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TECHNICAL NOTE

Effects of Alternative Food Types on Body Size and Survival of Hatchery-Reared Lake Sturgeon Larvae

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Abstract
Aquaculture programs benefit from feeding protocols that result in large larval body size and high survival. Despite high labor, processing, and material costs relative to alternative foods, feeding live foods generally results in high larval growth and survival. For many species, studies that identify alternative food types or feeding regimens that produce larvae with high survival and size comparable with wild cohorts are lacking. In a 35-d study, the effects of alternative food types (previously frozen *Artemia* and trout crumble starter diet (trout diet) on TL, weight per fish, and survival of larval Lake Sturgeon *Acipenser fulvescens* were quantified. From days 14 to 21 postexogenous feeding, larvae were transitioned from live *Artemia* to one of the alternative food types or remained feeding on live *Artemia* as the control. At the end of the study, TL and weight per fish of larvae fed live *Artemia* were significantly greater than larvae fed the alternative foods. Survival of larvae fed live or frozen *Artemia* was higher than larvae fed the trout diet. Lower body growth and survival of larvae fed the alternative foods demonstrate that the frozen and formulated foods are not appropriate diets for Lake Sturgeon larvae.

Aquaculture has become increasingly important as a management tool given worldwide declines in fish population abundances and distributions (Doroshov et al. 1983; Brown and Day 2002; Dempster et al. 2006). Refinement of aquaculture-rearing protocols that increase the efficiency and reduce rearing costs would be valuable. Thus, aquaculture research has largely focused on improving feeding techniques including feeding frequency, amount of feed, and use of alternative food types to improve growth and survival while reducing costs (Lindberg and Doroshov 1986; Shakourian et al. 2011; Achionye-Nzeh et al. 2012; Bauman et al. 2016).

Feeding techniques, such as the use of alternative food types that enhance both larval body size and survival are necessary for effective aquaculture programs (Doroshov et al. 1983). Improvement of aquaculture techniques is particularly important during the developmental period in which variable growth and high mortality compromise production goals (Li and Mathias 1982). In the wild, larval and juvenile survival is positively associated with body size (Anderson 1988). Therefore, alternative feeding techniques that improve both growth and survival during the larval period would benefit aquaculture programs (Crossman et al. 2011).

Offering live food can improve growth rates and survival for many species (Woods 2003; Bauman et al. 2016). Traditionally, live foods such as daphnia *Daphnia* spp. and

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brine shrimp *Artemia* spp. are fed to larvae at the onset of exogenous feeding (Ware et al. 2006; Luz and Portella 2015; Bauman et al. 2016). *Artemia* nauplii have been used extensively and successfully to rear larval fishes, even though it is not a natural food source. However, despite the benefits, live food is expensive, labor intensive, time consuming to prepare (Vedrasco et al. 2002; Hamlin et al. 2006), and may promote bacterial growth leading to disease (Smith and Hobden 2011). Preparation of live food requires specialized equipment and space for hatching, harvesting, and processing before feeding.

Alternative food types, on the other hand, may be less expensive and less labor intensive while still providing sufficient nutrients to larval fish. Formulated salmonid diets, Otohime larval fish formulated diet, or frozen invertebrates such as bloodworms and krill require limited processing or preparation, can be stored for extended periods (weeks to several months), and are generally less expensive than live food (Smith and Hobden 2011). In addition, formulated food is nutritionally consistent unlike live food, which can vary widely in nutrient or hatch quality (Hamre et al. 2013). However, the shelf life of formulated and frozen foods is limited (Poulter and Lawrie 1977). The success of utilizing alternative food types, which can be measured by growth and survival of larvae, varies greatly across species (Dabrowski et al. 1985; Ware et al. 2006; Kwiatkowski et al. 2008; Kappenman et al. 2011; Agh et al. 2013) and depends on the feeding regimens and type of food employed.

