Journal MVZ Cordoba
2022; january-april. 27(1):e2174.
https://doi.org/10.21897/rmvz.2174

Original

Blood biochemistry and morphometric in *Ichthyoelephas humeralis* (Characiformes: Prochilodontidae) of lotic ecosystems, Los Ríos province, Ecuador

Yuniel Méndez-Martínez[1]*; Mariuxi F. Cevallos-Chevez[1]; Ana R. Álvarez-Sánchez[1]; Aroldo Botello-Leon[2]; Danis M Verdecia Acosta[3].

[1]Universidad Técnica Estatal de Quevedo (UTEQ), Facultad de Ciencias Agropecuarias, Quevedo, Los Ríos, Ecuador
[2]Universidad Técnica Luis Vargas Torres (UTE-LVT), Facultad de Ciencias Agropecuarias, San Mateo, Esmeraldas, Ecuador.
[3]Universidad de Granma (UDG), Facultad de Ciencias Agropecuarias, Bayamo, Granma, Cuba.
*Correspondencia: ymendezm@uteq.edu.ec

Received: September 2020; Accepted: June 2021; Published: December 2021.

ABSTRACT

Objective. Evaluate the effects of the habitat zone and sex on the serum biochemical and morphometric response of *Ichthyoelephas humeralis* in lotic ecosystems of Los Ríos province, Ecuador. **Materials and methods**. One of the native species (*I. humeralis*) that are most commercialized in the cantons of Quevedo, Mocache and Fumisa of Los Ríos Province was identified, 60 specimens were captured for each area (180 total), the sexed and the live weight, length, thickness of the head, body and tail were determined; condition Factor and blood biochemistry (glucose, cholesterol and triglycerides). **Results**. For the morphometric indicators there was no zone-sex interaction. There were only significant differences ($p<0.05$) for the effect of sex on live weight, length, thickness of the head, body and tail with the highest values for males (284.98 g; 29.32 cm; 6.77 cm; 14.81 cm and 7.80 cm, respectively) except for the condition factor which did not differ statistically. For blood biochemistry the best results for glucose and triglycerides in Quevedo with 162 and 320.67 mg/dL, respectively while cholesterol was higher with 130 mg/dL for Fumisa. **Conclusions**. The effect of sex on morphometric indicators was evidenced, with the best results for males. While the blood biochemistry showed variability with respect to the areas with the highest results for Quevedo, due to fluctuations in natural conditions of the environment and food.

Keywords: Cholesterol; fish; glucose; sex; triglycerides; zone (*Source: DeCS*).

RESUMEN

Objetivo. Evaluar los efectos de la zona de habitat y sexo en la respuesta bioquímica sérica y morfométrica de *Ichthyoelephas humeralis* en ecosistemas loticos de la provincia Los Ríos, Ecuador. **Materiales y métodos.** Se identificó una de las especies nativas (*I. humeralis*) que más se comercializan en los cantones de Quevedo, Mocache y Fumisa de la provincia Los Ríos. Se capturaron

How to cite (Vancouver).
Méndez-Martínez Y, Cevallos-Chevez MF, Álvarez-Sánchez AR, Botello-Leon A, Verdecia-Acosta DM. Blood biochemistry and morphometric in Ichthyoelephas humeralis of lotic ecosystems, The Rios province, Ecuador. Rev MVZ Cordoba. 2022; 27(1):e2174. https://doi.org/10.21897/rmvz.2174

60 ejemplares por cada zona (180 total). Se realizó el sexado y se determinó el peso vivo, la longitud, el grosor de la cabeza, cuerpo y cola; factor de condición y bioquímica sanguínea (glucosa, colesterol y triglicéridos). **Resultados.** Para los indicadores morfométricos no hubo interacción zona-sexo. Solo existieron diferencias significativas ($p<0.05$) para el efecto del sexo sobre el peso vivo, longitud, grosor de la cabeza, cuerpo y cola, con los mayores valores para los machos (284.98 g; 29.32 cm; 6.77 cm; 14.81 cm y 7.80 cm, respectivamente) excepto para el Factor de condición el cual no mostró diferencias estadísticas. Para la bioquímica sanguínea los resultados más elevados para glucosa y triglicéridos en Quevedo con 162 mg/dL y 320.67 mg/dL, respectivamente mientras que para el colesterol fue de 130 mg/dL para Fumisa. **Conclusiones.** Se evidenció el efecto del sexo sobre los indicadores morfométricos, con los mejores resultados para los machos. Mientras que la bioquímica sanguínea mostró variabilidad con respecto a las zonas con los mayores resultados para Quevedo, producto a las fluctuaciones en condiciones naturales del ambiente y la alimentación.

Palabras clave: Colesterol; glucosa; peces; sexo; triglicéridos; zona (*Fuentes: DeCS*).

INTRODUCTION

Currently, there are more than 34.725 species of fish that represent 50% of all species of vertebrates (1). South America is characterized by being the continent with the greatest diversity, approximately 8.000 registered species, but information on biology, ecology, morphometry, and biochemistry is scarce. In the Los Ríos province, in Ecuador, 951 species of freshwater fish have been identified, however, studies have focused on their registration, leaving other aspects like optimal range for the different stages and categories of morphometric and blood indicators fish unknown (2).

