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TECHNICAL NOTE

The Effect of Different Surface-Cleaning Devices on the Success of Swim Bladder Inflation in Zander Larvae

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Abstract
The failure of initial swim bladder inflation (SBI) is one of the main obstacles to successful results in Zander (also known as Pikeperch) *Sander lucioperca* larviculture because the larvae are unable to penetrate the oil layer on the water surface to gulp air. There are numerous technical solutions for cleaning the water surface, including using a sprayer to emulsify the oil contamination and a skimmer for trapping the oil globules on the surface. To investigate the most appropriate method for improving the SBI success rate, three different devices were evaluated in triplicate tanks. In addition to the control tanks, which were not equipped with any surface-cleaning device other than overflow mesh, two sprayer designs (narrow, covering one-third of the tank's diameter, versus wide, covering the tank's entire diameter) and an air-blowing surface skimmer were set for a 16-d trial. Freshly hatched larvae (7,000 per tank) were divided into four treatment groups in twelve 250-L larval nursing tanks that shared a common recirculation system. Significantly higher rates of SBI were found in the tanks that were equipped with a wide-covering sprayer (30.6 ± 13.0%) compared with the control, skimmer, and narrow-covering sprayer groups (14.7 ± 7.5%, 4.8 ± 1.7%, and 12.2 ± 5.1%, respectively). Thus, the results of the present study indicate that the sprayer design that covers a large portion of the tank's diameter is an appropriate solution for enhancing SBI rates in Zander larviculture.

Noninflation of the swim bladder is a common problem in intensive larval rearing of many fish species (Chatain and Ounais-Guschemann 1990; Chatain 1994; Summerfelt 1996). This problem has serious adverse effects on the development and survival of the fish, as evidenced by reduced growth and survival rates and increases in the occurrence of spinal deformities due to aberrant energy-consuming swimming behavior (Wooley and Quin 2010; Bagowski et al. 2011; Summerfelt 2013). Zander (also known as Pikeperch) *Sander lucioperca* is a physoclistous fish; however, its larval stage is physostomous, featuring a transient pneumatic duct—an organ that enables the larvae to initially gulp air at the water surface to fill the swim bladder (Doroshev et al. 1981; Rieger 1995; Bagowski et al. 2011). However, once this organ atrophies the transient physostomous larvae lose the ability to fill the swim bladder (Demska-Zakęś et al. 2003). Swim bladder inflation (SBI) is a highly temperature-dependent, irreversible process that is influenced by several biotic and abiotic factors (Blecha et al. 2019). Some of the influential factors that have been documented in different species are light intensity, photoperiod, and tank color (Martin-Robichaud and Peterson, 1998; Trotter et al. 2003; Kurata et al. 2017; Palińska-Żarska et al. 2019; Suchocki and Sepulveda-Villet 2019). Finally, failure of SBI results from the inability of larvae to reach the water surface if it is covered by a layer of oil or if the surface access facilitates the entry of bacteria or organic debris to the swim bladder (reviewed by Summerfelt 2013). To the best of our knowledge, factors other than light intensity (Tielmann et al. 2017), such as tank features, water flow properties, and

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surface cleaning have not been evaluated as direct modifiers of the SBI process in intensive Zander larval-rearing operations.

In larviculture, the high viscosity of the water surface stems from the oil residues that accumulate from excess feed or dead larvae (Szkudlarek and Zakęś 2007), and this creates a barrier that prevents the larvae from reaching the water surface. Therefore, removing the surface film to promote SBI is considered critical to productive larviculture operations (Trotter et al. 2005). The strategies that are commonly used in hatcheries include either spraying the water surface to emulsify the oil film or skimming the oil to capture and retain it on part of the surface (Summerfelt 2013). The optimal technique is typically species specific. Thus, while in the case of Gilthead Seabream *Sparus aurata* blowers and traps have been found to be more appropriate (Chatain and Ounais-Guschemann 1990), using surface spray was more advantageous for successful SBI in Zander's North American relative, Walleye *Sander vitreus* (Clayton and Summerfelt 2010). Each of the mentioned strategies can be applied via different apparatus designs. In the case of sprayers, there is a paucity of irrigation sprayers on the market with different designs and modes of action. Flat nozzles that are directed vertically at the water surface are recommended for Walleye (Summerfelt 1996; Summerfelt and Johnson 2015). Although the number of sprays per tank surface area has been mentioned, the spraying diameter and its proportion of the diameter of the tank have not been defined.

The objective of the present study was to find the most appropriate method for cleaning the water surface to improve the efficiency of larval-rearing processes for Zander. Two different strategies (skimming versus spraying) and two sprayer designs (wide versus narrow) were tested in terms of their influence on SBI rates.