Alternative foods or feeding regimens such as cofeeding (feeding multiple food types simultaneously) or food transitioning (instantaneous or gradual change in food source) are often employed to improve larval growth and survival (Rosenlund et al. 1997; Ware et al. 2006). Transitioning from a live food to an alternative food is often used because larvae may not readily accept the alternative food at first feeding (Mohler 2003). In a hatchery setting, fish are transitioned to different food types as they grow. For example, live *Artemia* become too small of a food source for large larvae and juvenile fishes, so other foods such as thawed bloodworms are provided (Aloisi et al. 2006).

In addition to feeding regimens, alternatives to live food types are used. Frozen invertebrates such as bloodworms or *Artemia* can be bought or produced and stored before feeding. The cold storage of food is an attractive option as more time and energy can be spent producing food supplies during the less busy season of aquaculture production. In addition, hatches of live foods such as *Artemia* are highly variable. High quality hatches of live food are necessary, especially when fish production is at its peak, but if a hatch is poor, a higher quality hatch that was previously frozen may be a suitable alternative to feed to larvae. Formulated feeds are also attractive food options because they do not require harvesting and are nutritionally consistent (Smith and Hobden 2011); however, some fishes may not readily accept formulated food (Bauman et al. 2016) nor grow as quickly when feeding on it compared with fish feeding on live food (Achionye-Nzeh et al. 2012). Therefore, additional research is needed to evaluate alternative feeding techniques, especially for species of conservation concern.

Sturgeons are one of the most imperiled fish species groups (Baillie et al. 2004) but provide important economic stock as well. Internationally, sturgeons are prevalent in aquaculture settings as their meat and gametes (i.e., caviar) are highly sought after for human consumption (Williot et al. 2001). In addition, larval and juvenile sturgeons are reared in hatcheries for conservation programs (Crossman et al. 2011). Alternative feeding regimens have been employed for sturgeon aquaculture practices to reduce the costs of both the production of adults for gametes and meat and the larvae for conservation (Doroshov et al. 1983). Formulated foods have been fed to larval Beluga *Huso huso* and Pallid Sturgeon *Scaphirhynchus albus* (Wang et al. 1985; Kappenman et al. 2011). Beluga (Agh et al. 2012), Pallid Sturgeon (Ware et al. 2006), and Persian Sturgeon *Acipenser persicus* (Shakourian et al. 2011) have experienced high growth rates when co-fed live and alternative foods. Although, White Sturgeon *A. transmontanus* larvae fed semimoist formulated food survived equally well, but grew slower than larvae fed live food (Buddington and Doroshov 1984). Specially formulated sturgeon diets have been created and fed to Gulf Sturgeon *A. oxyrinchus desotoi* (Bardi et al. 1998). While research on alternative feeding techniques has been conducted on some sturgeon species, information relative to successful alternative diets or feeding techniques for Lake Sturgeon *A. fulvescens* is limited.

Lake Sturgeon is an imperiled species in the Laurentian Great Lakes region (Peterson et al. 2007), and populations are supplemented through conservation aquaculture programs by stocking hatchery-reared juveniles (Crossman et al. 2011). These programs focus on producing fish for stock-out that will experience high survival and are comparable in size with wild cohorts (Crossman et al. 2011). Effective feeding techniques at early life periods improve the likelihood these fish will survive in the wild. Yet, information characterizing the natural diet of larval Lake Sturgeon is lacking (Pollock et al. 2015). Thus, alternative feeding experiments are valuable to improve larval growth and survival, reduce feeding cost, and improve rearing efficiency.

For Lake Sturgeon, larvae are traditionally offered live *Artemia* nauplii at the onset of exogenous feeding (Harkness and Dymond 1961), but if larvae experience equivalent or higher growth rates and equivalent or higher survival as a function of employing alternative foods, costs of feeding larval Lake Sturgeon may be lower and efficiency would be improved (Smith and Hobden 2011). Frozen *Artemia* should be accepted by Lake Sturgeon larvae, but its effects on growth and survival of Lake Sturgeon larvae have not been tested. Trout starter diet has similar macronutrient composition to *Artemia* and has been fed to Lake Sturgeon in a hatchery setting but the quantitative effects on survival and body size were poorly documented (Aloisi et al. 2006).

