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Research Article

Survival of Eggs Spawned from Large Walleyes

Aubrey C Gonsorowski[1], Bryan D Sweet[2], Jill M Voorhees[1] and Michael E Barnes[1]*

[1]South Dakota Game, Fish and Parks, McNenny State Fish Hatchery, 19619 Trout Loop, Spearfish, SD 57783, USA

[2]Nebraska Game and Parks, North Platte State Fish Hatchery, 559 E State Farm Road, North Platte, NE 69101, USA

Abstract

Many fisheries professionals involved in walleye (*Sander vitreus*) culture exclude large females from spawning, believing that larger fish produce lower-quality eggs. However, the relationship between maternal size and egg survival in walleyes has not been extensively studied. The survival-to-hatch of eggs spawned from large female walleye was examined in this study. Female walleyes (n = 12) with a mean (SE) total length of 698 (15) mm from Lake McConaughy, Nebraska, USA were spawned in the spring of 2017. The eggs were fertilized and incubated in hatching jars. Mean (SE) survival to the eyed stage of egg development was 63.5 (5.0) % and was not significantly correlated to maternal total length. Mean fecundity was 321,088 eggs, with fecundity significantly and positively correlated to female total length. However, there was no relationship between egg size and female total length. These results indicate that large walleye produce eggs which survive as well as or better than those from smaller fish previously reported in the literature. Given the high egg survival and high fecundity, large female walleyes should be included in artificial spawning efforts to maximize spawning efficiencies.

Keywords: Egg survival; *Sander vitreus*; Spawning; Walleye

Introduction

Walleye (*Sander vitreus*) belong to the Percidae family and have a native range extending from northern Canada to the southern United States [1]. Because walleye are a popular sportfish species subject to overharvest [2], hatchery propagation and restocking efforts are routinely used to establish and maintain populations. An estimated 1 billion fry and fingerlings are stocked annually in the United States alone [3,4].

Hatchery rearing of walleye typically occurs by artificially spawning wild broodstock. Fertilized eggs are then incubated in hatcheries and the resulting newly-hatched fry or further-cultured juveniles are released back into natural systems [5]. Walleye egg survival to hatch is highly variable and there is a need to better understand the factors which influence egg survival and fecundity [6]. While the positive relationship between the size of female fish and fecundity is well known, [7-12] the effect of maternal size on egg survival has been less extensively studied [5,13,14].

Survival during hatchery incubation may be less in eggs from very large female percids [15]. In general, egg survival is positively related to egg size [12,16]. The largest eggs are produced by intermediate-sized fish, whereas the smallest and largest fish produce relatively smaller eggs [17,18]. Czensy et al. [5] stated that the higher metabolic demand of larger female walleyes impedes their ability to produce high-quality eggs. Similarly, Gatch et al. [19] reported that the eggs from smaller walleye tended have better survival to hatch. Survival-to-hatch of walleye eggs was also observed to be negatively related to female length adjust for age [13]. However, relationships between egg survival and female length, or egg survival and egg size, have not been confirmed in many walleye populations [1,5,13,20-22]. Given the large variation in the size of spawning walleyes and the need to maximize spawning efficiencies, it is important to determine if there is a relationship between the size of female walleyes and subsequent egg survival.

Historically, short-term 7.62 cm square mesh gill nets have been used to collect female walleyes for spawning at Lake McConaughy, Nebraska, USA. However, these relatively small mesh nets produced a considerable bi-catch of males. To eliminate the capture of unneeded males, larger 8.89 and 10.16 cm gill nets were used in 2017. While this substantially reduced male bi-catch, it also greatly increased the average size of the female walleyes captured. This provided a unique opportunity to assess the survival of eggs obtained from large walleyes.

The primary objective of this study was to document the survival of eggs spawned from large female walleyes from Lake McConaughy. A secondary objective was to examine any possible relationships among female size, fecundity, egg size, and egg survival.

Study Area

Lake McConaughy is a 14,459-ha impoundment of the North Platte River in western Nebraska, USA. At full pool, it is 35.4 km long, 6.4 km wide, 43.3 m deep, with a storage volume of 214,389 ha-m [23]. Walleye have been one of the predominant sport fish since the construction of Kingsley Dam created the reservoir in the early 1940s [24,25]. All spawning occurred at Lake McConaughy, with fertilized eggs transported to North Platte State Fish Hatchery, North Platte, Nebraska, USA for subsequent incubation.