METHODS

The trial was conducted in the experimental recirculation aquaculture system of the Research Institute for Fisheries and Aquaculture NAIK HAKI, Szarvas, Hungary. Fertilized Zander eggs were obtained from artificially propagated wild breeders, and after hatching the larvae were transferred to the larval nursing recirculation aquaculture system, which is composed of twelve 250-L tanks with black walls and a white conical bottom. Each tank was stocked with 7,000 volumetrically counted, newly hatched larvae (mean initial length 4.5 ± 0.1 mm) for a 16-d rearing period. The larval-nursing protocol was performed according to the procedure that was used for earlier studies that were performed at the facility (Ljubobratović et al. 2019a, 2019b). The larvae were fed with newly hatched *Artemia* nauplii every 3–4 h at the rate of 100–300 nauplii·larvae^{-1}·d^{-1}, depending on the size of the larvae. The photoperiod was set at 14 h light : 10 h dark, with a light intensity at the water surface of about 10 lx during the light period. The water flow was upwelling, with a water exchange rate of 30%/h at the beginning that was gradually increased to 75%/h by the end of the trial.

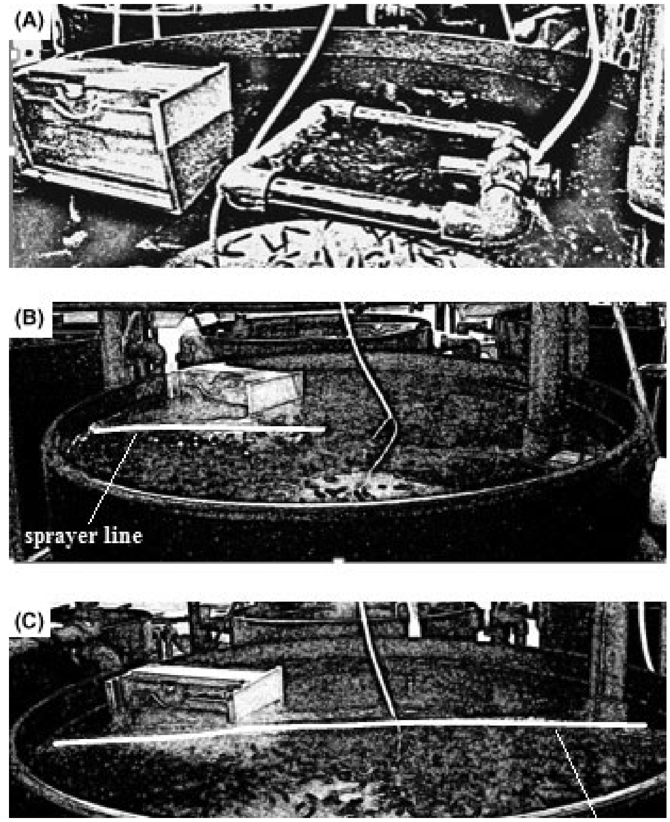

FIGURE 1. Surface-cleaning devices that were applied in the study: **(A)** Surface skimmer (SKIMMER), **(B)** flat fan-nozzle sprayer covering one-third of the tank's diameter (NARROW), and **(C)** flat fan-nozzle sprayer covering an entire tank's diameter (WIDE).

The larvae were distributed across four treatment groups. In addition to three control tanks that were not equipped with any surface-cleaning device other than overflow mesh (CONTROL), three different surface-cleaning devices were tested on three replicate tanks (Figure 1):

1. Surface skimmer (SKIMMER)—a floating PVC frame (20×20 cm) with an air inlet at one side, as described by Moretti et al. (1999:92–110; Figure 1A);
2. Narrow sprayer (NARROW)—a flat fan-nozzle sprayer covering one-third of the tank's diameter (Figure 1B);
3. Wide sprayer (WIDE)—a flat fan-nozzle sprayer covering the entire diameter of the tank (Figure 1C).

At the end of the experiment, at 16 d posthatch, individual total length was evaluated on a random sample of

50 larvae/tank. Additionally, a random sample of 200 larvae/tank was stocked in a solution of 0.2 mL/L phenoxyethanol and 10 g/L of kitchen salt and the fish were counted and graded in terms of whether the swim bladder was inflated or noninflated, thus whether it floated or sank (Steenfeldt 2015). Finally, all of the surviving fish from each tank were counted.