The objective of this study was to quantify the effects of alternative food types on body size and survival of Lake Sturgeon larvae using a combination of co-feeding and food transitioning. A trout diet and frozen *Artemia* were used as alternative food types, while live *Artemia* was used as the control because it is typically fed to larval Lake Sturgeon in hatcheries. The hypotheses were: (1) Lake Sturgeon larval body size and survival differs as a function of alternative feeding regimen, and (2) relationships among body size and survival differ over time.

METHODS

Study site.—This study was conducted at the Black River Streamside Rearing Facility (BRSRF) located along the upper Black River, Cheboygan County, Michigan. Water supplied to the BRSRF was taken directly from the river system and filtered through 100- and 50-μm filters to remove large sediments and macroorganisms. Water temperature was monitored hourly using a YSI ProODO Optical DO-Temp meter. Average daily water temperature ranged from 19.7°C to 26.0°C, and the overall average was 22.9 ± 1.4°C (mean ± SD) for the duration of this study.

Fertilization and larval rearing.—In June 2015, adult Lake Sturgeon were captured, and gametes from one male and eggs from one female were collected as described in Crossman et al. (2011). One cross was used for this experiment to minimize the potential for maternal or genetic effects on larval size and growth (Dammerman et al. 2015, 2016). Fertilization occurred within 6 h of gamete collection at the BRSRF following Bauman et al. (2015). Fertilized eggs were placed into Aquatic Eco-Systems (Pentair) J32 Mini-Egg hatching jars for incubation. At hatch, free embryos were reared in 3.0-L polycarbonate flow-through aquaria (Aquatic Habitats). Because free embryos seek refuge in substrate (Hastings et al. 2013), a single layer of 2.54-cm^3 sinking Bio-Balls (CBB1-S; Pentair) covered the aquaria bottoms until the onset of exogenous feeding.

At the onset of exogenous feeding (9 d posthatch), 20 larvae were randomly assigned to nine separate 3.0-L aquaria (n = 20 fish per 3.0-L aquaria) in a completely randomized design. Aquaria were located in series and aquaria placement was changed daily. The flow rate for each 3.0-L aquaria was approximately 290 ± 17.3 mL/min (mean ± SD) (i.e., 5.8 ± 0.4 aquaria cycles/h). A 9-h light: 15-h dark cycle was maintained using fluorescent lights.

Experimental treatments.—At the onset of exogenous feeding, 3.0-L aquaria, the experimental unit, were randomly assigned to three treatment groups, each replicated three times (n = 9 experimental units). Treatment groups were: (1) transitioning larvae to trout crumble starter diet #0 ranging from 0.3 to 0.6 mm in diameter (trout diet; BioProducts, Warrenton, Oregon), (2) transitioning to frozen and thawed *Artemia*, and (3) feeding live *Artemia* (the control; Great Salt Lake Strain, Premium Grade Brine Shrimp Eggs; Brine Shrimp Direct, Ogden, Utah). Percent nutritional composition was derived from peer-reviewed literature for live and frozen *Artemia* and from the product packaging for the trout diet (Table 1). In addition, to these nutritional compositions, this strain of *Artemia* contained approximately 5% omega-3 fatty acids (Brine Shrimp Direct). *Artemia* nauplii were harvested following manufacturer's protocols. Frozen *Artemia* coming from previous hatches or the same hatches as those offered as live *Artemia* were sieved after harvesting and immediately stored at −20°C. *Artemia* remained frozen for no more than 2 weeks before feeding to larvae to reduce the chance of nutrient degradation occurring.

Larvae were fed three times daily (0900, 1300, and 1700 hours) while water remained flowing through the aquaria, simulating stream conditions. Larvae in each 3.0-L aquarium were provided an equal amount of food by means of a 10-mL syringe. Larvae were fed based on a modified feeding regimen by Deng et al. (2003) and Bauman et al. (2016), which changed weekly based on the percentage of food offered and the weight of the larvae. This regimen started at the onset of exogenous feeding and was as follows: days 1–14 postexogenous feeding (PEF), 26% dry body weight per day (BW/d); days 15–28 PEF, 13% BW/d; days 29–35 PEF, 11% BW/d. Wet weight of *Artemia* was calculated from dry weight at dry weight = 0.1767·(sieved wet weight) − 0.0541 (Bauman et al. 2016).

