Received: 15 June 2018 | Revised: 18 December 2018 | Accepted: 23 December 2018

DOI: 10.1111/are.13970

ORIGINAL ARTICLE

WILEY Aquaculture Research

Slightly salinized water enhances the growth and survival of *Arapaima gigas* larvae

Thyssia Bomfim Araújo da Silva[1] | **Cláudia Maiza Fernandes Epifânio**[2] | **Francisco de Matos Dantas**[3] | **Thayssa Larrana Pinto da Rocha**[4] | **Ligia Uribe Gonçalves**[5] | **Jony Koji Dairiki**[6]

[1]Universidade Nilton Lins, Manaus, Amazonas, Brazil

[2]Programa de Pós Graduação em Aquicultura, Universidade Nilton Lins, Manaus, Amazonas, Brazil

[3]Instituto Federal do Amazonas, Manaus, Amazonas, Brazil

[4]Faculdade Metropolitana de Manaus, Manaus, Amazonas, Brazil

[5]Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas, Brazil

[6]Embrapa Amazônia Ocidental, Manaus, Amazonas, Brazil

Correspondence
Jony Koji Dairiki, Embrapa Amazônia Ocidental, Manaus, Amazonas, Brazil.
Email: jony.dairiki@embrapa.br

Funding information
Instituto Nacional de Pesquisas da Amazônia; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior; Fundação de Amparo à Pesquisa do Estado do Amazonas

Abstract

The aim of this study was to evaluate the survival and growth of *Arapaima gigas* larvae reared in slightly salinized water. Pirarucu larvae (183.1 ± 41.2 mg and 3.4 ± 0.3 cm) were stocked in PVC tanks (20 L; *n* = 4; 40 larvae per tank) in a static system. *A. gigas* larvae were reared in increasing levels of salinized water (0, 1, 2, 3 and 4‰) for a period of 15 days. Fish were fed six times a day with *Artemia* nauplii (2,900 nauplii per larvae per meal in the beginning). The salinized water increased by at least four times the *Artemia* nauplii lifespan, which prolonged the time of live food supply to *Arapaima* larvae. Pirarucu larvae kept in freshwater presented the lowest values in weight gain, final weight and survival. Larvae reared in water with 4‰ of salinized water showed the highest final weight. Slightly salinized water enhances the growth and survival of A. gigas larvae and it can be a simple practice with low cost that can be applied in the routine of pirarucu larviculture.

KEYWORDS

Artemia sp nauplii, paiche, pirarucu, salinity

1 | INTRODUCTION

Arapaima gigas is a carnivorous and obligate air-breathing fish, native throughout the Amazon basin. Its common name "Pirarucu" is of Tupi origin (pira = fish and urucu = red) which corresponds to the intense dominant colouration at the extremities of its scales (Venturieri & Bernardino, 1999). Pirarucu has become an important species to aquaculture due to its fast growth and high nutritional quality of flesh (Cortegano et al., 2017). It is considered one of the largest freshwater fish, reaching between 2 and 3 metres and weighing 200 kg (Imbiriba, 2001; Nelson, 2006; Saint Paul, 1986). It tolerates high stocking density, being resistant to handling, presents rapid growth of 10–12 kg in the first year of breeding (Brandão, Gomes, & Chagas, 2006; Rebaza, Rebaza, & Deza, 2010; Tavares-Dias, Araújo, Gomes, & Andrade, 2010). In 2016, approximately 8 million tons of this species were produced in Brazil (IBGE, 2016), which has been increasing in the last few years in this country (Lima, Tavares-Filho, & Moro, 2018). However, it is necessary to increase early *A. gigas* supply to meet the growing demand and to decrease the price of juveniles for its grow-out phase (Nuñez et al., 2011).

Larviculture requires more attention due to the large morpho-physiological transformations that occur in the fish (Portella et al., 2014; Zouiten, Khemis, Besbes, & Chantal, 2008). In the beginning of its exogenous feeding, the majority of fish larvae are dependent on live food, such as *Artemia* nauplii, a brine shrimp, which are the most commonly used in aquaculture. The cysts of *Artemia* nauplii are easy to obtain and hatch, as well as being resistant to abiotic variables, manipulation and diseases. These microorganisms are attractive to feed fish larvae and widely used in the world aquaculture due to their high swimming ability, nutritional value (in many cases, *Artemia* need to be enriched) and adequate size, varying from 400 to 600 μm (Conceição, Yúfera, Makridis, Morais, & Dinis, 2010; Lavens & Sorgeloos, 1996).

