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Fecundity of Lake Sturgeon (*Acipenser fulvescens*, Rafinesque) in Lake Winnebago, Wisconsin, USA

By Ronald M. Bruch[1], Glenn Miller[2], Michael J. Hansen[3]

[1]Wisconsin Department of Natural Resources, 625 E County Rd Y, Suite 700, Oshkosh, WI 54901, USA; [2]U.S. Fish and Wildlife Service, 2800 Lake Shore Drive East, Suite B, Ashland, WI 54806, USA; [3]University of Wisconsin – Stevens Point, College of Natural Resources, 800 Reserve Street, Stevens Point, WI 54481, USA

Summary

Sturgeon species are known for their relatively high fecundity, with some reported to carry as many as 7.7-million eggs. However, the fecundity of lake sturgeon (*Acipenser fulvescesn* Rafinesque) has not been thoroughly studied, with limited information available primarily in gray literature and agency reports. Our objectives were to quantify (1) the fecundity and gonadosomatic index (GSI) of female lake sturgeon in a winter F4 stage of development; 2) the average size and weight of F4 lake sturgeon eggs; and 3) relationships between lake sturgeon fecundity and fish weight, length, and age. Total length, weight, age, gonad weight, fecundity, egg diameter, and egg weight were sampled from 14 female lake sturgeon in an F4 stage of egg development in February 2005 from the Lake Winnebago System in Wisconsin. Mean fecundity was 383,529 eggs and the mean GSI was 22.9. Egg diameter averaged 2.74 mm and egg weight averaged 17.34 mg. Weight was the best predictor of fecundity ($r^2 = 0.66$). Fecundity data for lake sturgeon larger than 35 kg are needed to allow better estimation of fecundity for larger fish.

Introduction

Sturgeon species are well known for being highly fecund with a strong relationship between the body weight and numbers of fully developed eggs (Hochleithner and Gessner 1999). Fecundity reported in the literature for various sturgeon species ranges from as few as 8,000 eggs in an *Acipenser ruthenus* specimen (Berg 1948) to as many as 7,700,000 eggs in a *Huso huso* specimen (Babushkin 1947), though the number of eggs an adult female sturgeon carries has been traditionally reported as the number of eggs per kg of body mass.

Fecundity of lake sturgeon *(Acipenser fulvescens)* has been studied by Cuerrier (1949; cited in Harkness and Dymond, 1961), Dubreuil and Currier (1950), Harkness and Dymond (1961), and Sandilands (1987), but these studies examined relatively few fish, and may not have accounted for ovarian tissue mass or volume or ovaries in an F4 (black egg) development stage, as classified by Bruch et al. (2001). Knowledge of fecundity is important for understanding lake sturgeon life history and for modeling lake sturgeon population dynamics.

Our objectives were to quantify (1) the fecundity and gonadosomatic indices of female lake sturgeon in a winter F4 stage of development; (2) the average size and weight of F4 lake sturgeon eggs; (3) and relationships between fecundity and fish weight, length, and age. To reach our objective, we sampled female lake sturgeon harvested during a winter spear fishery in Lake Winnebago, Wisconsin, USA, during February 2005.

Material and Methods

Fourteen F4-stage (Bruch et al. 2001) adult female lake sturgeon were sampled from the winter spear fishery on the Lake Winnebago System, east-central Wisconsin, USA, in February 2005. Fish were measured in total length to the nearest 0.5-inch and weighed to the nearest 0.5-pound. Both gonads were carefully dissected and weighed separately to the nearest 0.01 pound. Weights of right and left ovaries were measured individually for the last three fish sampled after a consistent pattern of a substantial difference in size between the two ovaries was noticed while collecting individual ovary weights.

Three sub-samples of eggs were removed from each ovary at the anterior, middle, and posterior positions using a tablespoon to scrape a spoon-sized quantity of eggs from between ovarian folds without also collecting ovarian tissue. Egg sub-samples were weighed to the nearest 0.01 gram and all sub-sampled eggs were counted. Average diameter of eggs from each sub-sample was determined by lining up 10 randomly selected eggs along a millimeter ruler, measuring the total distance to the nearest millimeter, and dividing the total distance by 10.

The two ovaries of the last three fish sampled were processed into caviar to separate the eggs from the residual ovarian tissue and to determine the weight of ovarian tissue and eggs in each ovary. These data were combined with data previously collected during the production of caviar from two fish sampled in 2004. The leading ray of the left pectoral fin was removed from 13 of 14 fish sampled, dehydrated in a spine drying cabinet, and cross-sectioned proximal to the base of the fin ray with a Buehler isomet low-speed saw for age interpretation.