Beginning at the onset of exogenous feeding, larvae from each aquarium were batch-weighed once per week (each of nine 3.0-L aquaria replicates and treatments) to determine mean weekly weight per fish and to adjust feeding rates (percentage of food offered per meal) for the following week. All larvae within one aquarium were quickly but thoroughly blotted dry to remove water weight before weighing. The removal of water from larvae provided a more accurate body weight to ensure an appropriate amount of food was offered to larvae. In addition, beginning on 8 d PEF, a

TABLE 1. Nutritional composition (%; mean ± SD) of food types (trout crumble starter diet and *Artemia*) that were fed to Lake Sturgeon larvae (NA = value not available).

Component	Live *Artemia*[a]	Frozen *Artemia*[b]	Trout crumble starter diet
Crude protein	52.2 ± 8.8	55.6 ± 0.1	53
Lipid/fat	18.9 ± 4.5	20.1 ± 0.9	18 (minimum)
Carbohydrate	14.8 ± 4.8	NA	NA
Ash	9.7 ± 4.6	4.5 ± 0.2	NA
Fiber	NA	NA	1 (maximum)
Phosphorous	NA	NA	1.2 (minimum)

[a] Nutrient composition information derived from Léger et al. (1987).

[b] Nutrient composition information derived from Webster and Lovell (1990).

subsample of four to seven larvae per aquarium was photographed to measure TL using Image J 1.49 (NIH Image).

Beginning at 9 d posthatch, larvae in all treatments and replicates received live *Artemia* from day 1 to day 14 PEF of the experiment. Larvae were determined to feed exogenously on day 1 PEF as *Artemia* were observed in the gastrointestinal tract. In addition, larvae in the trout diet treatment were offered 100% BW/d trout diet for days 1–14 PEF (i.e., co-feeding) to eliminate the risk of larvae imprinting on only *Artemia*, which could hinder the later transition to trout diet.

Beginning on 15 d PEF, larvae were subjected to their respective alternative feeding regimens. Sturgeon larvae from the live *Artemia* treatment continued to receive live *Artemia* for the duration of the 35-d study, while larvae in the frozen *Artemia* and trout diet treatments were gradually transitioned to the respective alternative food types during days 15–21 PEF. Klassen and Peake (2008) found a transition to another food source after two full weeks of feeding on live *Artemia* improved the growth of Lake Sturgeon compared to an earlier or later transition. The BW/d percentages for each transition day are provided in Table 2; the total percent of food offered daily remained the same, but the type of food changed (i.e., live *Artemia* or alternative food). From days 22 to 35 PEF, larvae in the frozen *Artemia* and trout diet treatments received only frozen *Artemia* and trout diet, respectively.

Food was removed and aquaria were cleaned to reduce bacterial build-up; each morning before feeding, leftover food and silt were removed. Once weekly, larvae were moved to another aquarium that had been thoroughly cleaned with an iodophore solution. Water quality in each aquarium was similar as the water supplied to all aquaria came from the same source.

Statistical analysis.—The experimental unit in all analyses was the 3.0-L aquaria, each of which contained 20 fish per aquarium. Total length and weight (mean ± SD) per fish as a function of feeding regimen treatment by week were analyzed using autoregressive repeated-measures ANOVA. The data for mean TL and weight per fish were analyzed weekly as a function of treatment to determine interactions between week and treatments. The response variable of larval weight per fish included three replicates of each of three treatments measured six times (once every 7 d beginning on 0 d PEF). The TL response variable included three replicates of each of three treatments measured five times (once every 7 d beginning on 7 d PEF), given that the initial TL was not measured. Mean weight per fish and TL among treatment groups were compared using Tukey–Kramer multiple pairwise comparisons. Percent survival was estimated as the mean percent of larvae surviving from day 1 PEF through day 35 PEF. Mean percent survival at 35 d PEF was analyzed using a beta-distributed generalized linear model and ANOVA. All statistical analyses were conducted in SAS version 9.3 (SAS Institute, Cary, North Carolina). A P-value < 0.05 was considered statistically significant.