Several studies using *Artemia* nauplii in the first exogenous feed of fish larvae demonstrate an increase in the growth and survival rates for many species, especially for carnivorous species (Conceição et al., 2010; Jomori, Portella, & Luz, 2012; Tesser & Portella, 2011). However, *Artemia* nauplii present low life span when added in freshwater (Merchie, 1996) and protocols to support the *Artemia* nauplii survival in freshwater are necessary to improve the larviculture of high economic value fish, such as pirarucu.

An alternative protocol is the use of slightly saline water in larviculture indoor tanks. The use of NaCl in freshwater can extend the *Artemia* nauplii's lifetime, increase fish feeding and reduce water quality problems related to the mortality of nauplii in hypo-osmotic solution (Beux & Zaniboni Filho, 2006). Furthermore, it is possible to reduce energy consumption by the osmotic differences between the animal and the external environment and consequently increasing fish larvae growth (Fazio, Marafioti, Arfuso, Piccione, & Faggio, 2013; Sampaio & Bianchini, 2002).

Salinized waters promoted good growth in *Carassius auratus* with maximum 12‰ salinity and 31°C temperature (Imanpoor, Najafi, & Kabir, 2012) and *Mugil liza* (Lisboa, Barcarolli, Sampaio, & Bianchini, 2015) reared at salinity 24‰. The highest survivability of *Pelecus cultratus* larvae was obtained in salinity equal to 3‰ (Kujawa et al., 2017). Reduced mortality of *Ictalurus punctatus*, *C. auratus*, *Morone saxatilis* and *Acipenser oxyrinchus desotoi* challenged by *Flavobacterium columnare* and held in 1.0‰ salinity indicated that this level of salinity could be useful for reducing losses to columnaris in culture systems where salinity can be easily adjusted (Altinok & Grizzle, 2001). However, studies with salinity management with Neotropical freshwater species are still incipient. Therefore, this study aimed to propose new protocols to increase the lifetime of *Artemia* nauplii for its capture by pirarucu larvae.

2 | MATERIAL AND METHODS

2.1 | Hatching *Artemia* nauplii

In order to obtain *Artemia* nauplii (High 5 cysts, INVE Aquaculture), 50 g of cyst was used in incubators with a capacity of 15 litres in saline water (30‰), pH 8.0, at a temperature of 28°C, with constant aeration, kept under a 100 W or 1507 lumens lamp, for a period of 22 hr. The cysts were previously hydrated for 1 hr in fresh water. After the incubation period, the *Artemia* nauplii were filtered, quantified and supplied to the pirarucu larvae.

2.2 | Survival *Artemia* nauplii to increasing salinity

After hatching, *Artemia* nauplii were added in increasing levels of sodium chloride (NaCl): 0, 1, 2, 3 and 4‰ at a density of 10 nauplii/ml in 20 Beakers (200 ml; n = 4) with constant aeration during 40 hr. After the homogenization of each experimental unit, a sample of 1 ml of the solution was collected (1 to 6, 8, 10, 12, 14, 24, 32 and 40 hr post *Artemia* nauplii hatching) (water and *Artemia* nauplii; n = 3) and the number of alive and dead (immovable) nauplii was registered to calculate *Artemia* nauplii survival rate (lifespan).

2.3 | Fish performance

Arapaima gigas larvae were obtained from a natural spawning in a commercial fish farm (Coari/AM, Brazil). Larvae were collected when they started to swim to the water surface together with the breeding male and subsequently transported to Fish Farming Station of INPA, Manaus/AM, Brazil. The experiment was carried out in a completely randomized experimental design (n = 3) with five treatments, containing increasing levels of sodium chloride (NaCl): 0, 1, 2, 3 and 4‰ in water from artesian well. Groups of 40 pirarucu larvae (initial body weight 183.1 ± 41.2 mg and initial length 3.4 ± 0.3 cm) were distributed in the experimental units (circular polyethylene tanks, with a useful volume of 20 L), in a static system. Larvae were fed every 2 hr (7, 9, 11, 13, 15 and 17 hr) with *Artemia* nauplii newly hatched (2,900 nauplii per larvae per meal in the beginning). The quantities were increased (10% per day) over the 15 days of the trial. Fish management was according to the ethics of animal use by the Brazilian Society of Laboratory Animal Science (COBEA).