The bocachico (*Ichthyoelephas humeralis*) is one of the fish native species registered in Ecuador that lives in lotic ecosystems distributed from Colombia to Peru. It is a fish that can reach a live weight of 2.5 kg, and a length of 38.5 cm (3,4). Ovchynnyk (5) conducted the first studies on this and other native freshwater species in Ecuador reporting some biological aspects. Cadena (4), carried out a preliminary study regarding the length-weight relationship and stages of gonadal maturity of *I. humeralis*, determining that the total length fluctuates between 155 and 385 mm, while the weight varies between 49.7 and 883.5 g. The most advanced stages of sexual maturity were recorded from January to May and from July to August. Stewart et al (6), recorded 473 species and 225 genera, reporting 250 species, 100 genera and eight families for the first time in the Aguarico, Napo and Curaray affluents belonging to the Napo river system.

Florencio et al (7), carried out bioecological studies in the Abras de Mantequilla wetland using *I. humeralis* to study sexual maturity. Revelo and Elías (8) and Revelo (9) investigated some biological and fishing aspects of the main fish species in the water system of the Los Ríos province, determining the size range of *Brycon alburnus*, which was between 14 and 37 cm, while *I. humeralis* between 13 and 32 cm.

Recent studies have reported the characterization of morphological and meristic traits, performance, pulp parameters, and fatty acid composition in muscle tissue *Cichlasoma festae* comparing wild and cultivated conditions (10,11). Also, Rodríguez et al (12) studied the allometric relationship and growth models of *Cichlasoma festae* juveniles, obtaining growth models between length and weight, which would avoid stress due to fish handling and risks associated with pathologies.

González-Martínez et al (13) applied a multivariate analysis to characterize morphometric and meristic features of *Dormitator latifrons*, concluding that the morphological characteristics of this species are influenced by the production system, with the largest fish coming from fish farms where food availability is higher. Furthermore, in that study, sexual dimorphism was observed, although there were no large significant differences in morphometric measurements. Meristic counts had effect on the production system and sex, with small variation coefficients. These measurements are species-related and change very little.

Considering the above, there are few studies in *I. humeralis*, but morphometric and blood biochemistry information is still missing. Blood biochemical parameters in fish farming have proven to be a very useful tool to evaluate and monitor the health status of wild and captive organisms because they are species-specific and age-dependent physiological values. Several factors can cause temporary changes in the fish blood biochemistry, like the reproductive cycle, feeding, temperature, pH, and photoperiod. Biochemical tests provide 17 important indicators of metabolic disorders, deficiencies, and chronic stress before they present any clinical signs; so, it is important to know how these parameters can change over time (14).

Exogenous factors such as specimen handling, disease, and stress cause significant changes in the blood composition. Fluctuations in the concentration of cortisol, glucose and cholesterol have been detected due to manipulation and hypoxic stress (15). Some studies have been directed to determine hematocrits, hemoglobin, triglycerides, lymphocytes, monocytes, neutrophils, basophils, proteins, glucose, and leukocyte erythrocytes in some species like *E. maculatum*, *S. minor* and *I. conceptionis* (16); *B. amazonicus* (17) and *A. ocellatus* (18).

Physiological differences between gender are related to primary and secondary sexual characteristics and their adaptations, result of different strategies used for reproductive success, with marked differences in blood parameters between females and males due to a high metabolism in males. Although according to the report by Bastardo et al (19) that females have higher values in blood parameters. The variation of the results may be due to the different conditions in which the organisms were maintained in each study.

In this sense, it was indicated that age, sex, habitat, feeding, and migrations affect fish physiology, being able to affect the immune response and growth rate. It is also highlighted that fish are subject to overexploitation, and contamination of aquatic ecosystems because of urbanization, industrialization, indiscriminate use of chemicals in the agricultural sector, residues of agricultural inputs, vegetable and animal remains, to this are added the effects of climate change, and the increased presence of pathogens and diseases (20). The objective of this research was to evaluate the effects of habitat and gender on the morphometric and serum biochemical response of *I. humeralis* in lotic ecosystems of the Los Ríos province, Ecuador.

MATERIALS AND METHODS

Sampling area. This research was carried out in three areas of the Los Ríos province, Fumisa, Camarones area at 0°43′16′ S and 79°27′ W, the Pajarito enclosure belonging to the Mocache canton 1°8′03.92′′ S, 79°29′07.8′′ W, and Quevedo, an affluent of the River 1°2′30 S and 79°28′30 W (Figure 1). The climatic conditions of each of the places are reported in Table 1.

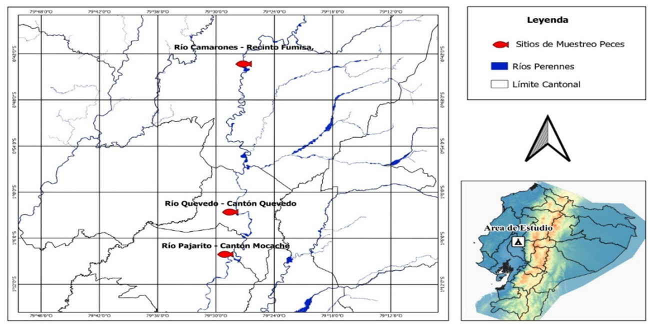

Figure 1. Map of sampling areas.

Table 1. Annual climatic conditions of three areas of the Province of Los Ríos, Ecuador.

