4°C until analysis in the laboratory. After sampling, alkalinity (indicator method) and total hardness (complexometric method) were determined.

Fish collection was carried out using a 10 m seine with a mesh size of 0.005 m, on the shore of the system. Subsequently, the fish were placed in a bucket and 3 to 4 drops of clove essence were added to anesthetize the organisms (García-Gómez *et al.*, 2002) and then they were placed in 10% formalin for preservation. For the biometry of the fish, a Vernier (0.1mm precision) was used to measure the standard length (Lp), total length (Lt) and height (A) of each of the organisms; With the help of an analytical balance (0.1 mg precision) the total weight (Pt) was obtained.

To determine the sex and gonad maturity of the organisms, a ventral cut was made from the anal opening to the muster girdle to expose the gonads. With the help of a stereoscope, the phases of ovarian development were determined, considering the proposal made by Contreras-MacBeat and Ramírez-Espinoza (1996). This species is characterized by sexual dimorphism. In the case of males, sex was determined through the observation of a structure called gonopodium and according to their development they were classified into immature and mature (Contreras-MacBeath and Ramírez-Espinoza, 1996).

With the help of a stereoscope and fine-tipped dissecting forceps, 10 scales were taken from the region between the pectoral fin and below the lateral line (without regenerated focus, scale with complete anterior and posterior edge). They were cleaned with a brush and water, mounted between two slides and labeled with the specimen number, month and year. Subsequently, with a microscope, the *circullis* of at least three scales were observed and counted, the distance from the focus of the scale to the anterior margin of the scale (radius) was measured.

To determine the size structure of the population based on sex, a size frequency distribution histogram was made, in which the number of modes (size classes) that make inference in the recruitment of organisms can be identified. To carry out the appropriate calculation of size intervals in the population, Sturges' rule is used (Guerra, 2014). Analysis of Covariance (ANCOVA) was applied to determine if there were differences between length and weight between the sexes; If there are any, then the weight-length relationship by sex was carried out, in addition to calculating said relationship for the total population.

The Weight-Length relationship was analyzed using the potential type equation: $P=aL^b$, where P is the weight of the individual in grams; L is the length of the organism in cm; a and b are constants which are estimated by linear regression analysis using the least squares method. This equation can be transformed into linear form by using logarithms (base 10) where b is a constant that determines the proportionality of the increases in length with respect to weight and log a is the intercept (Salgado *et al.*, 2005)., Log P =log a + b log b.

Because length is a linear magnitude and weight is equal to the cube of the height, if an individual maintains its shape as it grows, then growth is isometric ($b=3$). When $b>3$, individuals present positive allometric growth. On the other hand, when $b<3$, individuals preferentially increase their length and this indicates that it is a negative allometric growth (Froese, 2006; Nehemia et al. 2012). The type of growth (allometric or isometric) was obtained with the value of the slope of the weight-length graph, and to know if this value has a statistical difference, a check was made using the Student-t statistic (Salgado *et al.*, 2005).

To determine the sex ratio on a monthly and total basis, the chi-square distribution statistical test was performed ($p<0.05$) to which the Yates correction was applied (Guerra, 2014).

The condition factor was used as an indicator of the welfare state of the organisms. This relative or Le Creen (1951) condition factor (Kr) expresses in fish the relationship between the observed weight and the weight calculated according to the following mathematical expression: Kr= Pobs/P calc, where Pobs is the weight of the fish in grams and Pcalc the weight calculated based on the weight-length relationship (Weatherley and Gill, 1987).

The retrocalculation method (Gómez-Márquez *et al.*, 2020) was used to obtain the size-age relationship for which the radii of the scales were plotted against the observed lengths of the individuals at the time the scale sample was obtained. in order to define the type of relationship that exists between the individual's body and the hard structure (scale). Two models were applied to know which one best fits the species.

von Bertalanffy model (Salgado *et al.*, 2005):

$$Lt = L_{\infty}\left(1 - e^{-k(t-t_0)}\right) \quad \text{y} \quad Pt = P_{\infty}\left(1 - e^{-k(t-t_0)}\right)^b,$$

where Lt and Pt are the total length and weight at age (t), L∞ and P∞ is interpreted biologically as "the average weight or length of a very old fish" or "asymptotic weight or length". K) is a constant related to the metabolic rate. The constant t_0 sometimes called the "initial condition parameter", is the theoretical time in which the organism begins its growth b) is the constant that comes from the length-weight relationship (Sparre and Venema, 1997). To obtain the values of the constants of L∞, the Ford-Walford method was used and for K and t_0 parameters, the Beverton and Holt method was used (Salgado *et al.*, 2005).