Water quality parameters such as pH (6.87 ± 0.42), dissolved oxygen (7.29 ± 0.11 mg/L) and temperature (26.6 ± 0.9°C) were daily monitored by digital dissolved oxygen meter - YSI 85 and pH meter - 10A EcoSense. The tanks were cleaned daily and the total exchange water was carried out once a day. At the end of the experiment, fish were assessed to determine final weight, weight gain (WG = final weight − initial weight), survival (S = [final number of fish − initial number of fish] × 100) and condition factor using the reference Nehemia, Maganira, and Rumisha (2012).

2.4 | Statistical analysis

Data were submitted to exploratory analysis by outlier data test, variance homogeneity and range of the response variable. Data were evaluated using an ANOVA followed by post-hoc Tukey test, using the PRISM® statistical package. Optimum salinity concentration in the water was determined by polynomial regression analysis using of the STATISTICA 10.0 software.

3 | RESULTS

3.1 | Survival *Artemia* nauplii to increasing salinity

The lifespan of *Artemia* nauplii added in freshwater was up to 6 hr post hatching (HPH). Subsequently, the survival of *Artemia* nauplii submitted to 1‰ de NaCl was increased up to 24 HPH. This low increase in NaCl result in a survival rate four times higher than *Artemia* nauplii added in freshwater water. The *Artemia* nauplii maintained in a NaCl concentration of 2‰ survived up to 32 HPH,

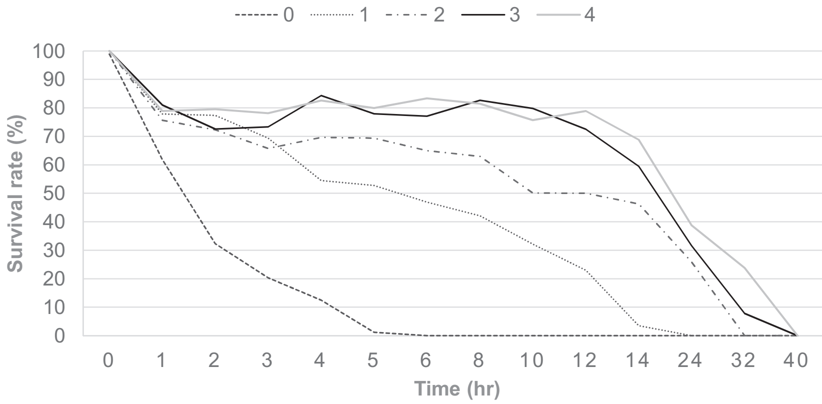

FIGURE 1 Survival rate of *Artemia* nauplii in salinities between 0 to 4 ‰

followed to *Artemia* nauplii at 3‰ and 4‰ of NaCl that survived up to 40 HPH (Figure 1).

3.2 | Arapaima larvae growth performance

The increasing addition of NaCl in *Arapaima* larvae water production during 15 days promoted better results in productive performance. Only animals kept exclusively in freshwater presented the lowest values in weight gain, final weight and survival (Table 1).

After 15 days, the total length of all *Arapaima* larvae was similar. The larvae maintained at concentrations of 4‰ NaCl presented the final weight (850.75 ± 56.72 mg) with medium values differing only from the fish maintained in freshwater (757.49 ± 10.23 mg) (Figure 2). The weight gain was increasing as the concentration was increased (Table 1) and significant differences were observed just between animals reared in 4 and 0‰ of NaCl in the water.

The survival rates were similar to all pirarucu larvae submitted to slightly saline water and freshwater, except the ones submitted to 1‰ in comparison with the freshwater. Animals raised in freshwater had the lowest survival rates. The condition factor were similar in whole treatments, with the 4‰ treatment being the only exception (Table 1).

4 | DISCUSSION

The survival of *Artemia* nauplii was directly influenced by the saline concentration of the water, with low survival when the salinity decreases, as observed by Beux and Zaniboni Filho (2006). Our results showed a short survival period of *Artemia* nauplii when added to freshwater (no more than 6 hr). On the other hand, the lifespan of 80% of *Artemia* nauplii added in water with increasing salinity levels was prolonged up to 14 hr after hatching. The adaptation of Brine Shrimp, *Artemia* sp nauplii (High5 cysts, INVE) from freshwater through brackish into marine waters shows the exceptional capacities of this animal group to survive with salinity changes. Osmoregulation is the main physiological mechanism that maintains the hypo-osmotic homeostasis of these animals (Thabet, Ayadi, Koken, & Leignel, 2017).