Area	Average temperature (°C)	Rainfall (mm)	Climate
Fumisa	21-31	2000-3500	Tropical
Mocache	20-30	1626-3500	Tropical semi humid
Quevedo	23-31	1750-2500	Tropical humid

Process. For this research, one of the native freshwater species (*I. humeralis*) that is most commercialized in the cantons of Quevedo, Mocache and Fumisa of the Los Ríos Province was studied. Sixty specimens were captured for each area (180 total), and gender was determined considering morphological characteristics (2,21).

Live weight and morphometric indicators. The fish were weighed individually on a digital scale ±0.01 g (PE 3600 Mettler-Toledo, Columbus, OH, USA), the length was determined with the help of a measuring tape (Truper, 3m-Fh, Distrito Federal, MX) from the tip of the mouth to the fin of the tail. A digital vernier caliper (GT-MA15 Gester, ±0.001 mm, Xiamen, CN) was used to measure the thickness of the head, body, and tail. The Condition Factor was determined according to the following formula: (live weight/total length^3) × 100 (22).

Biochemistry in blood plasma. One mililiter of blood was extracted from the hemal arch by puncturing the caudal artery, using 3 mL syringes (Bio-In, Guayaquil, EC), then the samples were placed in capillary tubes (Isolab, Laborgeräte GmbH, Eschau, DE) with heparinized inner surfaces, then centrifuged (Gemmy, PLC-05, Taipei, TW) at 1200 rpm for 10 min to obtain serum plasma and subsequently quantified glucose, cholesterol and triglyceride using commercial kit reagents (Human liquicolor, Wiesbaden, DE), samples were incubated for 25 min at 37°C (23). Absorbance (ABS) readings were performed on a spectrophotometer (SunostIk, SBA-733 Plus, Kunshan Road, CHN) at 510 nm for glucose, and 500 nm for cholesterol and triglycerides. All analyzes were performed in triplicate.

Statistical design and analysis. A completely randomized design was used with a factorial arrangement (3×2), three habitat areas, and gender (female and male). Kolmogorov-Smirnov and Bartlett tests were applied to the data obtained. Subsequently, a double classification analysis of variance (ANOVA) was carried out considering the area of habitat and gender as sources of variation. Tukey's test was used for the difference between the means. Between the weight and size of the fish, a correlation was determined. All statistical processing ($p \leq 0.05$) were performed with the IBM SPSS statistical program. 22.0.

RESULTS

For gender (Table 2), a greater number of females were found in all the studied areas (Fumisa, Mocache and Quevedo) with increases of 20, 13.34, 40 percentage units and as an average for this research of 24.44% of females above in comparison of the males.

Table 2. Gender frequency of *Ichthyoelephas humeralis* in the study habitat areas.

Area	Males (%)	Females (%)
Fumisa	40.00	60.00
Mocache	43.33	56.67
Quevedo	30.00	70.00
Average	37.78	62.22

Regarding morphometric features (Table 3), there was no habitat-gender interaction, with greater variability for males. There were only significant differences ($p<0.05$) related to gender on weight, length, thickness of the head, body, and tail, with the highest values for males (284.98 g; 29.32 cm; 6.77 cm; 14.81 cm and 7.80 cm, respectively) except for the Condition factor, which did not differ statistically ($p>0.05$). While for the inhabited areas, the condition factor showed differences with the best results (1.15) for Quevedo.

When analyzing the weight-length relationship, a correspondence between growth and weight was observed with adjustments of third-order polynomial equations for females in the three areas (Mocache, Fumisa and Quevedo) and R^2 values higher than 0.64. Whereas third order polynomial equations were established for males in Fumisa and Quevedo and for Mocache Potential with R^2 above 0.70 (Figures 2, 3 and 4).

For blood biochemistry, no habitat-gender interaction was recorded, with the highest fluctuations according to minimum and maximum for males and only effects of the area with the highest results for glucose and triglycerides were observed in Quevedo with 162.00 and 320.67 mg/dL; while cholesterol was higher with 130.00 mg/dL for Fumisa, although without significant differences with the Quevedo area. In the case of gender, no significant differences were observed, but the results were numerically higher for females (Table 4).

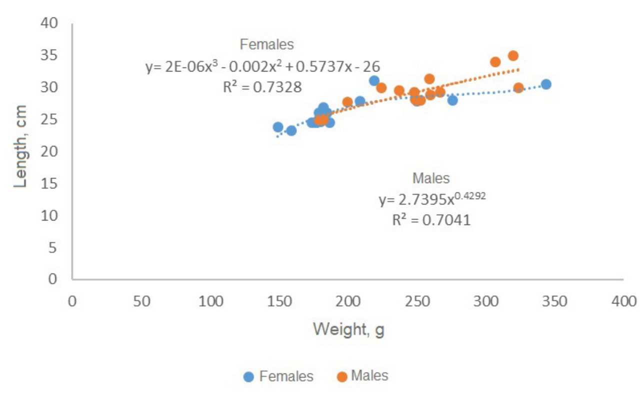

Figure 2. Weight-length relationship for *Ichthyoelephas humeralis* in the Mocache region.

