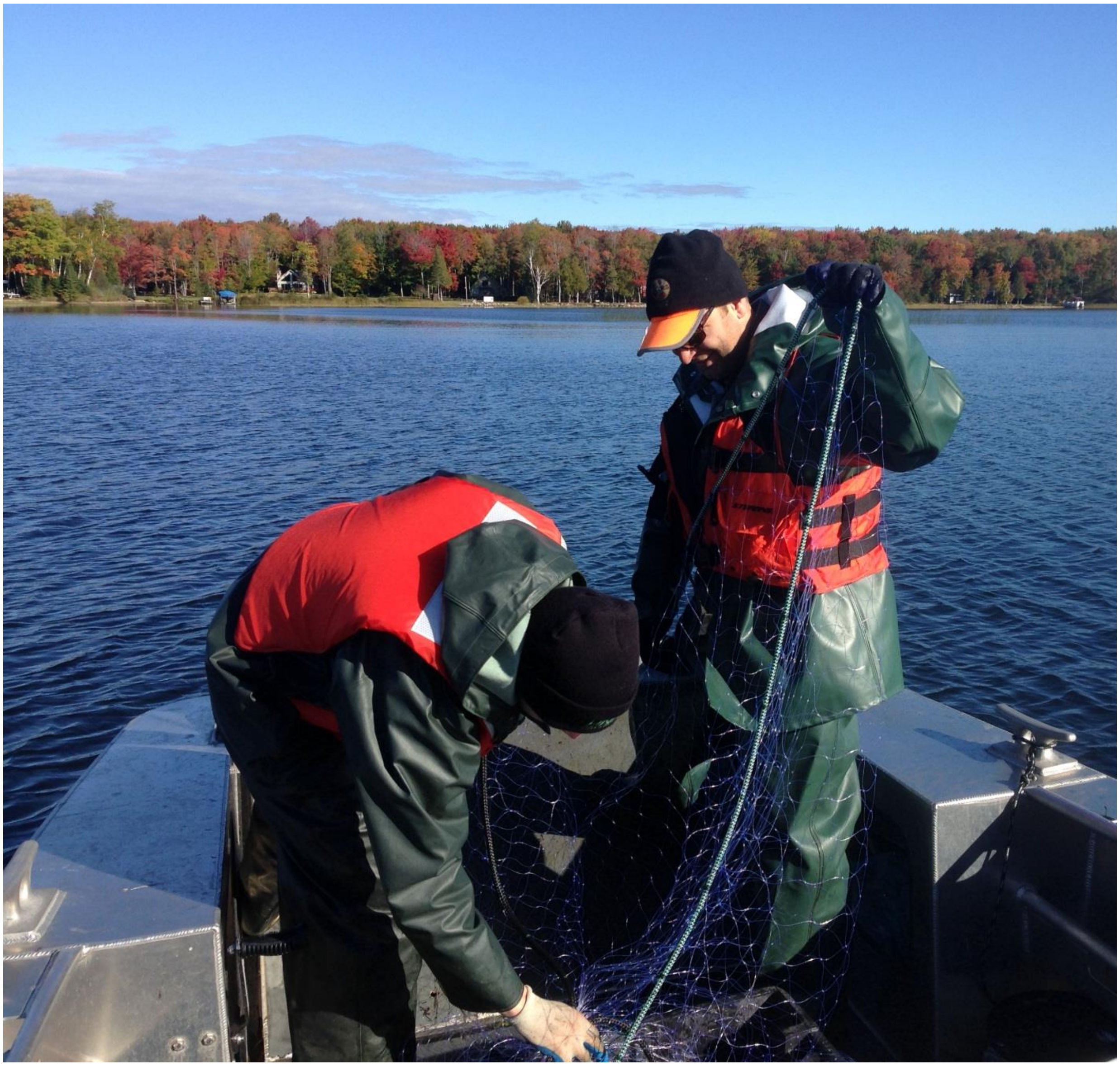
An assessment of the walleye (*Sander vitreus*) population in Brevoort Lake, Michigan



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Introduction

Brevoort Lake is an approximately 1,748.2 hectare lake located in Mackinac County, Michigan. Brevoort Lake is shallow with a maximum depth of approximately 10 meters and a bottom that is primarily composed of sand in shallow shoreline reaches and pulpy peat in deeper portions of the lake (Roelofs and Kilpela 1943). The lake has limited transparency with Secchi depths of 6-8 feet and does not undergo thermal stratification (Roelofs and Kilpela 1943). The lake supports both warm water and cool water fish species and is a popular fishing destination. In 2014 an estimated 19,913 angler hours of effort were spent on Brevoort Lake (Anonymous, 2014). Walleye did not naturally spawn in Brevoort Lake prior to the construction of a 610 meter artificial reef in 1984 (Colby et al. 1994).

In 2015 the Inland Fish and Wildlife Department at the Sault Ste. Marie Tribe of Chippewa Indians performed a paired spring and fall Walleye population abundance assessment on Brevoort Lake in calibration with the Little Traverse Bay Bands of Odawa Indians and the United States Forest Service. Coordinating partners on this assessment included the Bay Mills Indian Community, Michigan Department of Natural Resources, and Strait's Area Sportsman's Club.

Methods

Spring Walleye Survey

In the spring of 2015 the Sault Ste. Marie Tribe of Chippewa Indians (SSMT), the Little Traverse Bay Bands of Odawa Indians (LTBB) and the United States Forest Service (USFS) conducted a spring adult walleye population estimate in Brevoort Lake according the draft 1836 Ceded Territory walleye protocol. During the mark phase we collected the first two to three dorsal spines from each fish, place a uniquely numbered jaw tag, and sexed and measured each individual to the nearest mm.