The other model used is the Gompertz model, which has been used to describe growth in aquatic organisms, mainly fish (Salgado *et al*., 2005). The model is as follows (Gómez-Márquez *et al*., 2020):

$$P_t = P_\infty\, e^{-Be^{-kt)}} \quad \text{y} \quad L_t = e^{b-ce^{-kt}}$$

where, L(t) is the length at time "t", L∞ is considered the maximum observed length, B is the maximum growth rate, k is the intrinsic growth rate. The model was linearized to obtain the constants and the Microsoft Office Excel spreadsheet (2013) was used.

Finally, the longevity of the organisms was obtained from the Taylor equation (1958):

$$A_{0.95} = t_0 + \frac{2.996}{K}$$

Which means that it is the theoretical limit age or time required for the fish to reach 95% of its maximum length (L∞). To obtain longevity it is necessary to use the variables calculated with the von Bertalanffy model (K).

RESULTS

The Amate amarillo bordo, is a system with a maximum total depth of 4.5 m in the month of September and a minimum of 2.4 m in January and April, with a maximum water temperature of 26.08 °C (April) and a minimum of 21.3° C (January), with thermal stratification during sampling hours throughout the entire study. With respect to dissolved oxygen, the aquatic system has good oxygenation with an average of 8.8 mg L^{-1}, without detecting anoxia at the bottom of the bank and a clinograde curve behavior. Transparency (visibility to Secchi disk) recorded maximum values of 0.5 m during the rainy months (June to September).

During the study, a maximum pH value of 8.68 was obtained in the month of October and the minimum of 7.86 in August; in the other months there were values that ranged from neutral to slightly alkaline pH. Regarding total alkalinity, the maximum value was in June with 212 mg $CaCO_3$ L^{-1} and the minimum in February with 64 mg $CaCO_3$ L^{-1}; therefore, the aquatic system has high productivity. The total hardness of the board showed a variable behavior during the study, with a maximum value of 392 mg $CaCO_3$ L^{-1} and a minimum of 216 mg $CaCO_3$ L^{-1} (Table 1), so it can be said that the water in this system it is hard and the organisms have an efficient metabolism based on the water quality. When applying the Kruskal-Wallis statistical test to the data of the physical and chemical variables, it showed that, between the sampling months, there is a significant difference ($P<0.05$), which indicates that there was always variability in the behavior of each one of the variables.

Water parameters	Maximum	Minimum	Average
Temperature (C°)	26.08	21.3	24
Depth (m)	4.5	0.87	2.17
Transparency (cm)	0.5	0.25	0.37
Dissolved oxygen (m L^{-1})	17.7	4.03	8.8
Total alkalinity (mg $CaCO_3/L^{-1}$)	212	64	148
Total hardness (mg $CaCO_3/L^{-1}$)	392	216	302
pH	8.74	7.54	8.14

Table 1: Physical and chemical parameters recorded during the study period on board

During the study, 639 organisms were captured, 397 females, 93 males and 149 undefined. The minimum total length (Lt) of the organisms during the study was 1.1 cm and the maximum size (Lt) was 6.5 cm in total length. Table 2 shows the intervals obtained for females and males, as well as for indeterminate organisms.

It was observed that in the first sampling (September 2018), the smallest organisms and little variability in sizes were collected and during the October sampling, greater heterogeneity in sizes was recorded.

	Total length (cm)		Total weight (g)	
	Minimum	Maximum	Minimum	Maximum
Females	1.9	6.5	0.069	3.83
Males	1.7	4.5	0.04	1.12
Indeterminate	1.1	2.9	0.0089	0.21

Table 2: Biometry for females, males and indeterminates of *P. gracilis*

A histogram of size frequencies by sex was made, where the most representative size was in the range of 3.5-4.5 cm for females. The mode for males was in the range of 3 cm and for indeterminates it was 2-2.5 cm (Figure 1).