The higher survival of *Artemia* nauplii in waters with higher salt concentration could be an important factor that contributed to the pirarucu weight gain. Similar final length for all *A. gigas* larvae submitted to different saline concentrations indicates a possible spectrum to be used without damage to the animal growth. Moreover, the additional energy requirements for fish osmoregulation to maintain in hypo or hyperosmotic environments can hamper the fish growth when compared to those kept in an isosmotic environment or with an ideal saline spectrum (Pérez-Robles, Re, Giffard-Mena, & Díaz, 2012). Energy cost associated with osmoregulation can vary according the different ontogenetic developmental stages and the response to salinity may be species-dependent (Romano, Syukri, Karami, Omar, & Khalid, 2017). In some cases, the salinized water could impair the development. For *Clarias gariepinus* larvae, 10‰ of the salinity caused death within 48 hr (Britz & Hecht, 1989). Exposure to higher- and long-term salinity, significantly affects the growth and physiological response of *Clarias batrachus* (Sarma, Prabakaran, Krishnan, Grinson, & Kumar, 2013).

Arapaima gigas larvae maintained at 4‰ NaCl present a higher final weight than animals kept in freshwater. The increased salinity modifies the specific gravity of the medium reducing the energy floatation and saving food energy – around 10%–50% (Marshall & Bryson, 1998) – for body growth (Lam & Sharma, 1985). Moreover, changes in salinity result in different water intake rates, affecting the digestive enzymes activity by the salinity of the intestinal tract (Boeuf & Payan, 2001).

Many studies mention that suitable saline water reduce physiological stress (Jomori et al., 2012), the ionic and osmotic differences between external and internal fluids (Lam & Sharma, 1985; Riley, Hirano, & Grau, 2003; Wurts, 1995) and support the best results in productive performance (Amornsakun, Vo, Petchsupa, Pau, & Hassan, 2017; Britz & Hecht, 1989; Fiúza et al., 2015). Studies with freshwater fish have determined better productive results for many

TABLE 1 Zootecnichal variables of pirarucu larvae kept in slightly salinized water*

Treatment variables	0 ‰	1	2	3	4
Final weight (mg)	757.49 ± 10.23[b]	781.57 ± 12.53[ab]	820.79 ± 57.19[ab]	814.36 ± 32.53[ab]	850.75 ± 56.72[a]
Weight gain (mg)	574.49 ± 10.23[b]	598.87 ± 12.53[ab]	637.79 ± 57.19[ab]	631.36 ± 32.53[ab]	667.75 ± 56.72[a]
Final height (cm)	5.03 ± 0.10[a]	5.08 ± 0.08[a]	5.27 ± 0.14[a]	5.15 ± 0.05[a]	5.17 ± 0.13[a]
Survival rate (%)	95.63 ± 3.15[b]	100.00 ± 0.00[a]	96.00 ± 1.22[ab]	97.50 ± 2.04[ab]	98.13 ± 1.25[ab]
Condition factor	0.0058 ± 0.0006[b]	0.0058 ± 0.0006[b]	0.0058 ± 0.0006[b]	0.0058 ± 0.0006[b]	0.0060 ± 0.0006[a]

*Means (n = 4) ± *SD*. Means followed by equal letters, in the lines, do not differ, by Tukey's test, at 5% level.

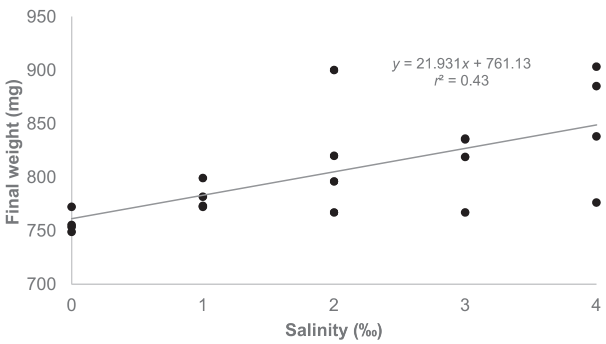

FIGURE 2 Final weight of *Arapaima gigas* larvae at increasing salinities

fish species in concentrations ranging from 0.5–2‰ (Jomori, Luz, Takata, Fabregat, & Portella, 2013; Luz, Costa, Ribeiro, Silva, & Rosa, 2013; Santos & Luz, 2009).

