Short Note [Nota corta]

EFFECT OF STOCKING DENSITY ON PRODUCTIVE PERFORMANCE OF JUVENILE OF THE BLACKSTRIPE CICHLID *Vieja fenestrata* (CICHLIFORMES: CICHLIDAE) †

[EFECTO DE LA DENSIDAD DE SIEMBRA EN EL DESEMPEÑO PRODUCTIVO DE JUVENILES DE LA MOJARRA NEGRA *Vieja fenestrata* (CICHLIFORMES: CICHLIDAE)]

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SUMMARY

Background: Native fish species are a developing alternative for sustainable aquaculture worldwide and in Mexico, the southern region is leading the efforts in freshwater species. **Objective:** To assess the effect of different stocking densities on the productive performance of native fish juveniles of blackstripe cichlid (*Vieja fenestrata*). **Methodology:** A one-factor randomized experimental design was used, evaluating in triplicate four stocking densities, 0.5 (L), 2 (M), 4 (H) and 6 (S) juvenile L^{-1}. The experiment lasted 30 days. Wet weight and total length were registered every 15 days and growth performance indices were obtained. **Results:** Growth and survival were superior (P<0.05) for densities L and M. However, the M density showed a higher (P<0.05) growth rate, weight gain, and condition factor. **Implications:** The stocking density showed an apparent effect on the growth and survival of juveniles of the blackstripe cichlid, with the M density showing the best results; however, a cost-benefit assessment is required before starting production of this tropical native species. **Conclusion:** Our results suggest that a territorial and/or food competition was probably responsible for the survival and growth obtained. Although more studies are required, it appears that *Vieja fenestrata* showed the typical patrons of behaviour of another most famous cichlids, as Nile tilapia, with high levels of aggression that depend on stoking density.

Key words: Growth; juvenile; native species; social hierarchy; survival.

RESUMEN

Antecedentes: Las especies de peces nativos son una alternativa en desarrollo para la acuicultura sostenible en todo el mundo y en México, la región sur está liderando los esfuerzos en especies de dulceacuícolas. **Objetivo:** Evaluar el efecto de diferentes densidades de siembra sobre el desempeño productivo de los juveniles de la especie nativa mojarra negra (*Vieja fenestrata*). **Metodología:** Se utilizó un diseño experimental aleatorizado de un factor, evaluando por triplicado cuatro densidades de siembra, 0,5 (L), 2 (M), 4 (H) y 6 (S) juveniles L^{-1}. El experimento duró 30 días. Se registró el peso húmedo y la longitud total cada 15 días y se obtuvieron índices de crecimiento. **Resultados:** El crecimiento y la supervivencia fueron superiores (P<0.05) para las densidades L y M. Sin embargo,

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la densidad M mostró la tasa de crecimiento, el aumento de peso y el factor de condición más altos (P<0.05). **Implicaciones:** La densidad de siembra mostró un efecto aparente sobre el crecimiento y la supervivencia de los juveniles de la mojarra negra, con la densidad M mostrando los mejores resultados; sin embargo, se requiere una evaluación de costo-beneficio antes de comenzar la producción de esta especie nativa tropical. **Conclusión:** Nuestros resultados sugieren que una competencia territorial y/o por alimento fue probablemente la responsable de la supervivencia y crecimiento obtenidos. Aunque se requieren más estudios, parece que *Vieja fenestrata* muestra los patrones típicos de comportamiento de otros cíclidos más famosos, como la tilapia del Nilo, con altos niveles de agresión que dependen de la densidad de siembra.
Palabras clave: Crecimiento; juvenil; especie nativa; jerarquia social; supervivencia.

INTRODUCTION

Aquaculture in Mexico usually produce only a few fish species, mostly introduced, such as tilapia, catfish, largemouth bass, trout, and carps (Álvarez-González *et al*. 2013). This has negative consequences for sustainable development of aquaculture. However, in recent years studies aimed at the implementation of native species culture that present optimum characteristics to tolerate regional conditions have been published (Arias-Rodríguez *et al*. 2008).