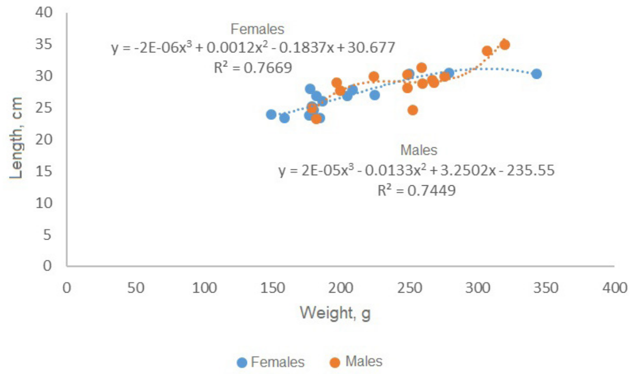

Figure 3. Weight-length relationship for *Ichthyoelephas humeralis* in the Fumisa region.

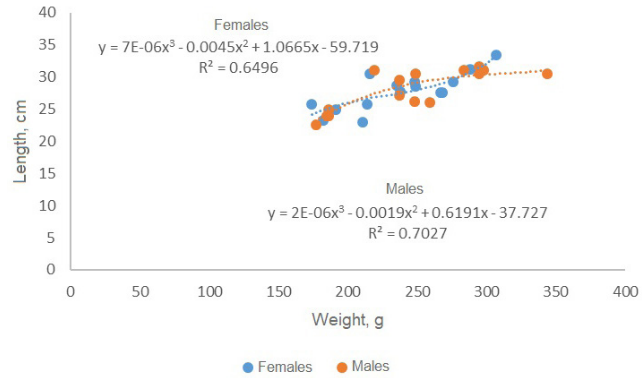

Figure 4. Weight-length relationship for *Ichthyoelephas humeralis* in the Quevedo region.

Table 3. Morphometric parameters of *Ichthyoelephas humeralis* in each habitat according to gender.

Parameters	Areas							Gender							
	Mocache	Fumisa	Quevedo	Min	Max	EE±	P	Female	Min	Max	Male	Min	Max	EE±	P
Weight (g)	226.87	225.90	242.10	149.00	344.00	18.13	0.20	215.51^{b}	149.00	343.00	247.73^{a}	177.00	344.00	5.67	0.03
Length (cm)	27.76	27.79	28.73	22.50	50.00	0.66	0.50	26.86^{b}	23.00	33.50	29.32^{a}	22.50	50.00	0.54	0.00
Head thickness (cm)	6.27	6.30	6.73	5.00	11.00	0.19	0.16	6.09^{b}	4.50	8.50	6.77^{a}	6.00	11.00	0.15	0.00
Body thickness (cm)	13.98	13.93	14.81	11.50	27.50	0.35	0.15	13.67^{b}	12.00	17.20	14.81^{a}	11.50	27.50	0.29	0.01
Tail thickness (cm)	7.57	7.83	7.18	5.00	11.50	0.19	0.05	7.26^{b}	5.00	9.50	7.80^{a}	6.00	11.5	0.15	0.01
FC	1.06^{b}	1.07^{b}	1.15^{a}	0.74	1.73	0.04	0.02	1.12	0.74	1.73	1.07	0.74	1.68	0.03	0.29

SE ± = Standard Error. ab Different superscripts differ significantly ($p<0.05$), within the rows. Condition factor = FC.

Table 4. Blood biochemistry parameters of *Ichthyoelephas humeralis* in each habitat according to gender.

Parameters (mg/L)	Areas							Gender							
	Mocache	Fumisa	Quevedo	Min	Max	EE±	P	Females	Min	Max	Male	Min	Max	EE±	P
Glucose	86.00^{c}	123.33^{b}	162.00^{a}	47.00	175.00	3.88	0.00	131.78	80.00	175.00	115.78	47.00	174.00	3.07	0.19
Cholesterol	88.00^{c}	130.00^{ab}	112.33^{bc}	56.00	153.00	2.66	0.04	113.78	57.00	153.00	106.44	56.00	145.00	3.71	0.56
Triglicerids	168.33^{b}	219.67^{b}	320.67^{a}	92.00	438.00	4.57	0.01	228.11	92.00	403.00	244.33	120.00	438.00	4.15	0.64

SE ± = Standard Error. Different superscripts differ significantly ($p<0.05$), within the rows.

DISCUSSION

The complexity and plasticity in fish reproductive biology determines a population structure in which gender proportion is not always 50/50 but depends on the resources allocation and natural selection (21). In studies of *Colossoma macropomum*, Pineda-Santis et al (24) reported proportions of 73.71% females and 26.09% males. Pacheco-Bedoya (25) and Álvarez-León (26) evaluated biological and fishing aspects of species captured in the Babahoyo river and an affluent of the Samborondón canton, finding different gender proportions, i.e., female-male percentages, for *A. rivulatus* (49.30-50.70%), *H. microlepis* (58.40-41.60%), *I. humeralis* (73.80-26.20%), and *E. mutisii* (61.40-38.60%) and 81.82-18.18% female-male rate for the Bogotá river. Gender variability could be given by the reproductive and spawning season, *I. humeralis* spawns in winter (December to March). Other factors like distribution, mortality, feeding, pH, and temperature of the water also affect gender proportion. Embryonic gonads, starting from a common rudiment, made up of somatic cells of the gonadal crest and gonadal primordial cells, can develop in two different adult organs, ovaries, or testes, affecting the demographic structure of the population (27).

