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Full Length Research

Recirculating aquaculture system-reared juvenile walleye survived and grew after stocking in Owen Dam, South Dakota, USA

Andrew S. Marchant[1], Bill H. Miller[2], Gene Gallinat[2], Cody Treft[3], Jill M. Voorhees[1], and Michael E. Barnes[1]*

[1]South Dakota Department of Game, Fish and Parks, McNenny State Fish Hatchery 19619 Trout Loop Spearfish, South Dakota 57783, USA.
[2]South Dakota Department of Game, Fish and Parks, 4130 Adventure Trail, Rapid City, South Dakota, 57702, USA.
[3]South Dakota Department of Game, Fish and Parks, Cleghorn Springs State Fish Hatchery,4725 Jackson Boulevard, Rapid City, South Dakota 577023, USA.

*Corresponding author. Email: mike.barnes@state.sd.us; Tel;605-642-6920

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ABSTRACT: Recirculating aquaculture system (RAS) technology is increasingly used to produce fish in recreational and conservation fish hatcheries. However, little is known about the post-stocking survival of RAS-reared walleye (*Sander vitreus*). This study evaluated the survival and growth of RAS-reared walleye stocked in Owen Dam, South Dakota, USA. RAS-reared juvenile walleye were stocked annually from 2023 to 2025. Walleye were collected by both trap nets and electrofishing during every sampling year, except for 2023, when no walleye were caught in trap nets. The total number of walleye captured from both netting and electrofishing was 16 in 2023, 219 in 2024, and 57 in 2025. Catch-per-unit-effort from electrofishing was 48 fish/h in 2023, 3.9 fish/h in 2024, and 44.4 fish/h in 2025. Trap net catch-per-unit effort was 0 in 2023, 35.8 fish/net night in 2024, and 4.0 fish/net night in 2025. Stock-length walleye over 254 mm were obtained from both trap nets and electrofishing during 2024 and 2025. Length-frequency distributions differed among survey years. These results indicate RAS-reared walleye survived and grew following stocking across multiple years in a small reservoir system. These results support the use of RAS as a viable tool for hatchery production of walleye for stocking recreational fishing waters.

Keywords: Post-stocking survival, RAS, walleye.

INTRODUCTION

Walleye (*Sander vitreus*) are a member of the Percidae family, with a native range extending from northern Canada to the southern United States (Johnston and Leggett, 2002). They are a very popular sport fish and have been widely introduced throughout the United States (Johnston *et al*., 2012; Feiner and Höök, 2015; Summerfelt *et al*., 2019). Because of absent or inconsistent natural reproduction and overexploitation, walleye fisheries are commonly maintained by hatchery rearing and stocking (Johnson, 1961; Sullivan, 2003; Hansen *et al*., 2015; Shaw *et al*., 2018; Raabe *et al*., 2020). In North America, an estimated one billion hatchery-reared walleye fry and juveniles are stocked annually (Fenton *et al*., 1996; Kerr, 2008; Kerr, 2011; Halverson, 2008).

Hatchery rearing of walleye typically occurs by artificially spawning wild broodstock (Gonsorowski *et al*., 2024). Fertilized eggs are incubated in hatcheries with the resulting newly hatched fry either directly stocked into recreational fishing waters or retained at the hatchery for further rearing to larger juvenile sizes (Czesny *et al*., 2005; Zebro *et al*., 2025). Traditionally, juvenile walleyes were reared via extensive culture using natural feed in large outside rearing ponds (Summerfelt *et al*. 1994; Harding and Summerfelt, 1994; Rogge *et al*., 2003; Kaatz *et al*., 2011; Ward, 2018). Recently, intensive culture of walleye juveniles in recirculating aquaculture systems (RAS) has emerged as an alternative to traditional pond rearing (Johnson *et al*., 2021).

