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Growth rates and weight-lenght relationship of *Ictalurus punctatus* and *Pangasius hypophthalmus* catfishes in commercial experimental conditions

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Abstract: Growth rates (weight and length) of two Channel Catfish (*Ictalurus punctatus)* and one Basa (*Pangasius hypophthalmus),* populations were asessed and growth-length relationship were estimated under commercial-experimental conditions. By using initial and final weights, and furcal lengths of fish; absolute, relative and specific growth rates were estimated. Double logarithmic regression models were fitted to estimate a and b parameters. Additionally, Fulton condition factor (K) was estimated. Results indicated that Local Channel catfish has better performance than Introduced population. Basa has the best growth performance (P<0.05) under conditions of the experiment. Parameter b, suggested an isometric growth in Channel catfish and slightly negative allometric growth in Basa population. K values indicated acceptable-good conditions of fishes, more favorable for Basa population. Some implications of results for catfish production and introduction of Basa are discussed.

Key words: Basa, catfish, condition factor, furcal length, growth, live-weight.

Tasa de crecimiento y relación largo – peso de los bagres *Ictalurus punctatus* y *Pangasius hypophthalmus* bajo condiciones comerciales experimentales. Resumen: Las tasas de crecimiento (peso vivo y longitud) de poblaciones de bagre de canal (*Ictalurus punctatus)* y una de basa (*Pangasius hypophthalmus)* fueron evaluadas y la relación talla-longitud fueron estimadas, bajo condiciones comerciales experimentales. Utilizando peso vivo y longitud furcal, inicial y final, las tasas de crecimiento absoluto, relativo y específico fueron estimadas. Fueron ajustados Modelos de regresión doble lograitmica para estimar los parámetros a y b. Adicionalmente, el factor de condición de Fulton (K) fue estimado. Los resultados indicaron que la población local de bagre de canal tuvo mejor desempeño que la pobación importada. El bagre Basa, mostró un mejor desempeño en crecimiento bajo las condiciones del experimento (P<0.05). El parámetro b, sugirió que bajo las condiciones del estudio, el bagre de canal tiene un crecimiento isométrico y el bagre basa un crecimiento ligeramente alométrico. Los valores de K indicaron condiciones buenas y favorables para los peces, mejores para el Basa. Se discuten, las implicaciones sobre la producción de bagre de canal y la introducción de Basa.

Palabras clave: Basa, Bagre, crecimiento, factor de condicion, longitud furcal, peso vivo.

Introduction

Fisheries and aquaculture are an important component of Mexico's primary economic sector. During 2018, provided 1.7 million tons of fish, with a value of USD 2799.7 million; 29% of this value came from aquaculture and 71% from fisheries (OECD, 2021).

Channel catfish (*Ictalurus punctatus*, Rafinesque, 1818) is one of the most important species for aquaculture in Mexico behind Tilapia (*Oreochromis spp.*), Carp (*Cyprinus carpio*, Linnaeus 1758) and Trout (*Oncorhynchus mykiss*, Walbaum 1792). This species is one of the Mexican freshwater fishes with the highest presence in American aquaculture. Since the 1970´s the farming of channel catfish in Mexico has begun and developed to become essential freshwater species produced under farm conditions (De la Rosa Reyna et al., 2014; Lara-Rivera et al., 2015). For its exploitation on aquaculture, Channel catfish has been introduced for farming in 20 states of the Mexican territory (Lara-Rivera et al., 2015). Pangasius is a South Asian catfish gender of siluriform fishes, including *Pangasius bocourti*, Savage, 1880 and *P. hypophthalmus*, Sauvage, 1878, native from the Mekong basin (Rathod, et al., 2018). Commercially, *P. hypophthalmus* has reached successful levels of production (Belton et al., 2011) and expansion, being introduced to many countries for farming purposes (Singh and Lakra, 2012). In Mexico, *Pangasius* is generically known as Basa and is not an officially recognized species. The National Aquaculture and Fisheries Commission (CONAPESCA for its spanish letters) considered and tagged *P. hypophthalmus* as an invasive species and suggested not to introduce nor permit its farming (Mendoza et al., 2013). Nevertheless, some Basa growth-out farms have been stablished in Mexican territory (e.g. Yucatan and Veracruz), and operate under closed tank and pond farm systems (Mendoza et al., 2013). Although the exact date and origin of this species introduction is unknown, the weak legislation on exotic fish species introduction and increasingly advertising-type information have probably boosted the interest of farmers for experimental Basa culture. Given the importance for catfish meat production, the present study was aimed to evaluate comparatively growth rates and weight-length relationships of Channel and Basa catfishes under commercial experimental conditions and document some growth parameters that could be for reference in similar aquaculture farming.