TABLE 2. Percent body weight per day (% BW/d) of different food types fed to Lake Sturgeon larvae during the transition period, days 15–21 postexogenous feeding (PEF). Alternate food comprised either frozen *Artemia* or trout crumble starter diet.

Day PEF	Live *Artemia* (% BW/d)	Alternate food (% BW/d)
15	90	10
26	75	25
17	60	40
18	50	50
19	40	60
20	25	75
21	10	90

RESULTS

Percent Survival

At the end of the study, larval percent survival varied among the treatment groups ($F_{2,\ 2}$ = 42.14, P = 0.023; Figure 1). Survival of larvae fed frozen or live *Artemia* was equivalent and high (98.3 ± 2.9; t_2 = 0, P = 1.0000). Larvae fed live (t_2 = 6.98, P = 0.0199) or frozen (t_2 = 6.98, P = 0.0199) *Artemia* experienced higher survival at 35 d PEF than larvae fed trout diet (19.0 ± 8.1). Larvae fed trout diet experienced high mortality from days 28 to 35 PEF where survival decreased from 90.0 ± 10.0 to 19.0 ± 8.1.

Body Weight per Fish

Body weight per fish varied among treatment groups over time ($F_{2,6}$ = 203.13, P < 0.0001; Figure 1). Weight per fish changed for larvae in each treatment group during the experiment ($F_{5,\ 30}$ = 952.48, P < 0.0001). A significant interaction was detected between treatment group and time ($F_{10,\ 30}$ = 160.27, P < 0.0001).

Weight per fish on days 7 and 14 PEF, when all larvae were fed live *Artemia*, were statistically equivalent among all treatment groups. Weight per fish of larvae in the frozen *Artemia* treatment group did not change between days 21 and 28 PEF (t_{30} = 1.05, P = 0.718) or between days 28 and 35 PEF (t_{30} = 0.27, P = 1.000) while being fed frozen *Artemia* exclusively. From days 28 to 35 PEF, weight per fish of larvae in the trout diet treatment group decreased (t_{30} = 4.42, P = 0.011), but weight per fish was highest at 35 d PEF; surviving fish experienced a doubling in weight per fish while feeding on trout diet exclusively (t_{30} = −5.92, P = 0.0002). At 21 d PEF, weight per fish for larvae fed live *Artemia* was greater than for larvae fed frozen *Artemia* (t_{30} = 5.19, P = 0.002). At 28 d PEF, weights per fish for larvae fed frozen *Artemia* (t_{30} = 25.25, P < 0.0001) or trout diet (t_{30} = 22.84, P < 0.0001) were less than for larvae fed live *Artemia* but were statistically equivalent to each other. At 35 d PEF, mean weights per fish of larvae in all treatment groups were different from one another; the weight per fish of