The water quality parameters in the tanks were monitored throughout the experiment. The water samples were taken at the outflow of the tanks twice per week, and the pH (8.46 ± 0.1 [mean ± SD]), ammonium-nitrogen (0.17 ± 0.1 mg/L), nitrite-nitrogen (0.03 ± 0.0 mg/L), and nitrate-nitrogen (1.01 ± 1.6 mg/L) were determined. Based on the daily measurements in each tank, temperature was maintained at 16.1 ± 0.3°C and the dissolved oxygen was maintained at 105.9 ± 1.0% saturation.

The data are presented as mean ± SD. The statistical analysis that was used was a one-way ANOVA, and all of the variables fulfilled the assumptions of normal distributions and homogeneity of variance. The differences among the treatment groups were assessed with Duncan's post hoc test. Values were considered significant at $\alpha < 0.05$.

RESULTS AND DISCUSSION

A single significant difference among the assessed parameters was observed with respect to SBI success (Table 1; Figure 2). A significantly higher SBI success rate occurred in the WIDE (30.6 ± 13.0 %) treatment groups compared with the CONTROL, SKIMMER, and NARROW groups (14.7 ± 7.5%, 4.8 ± 1.7%, and 12.2 ± 5.1%, respectively). This outcome leads to two conclusions. One is that the surface sprayer is a more appropriate surface-cleaning device for Zander larvae than the surface skimmer is. However, the second is that cleaning devices with similar modes of action but different final designs might differ significantly in terms of their efficacy. Thus, it may be assumed that sprayer that covers a wide portion of the tank diameter is the most appropriate technique for surface cleaning in larviculture for Zander, but the possibility of different surface-skimmer designs that are more effective cannot be excluded. However, the results of the present study agree with a similar study by Boggs and Summerfelt (2003), who found significantly higher SBI rates in Walleye larvae that were reared in tanks that were equipped with a sprayer instead of a surface skimmer. Likewise, Clayton and Summerfelt (2010) and

TABLE 1. Culture performance in larvae (initial length 4.5 ± 0.1) at 16 d posthatch. The data are presented as mean ± SD. Different lowercase letters indicate significant differences between treatments. Swim bladder inflation (SBI) rate is the percentage of fish with an inflated swim bladder.

Parameter	Control	Skimmer	Narrow	Wide
Final length	8.4 ± 0.0	8.4 ± 0.2	8.4 ± 0.1	8.4 ± 0.1
Survival (%)	22.9 ± 7.1	21.8 ± 3.2	20.8 ± 4.3	28.3 ± 10.7
SBI (%)	14.7 ± 7.5 z	4.8 ± 1.7 z	12.2 ± 5.1 z	30.6 ± 13.0 y

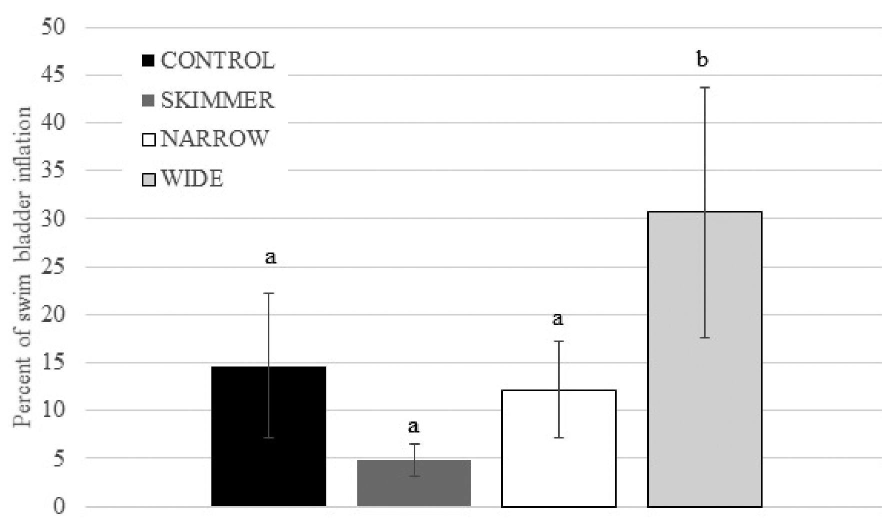

FIGURE 2. The effect of different surface-cleaning devices on the success of swim bladder inflation in 16-d posthatch larvae. Significantly different treatments are marked with different letters above the column.