***Corresponding author:** Michael E Barnes, South Dakota Game, Fish and Parks, McNenny State Fish Hatchery, 19619 Trout Loop, Spearfish, SD 57783, USA, Tel: +1-605-642-6920, Email: mike.barnes@state.sd.us

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Materials and Methods

Walleye spawning on Lake McConaughy occurred on 13 April 2017 as per standard operating procedures of the Nebraska Game and Parks Department. Male walleyes were collected from the lake by electrofishing. Milt was removed by mouth-pipetting of an approximately 4-mm diameter vinyl catheter inserted into the urogenital duct [26,27]. One milliliter of milt and two milliliters of walleye extender [28] were put into a 14-mm diameter test tube, stirred, and placed on ice until used.

Adult females were collected from the face of the Kingsley Dam using gill nets with mesh sizes of 7.62 cm, 8.89 cm, and 10.16 cm. Captured walleyes were removed every two hours and were alive during netting and spawning. Only twelve females with total lengths of 630 mm or greater were spawned and used in this study. Immediately prior to spawning, each female was towel-dried and spawned using the dry method [29]. Eggs were removed from gravid female walleyes by manual stripping, where the abdomen was gently squeezed. All eggs from a single female were expelled into a round plastic pan (25-cm diameter, 10-cm deep). One test tube containing the milt and extender solution was added to the pan of eggs. To activate the sperm, lake water (temp 5-to-8 °C, total hardness $CaCO_3$ 88-to-280 mg/L, pH = 7.5-to-8.9, total dissolved solids 418-to-739; [30]) approximately equal to the volume of eggs was added to the pan. The milt-water solution was stirred with a feather for approximately 60 seconds. Fuller's earth, a clay material consisting of bentonite (calcium-smectite) and palygorskite (attapulgite) [31], was added to the solution to neutralize the egg adhesive layer. The egg-milt-water-clay solution was then stirred for approximately 45-to-60 seconds, after which the eggs were rinsed with clean water. The eggs from each female were then transported discretely in water 115 km (approximately 1 hour transit) to the North Platte State Fish Hatchery. Total lengths to the nearest mm were recorded for each female after spawning.

Upon arrival at the hatchery, all eggs from each female were placed into separate, 6.1-L McDonald type hatching jars [32] and supplied with flow through well water (12.2 -to-13.4 °C). If the egg volume from a single female exceeded the capacity of one jar, an additional jar was used. After 24 hour the eggs had reached their maximum size (because of imbibing water) and removed from the jar. Egg size (number of eggs per mL of water displaced) and fecundity, the total number of eggs (based on water displacement), was then recorded. The eggs were placed back into the jar for incubation until the eyed stage of egg development. During incubation, the eggs received every-other-day, 10-minute treatments of 500 mg/L hydrogen peroxide (Perox-Aid; 35% by weight; Eka Chemicals, Inc., Marietta, Georgia, USA) for prevention of possible Saprolegniaceae water molds infestation and also to facilitate removal of organic debris from the jar. After 8-to-11 days, the dead eggs were removed. Egg size was determined for the remaining viable eggs and total egg numbers were determined again by water displacement. Percent survival was calculated using the following formula.

Survival (%) = (Number of Eyed Eggs / Number of Initial Eggs) x 100,

The SPSS statistical program (24.0, IBM, Armonk, New York, USA) was used for data analysis. Regression and correlation analysis was used to determine any possible relationships between the variables. Significance was pre-determined at $p < 0.05$.

Results

The total length of female walleyes sampled from Lake McConaughy, Nebraska ranged from 630 to 762 mm, with a mean ± SE length of 698 ± 15 mm (Table 1). Mean egg survival to hatch was 63.5%, mean fecundity was 321,088 eggs, and mean egg size was 132.7 eggs/mL.

Location	Age	Length (mm)	Fecundity	Egg size (eggs/mL)	Source
Lake McConaughy, Nebraska		698 ± 15	321,088 ± 31,533	132.7 ± 3	This Study
Lake Erie			48,000 – 614,000	1.721	[7]
Escanaba Lake, Wisconsin		381 – 456	18,000 – 60,000	0.9 – 3.4[a]	[11]
		457 – 557	40,000 – 140,000	1.5 – 2.9[b]	
Lake Oahe, South Dakota	6.8	518	48,000	85 – 160	[33]
Red Lakes, Minnesota	5 – 12	470 – 699	1,17,213		[34]
	6 – 13	360 – 609	44,409	1.6[a]	
Lake Winnebago, Wisconsin		442 – 615	43,255 – 227,181		[35]
Lake Winnipeg, Manitoba	4.7	270 – 600	15,000 – 130,000	0.57 – 0.95[a]	[36]
		400 – 725	50,000 – 250,000		[10]

Table 1: Mean (± SE) walleye total length, fecundity, and egg size from Lake McConaughy, Nebraska, along with similar information from other published studies.