The mark phase of this assessment began on April 27th when the USFS placed five trap nets along the southwestern edge of an artificial reef constructed off Black Point. On April 28th SSMT and LTBB placed three fyke nets along the southwestern shore of Christensen's Bay, located on the eastern end of Brevoort Lake. On April 29th, 2015 SSMT placed three additional fyke nets along the northeastern edge of the spawning reef and three more fyke nets to the southern shore of Christensen's Bay. On May 1st, the three fyke nets were moved from the northeastern side of the artificial reef to the southeastern end of Christensen's Bay. The westernmost net in Christensen's Bay collapsed on April 30th and bycatch prevented checking the easternmost net in Christensen's Bay May 2nd. Due to this high level of bycatch, the two easternmost nets in Christensen's Bay were pulled on May 2nd. All nets were pulled on May 3rd, 2015 because recaptured fish composed between 20% and 30% of the catch, unknown sex fish were being detected in increasing numbers, and catch per unit effort (CPUE) for all fish had been consistently declining. A total of 65 net nights were fished during the mark phase of the assessment. In addition to netting, LTBB electrofished for 2,718 seconds the evening of April 28th, 12,003 seconds the evening of April 29th, and 12,294 seconds the evening of April 30th.

The entire shoreline of Brevoort Lake was shocked for 31,352 seconds on May 4th for the recapture phase of the assessment.

Fall Walleye Netting Survey

In the fall of 2015 the SSMT conducted a fall walleye index netting (FWIN) assessment in Brevoort Lake. This consisted of setting 18 gillnet gangs that consisted of 8 panels each 1.8 m deep and 7.6 m long. The stretch mesh sizes for each panel were 25, 38, 51, 64, 76, 102, 127 and 152 mm. Initially 500x500 m grids were overlaid on Brevoort Lake in ArcMap version 10.3.1. Ten nets were set in grids sampled from the list of all grids intersecting the 2-5 m depth contour and 8 nets were set in grids sampled from the list of all grids intersecting the 5-15 m depth contour (Figure 1). Sample sizes for each depth stratum were proportionally allocated based on the total surface area of the lake within each depth stratum. For a detailed description of the FWIN protocol and site selection criteria see Morgan (2002).

Nets were set between October 4th and October 8th, 2015. The surface temperature of the lake ranged from a high of 14ºC on October 5th to a low of 12.3ºC on October 8th. Nets were set by making sure the lead anchor was in the sampling grid and desired depth stratum and then pulling the net perpendicular to the bank. Nets were fished overnight. All fish sacrificed were placed in bags labeled with the net and panel number. We attempted to release all non-target fish (*i.e.*, not Walleye) of catchable size that appeared fresh in the net alive. Flesh from sacrificed game fish was donated to the Sault Tribe Elder Program and the Sugar Island Powwow Committee. The sacrificed Muskellunge was donated to the Lake Superior State University fish collection so it could be used for educational purposes.

Fall Walleye Electrofishing Survey

An attempt was made to electrofish the entire shoreline of Brevoort Lake by LTBB, SSMT and USFS on October 14th, 2015. This effort was postponed due to inclement weather. The entire shoreline of Brevoort Lake was shocked for 28,943 seconds by LTBB and SSMT on the evening of October 22nd to sample young of the year Walleye.

Data Analysis

Spring Walleye Abundance Estimates

Prior to analysis tag numbers were removed from all recaptured individuals whose length differed more than 20 mm from the length of the individual with that tag number at initial capture. We also removed the tag number from recaptured fish if the sex differed between their handling dates. We explored the consistency of length estimation among recaptured individuals, and calculated catch per unit effort (CPUE) for both the netting and shocking portions of the mark phase.

Because the assessment occurred over a short period of time during the walleye spawning closure we assumed no mortality, recruitment, or tag loss occurred during the survey. While we replace three jaw tags over the course of the survey, the presence of a secondary mark (clipped dorsal spines) allowed crews to identify these individuals as previously marked fish.

We used the closed population time varying estimator developed by Darroch (1958) as described in Otis et al. (1978) to estimate the size of the spring adult walleye population in Brevoort Lake. This model allows the probability of capturing an individual to vary throughout the course of the survey. The estimate, and associated 95% profile likelihood confidence interval was constructed with the Rcapture package (Rivest and Baillargeon 2014) in the statistical computing package R version 3.0.1 (R Core Team 2013).

Fall Walleye Index Netting

Length frequency histograms were developed for all species with sample sizes larger than 30 fish. We also estimated relative weight for species with published standardized weight equations (Blackwell et al. 2000) and samples larger than 30 fish. Proportional stock density (*i.e.*, the estimated proportion of a stock greater than a given length) of Yellow Perch was calculated based on formula in Neumann and Allen (2007). Quality length was set to 200 mm and stock length was 130 mm (Gabelhouse 1984).

We estimated the proportion of young of the year, juvenile and adult walleye that were stocked in Brevoort Lake by collecting otoliths from all 75 captured individuals and screening for oxytetracycline (OTC) marks. Not all stocked fish in the adult age classes would have received OTC marks, but all stocked juvenile and young of the year fish were marked.