Successful RAS walleye rearing techniques have been developed and are mostly standardized with some modifications (Aneshansley *et al*., 2001; Zarnoch *et al*., 2010; Johnson and Summerfelt, 2015; Davidson *et al*., 2016; Johnson *et al*., 2021). However, there is limited information on the survival of RAS-reared juvenile walleye after they are stocked in recreational fishing lakes. Survival of male RAS-reared juvenile walleye at three years post-stocking was 5.4%, 34%, and 82% following three years of stocking in Lake Champlain, Vermont, USA (Johnson *et al*., 2021). However, these results were listed with minimal supportive information, such as study design, sampling effort, existing fish communities, environmental conditions, or other methods or variables that could have potentially affected the results. A small number of other studies have examined some post-stocking aspects of intensively-reared walleye, but only indicated the fish were "pellet-raised" for part of their hatchery rearing residence with no mention of RAS (Weber and Weber 2020; Grausgruber and Weber, 2021).

With the increasing availability of RAS-reared walleye, information is needed about their survival and growth after stocking into recreational fishing waters. Thus, the objective of this study was to determine if RAS-reared walleye survived and grew after release into Owen Dam, a small reservoir in South Dakota, USA.

MATERIAL AND METHODS

Study area

Owen Dam (45.466757º N, 102.40444 º W) is a 39-ha impoundment located in north-western South Dakota, USA, 4.8 km east and 6.4 km south of the town of Bison (Figure 1). The reservoir experienced a severe winterkill during the winter of 2022-2023, resulting in a near-complete loss of the existing fish community (SDGFP, 2023). Four fish species were stocked into Owen Dam in the spring of 2023: bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus nigricans*), yellow perch (*Perca flavescens*), and walleye (SDGFP, 2023). No walleye were present in Owen Dam before the winterkill event (SDGFP, 2023).

Walleye culture

Fertilized walleye eggs were incubated at Cleghorn Springs State Fish Hatchery, Rapid City, South Dakota, USA, in 2023, 2024, and 2025. The eggs used in 2023 originated from wild broodstock collected in South Dakota, and the 2024 and 2025 eggs were obtained from wild broodstock in Nebraska, USA. After hatching, the larval walleye were cultured in RAS at the hatchery. Fish were reared in four, 2.4 m^3 circular tanks. Flow rates per tank were initially set at 0.00126 $\frac{m^3}{s}$ and gradually increased to a maximum of 0.00284 $\frac{m^3}{s}$. Water temperature during rearing was initially 15.5℃ and progressively increased during the rearing period to approximately 22.2℃. Turbidity was maintained at approximately 50 NTU using Old Mine #4 ball clay (Kentucky-Tennessee Clay Company, Gleason, Tennessee, USA) in 2023, and NANNO 3600 algae (Reed Mariculture Inc., Campbell, California, USA) in 2024 and 2025. In 2023 and 2024, larval walleye were initially fed Otohime B2 (Marubeni Nisshin Feed Co., Ltd., Tokyo, Japan) and gradually transitioned to a 50:50 mixture of Otohime and Gemma (Skretting Nutreco, Stavanger, Norway) weaning diets. In 2025, larval walleye were fed exclusively Otohime B2 during rearing.

After approximately four to five weeks of rearing, juvenile walleye were transported and released into Owen Dam. The stocking dates for each year were 23 June 2023, 23 May 2024, and 10 June 2025. Mean individual fish weights for 2023, 2024, and 2025 were 0.600 g, 0.826 g, and 0.344 g, respectively. Owen Dam was stocked with 25,374 (651/ha) walleye juveniles in 2023, 20,000 (513/ha) juveniles in 2024, and 25,332 (650/ha) juveniles in 2025 (Table 1).