To identify the gender of *Cichlasoma festae* based on morphometric variations, Vivas-Moreira et al. (28) captured 500 specimens (weight in 20-50 g) in the Daule Peripa reservoir and the Peripa, Toachi and Baba rivers. The authors did not find differences between the sampling areas, while the relationships between variables (weight, total length, and length of the head) and gender were high, with r = 0.90-0.94. This variability in morphometric indicators associated with gender is probably strongly related to defensive or survival strategies of the species. For example, larger and heavier females can harbor larger eggs and ensure a better defense when they are most vulnerable, such as during laying. Contrary to a smaller size in males, which could mean a lower energy investment in growth but an increase in mobility capacity. In addition, this condition increases the ability to locate females, ease of courtship and forced insemination.

Results of the morphometric indicators (Table 3) coincide with those obtained by Caez et al (29), when evaluating *A. rivulatus* in the Quevedo River under cultivation and wild conditions, where 52 fish were sampled for each of the production forms, reporting fish weight between 90-228 g, total length of 14.8-21.8 cm, and head length of 3.4-6.6 cm. Therefore, they have used morphological and meristic characteristics to identify adaptation processes in nature and cultivated populations of the same species (30). Moreno et al (22) studied morphometric parameters of *Eremophilus mutisii* by sampling 33 specimens in the Bogotá River, of which 27 were female and 6 males, reported 222.7 and 181.1 g; 28.6 and 28.1 cm; 3.0 and 2.1 cm of body width; 3.2-3.1 and 0.9 and 0.8 of Condition Factor for females and males, respectively. With better performance from a numerical point of view for the females, results that differ from those found in our research where the males presented the highest values, this behavior may be due to the fact that the differences between populations are very difficult to explain, but it is known that the morphometric characteristics may have variability in responses to environmental conditions, consistent with the evolutionary hypothesis where it is stated that divergent habitats drive interspecific phenotypic diversification, which are important for predicting adaptive responses of freshwater fish species to different zones and anthropogenic currents modification. These morphological differences between populations of a species may be related to habitat conditions such as temperature, turbidity, food availability, water depth and flow (31,32,33).

In this sense, González et al (10) and González-Martínez et al (13), when evaluating the morphometric variations between two populations (wild and cultivated) of the species *Cichlasoma festae* and *Dormitator latifrons*, reported increases of 22.78 g, 0.61 and 2.26 cm for weight, Condition factor and the total length for *C. festea*; while, for *D. latifrons*, differences were only reported for weight with increases of 2.71 g. The introduction and crossbreeding of a fish (especially wild ones) lead to a high adaptation to a wide range of geographical locations, which leads to phenotypic variations regarding the pure stock (strains) of the reproducers. Hence, the cause of the variation in morphometric characters can be attributed in part to interspecific variability, which is under the influence of environmental parameters where fish adapts quickly change the necessary morphological characters. Therefore, the differences between both production systems could be explained by the availability of more food for fish in fish farms than in rivers, the latter depending more on climatic conditions (34). That is why, since there were no large fluctuations in these conditions in the different regions sampled, no differences were recorded between the areas. Ochoa-Ubilla et al (30), when studying the weight-length relationship of economically valuable species (*Ichthyoelephas humeralis*, *Leporinus ecuadoriensis*, *Brycon* spp., *Rhamdia cinerascens*, *Andinoacara rivulatus*, *Hoplias microlepis*, *Pseudocurimata* spp.) captured in Abras de Mantequilla wetland, Ecuador; potential growth equations were obtained for all species, but *I*. *humeralis*, *A*. *rivulatus* and *P*. spp., with negative allometric growth, while *H*. *microlepis*, *L*. *ecuadoriensis*, *Brycon* sp., and *R*. *cinerascens* with isometric growth. The differences between growth could be related to many factors, such as the size of the samples, size ranges, genetic aspects between groups of species and environmental conditions. In addition, the weight-length relationship can behave differently not only between species, but also within populations of the same species, since growth depends on environmental, nutritional, and genetic variations.

The Condition Factor relates to the fish body condition and reproductive status. Aspects that explain the results obtained by Moreno et al (22), where this parameter was higher for maturing females with more than 172 g, followed by spawned ones, those that are maturing with less than 172 g, and males. Similar results for the Condition Factor have been previously described for the painted catfish, *Pseudoplatystoma corruscans*, with values close to 1.19 for maturing females, 1.15 for spawned females and 1.1 for males in different stages of gonadal maturation. The decrease in the Condition Factor of the females during spawning is because the animals lose weight without decreasing their size (35).

For their part, Moreno et al (22) when evaluating the total length-live weight relationship of *Eremophilus mutisii* in maturing females and males, potential equations with R^2 higher than 0.88 ($p<0.05$) where the allometric coefficient of the total length-live weight relationship was higher for the females ($p<0.05$). This suggests that the increase in weight as a function of size is greater in females than in males, especially during gonadal maturation, which may be related to the differences that exist in the weight of the gonads, where the gonadosomatic index was superior for females.

The study of blood parameters in native fish (Table 4) is very limited. Serum biochemistry in fish can assess the animal's response to stress, diseases, and nutritional imbalances. The disorders that can occur from these factors depend on the species, age, physiological phase. The concentration of cortisol, glucose and cholesterol can be affected by hypoxic stress; therefore, these parameters are essential to know the state in which the animal is (18,36).