Material and methods

An experiment was completed, including fishes of the same hatching year (i.e. 2017) of two Channel Catfish (recently Introduced and Local) and one Basa catfish populations. The Channel catfish recently introduced (ICC) population was imported from a Georgia, USA farm. The local Channel catfish (LCC) population was initially from CONAPESCA, a government aquaculture center located in Coahuila, Mexico and transferred previously to Tamaulipas into the experiment site. Basa population, was from a local farm with regular production. Three populations were maintained in quarantine for 30 days for acclimation in two 350 m³ geomembrane line rustic ponds in the "Vista Hermosa" aquaculture laboratory of the Tamaulipas Bicentennial Sea University at La Pesca, Tamaulipas, Mexico, with continuous availability of freshwater from Soto La Marina River.

The three populations were submitted to growth-out conditions using 1 m^3 floating square cages (three repetitions by population) at a density of 250 fishes/m^3 considering the commercial common conditions used in dams and river growth-out farms (Lara-Rivera et al., 2015) that consider intermediate discussed average density after Schmittou (1969). Commercial feeding was provided to fishes (NUTRIPEC, Purina® 30% CP, 4mm pellet) ad libitum two times per day (8:00 and 15:00 h). Constant monitoring of water quality and mortality, during 40 days (See supplementary information). 50% water was refilled to the two ponds every week. constant aeration was supplied to the ponds through a Blower model EL-120w. Temperature and dissolved oxygen (mg/L) samples were taken 2 times a day inside each cage and pond with a YSI Mod 55 Oximeter (Xylem Inc, yellow Springs, OH, USA). Water quality samples were taken weekly. The recorded parameters were: pH; Ammonium, Nitrites and Nitrates, the determination was made with a YSI Photometer Mod. 9500 (Xylem Inc, yellow Springs, OH, USA). It should be noted that the ponds were siphoned every week to prevent the increase of Ammonium. For initial and final weight and length measurement, fishes were managed in circular tanks with 5 mg/L of clove (*Syzygium aromaticum*) essence (LASA, Cd. de Mexico, México) as an anesthetic for ease and safe manipulation. After measurement, fishes were immersed in circular tanks with potassium permanganate (QUIMSA, Victoria, Tamaulipas, Mexico) 0.5 mg/L, as a prophylactic strategy before reintroduction to the cages. Tanks were aeriated with two diffusion stone connected to a Blower model EL-120w.

Given the different initial weights from the three populations, sample size (Table I), and difficulty for contiuous individual recording of fish, growth comparison was based only on growth rates. Experimental data of weight (g) and furcal length (cm) was analyzed by fitting a linear model considering the fixed effects of pond and population using a Proc GLM using SAS v.9.4 software (SAS Institute Inc., Cary, NC, USA). Condition factor, for the three assessed populations was estimated with final measuerements data, after a normalty test examination, was compared by a similar linear model formerly described for growth and length traits.

With the population's least squares means of initial and final weights lengths, absolute growth rate (AGR, g/d), estimated as: AGR= $w_f - w_i$, where w_f= final weight or length and w_i= initial weight or length; relative growth rate (RGR, %), estimated as:

$$\frac{w_f - w_i}{t},$$

where w_f= final weight or length and w_i= initial weight or length, and t= time of experiment; and specific growth rate (SGR, %/d), estimated as estimated as:

$$\frac{\log w_f - \log w_i}{t} \times 100,$$

where Log w_f= logarithm of final weight or length and Log w_i= logarithm of initial weight or length, and t= time of experiment, all estimated after Lugert et al. (2016). A pairwise comparison was performed using an unequal variance *t*-test (Ruxton, 2006) for continuous traits and independent samples, considering an alpha=0.05, as follows:

$$t = \frac{\mu_1 - \mu_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

where: *t*= test statistic, μ_1= Population 1 sampling mean, μ_2= Population 2 sampling mean, s_1^2= Variance of population 1, s_2^2= Variance of population 2, n1= Population 1 sample size, n2= Population 2 sample size.