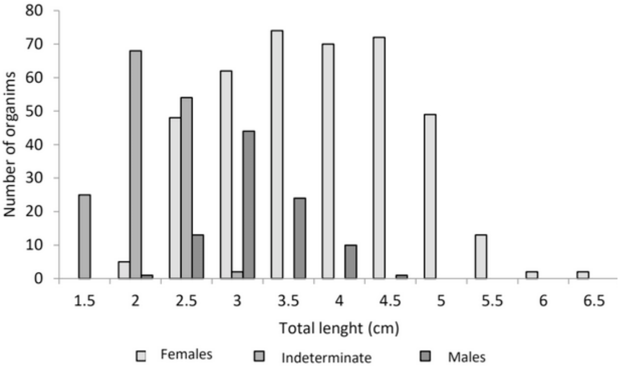

Figure 1. Size frequency distribution for *P. gracilis*

The sex ratio was 4.2:1 (Female:Male) (χ^2=187.36; $p<0.05$) and there was dominance of females (Figure 2) during 11 months of the study, while in August no significant statistical differences were recorded.

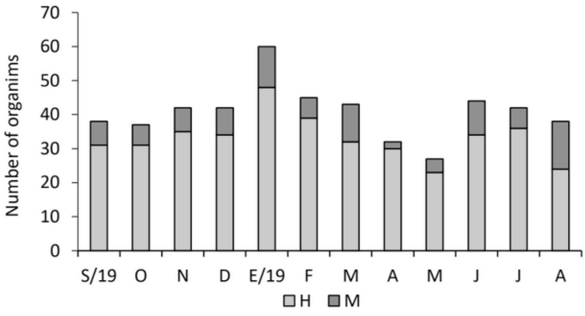

Figure 2. Temporal variation of the female-male ratio for *P. gracilis*

An ANCOVA was carried out to find out if there are differences between weight and height, taking into account sex, and it was obtained that between females and males there is a significant difference with respect to length and weight (F= 55.02, $p<0.05$). Because there are statistical differences between the sexes, the weight-length relationship (total length) was carried out independently.

The relationship between total length and standard length was estimated and a linear behavior was obtained between the variables and the model that represented this relationship was $Lp = 0.8648\ Lt - 0.0557$; R^2= 0.9927, which indicates that there is a high association between these variables, therefore, through one value of the variable, the other variable can be obtained.

Regarding the weight-length relationship for the *P. gracilis* population, it is represented by a potential model, where the value of the slope (b=3.15) indicated that the type of growth is positive allometric, this indicates that the growth of organisms tend to increase more in weight than in size. (Figure 3) and perhaps this growth is influenced by the maturation state of the females' gonads.

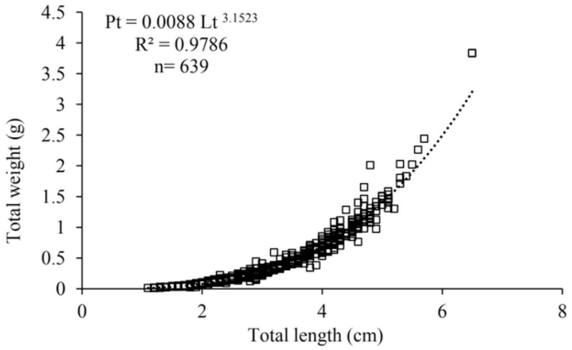

Figure 3. Length-weight relationship for the total population of *P. gracilis*

The same behavior was presented by males and females, whose slope value was bm=3.207 and bf=3.157 respectively, which was verified with the Student's t test ($P<0.05$) and which indicates positive allometric growth, greater increase in weight than in size.

$$Pt_F = 0.0087Lt^{3.157} \quad \text{y} \quad Pt_M = 0.0084\,Lt^{3.207}$$

In order to know if there are differences between the slopes of the length-weight relationship between sexes, a value of F=0.01; p=0.9381 was obtained; therefore, there is no statistically significant difference, indicating that the slope for both sexes is similar.