The culture of native species has great advantages, such as better adaptation to regional weather conditions and market acceptance, thanks to traditional consumption from part of the population. Additionally, native species culture represents one strategy to address the food security of the regional population (Atencio-García 2001; Rojas and Mendoza 2000). Nevertheless, the culture technology development of native fish species involves the generation of information on several aspects such as biology, nutrition, reproduction, early development (larvae, fry, juvenile), optimal physico-chemical culture parameters, its domestication process (Atencio-García 2001; Ross *et al*. 2008; Dávila-Camacho *et al*. 2019), as well as the zootechnical management protocols.

Wild populations of native fishes are mainly affected by overfishing, anthropogenic alterations of habitat and the introduction of exotic species (Martínez-Cárdenas *et al*. 2014). Therefore, diversification and experimentation with tropical native fish species are essential to create an aquaculture industry to protect the integrity of wild fish communities and contribute to its safety through repopulation protocols. However, one of the main constraints to the development of new fish species culture is the lack of knowledge to determine the potential of these species (Rojas and Mendoza 2000).

Studies on tropical native fish have begun on freshwater species of economic and cultural importance in the southern states of Mexico, like Tabasco and Chiapas. Species such as the bay snook (*Petenia splendida*), mayan cichlid (*Mayaherus urophthalmus*; before *Cichlasoma urophthalmus*) (Alvarez-González *et al*. 2013) and tropical gar (*Atractosteus tropicus*) (Márquez-Couturier *et al*. 2015). In Oaxaca, a tropical native species with artisanal fishing importance is the blackstripe cichlid (*Vieja fenestrata*), known locally by the common names of mojarra negra or morro colorado. The blackstripe cichlid is distributed in North America, from the Papaloapan River to southern Mexico (Froese and Pauly 2019). This species has been used in polyculture systems with Nile tilapia (*Oreochromis niloticus*) in floating cages and despite not reaching the same growth rate or survival, its adaptation to rearing conditions is promising, showing high acceptance in the regional markets.

Although native fish farming offers a great opportunity for developing sustainable aquaculture, also faces problems such as low survival values and heterogeneous growth. In this sense, García and Zaniboni (2006) indicate that the size differences generated by an inadequate stocking density could stimulate the appearance of cannibalism. This is more important in cichlid species, as they are very territorial and aggressive fish (Jiménez-Martínez *et al*. 2009). Therefore, to establish a successful culture of the blackstripe cichlid, it is necessary to overcome different problems involved in the production of these organisms, especially in the juvenile stage, to increase and homogenize its growth and survival rate.

There is a lack of advances in all zootechnic aspects, including the juvenile period management (considered a very delicate stage in their life cycle) of this tropical native species, the blackstripe cichlid, as well as all emerging species that are not yet domesticated. The present study aimed to evaluate the optimal stocking density in the juvenile stage of the blackstripe cichlid since is a basic parameter for future research.

MATERIAL AND METHODS

Fish acquisition

Juveniles of blackstripe cichlid (*V. fenestrata*) used in the present study were produced at the Aquaculture Station of the Universidad del Papaloapan using a broodstock of 30 fish (200-300 g) maintained in an outdoor circular geomembrane tank (10 m diameter), at a female-male ratio of 1:2. During this time, the broodstock were fed *ad libitum* with commercial floating pellets (3.5 mm, 32% protein and 6% lipids) three times a day. The diet provided was a commercial feed designed for Nile tilapia (Nutripec, Agribrands).

Once hatched fry were detected in the tank, 1200 juveniles were collected 15 days later and maintained in a 40 L plastic container. The wet weight and total length of juveniles collected were measured (mean ± S.E., 90 ± 0.01 mg and 1.71 ± 0.01 cm).

Experimental design

A completely randomized design with one factor (initial stocking density) was used to determine the effect of different culture densities on productive performance. The initial stocking densities used were four: 0.5 (low, L), 2 (medium, M), 4 (high, H), and 6 (very high, S) juveniles L^{-1} (15, 60, 120, and 180 fish per aquarium, respectively). Each density was carried out in triplicate. The experimental units used were acrylic aquaria of 0.45 x 0.45 x 0.42 m, with a water column of 12 cm and a water volume of 30 L in a closed recirculation system. The water in the recirculating system was filtered using a mechanical filter (Hayward, Model S310T2, Hayward Pool Products Inc.) and a biofilter containing only plastic bio-balls (Aquatic Eco-System, Model CBB1, Pentair Ltd.).