[a]Egg Size in mm

[b]Egg Size in mg

Fecundity was significantly and positively correlated with total length ($p < 0.001$; $R^2 = 0.864$; Figure 1). However, within the relatively concentrated lengths of the 12 fish sampled, there was no relationship between egg size and female total length ($p = 0.328$; $R^2 = 0.096$; Figure 2) or between survival to the eyed-egg stage total length ($p = 0.212$, $R^2 = 0.151$; Figure 3).

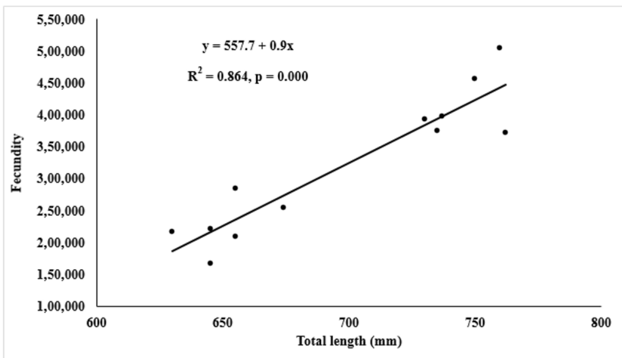

Figure 1: Scatter plot of total length and fecundity for female walleye from Lake McConaughy, Nebraska, with regression and correlation analysis.

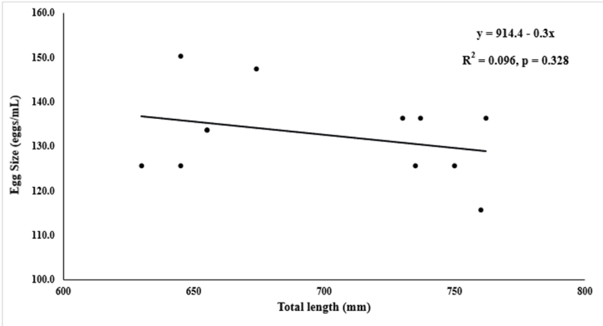

Figure 2: Scatterplot of total length and egg size for female walleyes from Lake McConaughy, Nebraska with regression and correlation analysis.

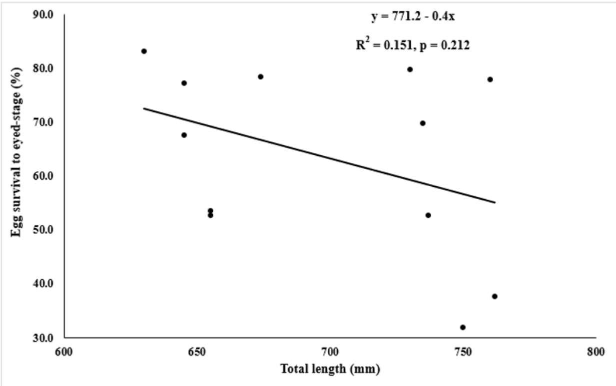

Figure 3: Scatter plot of total length and percent egg survival to the eyed stage for female walleye from Lake McConaughy, Nebraska, with regression and correlation analysis.

Discussion

The results of this study do not support the suggestion that eggs from large walleyes are of poor quality and exhibit relatively poor survival to hatch [13,15,19,37]. Although egg survival varied among the individual fish, the mean survival of 63.5% was similar to the 67-to-70% reported by Schneider et al. [38] from walleyes of unknown sizes. It is much higher than the 50-to-57% survival reported by Ward and Blackwell [39], and the 13-to-60% egg survival reported by Ward and Blackwell [40]. It was also higher than the 51% and 57.5% survival reported for eggs from various sizes of walleyes incubated at two production hatcheries [41,42]. In addition, survival to hatch of walleye eggs from Lake Oahe, South Dakota over several years has been reported to range from 50 to 60% [43-47]. In contrast, Czesny et al. [5] incubated small numbers of walleye eggs experimentally and reported survival to the eyed stage of development at over 90%. Johnson [48] incubated walleye eggs on a variety of natural substrates and reported survival rates to the eyed stage of development from 2.4 to 25%.