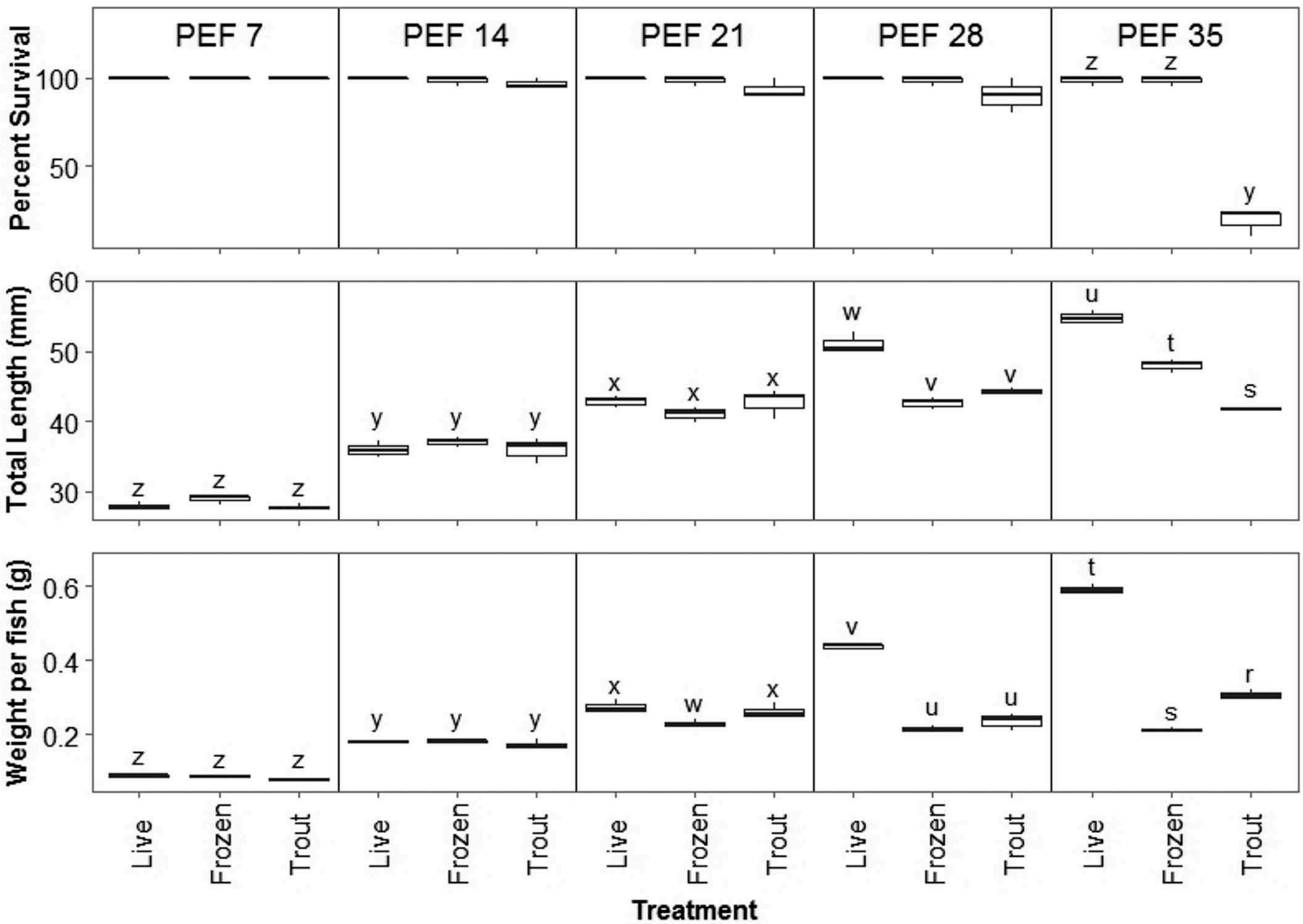

FIGURE 1. Box plot quantiles of weight per fish, total length, and cumulative percent survival per week (days postexogenous feeding; PEF) over the 35-d duration of the study. Larval Lake Sturgeon were hatched and reared at the Black River Sturgeon Rearing Facility in June–July 2015. Larvae were fed live *Artemia* as the control (Live), frozen and thawed *Artemia* (Frozen), or trout crumble starter diet (Trout) starting with a transition at 15 d PEF. Values within a box in the same column with different letters are significantly different from each other (repeated-measures ANOVA; $P < 0.05$). Cumulative percent survival values are provided, but a one-way ANOVA was performed only for values at 35 d PEF as values of 100% could not be compared among groups from days 7 to 28 PEF.

larvae fed live *Artemia* was significantly higher than weight per fish for larvae fed frozen *Artemia* ($t_{30} = 42.63$, $P < 0.0001$) or trout diet ($t_{30} = 31.94$, $P < 0.0001$), and weight per fish of larvae fed trout diet was significantly higher than weight per fish for larvae fed frozen *Artemia* ($t_{30} = -10.69$, $P < 0.0001$).