Fall Walleye Abundance Estimates

We estimated the spring abundance of Walleye in Brevoort Lake through our Fall Walleye Index Netting. Due to the large number of estimated parameters in this analysis, 10,000 bootstrap samples were drawn, with parameter estimates, and their associated confidence intervals, derived from these bootstrap distributions. The final population estimate was calculated as the median of the bootstrap distribution, with 95% confidence intervals calculated by the percentile method of Efron (1979) as presented in Manly (2007). To develop this estimate we calculated catchability (Ward et al. 2012) based on the number of marked and recaptured Walleye in the fall assessment. We corrected the number of marked fish from an annual survival estimate calculated via the approach developed by Robson and Chapman (1961) and presented in Miranda and Bettoli (2007). To develop an age length key for the spring sample, ages were estimated from dorsal spines for five or fewer fish of a given sex randomly sampled from each one cm length class by two independent agers. Within each bootstrap sample the ager was randomly selected for each fish. We developed a von Bertalanffy growth curve (Isely and Grabowski 2007) for Walleye in the spring sample, and removed all sexually mature adults caught in the fall netting effort whose size was smaller than the median estimated length of a two year old Walleye from the spring sample (387.3 mm). This median length corresponded well with to the length frequency histogram from the fall netting survey (Figure 2), providing support for the extrapolation of the size of Walleye to sub-adult individuals in the spring.

All analyses were performed in the program R version 3.0.1 (R Core Team 2013).

Results

Spring Walleye Abundance Estimates

A total of 1,338 walleye were captured and given a mark between April 28th and May 3rd, 2015 (Table 1). Of these, three individuals (0.2%) lost their initial jaw tag and had to be re-tagged. On average fish were estimated to be 0.55 mm smaller at their recapture, with a standard deviation of 4.93 mm. Therefore, more than 95.4% of all recaptured fish were measured to within a centimeter larger or smaller than at their original capture.

CPUE in the nets declined after the second day (Figure 3). An increase in CPUE of unknown sex fish, however, was observed at the end of the mark phase (Figure 3). These patterns were similar in the electrofishing effort, except for an increase in the number of females observed on April 30th (Figure 4).

Of the 30 previously marked individuals that were recaptured during the recapture phase of the estimate, we were unable to identify the sex of 1 individual. All individuals marked within that unknown individual's cm length class were male, indicating that this individual was also a male.

The closed population estimate where capture probability was allowed to vary by time estimated there were 5,733.2 adult Walleye in Brevoort Lake in the spring of 2015 (95% profile likelihood confidence interval from 5078.5 to 6532.2 Walleye).

In addition to Walleye, Northern Pike, Smallmouth Bass, Largemouth Bass, White Sucker, Rock Bass, Bluegill, Pumpkinseed, Yellow Perch, Bullhead, Carp, and Bowfin were also captured. All fish captured during the spring assessment were returned to the lake.

Fall Walleye Index Netting

We captured a total of 2,456 fish during the fall index netting, of which 2,429 were sacrificed (Table 2). Fourteen species were captured, but approximately 85.7% of all individuals were Yellow Perch. The Yellow Perch population was dominated by individuals less than 150 mm in length (Figure 5), with a proportional stock density of approximately 13.9% for individuals greater than 200 mm. In other words, only 73 of the 2,105 captured Yellow Perch were larger than approximately eight inches. Relative weight (W_R) of Yellow Perch was low (Figure 6) consistent with populations from northern latitudes and populations with low proportional stock density (Willis et al. 1991).

Young of the year Walleye averaged 194.4 mm in length (Figure 2), larger than the state average of 180 mm (Schneider et al. 2000). While W_R of Walleye in Brevoort Lake was low (mean = 84.9, Figure 7), this is within the upper 75% percentile of all walleye populations used to estimate a standard weight equation (Murphy et al. 1990). While Walleye in Brevoort Lake appear to be thinner for their length than the average population, they grow faster than average across their first five years of life (Figure 8). This growth appears to slow to below state average in the older age classes, however the growth index (14.9 mm) indicates the population growth rate is satisfactory (Schneider et al. 2000). Both the young of the year and juvenile age classes were dominated by stocked individuals (Table 3) indicating natural reproduction of Walleye in the last 3 to 4 years has been is negligible.

See Appendix A for length frequency histograms and plots of relative weight for Northern Pike, Spottail Shiner, Rock Bass and White Sucker.

Fall Walleye Abundance Estimates

Annual survival of adult male Walleye was estimated to be 0.777 (95% confidence interval from 0.757 to 0.796), which was higher than the annual survival of adult female Walleye estimated to be 0.718 (95% confidence interval from 0.673 to 0.751). Catchability of adult walleye in the fall netting was estimated to be 0.375 (95% confidence interval from 0.149 to 0.677). This is below the rangewide estimates for FWIN surveys in Ontario (0.98, P. Addison *personal communication*). These survival and catchability coefficients lead to an estimated spring abundance for 5,420.1 adult walleye (95% confidence interval from 2,587.8 to 18,799.7 Walleye).

Fall Walleye Electrofishing Survey

Eight non-young of the year Walleye were captured on October 14th, before the survey had to be suspended due to inclement weather. On October 22nd, 57 total walleye were captured, with five of those individuals in the young of the year length class.

Discussion

Both spring and fall adult Walleye population estimates produce similar density estimates of between 3.10 and 3.28 adult walleye per hectare. The adult walleye population was higher than the last estimate in 2011 of 4,251 fish (C. Bassett *unpublished data*). It is unclear if the change in the population estimate represents a true growth in the population, due to the differing effort and analysis methods employed in the 2015 survey. The juvenile Walleye population appears to almost exclusively come from a stocked origin. These density estimates are slightly above average estimated densities in stocked lakes in Northern Wisconsin. While the walleye population appears to be thin for its length, growth rates are above average for the state of Michigan.