Complementarily, a descriptive double logarithmic linear regression model determined the three populations' weight-length relationships (WLR), based on the final experimental data measurements after Froese (2006). Additionally, Fulton condition factors (FCF) were computed using the following equation: K= Px100/L^3, Where: K= Fulton Condition factor, P= Weight, L= Furcal length. As a reference, feed conversion ratio was estimated by population and cage, as follows: FCR= TFC/TWG, where: FCR: Feed conversion ratio, TFC: Total feed consumed by cage, and TWG: Total weight gain of the population by cage. The least square means ± standard error, were estimated for each population with estimations by pond.

Results

A growth experiment under commercial conditions was performed to compare different growth rate indicators in Channel Catfish and Basa populations. Table II, shows the absolute, relative and specific growth rates from assessed populations. The final recorded mortality of ICC, LCC and Basa catfish populations was, 15.0 %, 1.31 % and <1.0 %, respeectively. The three populations were significantly different (P<0.05) for live weight and furcal length growth rates. Basa catfish showed the higher growth rates for live weight, showing an increase in weight of 5.51 g per day doubling their

Table I. Initial weight and length characteristics of Channel and Basa catfishes inlcuded in the growth experiment.

Population	*n*	*Weight* *g*	*Min. – Max.* *g*	*Furcal lenght* *cm*	*Min. – Max.* *cm*
Introduced	985	195.09±43.78	14-512	22.99±2.73	12.2-39
Local	1123	134.08±31.06	12-273	21.29±1.94	8-56
Basa	363	200.34±61.92	81-600	27.23±3.87	20-44

weigth during the experiment. LCC population showed intermediate live weight growth rates, higher than the Introduced population. For furcal length, LCC population showed higher growth rates ($P<0.05$) than ICC and Basa populations(Table II). As an additional comparison, during the experiment estimates of K for ICC, LCC and Basa catfish populations, was 1.66±0.127, 1.84±0.127 and 1.65±0.179, respectively, however, with no differences ($P>0.05$) between populations.

The WLR of the three studied populations was assessed. Figures 1 and 2, show the logarithmic plots of data from ICC and LCC populations. The line of prediction estimated very similar b parameters ($R^2>0.95$) indicating isometric growth of the populations. Figure 3, shows Basa population WLR with a slightly lower b parameter (b= 2.92, $R^2>0.95$) that suggest a relative negative allometric of hypoallometric. Regarding to condition factor parameter (K), estimated in for this study, the three populations had significantly different LSmeans ($P<0.05$). LSM estimated for FCR in ICC, LCC and Basa catfish populations, were 1.31±0.004, 1.34±0.003, and 1.36±0.01 respectively, and showed significant differences between them ($P<0.05$).

Discussion

A growth assessment under commercial conditions to compare differences in growth rate of Channel Catfish and Basa populations was succesfully performed. In general, the three populations analyzed data exhibited large variability, which potentially might be used for selection purposes. Especially for Channel catfish, in which selection criterion is based generally on a mass selection for size and appearance traits (Parra-Bracamonte et al., 2011; Lara-Rivera et al., 2015). Estimated growth rates for weight and length indicated that LCC had better performance under commercial local conditions of the experiment (Table II). The use of growth rates suggested that local population has better performance, perhaps by its longer adaptation to the production conditions and feeding management.

On the other hand as expected, Basa catfish population showed the best performance increasing weight at a significantly ($P<0.05$) higher rate showing potentially higher productivity on biomass production during a determined period of stocking. Although, there is scarce documentation on the productive performance of Basa catfish in Mexico, this species has been described as one of the fastest-growing freshwater species in aquaculture in Asia (Khan et al., 2018; Rathod et al., 2018). Gurung et al. (2016) indicated that in Nepal, Basa grows 1.2-1.3 kg within 6 months and generally is harvested after 8 months, depending on the market's demand. Similarly, Khan et al. (2018) stated that, under Bangladesh farming conditions, Basa achieve a marketable size (approximately one kg) after 7–8 months of stocking. In Veracruz, Mexico, one report indicates that Basa can grow 900 g in 150 days at temperatures between 26 y 34 °C (Platas-Rosado et al., 2021).

It is important to remark that, although Channel Catfish is an endemic species of northeast Mexico, produced in local farms for over 40 years and currently extensively is used in many sates' aquaculture systems; comparatively to Basa, its

Table II. Absolute, relative and specific growth traits of weight and lenght estimations of introduced and local Channel catfish, and Basa populations in comercial experimental conditions.