Fecundity was modeled as linear and power functions of weight, length, and age. First, the intercept and slope were estimated using linear regression on data in original measurement scales. Second, for significant linear models, the intercept and slope were estimated using linear regression on the $\log_e$-transformed model (power function). To determine if fecundity changed non-linearly with weight, we tested the slope of the $\log_e$-transformed model (exponent of the power model) for significant departure from a value of 1.0 using a *t*-test, where the *t*-statistic was computed as the ratio of the parameter estimate to its standard error. If the slope of the $\log_e$-transformed model (exponent of the power model) did not differ significantly from a value of 1.0, we concluded that fecundity was linearly related to the predictor variable (length, weight or age). Weight and length were converted to metric units prior to analysis.

Results

Fecundity of the 14 lake sturgeon averaged 323,684 eggs (SE = 24,294; range = 153,672 – 460,270; Table 1) and the mean number of eggs per kg of body weight was 11,228 (SE = 578; range = 7,208 – 14,813). The 14 lake sturgeon averaged 160.5 cm in total length (SE = 2.4 cm; range = 147.3 – 177.8 cm), 28.51 kg in weight (SE = 1.18 kg; range = 21.32 – 37.65 kg), and 35 years of age (SE = 1.4 years; range = 30 – 45 years; Table 1). The mean GSI was 22.93 (SE = 1.32; range = 15.03 – 32.03) and the mean gonad weight (combined weight of both ovaries) was 6,607 grams (SE = 518.6 grams; range = 3,211 – 9,952 grams).

Eggs comprised an average of 84% of the mass of lake sturgeon ovaries (SE = 0.0418) and ovarian tissue comprised 16%. Ovaries from individual fish differed consistently in size, with the weight of one ovary averaging 20.8% larger than the other (range = 0.5 – 54.7%). For the three fish for which right and left ovaries were measured separately, the left ovary was 31% heavier than the right ovary for one fish, and the right ovaries were 15% and 9% heavier than the left ovaries for two fish.

The mean diameter of eggs from the 84 sub-samples was 2.74 mm (SE = 0.01 mm; Table 1). The mean diameter of eggs did not differ between large (2.733 mm) and small ovaries (2.743 mm) for individual fish. Mean egg weight was 17.34 mg (SE = 0.26; range = 12.73 – 29.51 mg) and the mean number of eggs per gram was 58.53 (range = 33.9 – 78.6 eggs per gram).

Weight was the best predictor of fecundity ($r^2 = 0.66$; $F = 22.8$; df = 1, 12; $P < 0.001$) and fecundity increased linearly with weight because the slope of the $\log_e$-transformed model (exponent of the power model) did not differ significantly from a value of 1.0 ($t = 1.77$; df = 12; $P = 0.10$; Figure 1). In contrast, length ($r^2 = 0.01$; $F = 0.1$; df = 1, 12; $P = 0.756$) and age ($r^2 = 0.66$; $F = 0.09$; df = 1, 12; $P = 0.322$) were poor linear predictors of fecundity.

Discussion

Our sample of only 14 female lake sturgeon is relatively small, but is larger than previous studies and sufficiently large to provide useful estimates of fecundity and egg characteristics. In addition, our results provide a base of information for use in modeling lake sturgeon population dynamics, and to which more data can be added to

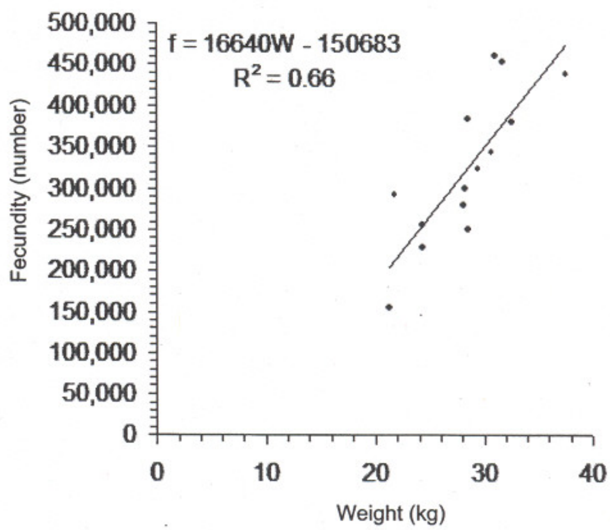

Fig. 1. Fecundity (number of eggs) versus weight (kg) for 14 lake sturgeon sampled from Lake Winnebago, Wisconsin, during February 2005.