Juveniles were fed five times a day (8:30, 11:00, 13:30, 16:00 and 18:30) at a feed rate adjusted to 20% of the total body weight per day using a balanced commercial diet (El Pedregal, 0.8 mm, 50% protein, 16% fat). Feeding adjustments were calculated after the first biometry (15 days), taking into account daily mortality and adjusting the feed rate to 10% of the total body weight per day. Water flow was closed in all aquaria for 10 min after the feeds were offered to promote feeding. Aquariums were siphoned daily to remove feces, uneaten feed particles, and dead fish. Water temperature was thermostatically adjusted (mean ± S.E., 28.04 ± 0.12 ºC) and together with DO (mean ± S.E., 6.31 ± 0.08 ppm) were monitored daily using a multiparameter water quality meter (Pro2030 - YSI, Yellow Springs Instrument Co., Inc.), while pH (mean ± S.E., 6.50 ± 0.01) and ammonium (mean ± S.E., 0.44 ± 0.02 mg L^{-1}), were measured using a multiparameter photometer (Hanna Instruments brand, Model: HI83303).

Random samples of 10 fish per aquarium (replicate) were collected on days 15 and 30 for calculation of mean wet weight (g) using a digital scale (± 0.01) (Scout Pro Model Sp 202, Ohaus Cor.) and total length from a digitized image using imaging software (ImageJ Version 1.52v).

Growth performance

The following fish performance indices were calculated from the wet weight and total length obtained from each biometry:

Specific growth rate (SGR) = (% per day) = [Ln FWW (g) – Ln IWW (g) / culture days] × 100

where: FBW = final wet weight,
IBW = initial wet weight

Average daily weight gain (ADW, mg per day) = [FWW (mg) – IWW (mg) / culture days]

Average daily length gain (ADL, mm per day) = [FTL (mm) – ITL (mm) / culture days]

where: FTL = final total length
ITL = initial total length

Percentage weight gain (PWG) = [FWW – IWW / IWW] × 100

Coefficient of variation (CV) = [SD / WW] × 100

where: SD = standard deviation

Condition factor (CF) = 100 × [WW (g) / TL $(cm)^3$]

Feed conversion ratio (FCR) = [FO / FWW – IWW]

where: FO = feed offered

Survival (S%) = [NFE / NFS] × 100

where: NFE = number of fish at the end of the experiment
NFS = number of fish stocked.

Statistical analysis

Levene’s test and residual plots were used to test the homogeneity of variance, and the Kolmogorov-Smirnov test was used to corroborate normality. A one-way ANOVA was used to compare the means among treatments of wet weight, total length, SGR, ADW, ADL, PWG, CV, FC, FCR, and survival (previously transformed using the arcsine square root). A significance level of $P < 0.05$ was used. Tukey’s HSD post-hoc test was used to identify differences among treatment means. The analyses were carried out using the Statgraphics Centurion XVI software (version 16.1.03).

RESULTS

The total food given per aquarium in each density was as follows; L = 3.28 ± 0.02 g, M = 12.58 ± 0.04 g, H = 22.36 ± 0.06 g and S = 30.24 ± 0.09 g (mean ± S.E.). The mean wet weight, total length, and survival of the four stocking densities evaluated are shown in Table 1. Statistical differences were observed in wet weight and total length at 15 and 30 days according to treatments. At 15 days, mean wet weight was higher (P<0.05) in the L density, in comparison to the rest of the densities evaluated. At 30 days, the L and M densities registered higher values of mean wet weight (P<0.05) in comparison to the H and S densities. The S density showed the lowest value of mean wet weight at both measuring days (P<0.05).

A higher value of total length was shown at 15 days in the L and M densities in comparison to the H and S (P<0.05). At 30 days, total length was higher (P <0.05) in the L density, compared to the M and H densities. Lower values of total length were observed in the S density on both sampling times (15 and 30 days) (P<0.05).