The final survival of pirarucu larvae was similar to all group of fish reared in the slightly saline water. It indicates the positive action of NaCl to improve the resistance of animals in the most critical phase of life. Several studies indicate that the use of NaCl in neotropical fish species larviculture contributes to similar or superior survival and growth results in relation to larvae reared in freshwater (Jomori et al., 2013; Luz & Santos, 2008; Santos & Luz, 2009) and tolerance to different salinity gradients is species-dependent. In addition, the salt concentrations tested can act as growth facilitators, resulting in highest weight gain. The use of slightly salinized water can be a simple practice with low cost to be applied in the routine of pirarucu larviculture.

The inverse relationship between survival rates and increasing salinities was reported for several freshwater fish, including, *Heterobranchus longifilis* (Fashina-Bombata & Busari, 2003), *Pimelodus maculatus* (Weingartner & Zaniboni Filho, 2004) and *Lophiosilurus alexandri* (Luz & Santos, 2008). However, this statement is correct until the salinity tolerance limit is reached. Improper salinity for freshwater species like some tetras and many catfish causes problems because they are sensitive to salt (Noga, 2010). Salinity stress may occur if young freshwater salmonids (parr) are prematurely transferred to saltwater before they are ready to undergo transformation into marine adapted fish (smolts). The knowledge of the *Arapaima* larvae tolerance in salinities up to 4‰ can be a useful tool for the use of NaCl in prophylactic procedures against pathogens (Dewi, Siallagan, & Suryanto, 2018; Magondu, Rasowo, Oyoo-Okoth, & Charo-Karisa, 2011).

5 | CONCLUSION

The use of NaCl concentration up to 4‰ resulted in higher weight gain and condition factor than pirarucu larvae reared in freshwater, possibly due to increasing the duration of *Artemia* survival and thus availability to the larvae and/or reducing energy requirements for osmoregulation. Future studies comparing NaCl with natural sea salt aiming at the survival of *Artemia* nauplii in addition to parasite control need to be carried out for the larviculture of this species. Besides that, the impact of discharged salinized water into receiving streams needs to be evaluated to avoid environmental problems, establishment of the nutritional values that the *Artemia* nauplii provide for pirarucu larvae and if the 4‰ concentration of NaCl does not affect the osmoregulation of the larvae.

ACKNOWLEDGMENTS

The authors are indebted to Instituto Nacional de Pesquisas da Amazônia (Inpa), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes) and Fundação de Amparo à Pesquisa do Estado do Amazonas (Fapeam) for partial funding of the research, structure and scholarship.

ORCID

Ligia Uribe Gonçalves https://orcid.org/0000-0002-5014-6986

Jony Koji Dairiki https://orcid.org/0000-0002-1899-6657

REFERENCES

Altinok, I., & Grizzle, J. M. (2001). Effects of low salinities on *Flavobacterium columnare* infection of euryhaline and freshwater stenohaline fish. *Journal of Fish Diseases*, *24*, 361–367. https://doi-org.ez103.periodicos.capes.gov.br/10.1046/j.1365-2761.2001.00306.x

Amornsakun, T., Vo, V. H., Petchsupa, N., Pau, T. M., & Hassan, A. B. (2017). Effects of water salinity on hatching of egg, growth and survival of larvae and fingerlings of snake head fish, *Channa striatus*. *Songklanakarin Journal of Science and Technology*, *39*, 137–142.

Beux, L. F., & Zaniboni Filho, E. (2006). Influência da baixa salinidade na sobrevivência de náuplios de *Artemia* sp. *Boletim do Instituto de Pesca*, *32*, 73–77.