In serum parameters of *Brycon amazonicus* and *Astronotus ocellatus* breeders, Van der Laan (3) found glucose and cholesterol levels of 64.39 mg/dL and 253.4 mg/ L, values within normal levels for these species (14.7-155.3 mg/dL and 78 to 397 mg/dL, respectively) (17), the glucose results reported in this study are higher in the Quevedo area (162 mg/dL) and lower for cholesterol 130 mg/dL. The variations found in these biochemical parameters may be due to inter or intraspecific factors like genetic variation, gonadal maturation, age, eating habit, stress, habitat, and climate. Slightly high glucose levels are closely related to the nutritional status, diet, and temperature to which the fish are subjected, and can cause a decrease in growth, an increase in glycogen in the liver and can eventually lead to death (37).

In *T*. *natans*, Hernández-Cuadrado et al (38) studied the ecophysiological effect on blood biochemistry in specimens captured in five areas, La Bahía swamp, Lagunar Complex of Malambo, Atlántico, Colombia; where two parallel studies were established in culture and wild conditions. The results showed the no differences between the different natural habitats and breeding ponds for cholesterol 280.00 and 281.00 mg/dL; glucose in captive fish did not differ (120.60 mg/dL), however, glucose varied in fish sampled in the wild with its highest values of 140.20 mg/dL. The higher glucose levels are due to the high energy requirement in the natural habitat. This expense may be related to the availability of space, possibly because the gluconeogenic process may be more accentuated, a process especially important for the central nervous system and red blood cells that need a continuous supply of glucose. Pollutants like naphthalene have been shown to affect the plasma glucose levels of *Oncorhynchus mykiss* in early stages of development (39). On the other hand, the lack of correlation found in this study between sex and blood parameters contrasts with the general trend among vertebrates where it is common for males to present slightly higher levels than females (40).

In conclusion, this study showed the effect of gender on morphometric indicators, with the best results for males while blood biochemistry showed variability regarding the sampled areas with the highest results for Quevedo because of fluctuations in natural conditions of the environment and food.

Conflict of interests

All authors declare that during the preparation and preparation of this work there was no conflict of interest.

Acknowledgements

Our thanks to Don Quirola, president of the Bella Vista artisanal fishing association for his support in catching the organisms. We thank Wendy Hidalgo for technical support in processing the samples. The research was supported by the Quevedo State Technical University (UTEQ). Support project for the call FOCYCYT-7th, project PFOC7-48-2020.

REFERENCES

1. Calderón-Peralta G, Ayora-Macías G, Solís-Coello P. Variación espacio-temporal de larvas de peces en el Golfo de Guayaquil, Ecuador. Bol Investig Mar. 2020; 49(1):135-156. http://dx.doi.org/10.25268/bimc.invemar.2020.49.1.778

2. Nugra F, Anaguano-Yancha F, Arízaga C, Zárate E, Brito J. Leucismo en el pez *Lebiasina bimaculata* (Characiformes: Lebiasinidae) en Guayas, Ecuador. Bio Colmb. 2018; 19(2):133-139. http://dx.doi.org/10.21068/c2018.v19n02a12

3. Van der Laan R. Family-group names of Fossil fishes. European J Taxon. 2018; 466:1-167. https://doi.org/10.5852/ejt.2018.466

4. Cadena M. Estudio preliminar de la relación longitud-peso y etapas de madurez gonadal de bocachico *Ichthyoelephas humeralis*. Rev Cien Mar Limn. 1981; 1(1):83-86. http://institutopesca.gob.ec/wp-content/uploads/2017/08/7.Estudio-Preliminar.pdf

5. Ovchynnyk M. Peces de agua dulce del Ecuador y sus perspectivas para desarrollar su cultivo. Latin American Studies Center: Michigan State University: USA; 1971.

6. Stewart D, Barriga R, Ibarra M. Ictiofauna de la cuenca del río Napo, Ecuador oriental: Lista anotada de especies. Politécnica. 1987; 12(4):9-63. https://bibdigital.epn.edu.ec/handle/15000/5066

7. Florencio A, Cadena M, Moya O, Villamar F. Aspecto bioecológicos en el humedal Abras de Mantequilla de *Icthyolephas humeralis* (bocachico). Revista Ciencias del Mar y Limnología. 1993; 3(1): 173-181. http://institutopesca.gob.ec/wp-content/uploads/2017/08/Estudio-bioecologico-de-la-laguna.pdf

8. Revelo W, Elías E. Aspectos biológicos de los principales recursos de aguas continentales, durante febrero y marzo del 2004 en la provincia de Los Ríos. Instituto Nacional de Pesca: Guayaquil, Ecuador; 2004. http://institutopesca.gob.ec/wp-content/uploads/2017/07/Resumen-aspectos-biol%C3%B3gicos-de-la-provincia-de-Los-R%C3%ADos.pdf

9. Revelo W. Aspectos biológicos y pesqueros de los principales peces de del sistema hídrico de la provincia de Los Ríos durante 2009. Boletín Científico y Técnico. Instituto Nacional de Pesca. Guayaquil-Ecuador. Boletín Científico Técnico. 2010; 21(7):53-84. https://aquadocs.org/bitstream/handle/1834/4790/2.%20PUBLICACION%202009%20AGUA%20DULCE.pdf?sequence=1&isAllowed=y