The Yellow Perch population in Brevoort Lake appears to be dominated by individuals in a small size class. Despite their small size, over 98% of all tested Yellow Perch were sexually mature. However, the proportional stock desnsity and W_R of Yellow Perch were not out of the ordinary for what has been observed in other Northern populations (Willis et al. 1991). Aging structures have been collected which could be analyzed in the future to test growth rates in this population relative to the state average.

Table 1. The number of males (♂), females (♀), and unknown sex (?) walleye captured on a given date with a given method during the spring walleye abundance survey.

Date	Method	Effort	Capture				Mark				Recapture			
			♂	♀	?	Total	♂	♀	?	Total	♂	♀	?	Total
4/28/2015	Trap Net	5 net nights	151	40	1	192	0	0	0	0	0	0	0	0
	Electrofish	2,718 seconds	91	12	0	103	151	40	1	192	11	3	0	14
4/29/2015	Trap, Fyke Net	8 net nights	310	32	4	346	231	49	1	281	4	2	0	6
	Electrofish	12,003 seconds	111	9	5	125	537	79	5	621	29	0	0	29
4/30/2015	Trap, Fyke Net	13 net nights	201	44	3	248	619	88	10	717	14	5	0	19
	Electrofish	12,294 seconds	19	40	16	75	806	127	13	946	6	1	1	8
5/1/2015	Trap, Fyke Net	14 net nights	174	23	4	201	819	166	28	1013	33	4	1	38
5/2/2015	Trap, Fyke Net	13 net nights	125	7	8	140	960	185	31	1176	32	3	0	35
5/3/2015	Trap, Fyke Net	12 net nights	58	4	11	73	1053	189	39	1281	13	0	3	16
5/4/2015	Electrofish	31,352 seconds	66	8	56	130	1098	193	47	1338	29	0	1	30

Table 2. The number fish of a given species caught, sacrificed and released during the Fall Walleye Index Netting from October 4th to October 8th, 2015.

Species	Captured	Sacrificed	Released
Bluegill	1	1	0
Bowfin	1	0	1
Bullhead	5	4	1
Cisco	1	1	0
Common Carp	1	1	0
Muskellunge	2	1	1
Northern Pike	56	41	15
Pumpkinseed	4	4	0
Rock Bass	68	67	1
Smallmouth Bass	7	2	5
Spottail Shiner	32	32	0
Walleye	75	75	0
White Sucker	98	97	1
Yellow Perch	2105	2103	2
Total	2456	2429	27

Table 3. The number Walleye of either stocked or natural origin in the young of the year (YOY), juvenile and adult age classes in Brevoort Lake. Samples were collected during the Fall Walleye Index Netting from October 4th to October 8th, 2015.

Age Class	Stocked	Natural	Unknown	Total
Young of the Year	11	1	0	12
Juvenile*	35	1	1	37
Adult‡	6	20	0	26

* One juvenile sample was unreadable.

‡ Not all stocked Walleye in the adult age classes received an OTC mark, indicating this is an upper bound on the proportion of adult walleye naturally produced in the lake.

Figure 1. FWIN sampling grids located on Brevoort Lake. Shading indicates depth stratum, with less than 2 m deep, 2-5 m depths, and 5-15 m depths indicated by progressively darker shading. Net grids in the 2-5 m stratum are indicated by open squares, and net grids in the 5-15 m stratum are indicated by cross-hatched squares.

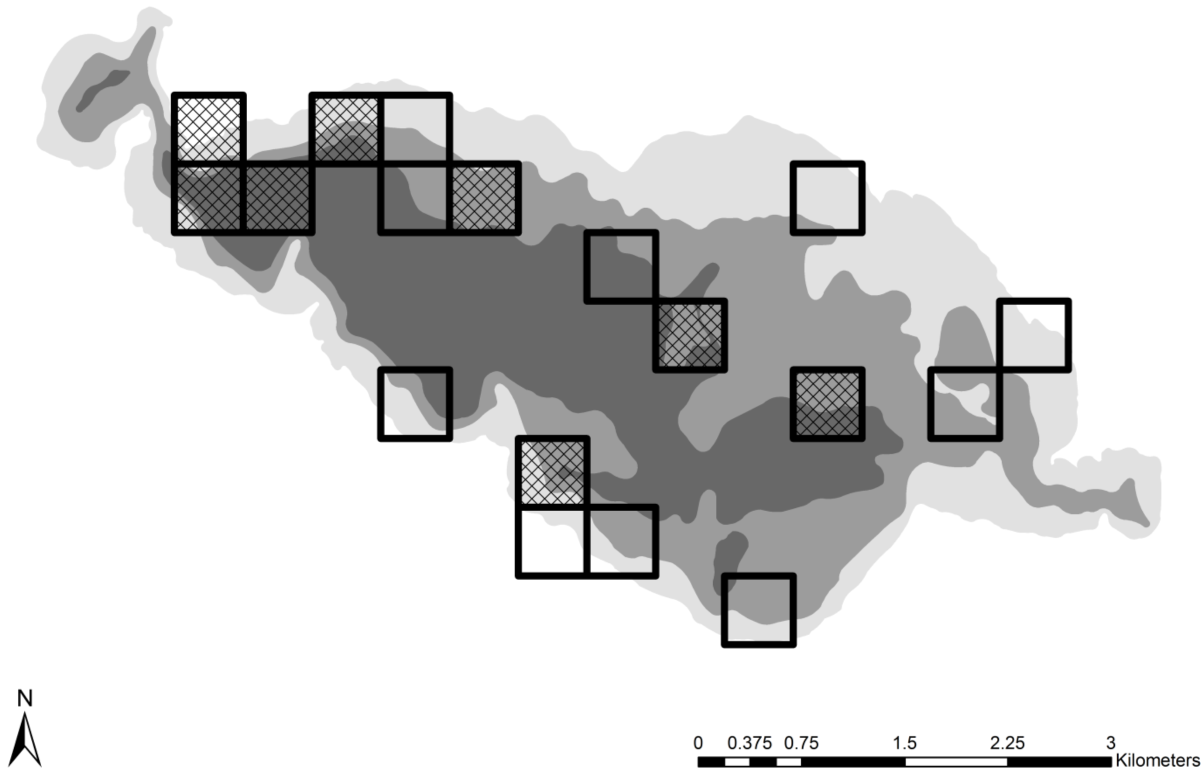


Figure 2. Length frequency histogram of Walleye captured in the Fall Walleye Index Netting survey.