The results of this study are limited by the small sample size of 12 and the focus only on large females. Smaller females were originally included in the study design, but because of limitations resulting from this research as part of normal spawning and hatchery operations, only the spawns from the 12 large fish in this study could be incubated.

Previous research has also reported the lack of relationship between female length and egg survival observed in this study. Czesny et al. [5] also observed no correlation between female size and egg survival to the eyed stage, with the female walleyes ranging from 465 to 885 mm. However, other studies have reported a positive relationship between maternal size and egg quality or survival [14,49,50]. The current study and Czesny et al. [5] examined survival to the eyed stage egg development, instead of survival to hatch. Both metrics of survival are nearly perfectly correlated [51] and can likely be used interchangeably. Egg mortality typically occurs early in development, with over 80% of walleye egg mortality occurring in the first 50 to 100 hours after fertilization [52].

At a mean fecundity of over 320,000 eggs, the large female walleye from Lake McConaughy produced more eggs than other stocks with smaller females. Miller and Erb [33] reported a mean fecundity of 117,213 eggs from female walleyes with total lengths ranging from 470 to 699 mm from Red Lakes, Minnesota, USA. Fecundity of walleyes from 400 to 725 mm from Lake Winnipeg, Manitoba, Canada ranged from 50,000 to 250,000 eggs/female [10]. The positive relationship between maternal length and fecundity observed in this study is typical for walleye [2,7,15] and other fishes [53-58]. It is also possible that eggs may have been retained within the spawned female walleyes in this study [59]. If this occured, actual fecundity may be higher.

The egg size of approximately 133 egg/mL of water displaced is similar to that observed in walleye from South Dakota, which is in relatively close proximity to Lake McConaughy [33]. It is also comparable to the range of 85-to-160 eggs/mL reported by Malison and Held [60]. Unfortunately, no direct comparison can be made to the egg size expressed as egg diameter (mm) reported in other studies [7,34] or mass (mg) [11,36], limiting direct comparisons to many other walleye populations.

It is not surprising that there was not a significant positive relationship between egg size and female total length. The small sample size and the limited variation in fish size likely precluded any such relationship. Correlations between female walleye size and egg size have been reported previously, with the strength of such relationships greatest on the upper and lower latitudinal limits of walleye range [1].

The large walleyes spawned in this study were not aged. Other studies with a variety of fish species have linked egg size to maternal age, with older females potentially producing smaller eggs and intermediate ages producing the largest eggs [14]. However, this has not been shown with walleyes [5,10]. Johnston [13] attributed older age in walleyes as the main factor for larger egg size. In the Great Lakes Region, excluding age data and accounting only for length did not account for egg size variation in walleye [48].

This study is the first to focus specifically on the survival of eggs from large walleyes. While other studies included walleye similar in size to those used in this study, egg survival, egg size, and fecundity specific to large females could not be determined because the information from large females was combined with small-to-intermediate sized fish [10,34].

Conclusion

In conclusion, the egg survival observed in this study of large walleyes from Lake McConaughy, Nebraska indicate females should not be excluded from hatchery spawning operations based solely on maternal length. In addition, the positive relationship between fecundity and maternal length means that large female walleyes will likely produce more eggs, thereby decreasing the number of fish needed to be spawned to meet egg needs. However, these results could be lake dependent, so examining other populations with a variety of sizes would be beneficial.

Author Contributions

Conceptualization, B.D.S; methodology, A.C.G, B.D.S, J.M.V., and M.E.B.; formal analysis, A.C.G, J.M.V., and M.E.B.; investigation, B.D.S.; data curation, B.D.S; writing-original draft preparation, A.C.G.; writing-review and editing, A.C.G, B.D.S, J.M.V., and M.E.B.; visualization, J.M.V., and M.E.B.; supervision, M.E.B. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

This experiment was performed within the guidelines set out by the Aquatics Section Research Ethics Committee of the South Dakota Game, Fish and Parks (approval code, SDGFPARC20203) and within the guidelines for the Use of Fishes in Research set by the American Fisheries Society.

Data Availability Statement

Data available upon request.

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Conflicts of Interest

The authors declare no conflict of interest.

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