10. González MA, Rodríguez JM, Angón E, Martínez A, García A, Peña F. Characterization of morphological and meristic traits and their variations between two different populations (wild and cultured) of *Cichlasoma festae*, a species native to tropical Ecuadorian rivers. Arch Anim Breed. 2016; 59:435–444. http://dx.doi.org/10.5194/aab-59-435-2016

11. González MA, Angón E, Rodríguez J, Moya A, García A, Peña F. Yield, flesh parameters, and proximate and fatty acid composition in muscle tissue of wild and cultured Vieja Colorada (*Cichlasoma festae*) in tropical Ecuadorian river. Spanish Journal of Agricultural Research. 2017; 15(3):e0604. https://doi.org/10.5424/sjar/2017153-10271

12. Rodríguez J, Angón E, González M, Perea J, Barba C, García A. Allometric relationship and growth models of juveniles of *Cichlasoma festae* (Perciforme: Cichlidae), a freshwater species native in Ecuador. Revista de Biología Tropical. 2017; 65(3):1185-1193. http://dx.doi.org/10.15517/rbt.v65i3.26173

13. González-Martínez A, Lopez M, Molero HM, Rodriguez J, González M, Barba C, García A. Morphometric and Meristic Characterization of Native Chame Fish (*Dormitator latifrons*) in Ecuador Using Multivariate Analysis. Animal. 2020; 10(1805):1-19. http://dx.doi.org/10.3390/ani10101805

14. Enayat-Gholampour T, Fadaei-Raieni R, Pouladi M, Larijani M, Pagano M, Faggio C. The Dietary Effect of Vitex agnus-castus Hydroalcoholic Extract on Growth Performance, Blood Biochemical Parameters, Carcass Quality, Sex Ratio and Gonad Histology in Zebrafish (*Danio rerio*). Applied Science. 2020; 10(1402):1-10. http://dx.doi.org/10.3390/app10041402

15. Canham R, González-Prieto AM, Elliott JE. Mercury Exposure and Toxicological Consequences in Fish and Fish-Eating Wildlife from Anthropogenic Activity in Latin America. Integr Environ Assess Manag. 2021; 17(1):13–26. http://dx.doi.org/10.1002/ieam.4313

16. Sáez G, Chero J, Cruces C, Minaya D, Rodriguez C, Suyo B, et al. Parámetros hematológicos y de bioquímica sanguínea en diez especies de peces marinos capturados por pesquería artesanal en la Bahía del Callao, Perú. Rev Inv Vet Perú. 2018; 29(4):1161-1177. http://dx.doi.org/10.15381/rivep.v29i4.15204

17. Gonzales A, Curto G, Fernández-Mendez C. Parámetros hematológicos de reproductores de *Brycon amazonicus* (Bryconidae) en cultivo. Rev. Inv. Vet. Perú. 2019; 30(1):133-142. http://dx.doi.org/10.15381/rivep.v30i1.14935

18. Gonzales-Flores A, Huanuiri K, Vasquez J, Guerra F, Fernández-Méndez C. Caracterización hematológica de *Astronotus ocellatus* (Cichliformes: Cichlidae): especie de importancia económica en la Amazonía peruana. Rev Inv Vet Perú 2020; 31(2):e17827. http://dx.doi.org/10.15381/rivep.v31i2.17827

19. Bastardo H, Guedez C, León M. Características del semen de trucha arcoíris de diferentes edades, bajo condiciones de cultivo en Mérida, Venezuela. Zootecnia Trop. 2004; 22(3). http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S0798-72692004000300006

20. Morante-Carriel L, Canchignia HF, Morante-Carriel J, Romero-Meza R, Moreria AC, Abasolo-Pacheco F. Bacterias con potencialidades para la degradación de hidrocarburos en suelos contaminados de Quevedo, Ecuador. Revista Cubana de Ciencias Biológicas. 2018; 6(3):1-8. http://www.rccb.uh.cu/index.php/RCCB/article/view/257/322

21. Rodríguez-Pulido JA, Mira-López TM, Cruz-Casallas PE. Determinación, diferenciación sexual y pubertad en peces. Orinoquia. 2018; 22(1):80-91. http://dx.doi.org/10.22579/20112629.487

22. Moreno JM, Aguilar FA, Boada NS, Rojas JA, Prieto C. Análisis morfométrico e índices corporales del capitán de la sabana (*Eremophilus mutisii*). Rev Med Vet Zoot. 2019; 66(2):141-143. http://dx.doi.org/10.15446/RFMVZ.V66N2.82433

23. Trinder P. Determination of Glucose in blood using glucose oxidase with an alternative oxygen acceptor. Ann Cinin Biochem. 1969; 6:24-27. http://dx.doi.org/10.1177/000456326900600108

24. Pineda-Santis H, Restrepo LF, Olivera-Ángel M. Comparación morfométrica entre machos y hembras de Cachama Negra (*Colossoma macropomum*, Cuvier 1818) mantenidos en estanque. Rev Col Cienc Pec. 2004; 17(4):24-29. https://revistas.udea.edu.co/index.php/rccp/article/view/323956/20781136

25. Pacheco-Bedoya JL. Aspectos biológicos y pesqueros de las principales especies capturadas en el río Babahoyo y afluentes en el cantón Samborondón de la provincia del Guayas. Instituto Nacional de Pesca: Ecuador; 2018. http://www.institutopesca.gob.ec/wp-content/uploads/2018/01/Aspectos.-Biol%C3%B3gicos-y-Pesqueros-R%C3%ADo-Babahoyo-y-Afluentes-Cant%C3%B3n-Samborond%C3%B3n-2015-2.pdf