Fish collection after stocking

Trap nets and boat electrofishing were used to recapture walleyes after their release into Owen Dam. Six standard trap nets (two 0.9 x 1.5-m frames, three 0.9-m diameter hoops, a single throat, a 0.9 x 15.2-m lead, and 19-mm bar knotted mesh) were set on 29 June 2023, 26 June 2024, and 18 June 2025. Nets were set overnight in nearshore habitat for approximately 24 hours and retrieved the following day. Daytime boat electrofishing was conducted on 11 October 2023, 17 September 2024, and 3 September 2025 using pulsed DC at 60 pulses/s. Electrofishing effort was divided into 10-minute runs and consisted of 20 minutes of on-time effort in 2023, 62 minutes in 2024, and 38.5 minutes in 2025. Walleye captured during netting or electrofishing were measured for total length to the nearest mm and weighed to the nearest g.

Catch per unit effort (CPUE) an index of relative abundance (Maunder *et al*., 2006), was defined as the number of walleye captured per hour of on-time electrofishing effort and the number of walleyes captured per trap net-night (SDGFP, 2025). In addition, CPUE for Stock-length (≥254 mm, Gabelhouse 1984) walleye (CPUE-S) was calculated. Stock length represents the size when the walleye were considered recruited to the population. Walleye condition was quantified with relative weight (Wr) and was calculated as described by Blackwell *et al*. (2000), with the appropriate standard weight equation used for walleye <150 mm and ≥150 mm.

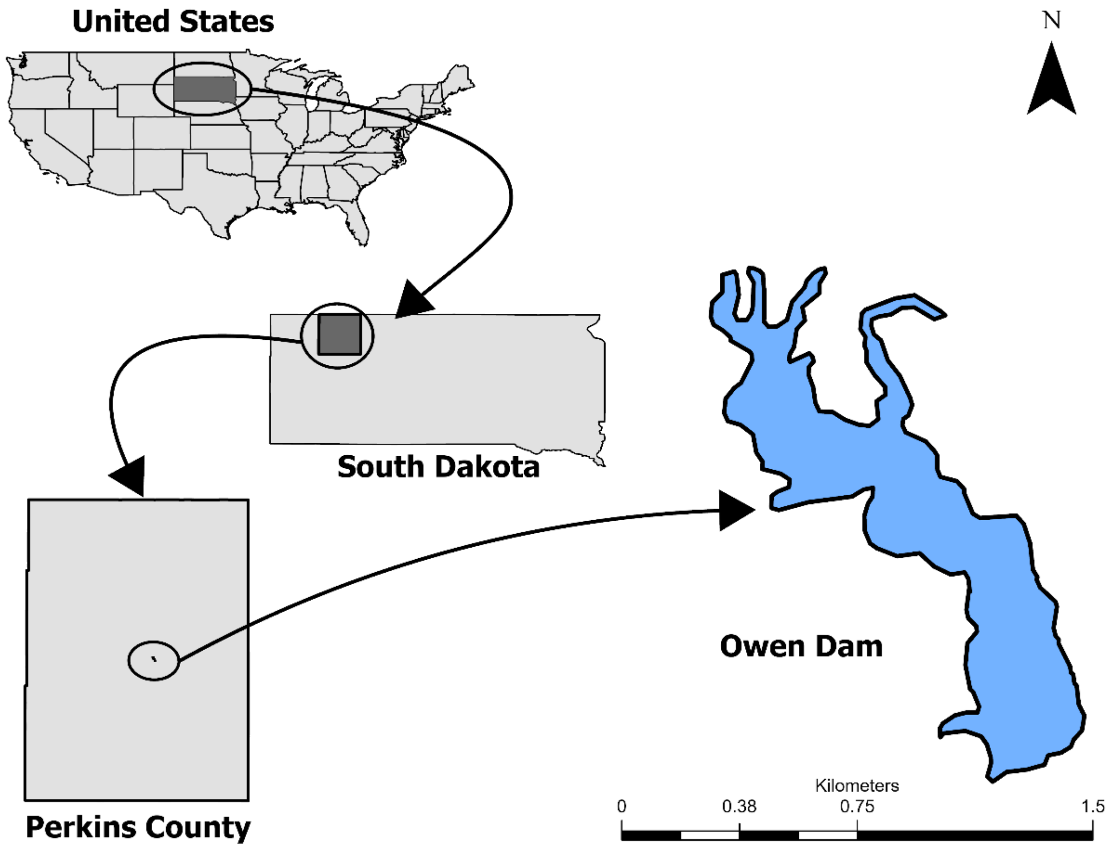

Figure 1. Location of Owen Dam in Perkins County, South Dakota, USA.