Barrows et al. (1993) found that the sprayer was essential for high SBI rates in this close relative of Zander. On the contrary, results in Gilthead Seabream that were obtained by using a sprinkler and hydro jets had a secondary effect of inducing turbulence in the upper layer of the water, making the surface inaccessible to the most of the larvae (Chatain and Ounais-Guschemann 1990). Generally, the use of a surface skimmer significantly contributes to diminishing the problem of noninflation of the swim bladder in Sea Bass (also known as European Bass) *Dicentrarchus labra* and Gilthead Seabream culture (Koumoundouros et al. 2000). Finally, rather high SBI rates in Zander that were obtained by using a sprayer were reported earlier in a larviculture study that evaluated different stocking densities (Szkudlarek and Zakęś 2007). The results of the present study fall within the wide range of recently published data on survival and SBI rate in Zander larvae in our (Ljubobratović et al. 2019a, 2019b) and others' experimental facilities (Colchen et al. 2020). The reason for such high variation might be caused by different nutritional, environmental, and/or genetic factors (El Kertaoui et al. 2019; Colchen et al. 2020). According to the results of our study and other accessible data in the literature that we reviewed, the sprayer seems to be the best-fitting solution for Zander larviculture. In line with the second outcome of the present study, spray coverage had an important role on SBI rates in a study that was conducted by Moore et al. (1994). However, next to the enhanced surface-cleaning efficacy proportional to a wider spray-covering area, other modes of action could be possible. Namely, based on our observations and previous descriptions of the sprayer's action (Summerfelt 1996), the flat fan nozzle might be forming microbubbles below the water surface, and possible air-gulping from the water column was described earlier for Zebrafish *Danio rerio* and recently confirmed in Walleye larvae as well. Therefore, to fully understand the effects of flat fan-nozzle sprayers, future studies should evaluate the occurrence of microbubbles under wide flat fan-nozzle sprayers and the potential use of this type of surface-cleaning device for improving initial larval SBI rates. Finally, to the best of our knowledge these are the first data on different surface-cleaning methods for Zander larviculture. It is reasonable to conclude that a sprayer design that covers a large share of the tank diameter is the most appropriate solution for Zander larviculture.

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REFERENCES

Bagowski, C. P., L. D. Berola, E. Schoonheere, I. Wilms, S. Kabli, A. Alia, and H. J. de Groot 2011. Effects of hypoxia on buoyancy control and the development of lordosis in physostomous and physoclistous fish species. Research and Reviews in BioSciences 5:1–7.

Barrows, F. T., G. A. Kindschi, and R. E. Zitzow 1993. Detecting swim bladder inflation in fingerling Walleyes. The Progressive Fish-Culturist 55:90–94.

Blecha, M., O. Malinovskyi, L. Veselý, J. Křiš an, and T. Policar 2019. Swim bladder inflation failure in Pikeperch (*Sander lucioperca*) larvae in pond culture. Aquaculture International 27:983–989.

Boggs, C. T., and R. C. Summerfelt 2003. Enhancing the gas bladder in larval Walleye: comparison of two methods for removing and oily film from the water surface of culture tanks. Pages 19–20 *in* T. P. Barry and J. A. Malison, editors. Enhancing the gas bladder in larval Walleye: comparison of two methods for removing and oily film from the water surface of culture tanks. University of Wisconsin Sea Grant Institute, Madison.

Chatain, B., and N. Ounais-Guschemann 1990. Improved rate of initial swim bladder inflation in intensively reared *Sparus auratus*. Aquaculture 84:345–353.

Chatain, B. 1994. Abnormal swimbladder development and lordosis in Sea Bass (*Dicentrarchus labrax*) and Sea Bream (*Sparus auratus*). Aquaculture 119:371–379.

Clayton, R. D., and R. C. Summerfelt 2010. Gas bladder inflation in Walleye fry cultured in turbid water with and without a surface spray. North American Journal of Aquaculture 72:338–342.

Colchen, T., E. Gisbert, D. Krauss, Y. Ledoré, A. Pasquet, and P. Fontaine 2020. Improving Pikeperch larviculture by combining environmental, feeding and population factors. Aquaculture Reports 17:100337.

Demska-Zakęś, K., A. Kowalska, and Z. Zak 2003. The development of the swim bladder of Pikeperch *Sander lucioperca* (L.) reared in intensive culture. Archives of Polish Fisheries 11:45–55.

Doroshev, S. I., J. W. Cornacchia, and K. Hogan 1981. Initial swim bladder inflation in the larvae of physoclistous fishes and its importance for larval culture. Conseil permanent international pour l'exploration de la mer 178:495–500.

El Kertaoui, N., I. Lund, H. Assogba, D. Domínguez, M. S. Izquierdo, S. Baekelandt, V. Cornet, S. N. Mandiki, D. Montero, and P. Kestemont 2019. Key nutritional factors and interactions during larval development of Pikeperch (*Sander lucioperca*). Scientific Reports 9:7074.