The relative condition factor (Kr) for the entire population of organisms showed a particular behavior that is closely related to the temperature of the aquatic system (Figure 4). It can be seen that throughout the study there were two months in which the condition factor increased, and that it is graphically correlated with the increase in temperature, one in the month of October with a value of K=1.68 and a temperature of 24.8°C and another in April with values of K=1.61 and 26.7°C, while in the month of January there is a decrease where K=1.08 and the temperature decreases to its lowest value of 22.06°C, although during throughout the study the fish in the aquatic system were in good condition

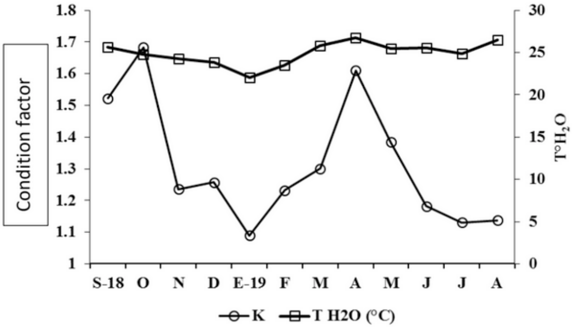

Figure 4: Temporal variation of the relative condition factor and water temperature for the *P. gracilis* population

The age of 365 individuals of *P. gracilis* was determined, and for this, 1090 scales were analyzed, from which the radius and number of *circullis* of each one were obtained. The total length-radius relationship of the scale showed a behavior between these potential type variables with origin different from zero, which was the one that had the best fit, based on the value of the coefficient of determination, which indicates that there is no a direct linear proportionality between these variables. During the study, a minimum radius of 0.15 mm was obtained for an organism with a total length of 1.1 cm and a maximum of 1.87 mm for a fish with a total length of 6.5 cm. The relationship was as follows: Lt = 4.386 R $^{0.514}$; $R^2 = 0.637$.

To validate the data on the deposit of growth marks on the scales, a culture of *P. gracilis* was made under laboratory conditions, trying to maintain the same environmental conditions that were most suitable or similar to the Amate amarillo bordo, in order to know the time in which the *circullis* are deposited. It was observed that each mark was deposited every 3 days and with this value, the estimated age of each of the organisms was obtained.

When the *circullis* were counted, it was obtained that the minimum age is 0.4 months (12 days) in organisms with a length of 1.1 cm, and the maximum number of *circullis* corresponds to an age of 4 months, in organisms with a length of 6.5 cm. 9 age groups with their respective length were obtained and the Gompertz and von Bertalanffy models were calculated with them.

When making the graph of all the length data with each of the ages, the behavior of the length-age distribution is curvilinear with moderate atypical data between the age of 0.5 and 2 months; the maximum recorded age is 4 months with a total length of 6.5 cm (Figure 5). The sizes that make up the 2- and 3.5-month group apparently have a greater number of fish and the data show a normal trend in behavior.

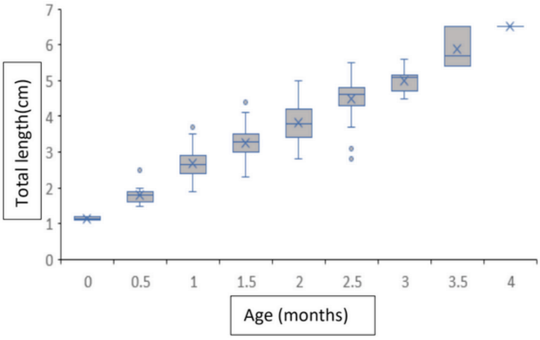

Figure 5: Distribution of total length data in relation to age of *P. gracilis*

Based on the values obtained from the constants of both models, the model that best describes the growth of the fish is that of Gompertz model, whose values were more congruent with the observed values of the population, unlike the von Bertalanffy model that overestimate the maximum size values for the fish. Therefore, the Gompertz model was represented as follows for the total population in length (figure 6):

$$Lt = 10.0742 * e^{-e^{(-0.3782*(age-1.9033))}}$$

And by weight (figure 7):

$$Pt = 4.0315\, e^{-5.6210*e^{-0.5841*age}}$$

Using these equations, the corresponding age-length figures were obtained, which presents a behavior with a tendency towards a straight line for height, in which it can be observed that in the first months it has a rapid increase in height, in addition to the fact that the value of the growth constant (K), expresses a rapid growth rate, therefore, it will reach its asymptotic length in a shorter time.