Bouef, G., & Payan, P. (2001). How should salinity influence fish growth? *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology*, *130*, 411–423. https://doi.org/10.1016/s1532-0456(01)00268-x

Brandão, F., Gomes, L. C., & Chagas, E. C. (2006). Respostas de estresse em pirarucu (*Arapaima gigas*) durante práticas de rotina em piscicultura. *Acta Amazônica*, *36*, 349–356. https://doi.org/10.1590/S0044-59672006000300010

Britz, P. J., & Hecht, T. (1989). Effect of salinity on growth and survival of African sharptooth catfish (*Clarias gariepinus*) larvae. *Journal of Applied Ichthyology*, *5*, 194–202. https://doi.org/10.1111/j.1439-0426.1989.tb00492.x

Conceição, L. E. C., Yúfera, M., Makridis, P., Morais, S., & Dinis, M. T. (2010). Live feeds for early stages of fish rearing. *Aquaculture Research*, *41*, 613–640. https://doi.org/10.1111/j.1365-2109.2009.02242.x

Cortegano, C. A. A., Godoy, L. C., Petenuci, M. E., Visentainer, J. V., Affonso, E. G., & Gonçalves, L. U. (2017). Nutritional and lipid profles of the dorsal and ventral muscles of wild pirarucu. *Pesquisa Agropecuária Brasileira*, *52*, 271–276. https://doi.org/10.1590/S0100-204X2017000400007

Dewi, R. R., Siallagan, W., & Suryanto, D. (2018). The efficacy of sodium chloride application in the control of fish Lice (*Argulus* sp) infection on tilapia (*Oreochromis niloticus*). *Acta Aquatica: Aquatic Sciences Journal*, *5*, 4–7. https://doi.org/10.29103/aa.v5i1.584

Fashina-Bombata, H. A., & Busari, A. N. (2003). Influence of salinity on the developmental stages of African catfish *Heterobranchus longifilis* (Valenciennes, 1840). *Aquaculture*, *224*, 213–222. https://doi.org/10.1016/S0044-8486(03)00273-4

Fazio, F., Marafioti, S., Arfuso, F., Piccione, G., & Faggio, C. (2013). Influence of different salinity on haematological and biochemical parameters of the widely cultured mullet, *Mugil cephalus*. *Marine and Freshwater Behavior and Physiology*, *46*, 211–218. https://doi.org/10.1080/10236244.2013.817728

Fiúza, L. S., Aragão, N. M., Ribeiro Junior, H. P., Moraes, M. G., Rocha, I. R. C. B., Lustosa Neto, A. D., … Costa, F. H. F. (2015). Effects of salinity on the growth, survival, haematological parameters and osmoregulation of tambaqui *Colossoma macropomum* juveniles. *Aquaculture Research*, *46*, 1–9. https://doi.org/10.1111/are.12224

IBGE (2016). *Produção da Pecuária Municipal 2016* (p. 53). Rio de Janeiro, Brazil: IBGE.

Imanpoor, M. R., Najafi, E., & Kabir, M. (2012). Effects of different salinity and temperatures on the growth, survival, haematocrit and blood biochemistry of Goldfish (*Carassius auratus*). *Aquaculture Research*, *43*, 332–338. https://doi.org/10.1111/j1365-2109.2011.02832.x

Imbiriba, E. P. (2001). Potencial da criação de pirarucu, (*Arapaima gigas*), em cativeiro. *Acta Amazônica*, *31*, 299–316.

Jomori, R. K., Luz, R. K., Takata, R., Fabregat, T. E. H. P., & Portella, M. C. (2013). Água levemente salinizada aumenta a eficiência da larvicultura de peixes neotropicais. *Pesquisa Agropecuária Brasileira*, *48*, 809–815. https://doi.org/10.1590/S0100-204X2013000800001

Jomori, R. K., Portella, M. C., & Luz, R. K. (2012). Effect of salinity on larval rearing of pacu *Piaractus mesopotamicus*. *Journal of the World Aquaculture Society*, *43*, 423–432. https://doi-org.ez103.periodicos.capes.gov.br/10.1111/j.1749-7345.2012.00570.x

Kujawa, R., Lach, M., Pol, P., Ptaszkowski, M., Mamcarz, A., Nowosad, J., … Kucharczyk, D. (2017). Influence of water salinity on the survival of embryos, and growth of the sichel larvae *Pelecus cultratus* (L.) under controlled conditions. *Aquaculture Research*, *48*, 1302–1314. https://doi.org/10.1111/are.12972

Lam, T. J., & Sharma, R. (1985). Effects of salinity and thyroxine on larval survival, growth and development in the carp, *Cyprinus carpio*. *Aquaculture*, *44*, 201–212. https://doi.org/10.1016/0044-8486(85)90244-3

Lavens, P., & Sorgeloos, P. (Eds.). (1996). *Manual on the production and use of live food for aquaculture*. FAO Fisheries Technical Paper. No. 361. Rome, Italy: FAO. 295 p.