Table 1. Recirculating aquaculture system-reared walleye culture at Cleghorn Springs State Fish Hatchery and stocking information for Owen Dam, South Dakota in 2023, 2024, and 2025.

Parameters	2023	2024	2025
Broodstock	South Dakota	Nebraska	Nebraska
Feed Fed	Otohime + Gemma	Otohime + Gemma	Otohime
Turbidity source	Clay	Algae	Algae
Stocking date	23 June	23 May	10 June
Number stocked	25,374	20,000	25,332
Biomass stocked (kg)	15.213	16.511	8.716
Fish weight (g)	0.600	0.826	0.344

Data analysis

Length-frequency distributions were summarized by survey year and sampling method using 10-mm length bins. Annual differences in walleye size structure were evaluated using boxplots of total length by survey year by gear type, with individual fish lengths overlaid to illustrate variation among sampling methods. Data were analyzed using R (R Core Team, 2013). Differences in walleye total length by gear type among survey years were evaluated using a nonparametric Kruskal-Wallis rank-sum test because of non-normal length distributions. When significant differences were detected, pairwise comparison among survey years was conducted using Dunn's post-hoc test with Holm adjustment to identify differences in median walleye length among years. Statistical significance was predetermined at $p < 0.05$.

RESULTS

Walleye were collected in Owen Dam by both trap nets and electrofishing during every sampling year, except 2023, when no walleye were caught in trap nets (Table 2). The total number of walleye captured from both trap netting and electrofishing was 16 in 2023, 219 in 2024, and 57 in 2025.

Table 2. Catch per unit effort [CPUE; (80% confidence interval)], catch per unit effort of stock length fish [CPUE-S; (80% confidence interval)], and relative weight [Wr; (90% confidence interval)] of walleye captured by trap nets (CPUE = fish per trap night) and electrofishing (CPUE = fish per hour effort) from Owen Dam, South Dakota, in 2023, 2024, and 2025.

Parameters	2023	2024	2025
Trap Net			
N	0	215	24
CPUE	0	35.8 (11.5)	4.0 (1.5)
CPUE-S	0	6.0 (2.2)	3.8 (1.5)
Wr	-	88 (3)	90 (2)
Electrofishing			
N	16	4	33
CPUE	48.0 (55.4)	3.9	52.7 (21.2)
CPUE-S	0	2.9	4.5 (4.7)
Wr	87 (2)	80 (8)	88 (4)