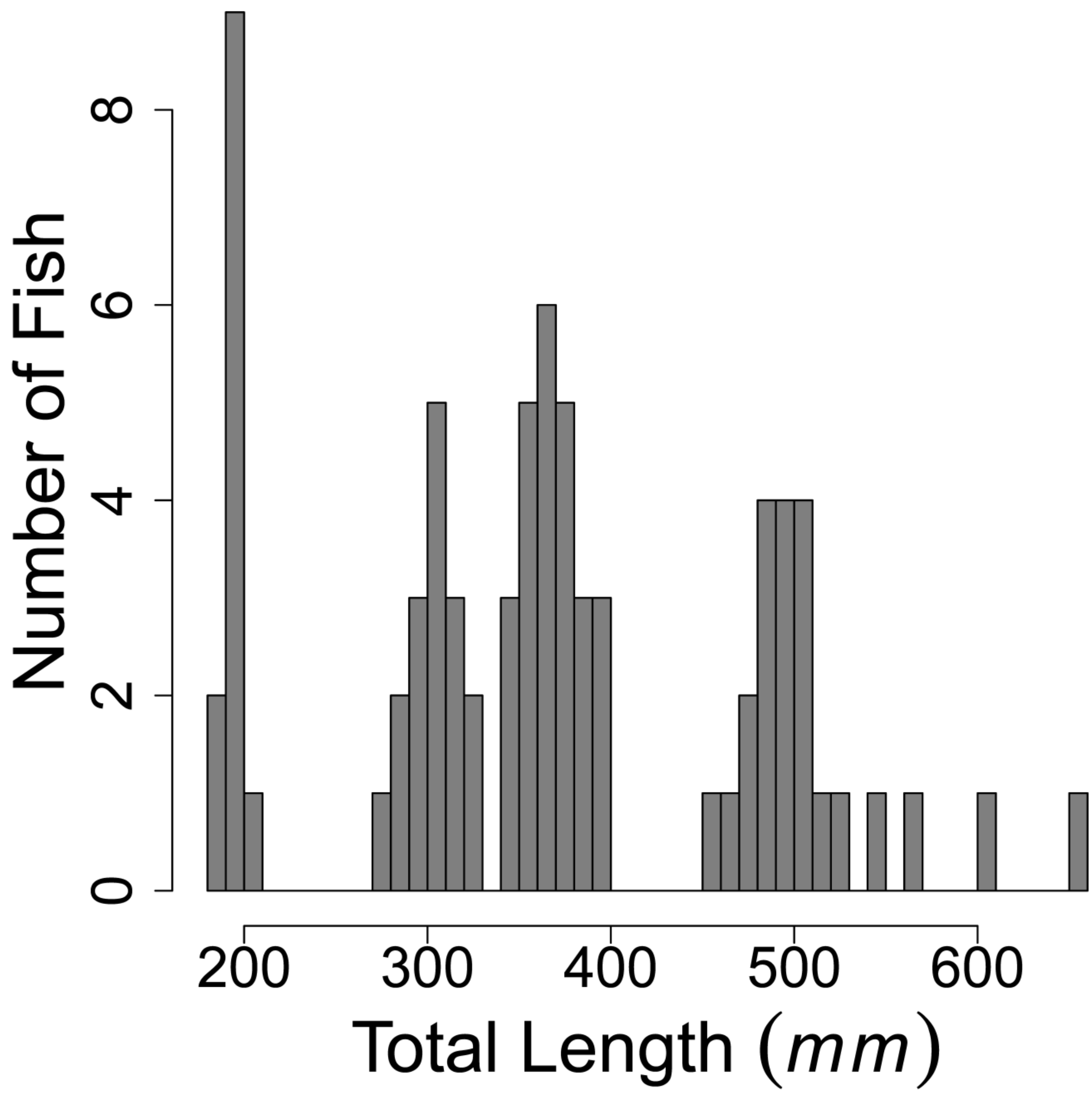


Figure 3. Catch per unit effort (CPUE) from trap and fyke nets deployed off the artificial spawning reef and in Christensen's Bay in Brevoort Lake between April 28th and May 3rd, 2015.