Total Length

Larval TL varied by treatment group over time ($F_{2,\ 6} = 55.71$, $P = 0.0001$; Figure 1). Larval TL in each treatment group increased significantly during the experiment ($F_{4,\ 24} = 512.60$, $P < 0.0001$). A significant interaction between treatment group and time was detected ($F_{8,\ 24} = 28.22$, $P < 0.0001$).

Larval mean TL was statistically equivalent among treatments at days 7, 14, and 21 PEF. Larvae fed live *Artemia* continued to increase in TL throughout the experiment. From day 21 to day 28 PEF, larvae fed frozen *Artemia* ($t_{24} = -1.81$, $P = 0.874$) and larvae fed trout diet ($t_{24} = -1.77$, $P = 0.889$) did not increase in TL. At 35 d PEF, larvae fed the trout diet had decreased in TL, but not significantly ($t_{24} = 2.88$, $P = 0.272$). Larvae fed live *Artemia* had a longer TL at 28 d PEF than larvae fed frozen *Artemia* ($t_{24} = 9.73$, $P < 0.0001$) or the trout diet ($t_{24} = 7.78$, $P < 0.001$). Larval TL in each treatment differed significantly at 35 d PEF; larvae fed live *Artemia* were significantly longer than larvae fed frozen *Artemia* ($t_{24} = 7.78$, $P < 0.0001$) or the trout diet ($t_{24} = 14.94$, $P < 0.0001$), and larvae fed frozen *Artemia* were longer than larvae fed the trout diet ($t_{24} = 7.16$, $P < 0.0001$).

DISCUSSION

This study quantified the effects of two alternative food types, compared with the standard approach of offering live *Artemia*, on the body size and survival of larval Lake Sturgeon. This study weaned sturgeon larvae off live *Artemia* using a gradual transition to an alternative food type as transitioning can improve the acceptance of other food types (Ware et al. 2006). Larvae fed live *Artemia* (the control) had high survival and were the largest larvae at the end of the 35-d study period, while larvae fed the two alternative diets experienced low growth or survival.

Larvae fed live or frozen *Artemia* experienced high survival throughout the study and at the end of the study had equivalent cumulative survival, and nearly all larvae survived. Larvae fed the trout diet had the lowest survival throughout the study. High mortality in larvae fed the trout diet occurred between days 29 and 35 PEF, which was most likely due to starvation as larvae fed the trout diet were emaciated. In a meta-analysis of freshwater fishes, Sales (2011) found mortality rates to be 2.5 times higher in fish fed formulated diets than fish fed live *Artemia*; mortality rates for larvae fed the trout diet were higher than this value in this study.

Larvae that were in the control treatment had the largest body size at the end of the study. While feeding on live *Artemia*, all larvae increased in body size. Despite being offered a greater amount of food initially (100% BW/d trout diet and 26% BW/d live *Artemia*), body size of larvae fed the trout diet was similar to that of larvae fed frozen or live *Artemia*. After transitioning to frozen *Artemia*, larvae increased in TL but did not gain weight. These results are similar to Woods (2003) and Mohler et al. (2000) who documented that young Large-bellied Seahorses *Hippocampus abdominalis* and Atlantic Sturgeon *A. oxyrinchus oxyrinchus*, respectively, fed frozen *Artemia* had lower growth but similar survival to young fed live *Artemia*. After transitioning to the trout diet, larvae did not increase in body size as much as larvae fed live *Artemia* did. These results contrast with Ware et al. (2006) and Kwiatkowski et al. (2008) in which Shortnose Sturgeon *A. brevirostrum* and chubs (family Cyprinidae), respectively, that were transitioned to formulated food experienced similar growth as fish fed live *Artemia*.