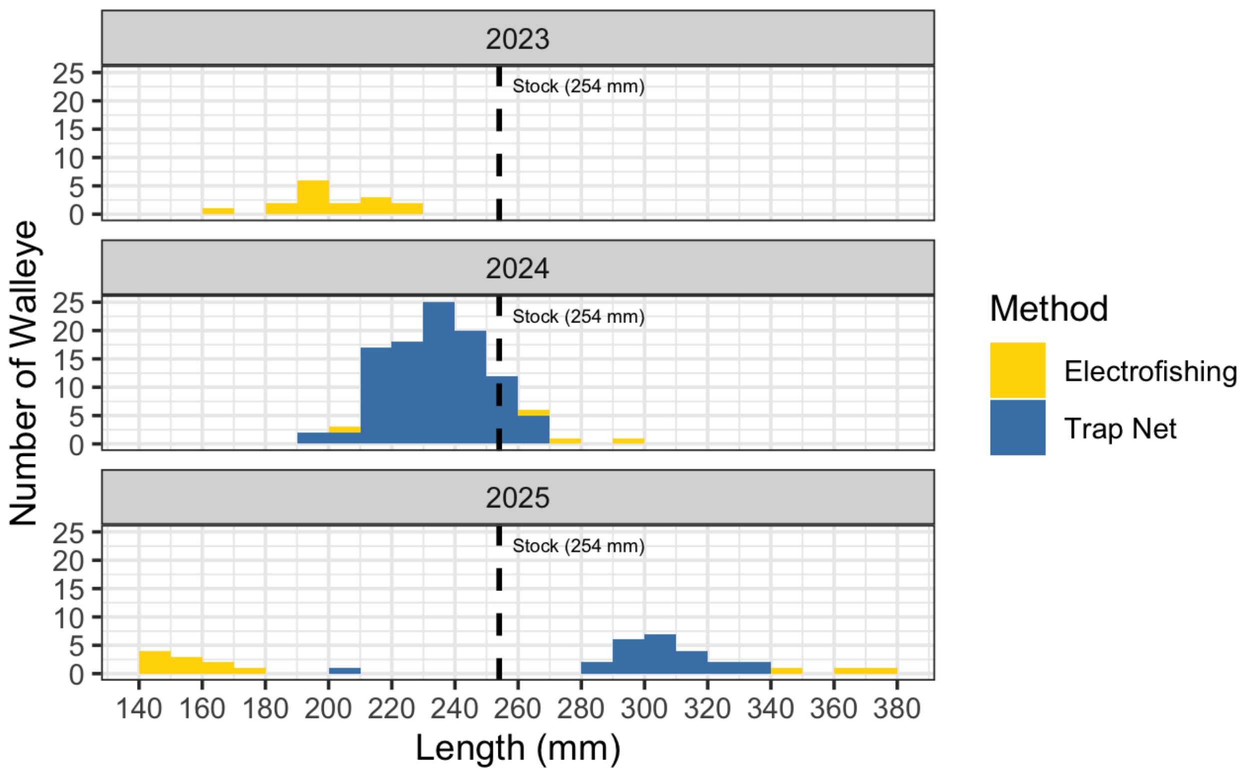

Figure 2. Length-frequency distributions of RAS-reared walleye captured at Owen Dam, South Dakota, in 2023, 2024, and 2025 with electrofishing and trap netting. The dashed line represents the walleye stock length category threshold.

In 2023, electrofishing conducted approximately four months after stocking captured 16 walleye during 20 minutes of on-time effort (48 fish/h CPUE) while no fish were caught in trap nets. In 2024, electrofishing captured four walleye in 62 minutes of on-time effort (3.9 fish/h), while trap nets caught 215 walleye over six net-night (35.8 fish/net-night CPUE). In 2025, 33 walleye were electrofished during 38.5 minutes of effort (44.4 fish/h), with 24 walleye caught in trap nets over six net-nights (4.0 fish/net-night). Stock-length walleye exceeding 254 mm werecollected in both trap nets and electrofishing during 2024 and 2025.

Length-frequency distributions differed among survey years and sampling methods (Figure 2). In 2023, walleye