Survival reported differences only at 30 days, with the S density showing a lower percentage of survival (P<0.05) in comparison to the rest of the densities evaluated. The H density showed a higher (P<0.05) percentage of survival than the S density, and lower (P<0.05) than the L and M densities. No statistical differences (P>0.05) were observed between the L and M densities.

Specific growth rate (SGR), average daily weight gain (ADW), average daily length gain (ADL), percentage weight gain (PWG), coefficient of variation (CV), condition factor (CF), and feed conversion rate (FCR) for all densities at 15 and 30 days are given in Table 2. At 15 days, the L density showed higher values of SGR, ADW, and PWG in comparison to the rest of the densities (P<0.05). No statistical differences (P>0.05) were observed for ADL between the L and M densities, while a lower value was observed in the S density (P < 0.05). The CF registered a lower value (P < 0.05) in the M density, in comparison to the L and S densities. No differences were observed between the four densities evaluated for the CV (P>0.05). A higher value of FCR was observed in the S density (P<0.05) in comparison to the L and M densities. No statistical differences (P>0.05) were registered between the H density and the rest of the densities.

At 30 days, the SGR and PWG showed differences, with the L density showing a lower value than that observed in the M and H densities (P<0.05). For the ADW and CF, higher values were observed in the M density (P<0.05), in comparison to the L, H and S densities. No significant differences (P>0.05) were registered between the four densities evaluated for the ADL, CV, and the FCR.

DISCUSSION

High stocking densities and social dominance in commercial aquaculture can cause chronic stress, which negatively affects productivity at harvest (Muñoz *et al*. 2015). Therefore, to achieve higher growth and survival in the early stages of fish development, it is required to determine the appropriate stocking density, since the impact on these two parameters may be responsible for the economic benefits of the culture (Ferdous *et al*. 2014; Abaho *et al*. 2020). Determining optimum stocking density will allow to address other aspects, such as growth performance, survival, nutritional aspects, and genetic improvement (sex reversal). An adequate population density implies a lack of dominant behavior, which contributes to maintaining homogeneous groups and increases productivity (Santana *et al*. 2020). In cichlids such as Nile tilapia, this behavior has been revised by several authors, and although there is a lack of consensus, an optimum feeding strategy and stocking density eliminates aggression, reducing stress and maximizing growth and survival (Barcellos *et al*. 1999; Garcia *et al*. 2013; Ellison *et al*. 2018; Gonçalves *et al*. 2019).

Table 1. Wet weight (WW, g), total length (TL, cm) and percentage of survival (SV) (±S.E.) of blackstripe cichlid (*Vieja fenestrata*) cultured at four different stocking densities during the juvenile stage (30 days).

Day	Stocking density			
	L	M	H	S
15				
WW	$0.36±0.01^a$	$0.33±0.01^b$	$0.31±0.01^b$	$0.29±0.01^c$
TL	$2.63±0.01^a$	$2.60±0.02^a$	$2.53±0.01^b$	$2.43±0.03^c$
SV	$100.00±0.00^a$	$100.00±0.00^a$	$100.00±0.00^a$	$99.63±0.37^a$
30				
WW	$0.71±0.01^a$	$0.71±0.01^a$	$0.66±0.01^b$	$0.60±0.01^c$
TL	$3.33±0.07^a$	$3.25±0.06^b$	$3.21±0.01^c$	$3.15±0.01^d$
SV	$88.89±2.22^a$	$86.11±1.11^a$	$81.11±2.00^b$	$75.63±0.58^c$

L = Low (0.5 fish L^{-1}), M = medium (2 fish L^{-1}), H = high (4 fish L^{-1}), S = super high (6 fish L^{-1}). Values in each row superscripted with different letters indicate significant differences between densities (P<0.05).

Table 2. Specific growth rate (SGR), average daily weight gain (ADW), average daily length gain (ADL), percentage weight gain (PWG), coefficient of variation (CV), condition factor (CF) and feed conversion rate (FCR) (±S.E.) of blackstripe cichlid (*Vieja fenestrata*) cultured at four different stocking densities during the juvenile stage (30 days).