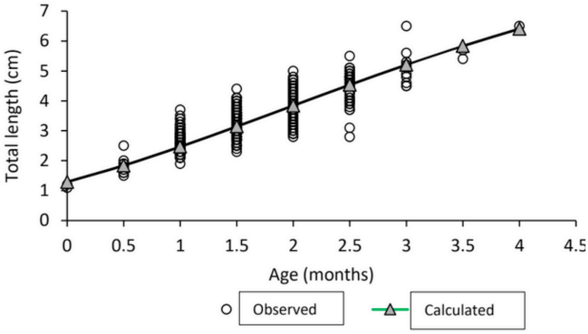

Figure 6: Gompertz growth curve in length for the *P. gracilis* population

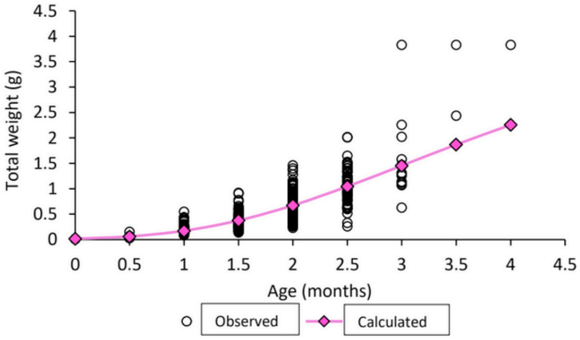

Figure 7: Gompertz growth curve in weight for the *P. gracilis* population

After having obtained the constants of the Gompertz model as well as those of von Bertalanffy, although this last model overestimated the growth values of the organisms, the longevity or maximum age for *Poeciliopsis gracilis* was obtained, this with the help of the equation Taylor (1958), which was 2 years, under natural conditions.

DISCUSSION

In recent decades, fishing in continental waters has increased due to the construction of artificial reservoirs (dam, banks, etc.) on permanent currents and in some cases where water is scarce, to retain the liquid, for different purposes such as the supply for irrigated agriculture, sometimes as sources of recreation and currently, for the production of high-quality protein fish resources, with the aim of developing various fisheries with species of commercial interest.

These small surface systems in hectares are known under the terms "small reservoirs" (Remedios, 2001), "microreservoirs" or "bordos" (Quiroz and Díaz, 2010), and refer to the constructed epicontinental bodies of water, with the purpose of capturing rainwater for irrigation in agriculture or as watering holes for livestock (Arredondo-Figueroa and Flores-Nava, 1992). It must be noted that "microreservoirs" or "bordos", are aquatic systems smaller than 10 ha, constitute 84% of the total water bodies in Mexico (Quiroz *et al.*, 2009), which largely reflects the water dependence on to the climate.

Based on the work carried out by Rivera and Hernández (2011) and supported by the classification of Lewis Jr. (1983), this microreservoir presented characteristics of being continuous warm polymictic, since it recorded various periods of mixing during the night. and is stratified by a period of time during the day, all in a 24 hour cycle. Schindler (1991) mentions that shallow lakes can stratify and break stratification several times in the summer, as a result of the windy period, and that polymictic lakes are so common in the tropics, where in some cases, diurnal changes in temperature. They are so large that they induce mixing of the water column. This influences the behavior of the system, as well as that of the organisms by having an important participation in the solubility of gases, in photosynthetic rates, in the growth, reproduction of the species, as well as influencing the modification of the fish metabolism metabolism

When reviewing the data of the parameters reported in this study, in general it can be said that the Amate amarillo bordo, is a shallow aquatic system (less than five meters) and can be considered productive because it presents average depth values less than 2, since it favors the interrelation between the surface and the bottom materials, which makes it more productive (Arredondo and Ponce, 1998; Quiroz and Díaz, 2010; Gómez-Márquez *et al.*, 2023). Regarding the amount of salts present, it shows a high ionic charge and alkaline reserve because the higher the concentration of ions, the conductivity of the water increases, in addition to the fact that the pH values recorded in the study period maintain a slightly alkaline trend (Solís-Castro *et al.*, 2018).