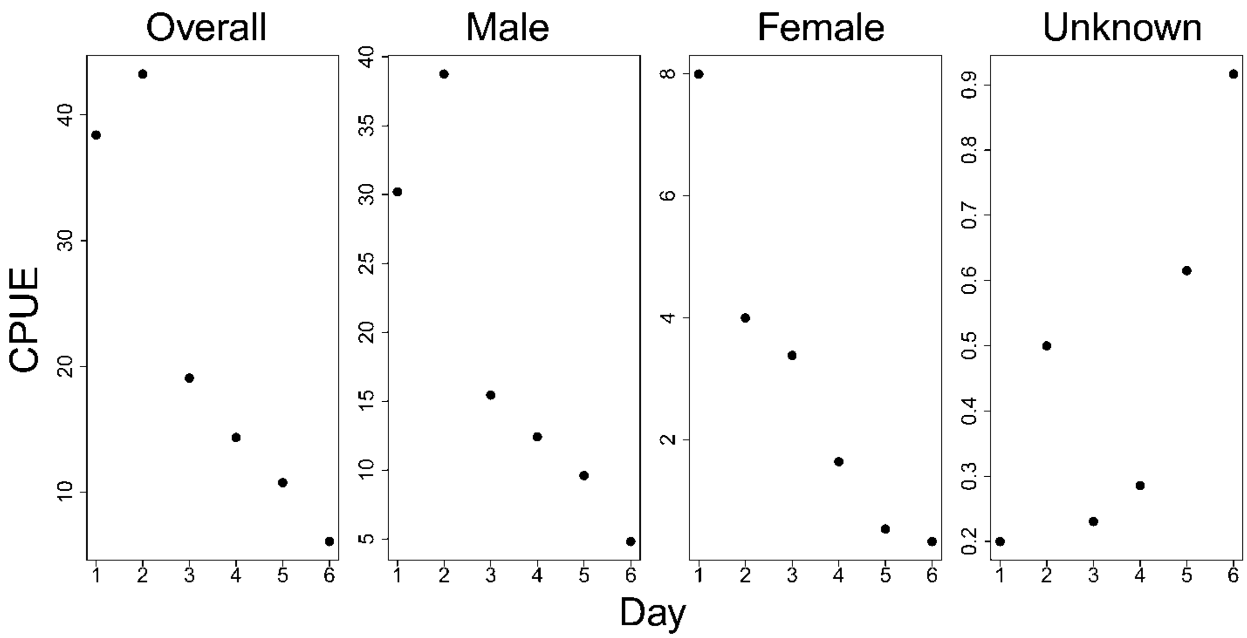


Figure 4. Catch per unit effort (CPUE) from electrofishing runs completed in Brevoort Lake between April 28th and April 30th, 2015.

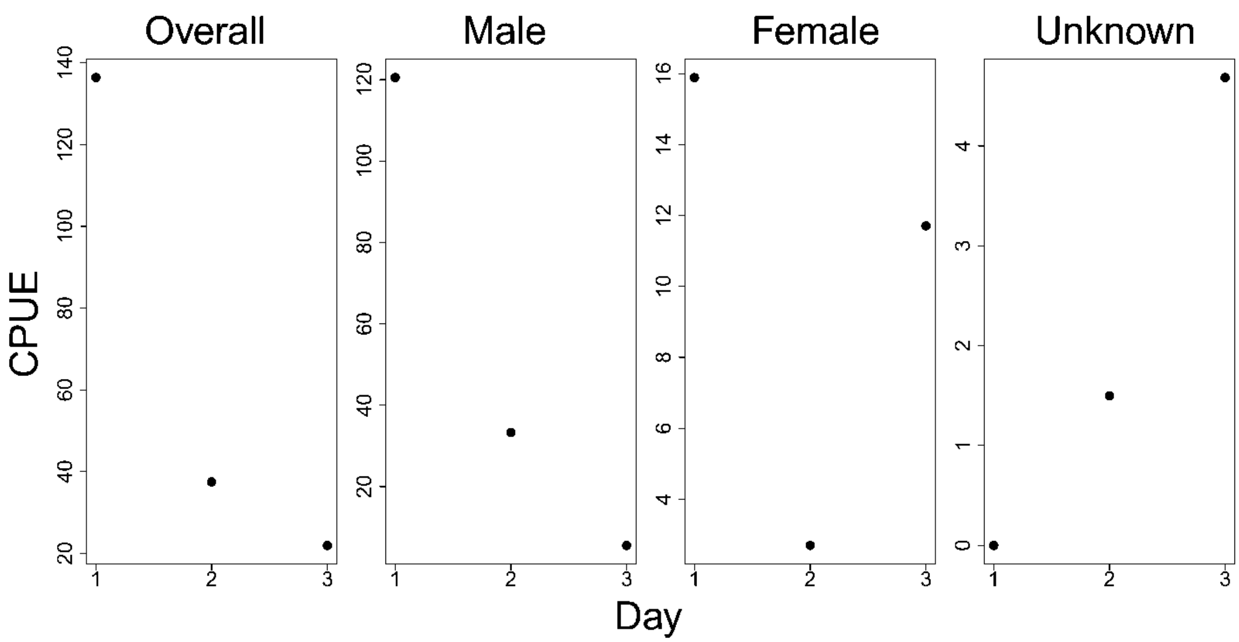


Figure 5. Length frequency histogram of Yellow Perch captured in the Fall Walleye Index Netting survey.