Koumoundouros, G., P. Divanach, A. Savaki, and M. Kentouri 2000. Effect of three preservation methods on the evolution of swimbladder radiographic appearance in Sea Bass and Sea Bream juveniles. Aquaculture 182:17–25.

Kurata, M., Y. Tamura, T. Honryo, Y. Ishibashi, and Y. Sawada 2017. Effects of photoperiod and night-time aeration rate on swim bladder inflation and survival in Pacific Bluefin Tuna, *Thunnus orientalis* (Themminck & Schlegel), larvae. Aquaculture Research 48:4486–4502.

Ljubobratović, U., G. Péter, R. N. Alvestad, and A. Rónyai 2019a. Alcalase enzyme treatment affects egg incubation and larval quality in Pikeperch (*Sander lucioperca*). Aquaculture International 27:917–929.

Ljubobratović, U., G. Péter, Z. Sándor, N. Kugyela, and A. Rónyai 2019b. The effect of hormonal preparation (gonadotropins vs. gonadoliberins) on pre-seasonally obtained eggs and larvae quality in Pikeperch (*Sander lucioperca* L.). Aquaculture International 27:1009–1024.

Martin-Robichaud, D. J., and R. H. Peterson 1998. Effects of light intensity, tank colour and photoperiod on swimbladder inflation success in larval Striped Bass, *Morone saxatilis* (Walbaum). Aquaculture Research 29:539–547.

Moore, A., M. A. Prange, B. T. Bristow, and R. C. Summerfelt 1994. Influence of stocking densities on Walleye fry viability in experimental and production tanks. Progressive Fish-Culturist 56:194–201.

Moretti, A., M. P. Fernandez-Criado, G. Cittolin, and R. Guidastri 1999. Manual on hatchery production of Seabass and Gilthead Seabream, volume 1. Food and Agriculture Organization of the United Nations, Rome.

Palińska-Żarska, K., S. Krejszeff, M. Łopata, and D. Żarski 2019. Effect of water hardness, temperature, and tank wall color, on the effectiveness of swim bladder inflation and survival of Eurasian Perch (*Perca fluviatilis*, L.) larvae reared under controlled conditions. Aquaculture International 27:931–943.

Rieger, P. W. 1995. Direct evidence of physotomous gas bladder inflation in physoclistous fish larvae. Report for Fisheries and Aquatic Sciences, Mead & Hunt, Madison, Wisconsin.

Steenfeldt, S. 2015. Culture methods of Pikeperch early life stages. Pages 295–312 *in* P. Kestemont, K. Dabrowski, and R. C. Summerfelt, editors. Biology and culture of percid fishes. Springer, Dordrecht, The Netherlands.

Suchocki, C. R., and O. J. Sepulveda-Villet 2019. The role of phototaxis in the initial swim bladder inflation of larval Yellow Perch (*Perca flavescens*). International Aquatic Research 11:33–42.

Summerfelt, R. C. 1996. Intensive culture of Walleye fry. Pages 161–185 *in* R. C. Summerfelt, editor. Walleye culture manual. Iowa State University, Ames.

Summerfelt, R. C. 2013. Gas bladder inflation in larval fish aquaculture. Pages 125–142 *in* J. G. Qin, editor. Larval fish aquaculture. Nova Science Publishers, Hauppauge, New York.

Summerfelt, R. C., and J. A. Johnson 2015. Intensive culture of Walleye from egg incubation to juvenile. Pages 313–335 *in* P. Kestemont, K. Dabrowski, and R. Summerfelt, editors. Biology and culture of percid fishes. Springer, Dordrecht, The Netherlands.

Szkudlarek, M., and Z. Zakęś. 2007. Effect of stocking density on survival and growth performance of Pikeperch, *Sander lucioperca* (L.), larvae under controlled conditions. Aquaculture International 15:67–81.

Tielmann, M., C. Schulz, and S. Meyer 2017. The effect of light intensity on performance of larval Pike-Perch (*Sander lucioperca*). Aquculture Engineering 77:61–71.

Trotter, A. J., S. C. Battaglene, and P. M. Pankhurst 2003. Effects of photoperiod and light intensity on initial swim bladder inflation, growth and post-inflation viability in cultured Striped Trumpeter (*Latris lineata*) larvae. Aquaculture 224:141–158.

Trotter, A. J., P. M. Pankhurst, and S. C. Battaglene 2005. A finite interval of initial swimbladder inflation in *Latris lineata* revealed by sequential removal of water-surface films. Journal of Fish Biology 3:730–741.

Wooley, L. D., and J. G. Quin 2010. Swimbladder inflation and its implication to the culture of marine finfish larvae. Reviews in Aquaculture 2:181–190.