Mejía-Mojica *et al.,* (2012) mention that 62% of the ichthyofauna found in the state of Morelos is introduced and *P. gracilis* is considered a non-native, exotic species, whose economic or ecological importance had not been studied until that moment. Furthermore, in a study on the fauna of the state of Morelos, the species with the highest number of individuals were always fish belonging to the Poeciliidae family, which make up 83% of all captured individuals, and of this family, *P. gracilis* it represented 58% of the captures (Mejía, 2018). This is why when you want to evaluate the growth of fish that occur in aquatic systems, it is necessary to take into account the endogenous and exogenous factors that affect it and that the size that the organisms reach will depend on the availability of food, photoperiod, temperature and dissolved oxygen (Gómez-Márquez *et al.*, 2020).

The sizes of the organisms captured in this study are within the size ranges recorded by other authors (Ayala and Vera, 2007; Gutiérrez and Hernández, 2007; Gómez-Márquez *et al.*, 2008; Sánchez, 2019) for different systems aquatic species in the state of Morelos, in addition to the fact that the same fishing gear and mesh size were used. Likewise, females were larger in both weight and length, compared to males.

During the study, a sex ratio was obtained in which there was always dominance by the females, which agrees with what was reported for *P. gracilis* by Contreras-MacBeath and Ramírez-Espinoza (1996), García-Navarrete *et al.* (2000), Gómez-Márquez *et al.* (2008) and Sánchez (2019). authors who report the same behavior for the same species. Gómez-Márquez *et al.* (1999) and Brindis (2019), mention the same trend of female dominance in the sex ratio for *Heterandria bimaculata* (=*Pseudoxiphophorus bimaculatus*), belonging to the same family as *P. gracilis*.

Snelson (1989), McKellar and Hendry (2011) and Zúñiga-Vega *et al.* (2012) report that wild populations of many poecilids are in favor of females and that this is the result of differential mortality between the sexes, since females have high survival rates due to their larger size, weight and color. less noticeable than that of males. A more reasonable explanation is that males have high mortality attributed to several causes including competition between males for females, predation, resource limitation, high susceptibility to stress and an accelerated metabolism. In some ways, having a greater proportion of females in the population can be important, since this can ensure the survival of the species and the recruitment of organisms to the population; therefore, the possible dissemination through different environments where it can adapt. In this microreservoir, the presence of *Poecilia sphenops* organisms as well as *Pseudoxiphophorus bimaculatus* has been recorded (Brindis, 2019), which causes an invasion of the ecological niche, which can possibly affect the fecundity of *P. gracilis*, causing there to be decrease or increase in certain months, due to competition for space, food and habitat.

The weigh-length relationship of the species in this study registered a positive allometric growth for the population, as well as females and males; These same results are reported by Ayala and Vera (2007), Gómez-Márquez *et al.* (2008) and Sánchez (2019). Therefore, the weight-size relationship continues to maintain its behavior, except that, in the aquatic system studied, it tends towards isometry, since there is no significant statistical difference in the value of b=3 when the t-Student test was applied.

When comparing the values of the slopes of the length-weight relationship of females and males, it was observed that there is no statistically significant difference, compared to what Miranda *et al* (2009) mentions, who recorded the opposite and mention that this is due to the variability of the environmental factors presented by the aquatic system. It is very possible that this type of growth, where the organisms present positive allometry, is affected by increasing weight due to the effect of sexual maturity, mainly in females, due to the reproductive process.

McKellar and Hendry (2011) point out that factors such as habitat, feeding habits and seasonal growth intervals can contribute to differences in growth in fish. Other factors such as the quantity and quality of food available in the community, trophic level, number of organisms examined, temperature and sex, which are important and must be considered in the study of the growth of organisms.

The Le Cren condition factor remained with values greater than 1 throughout the year, which indicates that *P. gracilis* is in good condition. Sánchez (2019) also observed similar behavior. This means that the aquatic system presents adequate conditions for the development of the species, as mentioned by Gómez-Márquez *et al.* (2008).

To determine the age of these organisms, the first study with this species and with the hard structure used was carried out by Gutiérrez and Hernández (2007) in an artificial reservoir in the state of Morelos, who reported that the deposition of the circullis was a the 3.2 days under laboratory conditions or similar to the aquatic system (Emiliano

Zapata Dam), similar to what was observed in this study, which was 3 days on average, the time necessary for the deposition of each *circulli* and this difference may be due to the physical and chemical factors of water.