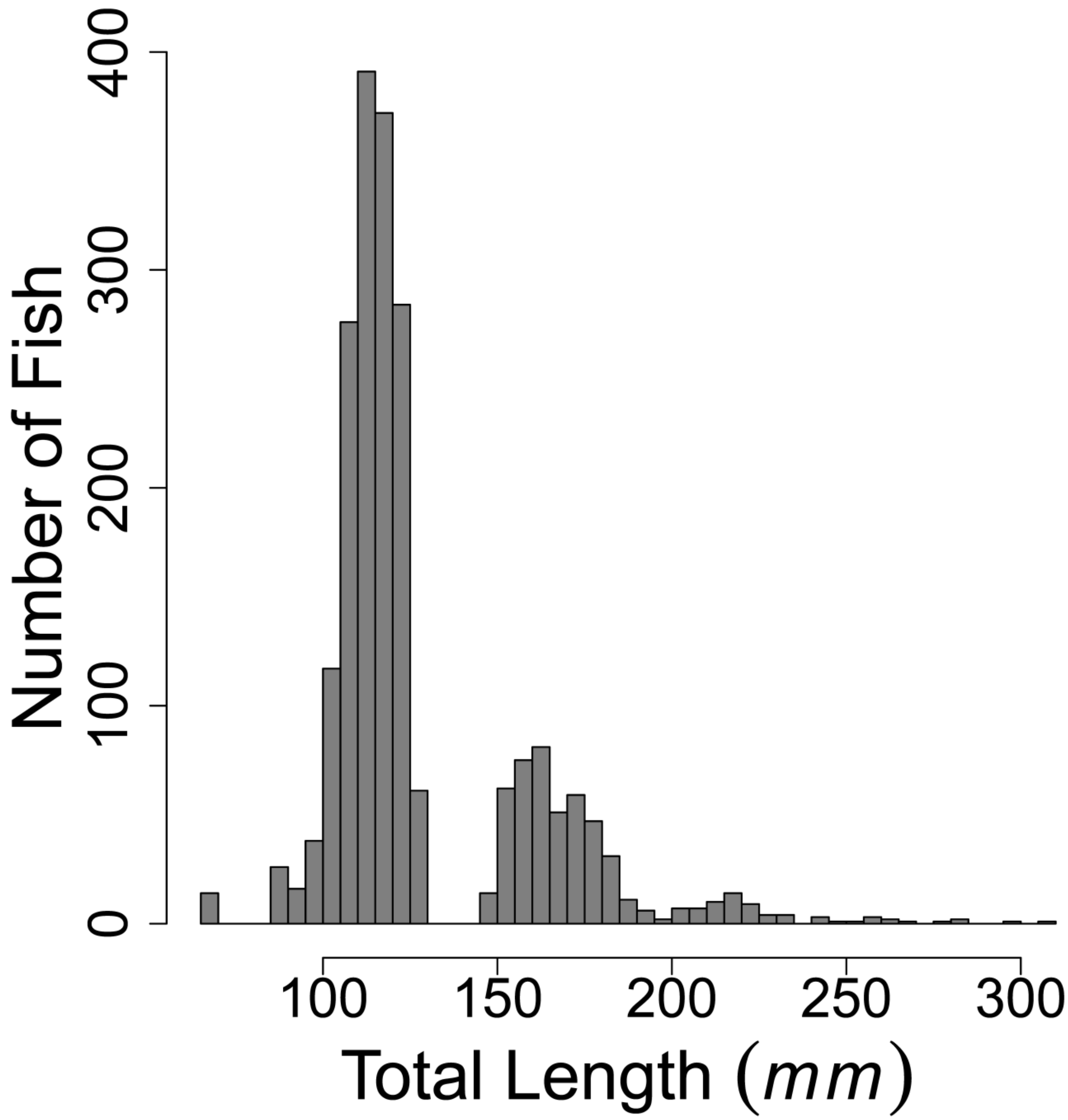

Number of Fish
0
100
200
300
400
100
150
200
250
300
Total Length (mm)

Figure 6. Relative weight (W_R) of Yellow Perch captured in the Fall Walleye Index Netting survey.