Lima, A. F., Tavares-Filho, A., & Moro, G. V. (2018). Natural food intake by juvenile *Arapaima gigas* during the grow-out phase in earthen ponds. *Aquaculture Research*, *49*, 2051–2058. https://doi.org/10.1111/are.13662

Lisboa, V., Barcarolli, I. F., Sampaio, L. A., & Bianchini, A. (2015). Acclimation of juvenile *Mugil liza* Valenciennes, 1836 (Mugiliformes: Mugilidae) to different environmental salinities. *Neotropical Ichthyology*, *13*, 591–598. https://doi.org/10.1590/1982-0224-20140123

Luz, R. K., Costa, L. S., Ribeiro, P. A. P., Silva, R. F., & Rosa, P. V. (2013). Influência do tempo de transporte para juvenis de pacamã (*Lophiosilurus alexandri*). *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, *65*, 1895–1898. https://doi.org/10.1590/S0102-09352013000600044

Luz, R. K., & Santos, J. C. E. (2008). Avaliação da tolerância de larvas do pacamã *Lophiosilurus alexandri* Steindachner, 1877 (Pisces: Siluriformes) a diferentes salinidades. *Acta Scientiarum: Biological Sciences*, *30*, 345–350. https://doi.org/10.4025/actascibiolsci.v30i4.791

Magondu, E. W., Rasowo, J., Oyoo-Okoth, E., & Charo-Karisa, H. (2011). Evaluation of sodium chloride (NaCl) for potential prophylactic treatment and its short-term toxicity to African catfish *Clarias gariepinus* (Burchell 1822) yolk sac and swim-up fry. *Aquaculture*, *319*, 307–310. https://doi.org/10.1016/j.aquaculture.2011.06.038

Marshall, W. S., & Bryson, S. E. (1998). Transport mechanisms of seawater teleost chloride cells: An inclusive model of a multifunctional cell. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, *119A*, 97–106. https://doi.org/10.1016/S1095-6433(97)00402-9

Merchie, G. (1996). Artemia: Use of nauplii and metanauplii. In P. Lavens, & P. Sorgeloos (Eds.), *Manual on the production and use of live food for aquaculture. FAO Fisheries Technical Paper. N. 361* (pp. 137–160). Rome, Italy: FAO.

Nehemia, A., Maganira, J. D., & Rumisha, C. (2012). Length-weight relationship and condition factor of tilapia species grown in marine and fresh water ponds. *Agriculture and Biology Journal of North America*, *3*, 117–124.

Nelson, J. S. (2006). *Fishes of the world* (p. 601). Edmonton, Canada: University of Alberta, John Wiley & Sons.

Noga, E. J. (2010). *Fish disease: Diagnosis and treatment* (2nd ed., p. 536). Ames, IA: Wiley-Blackwell.

Nuñez, J., Chuu-Koo, F., Berland, M., Arévalo, L., Ribeyro, O., Duponchelle, F., & Renno, J. F. (2011). Reproductive success and fry production of the paiche or pirarucu, *Arapaima gigas* (Schinz), in the region of Iquitos. *Peru Aquaculture Research*, *42*, 815–822. https://doi.org/10.1111/j.1365-2109.2011.02886.x

Pérez-Robles, J., Re, A. D., Giffard-Mena, I., & Díaz, F. (2012). Interactive effects of salinity on oxygen consumption, ammonium excretion, osmoregulation and Na+/K+-ATPase expression in the bullseye puffer (*Sphoeroides annulatus*, Jenyns 1842). *Aquaculture Research*, *43*, 1372–1383. https://doi.org/10.1111/j.1365-2109.2011.02940.x

Portella, M. C., Jomori, R. K., Leitão, N. J., Menossi, O. C. C., Freitas, T. M., Kojima, J. T., … Carneiro, D. J. (2014). Larval development of indigenous South American freshwater fish species, with particular reference to pacu (*Piaractus mesopotamicus*): A review. *Aquaculture*, *432*, 402–417. https://doi.org/10.1016/j.aquaculture.2014.04.032

Rebaza, M., Rebaza, C., & Deza, S. (2010). Densidad de siembra para cultivos de paiche en jaulas flotantes. *Aquavisión*, *6*, 26–27.