Day	Stocking density			
	L	M	H	S
15				
SGR	9.10±0.10^{a}	8.37±0.08^{b}	8.10±0.12^{bc}	7.61±0.19^{c}
ADW	18.36±0.38^{a}	15.72±0.26^{b}	14.85±0.38^{bc}	13.36±0.56^{c}
ADL	0.061±0.001^{a}	0.059±0.001^{a}	0.054±0.001^{b}	0.048±0.002^{c}
PWG	291.74±5.63^{a}	250.93±4.18^{b}	237.09±6.06^{bc}	213.32±8.95^{c}
CV	13.88±2.78^{a}	15.61±0.31^{a}	13.47±1.97^{a}	16.95±5.44^{a}
CF	2.01±0.01^{a}	1.85±0.02^{b}	1.95±0.02^{ab}	2.03±0.03^{a}
FCR	1.09±0.02^{a}	1.19±0.02^{a}	1.26±0.03^{ab}	1.41±0.06^{b}
30				
SGR	4.43±0.07^{a}	5.20±0.06^{b}	4.93±0.10^{b}	4.75±0.16^{ab}
ADW	23.18±0.48^{a}	25.93±0.32^{b}	23.13±0.42^{a}	20.38±0.46^{c}
ADL	0.046±0.002^{a}	0.043±0.001^{a}	0.045±0.001^{a}	0.048±0.001^{a}
PWG	94.50±2.17^{a}	118.03±2.00^{b}	109.67±3.22^{b}	104.11±4.90^{ab}
CV	13.88±1.01^{a}	12.92±0.95^{a}	14.09±1.38^{a}	15.26±1.15^{a}
CF	1.92±0.10^{a}	2.08±0.11^{b}	1.98±0.23^{a}	1.90±0.33^{a}
FCR	2.48±0.05^{a}	2.11±0.05^{a}	2.22±0.04^{a}	2.34±0.04^{a}

L = Low (0.5 fish L^{-1}), M = medium (2 fish L^{-1}), H = high (4 fish L^{-1}), S = super high (6 fish L^{-1}). Values in each row superscripted with different letters indicate significant differences between densities ($P<0.05$).

At densities below optimal (depending on the fish size and the space of the containment unit) the fish will have more space, which makes difficult to trace food particles, increasing food waste in aquariums or ponds. This will be reflected negatively in production costs and can hardly be compensated with the low number of fish that can be obtained at the time of harvest (Chakraborty and Banerjee 2010). On the other hand, at densities above optimal, competition for food and space will increase and the establishment of social hierarchies will lead to higher stress, leading to a reduction in food use, growth rate, and survival (Aksungur *et al*. 2007; García *et al*. 2013).

The results obtained for WW and TL showed that higher growth was obtained in low and medium densities (L and M). This was probably caused by low food and territory competition, which allowed a higher consumption and assimilation of nutrients from the food. Similar results were observed, in terms of final weight and length, in the native cichlid *Cichlasoma beani* by Aragón-Flores *et al*. (2014). These authors report that the treatment with the lower density resulted in heavier and larger fish, attributing it to the lack of competition, based on the aggression levels observed during feeding in the higher densities.

In other native cichlids of commercial interest, *Petenia splendida* and *M. urophthalmus*, Jiménez-Martinez *et al*. (2009) evaluated different stocking densities at the larvae stage (0.5, 1, 5, 10, and 20 larvae L^{-1}) and observed that the average weight and length were higher in the lower densities of both species. These results, those of Aragón-Flores *et al*. (2014) and the ones presented in this work support the idea that stocking density has a clear effect on growth during the early stages of development, especially in territorial and aggressive fish species like the members of the cichlid family. In these species, higher densities increase the competition for food, causing the strongest organisms (usually those of larger size) to feed first and restrict the small ones to feed, which is reflected in growth and survival (Álvarez-González *et al*. 2001; Costa *et al*. 2017).