Both frozen and live *Artemia*, but not the trout diet, were determined to be ingested based on visual observation of larval gastrointestinal tract coloration of its contents. Larvae fed the trout diet may only have ingested live *Artemia*, causing the larvae to starve when only offered the trout diet as no trout diet was observed in the gastrointestinal tract of the larvae. Larvae did not feed on formulated foods in DiLauro et al.'s (1998) and Bauman et al.'s (2016) studies either. Lake Sturgeon larvae that fed on the trout diet should not have been limited by gape. The trout diet crumble size ranged from 0.3 to 0.6 mm, and larvae larger than 0.10 g should be able to consume this size of crumble (Chebanov and Galich 2013). Larvae consumed frozen *Artemia*, but larvae either experienced poor assimilation efficiency or ate less than larvae fed live *Artemia*. In addition, nutrients needed for growth may have leached out of the frozen *Artemia*, resulting in stunted growth (Hamre et al. 2013). In other analyses, within 10 min the majority of nutrients were leached from frozen *Artemia* that had been thawed and placed in water (Grabner et al. 1981; Sharma and Chakrabarti 2009). In this study, some nutrients in the frozen and thawed *Artemia* may have leached out before being consumed.

Feeding responses of larval Lake Sturgeon may affect the ability to transition to alternative foods. A different method of offering a trout diet, such as continuous feeding using an automatic feeder, may be more likely to initiate feeding but may not be cost effective. Kappenman et al. (2011) used a belt feeder to successfully feed Otohime, a commercial fish feed, to Pallid Sturgeon larvae. The continuous movement of food in the water column may activate a feeding response because Lake Sturgeon feed in the water column (Anderson 1984). Live foods move continuously, which may physically or electrically stimulate sturgeon barbels, initiating a feeding response. The feeding response in Lake Sturgeon may also be triggered chemically through the presence of specific amino acids (Kasumyan and Taufik 1994), and these amino acids could be degraded in trout diet or frozen *Artemia* (Grabner et al. 1981), reducing the feeding response. In addition, feeding semimoist food rather than dry food may have increased the appeal of the trout diet leading to a higher acceptance of this food type (Buddington and Doroshov 1984).

Natural diets of wild sturgeon may affect their ability to transition to alternative foods. In rivers, larval Lake Sturgeon drift nocturnally in the upper water column (Caroffino et al. 2009). Potential prey items such as zooplankton also inhabit the upper water column. In the hatchery setting, the trout diet and frozen *Artemia* settled near the bottom, despite the flow-through aquaria system, while live *Artemia* moved in the water column. The Lake Sturgeon larvae, in turn, fed within the water column. Feeding on frozen *Artemia* or the trout diet on the bottom of the aquaria is not a natural feeding response for larvae and could explain why larvae fed frozen *Artemia* or the trout diet did not grow as well as those fed live *Artemia*. In addition, wild Lake Sturgeon juveniles primarily feed on macroinvertebrates (Kempinger 1996; Chiasson et al. 1997; Beamish et al. 1998; Jackson et al. 2002). Foods such as the trout diet that are composed of fish meal and fish oil may not be attractive to Lake Sturgeon larvae. However, other sturgeons such as Pallid Sturgeon primarily feed on fish in the wild (Gerrity et al. 2006; Wanner and Shuman 2007), which may allow an easier transition to an alternative, larval fish diet such as Otohime (Kappenman et al. 2011). Larvae may also be inherently conditioned to feed and grow better on live foods in general (Lindberg and Doroshov 1986).

Low survival or poor growth associated with alternative food types experienced during rearing is inconsistent with the time and resources expended to rear species of conservation concern, despite live foods not being economically viable for large-scale production or nutritionally consistent. Our results show that for small-scale production facilities feeding sturgeon larvae live food will result in large body size and high survival. A balance among the cost of rearing, survival, and size at stocking is required as postrelease survival depends on size at stock-out, with larger size increasing the potential of survival (Anderson 1988). Furthermore, for species of conservation concern, it is prudent to have high survival in the stocked cohort. Therefore, feeding live *Artemia* to Lake Sturgeon in a small-scale hatchery setting is recommended as larger body size and high survival are achieved compared with larvae fed frozen *Artemia* or trout diet.

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