	Live weight		
Population	*AGR grams/day*	*RGR %*	*SGR %/day*
Introduced	1.28±0.001 c	40.63±0.20 c	0.25±0.001 c
Local	2.03±0.001 b	94.73±0.07 b	0.48±0.001 b
Basa	5.51±0.003 a	101.91±0.19 a	0.84±0.002 a
	Furcal lenght		
Population	AGR cm/day	RGR %	SGR %/day
Introduced	0.032±0.001 c	8.497±0.20 b	0.06± 0.001 c
Local	0.105±0.001 a	29.979±0.07 a	0.19±0.001 a
Basa	0.059±0.001 b	7.606±0.02 c	0.09±0.002 b

AGR: Absolute growth rate. RGR: Relative growth rate. SGR: Specific growth rate. Estimations with different letter by population are significantly different ($p<0.01$).

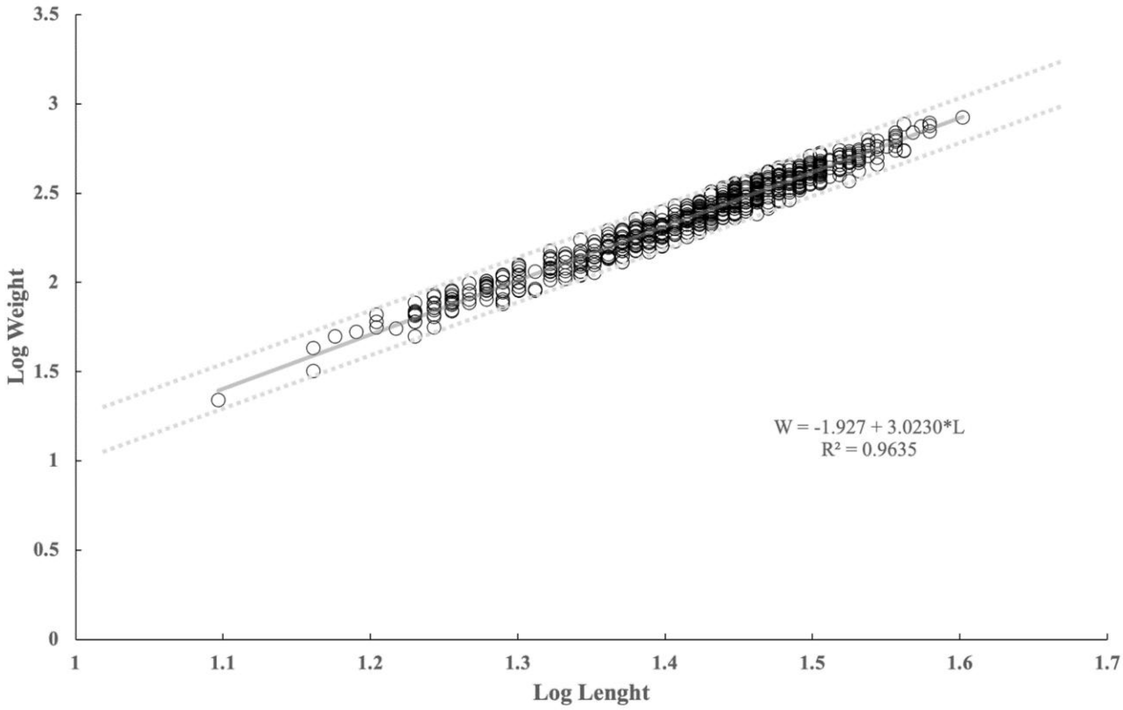

Figure 1. Double-logarithmic plot of data of introduced Channel catfish (*Ictalurus punctatus*) weight and length growth under commercial experimental conditions. n= 753. Coefficient of variation= 1.77%. 95% CL α: -1.957-1.897; 95% CL b: 3.040-3.060.