Riley, L. G., Hirano, T., & Grau, E. G. (2003). Effects of transfer from seawater to fresh water on the growth hormone insulin-like growth factor-I axis and prolactin in the Tilapia, *Oreochromis mossambicus*. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology*, *136*, 647–655. https://doi.org/10.1016/S1096-4959(03)00246-X

Romano, N., Syukri, F., Karami, A., Omar, N., & Khalid, N. (2017). Salinity-induced changes to the survival, growth and glycogen distribution in the early fry stages of silver barb, *Barbodes gonionotus* (Bleeker, 1850). *Journal of Applied Ichthyology*, *33*, 509–514. https://doi.org/10.1111/jai.13338

Saint-Paul, U. (1986). Potential for aquaculture of South American freshwater fishes: A review. *Aquaculture*, *54*, 205–240. https://doi.org/10.1016/0044-8486(86)90329-7

Sampaio, L. A., & Bianchini, A. (2002). Salinity effects on osmoregulation and growth of the euryhaline flounder *Paralichthys orbignyanus*. *Journal of Experimental Marine Biology and Ecology*, *269*, 187–196. https://doi.org/10.1016/S0022-0981(01)00395-1

Santos, J. C. E., & Luz, R. K. (2009). Effect of salinity and prey concentrations on *Pseudoplatystoma corruscans*, *Prochilodus costatus* and *Lophiosilurus alexandri* larviculture. *Aquaculture*, *287*, 324–328. https://doi.org/10.1016/j.aquaculture.2008.10.014

Sarma, K., Prabakaran, K., Krishnan, P., Grinson, G., & Kumar, A. A. (2013). Response of a freshwater air-breathing fish, *Clarias batrachus* to salinity stress: An experimental case of the farming in brackishwater areas in Andaman, India. *Aquaculture International*, *21*, 183–196. https://doi.org/10.1007/s10499-012-9544-2

Tavares-Dias, M., Araújo, C. S. O., Gomes, A. L. S., & Andrade, S. M. S. (2010). Relação peso e comprimento e fator de condição relativo (Kn) do pirarucu *Arapaima gigas* Schinz, 1822 (Arapamidae) em cultivo semi-intensivo no estado do Amazonas, Brasil. *Revista Brasileira de Zoociências*, *1*, 59–65.

Tesser, M. B., & Portella, M. C. (2011). Estimulantes alimentares para larvas de pacu. *Revista Brasileira de Zootecnia*, *40*, 1851–1855. https://doi.org/10.1590/S1516-35982011000900002

Thabet, R., Ayadi, H., Koken, M., & Leignel, V. (2017). Homeostatic responses of crustaceans to salinity changes. *Hydrobiologia*, *799*, 1–20. https://doi.org/10.1007/s10750-017-3232-1

Venturieri, R., & Bernardino, G. (1999). Pirarucu. Espécie ameaçada pode ser salva através do cultivo. *Revista Panorama da Aquicultura*, *53*, 13–21.

Weingartner, M., & Zaniboni Filho, E. (2004). Efeito de fatores abióticos na larvicultura de pintado amarelo *Pimelodus maculatus* (Lacépède, 1803): Salinidade e cor de tanque. *Acta Scientiarum. Animal Sciences*, *26*, 151–157. https://doi.org/10.4025/actascianimsci.v26i2.1859

Wurts, W. A. (1995). Using salt to reduce handling stress in channel catfish. *World Aquaculture*, *26*, 80–81.

Zouiten, D., Khemis, I. B., Besbes, R., & Chantal, C. (2008). Ontogeny of the digestive tract of thick lipped grey mullet *Chelon labrosus* larvae reared in "mesocosms". *Aquaculture*, *279*, 166–172. https://doi.org/10.1016/j.aquaculture.2008.03.039

How to cite this article: Araújo da Silva TB, Epifânio CMF, Dantas FDM, Rocha TLPD, Gonçalves LU, Dairiki JK. Slightly salinized water enhances the growth and survival of *Arapaima gigas* larvae. *Aquac Res*. 2019;50:951–956. https://doi.org/10.1111/are.13970