26. Álvarez-León R. Registros de los hallazgos originales de peces dulceacuícolas de Colombia, entre 2010 y 2019. Bol Cient Mus Hist Nat. 2019; 23(2):259-279. http://www.scielo.org.co/pdf/bccm/v23n2/0123-3068-bccm-23-02-00259.pdf

27. Castro RMC, Polas CNM. Small-sized fish: the largest and most threatened portion of the megadiverse neotropical freshwater fish fauna. Biota Neotropica. 2020; 20(1):e20180683. http://dx.doi.org/10.1590/1676-0611-BN-2018-0683

28. Vivas-Moreira R, González-Veliz M, Rodríguez-Tobar J, Torres-Navarrete Y. Identificación del sexo en vieja colorada (*Cichlasoma festae*) en base en la variación morfométrica. Centrosur. 2020; 1(6):1-10. http://dx.doi.org/10.37959/cs.v1i6.27

29. Caez J, González A, González MA, Angón E, Rodríguez JM. Application of multifactorial discriminant analysis in the morphostructural differentiation of wild and cultured populations of Vieja Azul (*Andinoacara rivulatus*). Turk J Zool. 2019; 43:1-15. http://dx.doi.org/10.3906/zoo-1903-31

30. Ochoa-Ubilla BY, Mendoza-Nieto KX, Vivas-Moreira R, Undánigo-Zambrano J, Ferrer-Sánchez Y. Estructura de tallas de captura y relación longitud-peso de peces nativos en el humedal Abras de Mantequilla, Ecuador. Cienc Tecn UTEQ. 2016; 9(2):19-27. https://dx.doi.org/10.18779/cytuteq.v9i2.19.g8

31. Gutiérrez X, Aguilera A, Aatland A. Aprendiendo Acuicultura: Calidad del agua en la producción de smol. Salmonexpert. 2015; 5:28-36. https://www.salmonexpert.cl/article/calidad-de-agua-en-la-produccion-de-smolt/

32. Rodríguez J, González A, Angón E, Vivas R, Barba C, González MA, et al. Efecto del tamaño de las reproductoras en la producción de alevines de *Cichlasoma festae* en condiciones semicontroladas en Ecuador. ITEA-Información Técnica Económica Agraria. 2019; 20:1-13. http://dx.doi.org/10.12706/itea.2019.021

33. Foster K, Bower L, Piller K. Getting in shape: habitat-based morphological divergence for two sympatric fishes. Getting in shape: habitat-based morphological divergence for two sympatric fishes. Biological Journal of the Linnean Society. 2015; 114: 152–162. https://academic.oup.com/biolinnean/article/114/1/152/2416061

34. Kelley JL, Davies PM, Collin SP, Grierson PF. Morphological plasticity in a native freshwater fish from semiarid Australia in response to variable water flows. Ecology and Evolution. 2017; 7:6595–6605. http://dx.doi.org/10.1002/ece3.3167

35. Rodrigues RM, Febré NN, Amadio SA, Tuset VM. Plasticity in the shape and growth pattern of asteriscus otolith of black prochilodus *Prochilodus nigricans* (Teleostei: Characiformes: Prochilodontidae) freshwater Neotropical migratory fish. Neotropical Ichthyology. 2018; 16(4):e180051. http://dx.doi.org/10.1590/1982-0224-20180051

36. Vargas M. Parámetros hematológicos y bioquímicos del capitán de la sabana en diferentes sistemas de explotación. Zoociencia. 2019; 6(1):1-6. https://revistas.udca.edu.co/index.php/zoociencia/article/view/1283

37. Ahmadniaye-Motlagh H, Sarkheil M, Safari O, Paolucci M. Supplementation of dietary apple cider vinegar as an organic acidifier on the growth performance, digestive enzymes and mucosal immunity of green terror (*Andinoacara rivulatus*). Aquaculture Research. 2020; 51:197–205. http://dx.doi.org/10.1111/are.14364

38. Hernández-Cuadrado EE, Vargas-Zapata CL, Rodríguez-De la Vega AJ. Bioquímica sanguínea e inferencias ecofisiológicas en *Typhlonectes natans* (Amphibia: Gymnophiona) de la región caribe colombiana. Rev Acad Colomb Cienc. 2011; 35(134):13-22. http://www.scielo.org.co/scielo.php?pid=S0370-39082011000100002&script=sci_abstract&tlng=es

39. Tintos A, Gesto M, Álvarez R, Míguez JM, Soengas JL. Interactive effects of naphthalene treatment and the onset of vitellogenesis on energy metabolism in liver and gonad, and plasma steroid hormones of rainbown trout *Oncorhynchus mikiss*. Comparative biochemistry and Physiology. 2006; 144:155-165. http://dx.doi.org/10.1016/j.cbpc.2006.07.009

40. Veettil C, Chidambaran K. Acute toxicity of triclosan on the native freshwater fish, *Anabas testudineus* (Bloch, 1792): behavioral alterations and histopathological lesions. Int J of Life Sciences. 2018; 6(1):166-172. http://oaji.net/articles/2017/736-1520621653.pdf