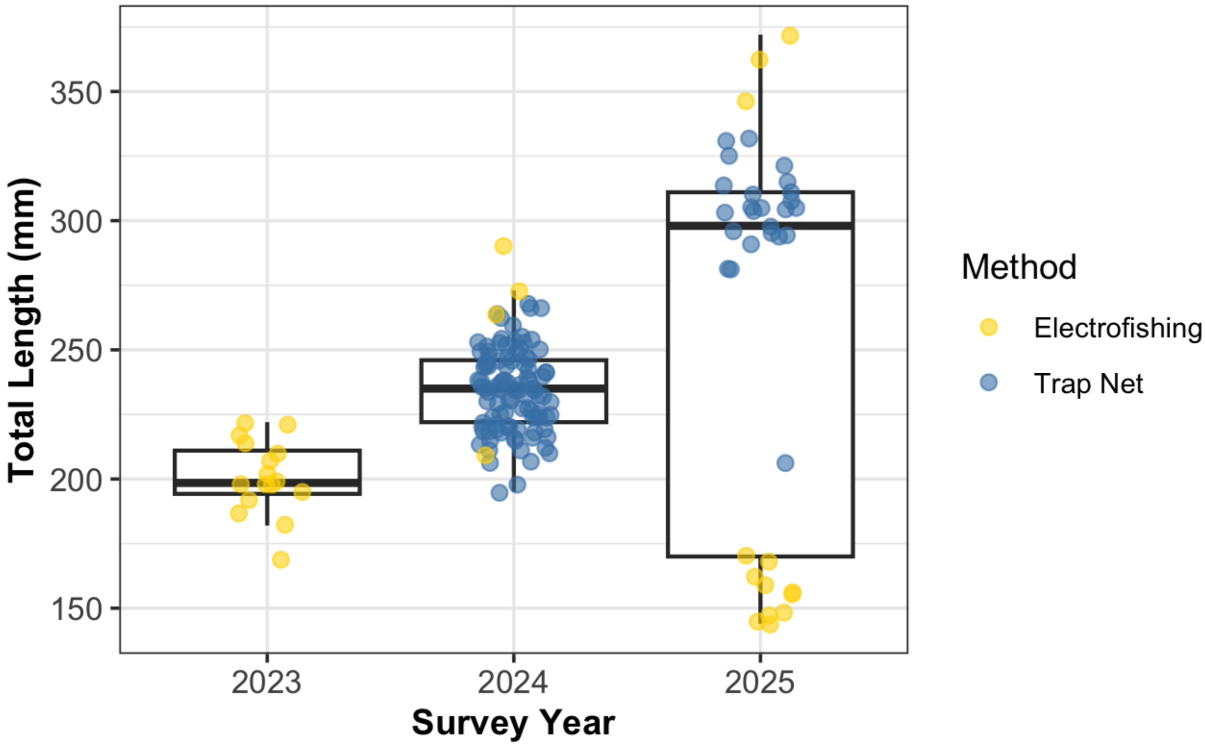

Figure 3. Total length (mm) boxplots of recirculating aquaculture system-reared walleye captured at Owen Dam, South Dakota, after stocking. Walleye were collected with electrofishing (provide month for each year) and in trap nets (provide month for each year). The horizontal line within each box represents the median length of walleye sampled for the given survey year, and the box bounds indicate the interquartile range (25th – 75th percentiles). Points represent individual fish lengths, colored by sampling method.

captured during electrofishing had total lengths mostly from 180 to 230 mm. In 2024, most walleye captured had total lengths between 200 and 280 mm. In 2025, electrofishing samples were dominated by juvenile walleye, while trap-net samples consisted primarily of walleye exceeding stock length.

Median walleye total length significantly differed among the three years ($X^2 = 33.83$, df $= 2$, $p = 4.51 \times 10^{-8}$; Figure 3). The median total length of 198.5 mm in 2023 was significantly different from the 235 mm in 2024 ($p = 1.92 \times 10^{-5}$) and 298 mm in 2025 ($p = 1.83 \times 10^{-8}$). Median total lengths were also significantly different between 2024 and 2025 ($p = 3.89 \times 10^{-3}$). Mean relative weight ranged from 80 to 90 and was primarily in the upper 80s.

DISCUSSION

Because no walleye were present in Owen Dam prior to the stocking of RAS-reared fish, all walleye captured during this study were RAS-reared individuals. This study indicates that walleye reared in RAS survived and grew after being stocked into Owen Dam. The 2023 and 2024 cohorts were captured at four months following stocking and at older ages. They also survived and grew to stock-length sizes. The relative weights in the upper 80s indicated that the stocked walleye were able to find and capture food (Porath and Peters, 1997). These results support the brief account of RAS-reared walleye post-stocking survival described by Johnson *et al*. (2021). RAS-reared juvenile walleye were caught three years after stocking for each of the three different years that the fish were stocked, just as with the present study, where post-stocking survival was not limited to just one stocking year. Johnson *et al*. (2021) documented up to 82% survival of RAS-reared juvenile walleye at three years post-stocking, compared to only 18% survival of traditionally pond-reared fish.