The organisms we worked with, have cycloid scales as mentioned by Coad (2017), which is why the *cirullis* were counted from the focus to the anterior margin, because this species and the majority of viviparous species do not present more than two growth marks in the bone structures, as a consequence of the longevity that this type of organisms have, therefore the scale is considered the best bone structure for obtaining age, since the otoliths, being a structure very small, the growth marks are difficult to observe and although it was done, only one mark could be registered.

A minimum age of 0.4 months (Lt=1.1) and a maximum age of 4 months (Lt= 6.5) was obtained, unlike what was reported by Gutiérrez and Hernández (2007), who recorded a minimum age of 0.5 months and a maximum of 11.5 months for the organisms from the Emiliano Zapata dam, Mor. This difference is due to the fact that the aquatic systems from which the organisms were extracted, have different physical and chemical characteristics, which directly influences the presence of the organisms. However, this does not prevent the existence of organisms older than those reported on bordo, but due to the capture technique and gear used, it was not possible to capture them.

Some hypotheses, as mentioned by Egger *et al*. (2004), point out that the temporal variation in temperature, the quality and quantity of available food, as well as the fluctuation in organisms in terms of their condition associated with spawning, allow the deposit of growth marks in different structures hard that can be used for age and growth studies. Likewise, Snelson (1989) recommends reading hard structures as the best technique for determining age in short-lived or low-lived fish.

The von Bertalanffy growth model is the most used in fisheries (Arkhipkin and Roa-Ureta, 2005), and assumes that environmental conditions are constant (Araya and Cubillos, 2006), in addition, it maintains that growth in fish is conditioned to physiological processes and which is the net result of two opposite processes, catabolism and anabolism as proposed by von Bertalanffy (1938; cited in Gómez-Márquez *et al.,* 2020) from the approach of the growth model. Despite this, the values obtained for this model for the species under study were not obtained adequate values to model growth, as they overestimated the maximum size for the population and both sexes; Therefore, the information had to be discarded because the data obtained was not consistent with the information on the species presented by other authors.

Therefore, the model that best fit the observed population data and for both sexes of *P. gracilis* was the Gompertz growth model. Katsanevakis (2006) demonstrated that the Gompertz model better describes the absolute growth of many aquatic species, as happened in this study, in addition to helping to model growth where there are very young ages (Cadima, 2003). On the other hand, Gómez-Márquez *et al*. (2022) report that in the culture of *Artemia franciscana*, the von Bertalanffy model was used and it was observed that the values obtained were overestimated, compared to applying the Gompertz model, which more adequately represented the growth of the species.

Snelson (1989) mentions that growth and age are genetically and socially influenced in some poecilids and environmental characteristics and available resources have a direct influence on growth; it is also said that females continue their normal growth. In many species of fish, growth decreases in both sexes upon reaching sexual maturity, which is why it has been shown to be more pronounced in males than in females, mainly due to the reproduction process (Sanchez, 2019).

Farr (1989) reports that the differences in the size of this family can be explained in terms of the fact that females take longer to mature and continue to grow throughout their life, whereas males mature quickly and once the gonopodium has been completely formed, they have very low growth rates, and they do not live long after reaching sexual maturity. Likewise, he cites that the growth rate or catabolism constant (K) is one of the factors that most influence the growth equation when the fish is young. Therefore, the inverse relationship between L∞ and k is considered to be a typical difference between the reproductive physiology and sexual behavior of organisms.

Snelson (1989) cites that the species of this family show rapid development, which is why their life span is short, which is why a longevity of 2 years was obtained. Gómez Márquez (personal communication) mentions that under aquarium conditions the poecilids with which he has worked, they have reached a longevity of 3 years.

Therefore, during the study on the Amate amarillo bordo, adequate conditions were maintained, both physical and chemical, so that the organisms were in good condition as observed with the calculated condition factor. Regarding the growth models applied for *Poeciliopsis gracilis*, the Gompertz model turned out to be the most appropriate, since with it an asymptotic length closer to the observed data was obtained.

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