Table 1
Total length, weight, age, gonad weight, gonadosomatic index (GSI), fecundity, egg diameter, egg weight, and eggs/kg for 14 lake sturgeon sampled from Lake Winnebago, Wisconsin, during February 2005.

Total Length (cm)	Weight (kg)	Age (years)	Gonad Weight (g)	GSI (%)	Fecundity (number)	Egg Diameter (mm)	Egg Weight (mg)	Eggs per kg
147.3	30.8	45	7,829	25.4	342,457	2.73	20.6	11,103
148.6	24.4	31	5,352	21.9	226,732	2.83	20.1	9,257
151.1	21.8	32	5,669	26.0	291,238	2.62	16.4	13,376
153.7	31.1	35	9,952	32.0	460,270	2.92	18.2	14,813
156.2	21.3	30	3,211	15.1	153,672	2.67	17.7	7,208
156.2	28.6	--	8,432	29.5	383,529	2.88	18.5	13,421
160.0	32.7	35	8,391	25.7	379,186	2.77	18.8	11,610
161.3	28.1	35	5,234	18.6	278,887	2.70	15.8	9,917
161.3	24.5	30	4,540	18.5	254,965	2.73	15.0	10,409
166.4	31.8	32	8,655	27.3	452,493	2.70	16.2	14,251
167.6	29.5	32	6,704	22.7	322,377	2.70	17.5	10,934
170.2	37.6	39	7,911	21.0	437,780	2.60	15.2	11,628
170.2	28.3	44	5,669	20.0	297,521	2.72	16.0	10,494
177.8	28.6	36	4,926	17.2	250,461	2.77	16.5	8,765

Table 2
Number of fish examined, mean weight, mean fecundity (number of eggs), and mean number of eggs per kg for lake sturgeon.

Study	Origin	Number of Fish examined	Mean Fish Weight (kg)	Estimated Mean Fecundity	Mean Number of Eggs per kg of Fish
Cuerrier (1949)	Lake St. Peter, Ontario, Canada	9	23.9	295573	12264
Dubreuil and Cuerrier (1950)	Ottawa River, Canada	4	9.0	118205	11467
Harkness and Dymond (1961), and von Bayer (1910)*	Lake Erie	3	65.6	583661	8744
Sandilands (1987)	Kenogami River, Ontario, Canada	2	13.3	120998	8797
Present Study (2005)	Lake Winnebago System, Wisconsin, USA	14	28.5	323684	11228

increase the precision of fecundity estimates over a wider range of fish sizes, especially for fish heavier than 35 kg.

Our findings are similar to previous studies of lake sturgeon fecundity (Table 2; Cuerrier 1949; Dubreuil and Currier 1950; Harkness and Dymond 1961; and Sandilands 1987). Despite wide variation in the mean size of fish examined in these studies, which also likely accounts for the wide range in mean fecundity reported, mean numbers of eggs per kg of fish are relatively consistent among studies.

Our estimate of mean egg diameter for fully-developed lake sturgeon eggs is within the range of mean egg diameters found by other investigators (von Bayer 1910; Harkness and Dymond 1961; Sandilands 1987). In addition, our estimate of mean egg weight (58.53 eggs per gram) is similar to the estimate of mean egg size found by Fred Binkowski (50 ovulated, unfertilized eggs per mL; University of Wisconsin-Milwaukee Great Lakes WATER Institute, unpublished data).

Our estimate of the number of eggs per kg of body weight was similar to estimates from other studies of lake sturgeon fecundity (Table 2), though the limited data on fecundity of lake sturgeon heavier than 35 kg makes this estimate tenuous for large lake sturgeon. Our estimate of the fecundity-weight relationship for lake sturgeon indicates that fecundity of lake sturgeon would be overestimated for fish lighter than 27 kg and underestimated for fish heavier than 28 kg using an estimate of 11,228 eggs per kg of fish body weight. To avoid such bias, our linear model using weight as the independent variable is the best estimator of fecundity. In contrast, we found that total length and age were poor predictors of fecundity, likely because the 14 fish in our analysis encompassed a narrow range of lengths and ages. To strengthen our analyses, a larger range of sizes and ages of lake sturgeon are needed.

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Author's address: Ronald Bruch
Wisconsin Department of Natural Resources
625 E County Rd Y, Suite 700
Oshkosh, WI 54901, USA,
e-mail: ronald.bruch@dnr.state.wi.us