Stocking density and fish size at stocking are important factors influencing post-stocking survival of walleye (Fayram *et al*., 2005b; Kampa and Hatzenbeler, 2009; Johnson *et al*., 2021; Lawson *et al*., 2022). In this study, walleye were stocked at relatively high densities (mean = 606 walleye/ha). Fayram (2005b) suggested an appropriate stocking rate of 75 walleye/ha. The relatively high stocking rates used in this study could be problematic, potentially leading to density-dependent growth reductions (Fox and Flowers, 1990; Bohlin *et al*. 2002), cannibalism (Hansen *et al*., 1998), and decreased cost-efficiencies

(Fayram *et al*., 2005b). Despite stocking densities exceeding this recommendation, RAS-reared walleye at Owen Dam survived and grew over multiple years. The RAS-reared walleyes stocked in this study were also smaller than the nearly 1 gm walleyes stocked in the only other study documenting the post-stocking survival and growth of walleyes reared in RAS (Johnson *et al*., 2021).

Interactions with other fish species may have influenced walleye stocking success at Owen Dam in this study. In the spring of 2023, prior to juvenile walleye stocking, 262 adult largemouth bass ranging from approximately 100 to 330 mm total length, 200 bluegills ranging from approximately 100 to 200 mm, and 1,000 yellow perch were stocked into Owen Dam (SDGFP, 2025). Largemouth bass are recognized as strong predators of juvenile walleye, with numerous studies documenting juvenile walleye in bass diets (Fayram *et al*., 2005a; Freedman *et al*., 2012; Davis and Isermann, 2024). However, evidence regarding the extent to which largemouth bass predation limits walleye stocking success remains mixed, particularly when walleye are stocked at larger sizes than those used in this study (Freedman *et al*., 2012; Fayram *et al*., 2005a).

Limitations

The results of this study could have been impacted by gear sampling efficiency. When attempting to sample juvenile walleye populations, both trap netting and electrofishing have limitations and biases (Rogers *et al*., 2005; Fischer and Quist, 2014; Miller *et al*., 2018). Their effectiveness is also dependent on environmental conditions and the time of year (Rogers *et al*., 2005; Wang *et al*., 2009; Fischer and Quist, 2014). However, while the CPUE observed in this study may or may not be representative of the actual walleye population, the results of this study clearly indicate that RAS-reared walleye survive and grow after stocking.

It is not possible to determine survival rates, as well as the impact of different yearly hatchery rearing practices, because the fish obtained from Owen Dam were not aged. In addition, the year-to-year variability in sampling effort, along with the lack of consideration of environmental variabilities, does not permit robust evaluations of each stocking event. This study was only undertaken to show that RAS-reared walleyes can survive and grow after release into the wild.

Although this study used two different geographically separated walleye broodstocks, it is possible that the genetic strains of walleye used may also have impacted the results (Galarowicz and Wahl, 2003; Quist *et al*., 2003; Waterhouse *et al*., 2014). Lastly, RAS walleye rearing techniques continue to be refined, improving rearing efficiencies and ultimately the product produced. Even in this study, which generally used the techniques described by Johnson *et al*. (2021), year-to-year differences occurred and could have potentially affected the post-stocking survival that was observed.

Conclusion

To our knowledge, this is only the second study to document the post-stocking survival of juvenile walleye reared using RAS technology. Rapid post-stocking growth to stock length in two years was also observed, indicating recruitment to the population. These results support the use of RAS as a viable tool for hatchery production of walleye for stocking recreational fishing waters. However, the biota and environmental conditions are unique for each lake, making it difficult to generalize about the use of stocked fish produced by any technique. Research to determine the performance of RAS-reared walleyes stocked in established fisheries is needed, as is experimentation on the RAS rearing techniques required to maximize post-stocking fitness and survival of walleyes, including establishing optimal rearing densities and sizes at stocking.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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