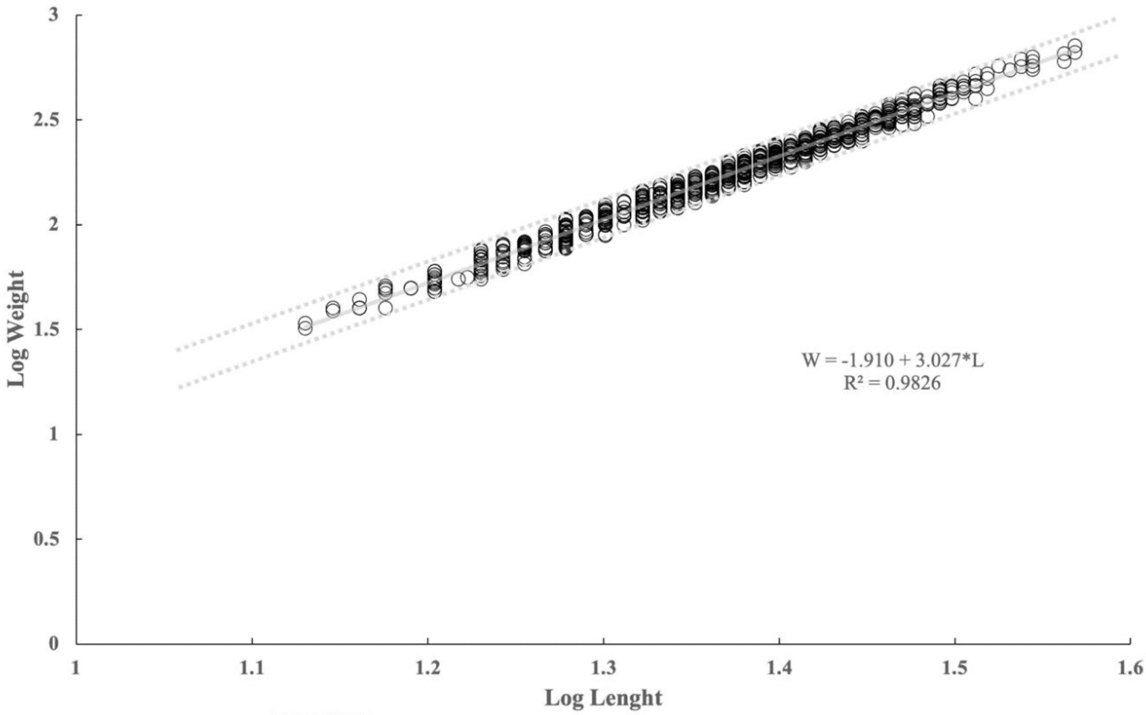

Figure 2. Double-logarithmic plot of data of local Channel catfish (*Ictalurus punctatus*) weight and length growth under commercial experimental conditions. n= 868. Coefficient of variation= 1.98%. 95% CL α: -2.098-1.723; 95% CL b: 3.012-3.039.