Although cichlids are known for their aggressive behavior, native fish species of different taxonomical groups that are currently being studied for commercial purposes have also shown similar results. Martínez-Cárdenas *et al*. (2020) reported in

Atractosteus tropicus juveniles, that the higher growth observed in the lower-density group could be related to the decrease in stress-related factors that arise from intraspecific competition during feeding.

SGR and PWG showed values significantly higher in the M and H densities in comparison to the L density at 30 days while ADW and ADL registered the higher values in the M and S densities, respectively. This could have been caused by the increase in mortality observed from day 15 of culture, which affected the initial stocking density. El-Sayed (2002) found in Nile tilapia fry that SGR and PWG were negatively correlated with density, with the lower densities (3 and 5 fry L^{-1}) showing the best results. Martínez-Cárdenas *et al*. (2020) tested three stocking densities in *A. tropicus* juveniles and found higher growth in terms of SGR and ADW at a low density of 100 juveniles m^{-3} (0.1 juvenile L^{-1}). In *Vieja melanurus* (before *Cichlasoma Synspilum*), Amador-del Ángel *et al*. (2002) reported higher SGR value for the lower density (0.5 fry L^{-1}). Biswas *et al*. (2013) in pearlspot cichlid (*Etroplus suratensis*) reported a PWG of 0.10 g day^{-1} for a density of 150 fingerling m^{-3} (0.15 fingerling L^{-1}) which is higher than the obtained (0.06 g day^{-1}) at a density of 450 fingerling m^{-3} (0.45 fingerling L^{-1}). Comparing these findings (increase in stocking density negatively affected growth parameters) with our results, where the L density showed a lower growth parameter at the end of the experiment compared to the medium (M) and higher (H) densities could indicate that the densities evaluated were not high enough to reduce the productive parameters by the increase of intraspecific aggression. Similar results have been observed in *O. niloticus*, blue discus (*Symphysodon aequifasciatus*), and short-tailed pipefish (*Microphis brachyurus*) (Osofero *et al*. 2009; Tibile *et al*. 2016; Martínez-Cárdenas *et al*. 2022).

Although the CV was higher in the S group, it did not record statistical differences in comparison to the rest of the densities evaluated. This indicates that the stocking densities evaluated had no apparent effect on the values of CV obtained. The percentages of CV observed were lower than those reported in other native fish species (Martínez-Cárdenas *et al*. 2020, 2022), despite the increase in mortality towards the end of the experiment. The role of inter-individual competition as well as a dominant hierarchy in the increase of the CV has been pointed out by several authors (Adams *et al*. 2000; Ling *et al*. 2016). In the present study, is probable that these two aspects influence survival (increased mortality because of higher levels of aggression and/or cannibalism), however, were not high enough to cause a wide dispersion of the wet weight obtained.

Condition factor (CF) is a criterion normally used to assess the well-being or the nutritional status of a fish, defined by the amount of energy possessed (fat content available) by that fish to perform various functions, including growth and reproduction (Jones *et al*. 1999; Neff and Cargnelli 2004; Gupta *et al*. 2012; Leyton *et al*. 2015). Additionally, it can be used to assess the physiological status under a potential stressor (Hoque *et al*. 1998; Cifuentes *et al*. 2012) such as a high stocking density. In the present work, the CF values at 30 days did not show significant variations between the different densities, except for the M density. This could indicate that the densities evaluated were not high enough to cause alterations in the physiological state of the fish or that the fish were not nutritionally stressed during the experiment, as suggested by Martínez-Cardenas *et al*. (2022) in a similar work in *Microphis brachyurus*.

Currently, there is no available information related to the optimum CF values for this species, however, for healthy and normally growing cichlids like Nile tilapia and its hybrids values close to 2.0 have been reported (Fish Breading Association 2003; El-Saidy and Gaber 2005; Crab *et al*. 2009; Gupta *et al*. 2012; Juárez-Juárez *et al*. 2017). In the present research, values close to 2.0 were observed, indicating growth similarities in morphological conformation between the blackstripe cichlid and the Nile tilapia, probably related to the fact that both species belong to the Cichlidae family.