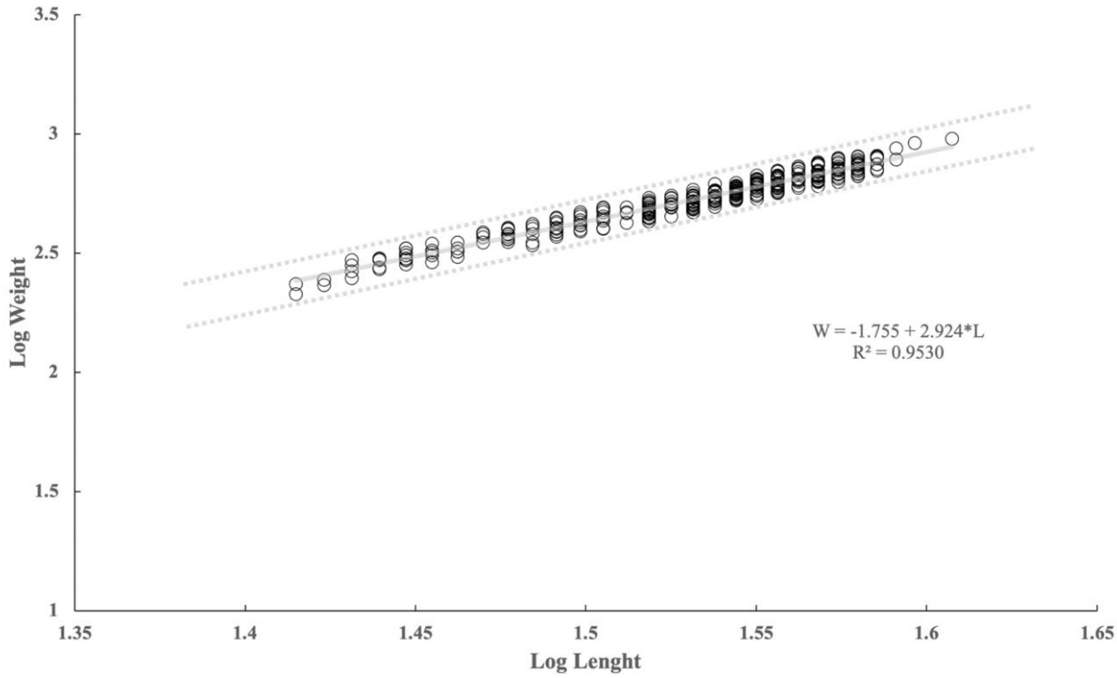

Figure 3. Double-logarithmic plot of growth data of Basa catfish (*Pangasiodon hypopthalmus*) weight and length growth under commercial experimental conditions. n= 351. Coefficient of variation= 0.97%. CL α: -1.808-1.702; 95% CL b: 2.890-2.958.

market size is usually around a year to produce an average weight of 0.5 kg, depending on farming and market conditions. These differences are impossible to ignore and might be significant for local producers, considering the profitability of local aquaculture farming systems. Further evaluations might clarify these claimed outcomes, considering specific conditions, longer assessment, and age that were not possible to consider for the present analysis.

In the other hand, the WLR can be considered a valuable tool for fisheries management since can be used for converting lengths into biomass, determine the fish condition, compare fish growth among areas, and complement species-specific reproduction and feeding studies (Froese, 2006, Froese et al., 2011). Here differences between estimated isometric (Channel catfish) and relative allometric (Basa) growth, can be interpreted as fishes that weigh less than their length predicts or, related to the better feeding condition of small organisms at the time of sampling (Froese, 2006).

Regarding to K parameter, this index of interaction between the biotic and abiotic factors in the physiological condition of fishes (Lohani and Ram, 2018) is also a useful index for monitoring of feeding intensity, age, relative robustness, and growth rates of fish considering the environmental conditions in which fish develop (Anene, 2005). To the best of our knowledge, there are few published criterions available to contrast determined conditions on the assessed species. However, based on salmon data, Barnham and Baxter (1998) indicated, that a K=1.20 qualifies acceptable fais fish and a K=1.40 is a good well-proportionated fish. Therefore, using this criterion, assessed populations could be considered satisfacory condition more favorable for Basa population.

Implications: Growth rates were efficient indicators suggesting potential fish productivity. These functions describe growth very simplified and produce good predictions in short-trail experiments (Lugert et al., 2016). Comparatively, LCC population showed better performance than ICC, but Basa confirmed its ability for biomass production in shorter periods. Although a broad line of adverse consequences has been proposed (Mendoza et al., 2013) on the introduction of Basa to Mexico's conditions, the actual benefits and risks of its production in Mexico have not been assessed. Yet its culture and use are spreading through the national territory as an aquaculture alternative (Platas-Rosado et al., 2021).

A compulsory comparison of successful species introduction in Mexico is the revealing example of Tilapia, an exotic group of African species, introduced to Mexico since the 1960s, that currently is in every state in Mexico and is considered one of the most important freshwater culture species in Mexico compared to any country in America (Fitzsimmons, 2000). Although the socio-economical impact that Tilapia represents for rural aquaculture systems in Mexico is unquestionable, very few studies have documented the ecological impact of this formerly exotic and invasive species as suggested by García-Vásquez et al. (2017) and Grácida-Juárez et al. (2022).

It is likely shortly that formerly Channel Catfish or other species producers will experiment Basa benefits taking advantage of their available infrastructure. Furthermore, Mexico is an active importer of Basa meat, and the imports from Vietnam in 2021, represent US$20.4 million (VASEP, 2021). Given the facts, a pragmatic and ideal perspective on Basa use, is the legislation of controlled farming (e.g., ponds) of this species, already ongoing, avoiding the highly possible invasion of rivers and dams, and in the same time allowing the economic benetif for farmers.

Conclusions

This is the first growth comparative analysis including *Pangasius hypopthalmus* in Mexico. Under the experimental conditions, the LCC population had better performance compared than the ICC population, but Basa has superior growth performance with a higher potential for biomass production. Further and more specific studies will support the present outcomes. Practical implication of this results is the possibility of controlled farming of Basa catfish.

Ethical statement

The present investigation did not involve regulated animals and did not require approval by an Ethical Committee, however, all applicable international, national, and/or institutional guidelines for the care and use of fishes were observed by the authors and supervised by DVM in charge of “VistaHermosa” aquaculture laboratory.

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