The FCR measures feed expenditure to convert into 1 kg of meat, therefore, the closer this value is to the unit, the more efficient the feed-to-meat conversion (Ellis *et al*. 2002; Zafra *et al*. 2019). In the present study, during the first 15 days of culture, FCR values remained below 1.5, values considered optimal for the growth of aquaculture species. However, for the last 15 days of culture, high values (above 2.0) were observed in all groups. This could have been caused by the growth achieved, the appearance of social stress, probably caused by agonistic interactions (characteristic of cichlids), and/or the increase in mortality. Another probable cause that could contribute greatly to the observed FCR values is acute type stress caused by manipulation during biometrics (random capture of juveniles thorough net chasing for measuring), which took place 15 days after stocking and could generate inhibition in the appetite of fish and the inefficient use of the food provided (Muñoz *et al*. 2015), especially in the high-density groups, where the greater number of social interactions likely led to a higher level of stress that resulted in aggressive behavior. El-Sayed (2002) observed a lower efficiency in the use of food in Nile tilapia fry in the lowest stocking density (3 fry L^{-1}), attributed to the lack of competition for food and social hierarchy, in addition to the difficulty of tracking food. Chakraborty and Banerjee (2010) reported that very low population densities can lead to lower efficiency in the use of food, resulting in lower growth. Finally, the fixed amount of food provided to each treatment and the unknown amount of food not consumed or wasted probably influenced the FCR values obtained (Anguas-Vélez *et al*. 2003). At the end of the present experiment, FCR values of

2.11 to 2.48 were reached, values lower than those reported by El-Sayed (2002) in Nile tilapia fry (2.65 to 3.45) and Mensah *et al*. (2013) in fry of the same species (2.34 to 3.13). Amador-del Ángel *et al*. (2002) reported higher values of FCR in *V. melanurus*, using densities like those evaluated in our work.

The survival observed in the present work ranged from 75.6 to 88.8%, with the L and M densities showing the highest survival rate in comparison to the highest densities (H and S). In our work, the increase in stocking density negatively affected survival, probably caused by the reduction in available space, which generates competition for territory and food, by the establishment of social hierarchies that cause the dominant fish (usually the strongest and largest) feed first, consuming more food and limiting its access to smaller fish, resulting in its removal from the population (Álvarez-González *et al*. 2001; Mensah *et al*. 2013; Costa *et al*. 2017). Suleiman and Solomon (2017) reported in North African catfish (*Clarias gariepinus*) that a possible cause for the low survival as the density in fry increases, is due to stress experienced because of aggressive feeding behavior as energy destined for growth is spent on frenetic feeding activities.

Jiménez-Martínez *et al*. (2009) observed higher survival rates at low densities in native fish species such as *C. urophthalmus* and *P. splendida*, indicating that lower densities (5 and 10 juveniles L^{-1}) are the most suitable, with survival rates ranging from 83% to 98%, percentages higher than those reported in the present work. In *V. melanurus*, Amador-del Ángel *et al*. (2002) reported a survival of 83.3 to 87.5%, using stocking densities similar to those reported in the present study (0.5, 1.0, 1.5 and 2.0 fry L^{-1}).

CONCLUSIONS

The growth and survival of the blackstripe cichlid were comparable with the obtained in other native cichlid fish species currently evaluated as possible alternatives for the development of the aquaculture in the southern region of Mexico. This supports the idea that the blackstripe cichlid is an excellent alternative for commercial culture. The stocking density showed a clear effect on the growth and survival of juveniles of the blackstripe cichlid. A higher growth (SGR, ADW, and PWG) and survival were observed in the M density at the end of the experiment. Based on the results, it is recommendable a stocking density of 2 juvenile L^{-1}, however, a cost-benefit assessment is required to recommend a stocking density before starting a pilot production level in this native species.

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Conflict of interest. The authors declare that they have no competing interests.

Compliance with ethical standards. The experimental procedures followed the guidelines accepted by the Universidad del Papaloapan. After the experiment, the remaining juveniles were transferred to an artificial lagoon inside the Universidad del Papaloapan, where the fish were let to be free.

Data availability. Data are available with J.P. Alcántar-Vázquez, jupasoul@hotmail.com upon reasonable request.

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