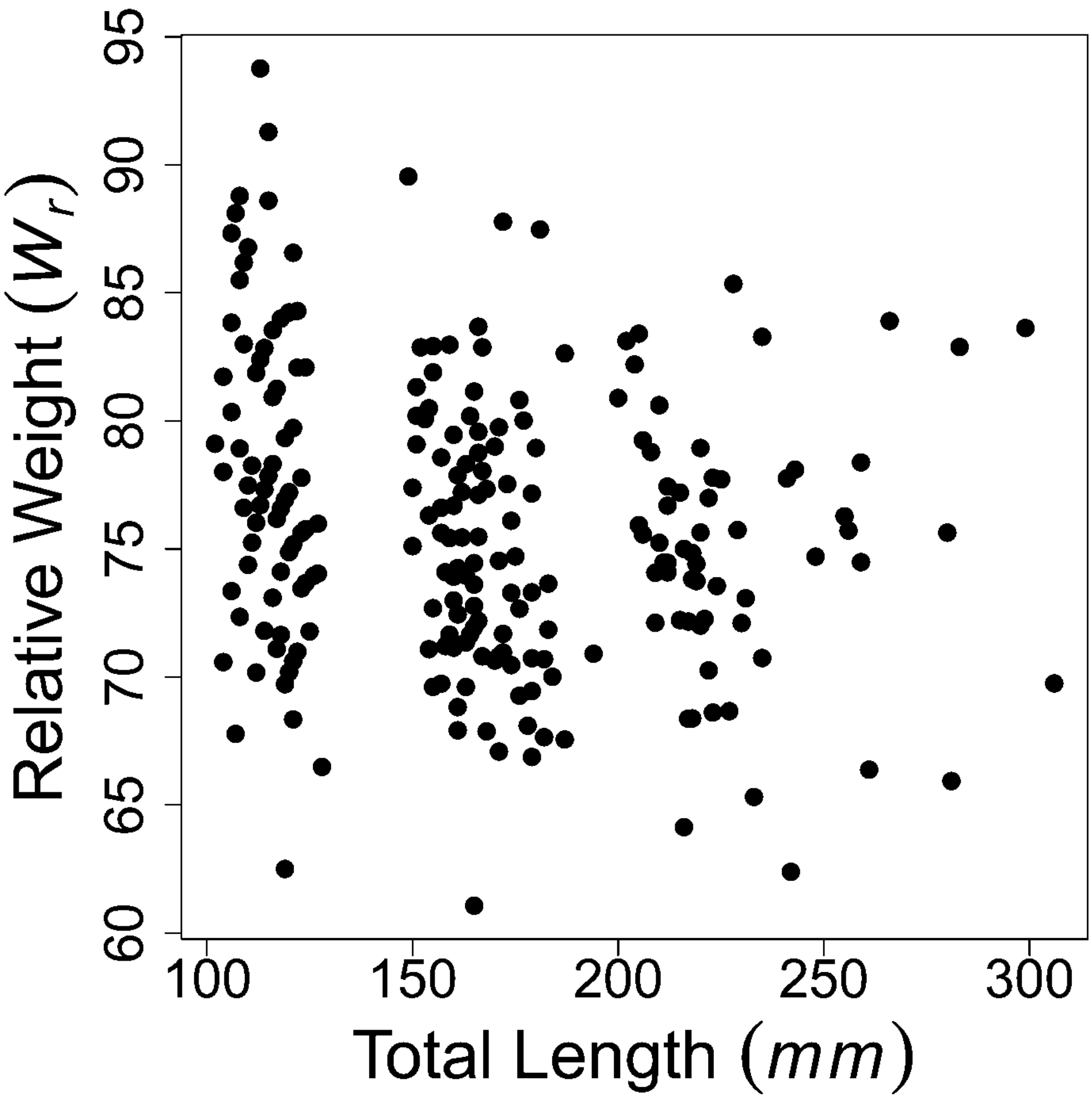


Figure 7. Relative weight (W_R) of Walleye captured in the Fall Walleye Index Netting survey.

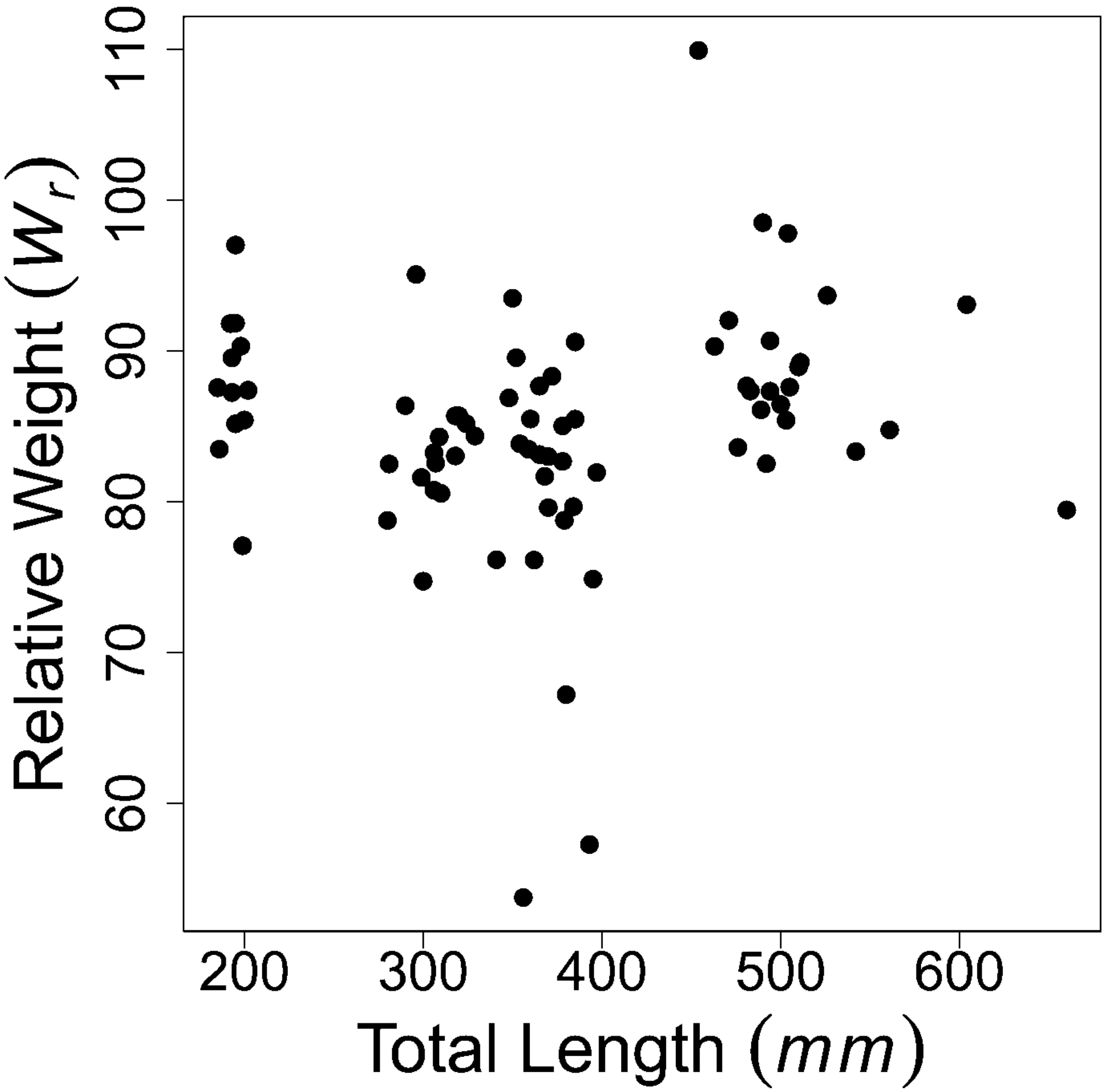
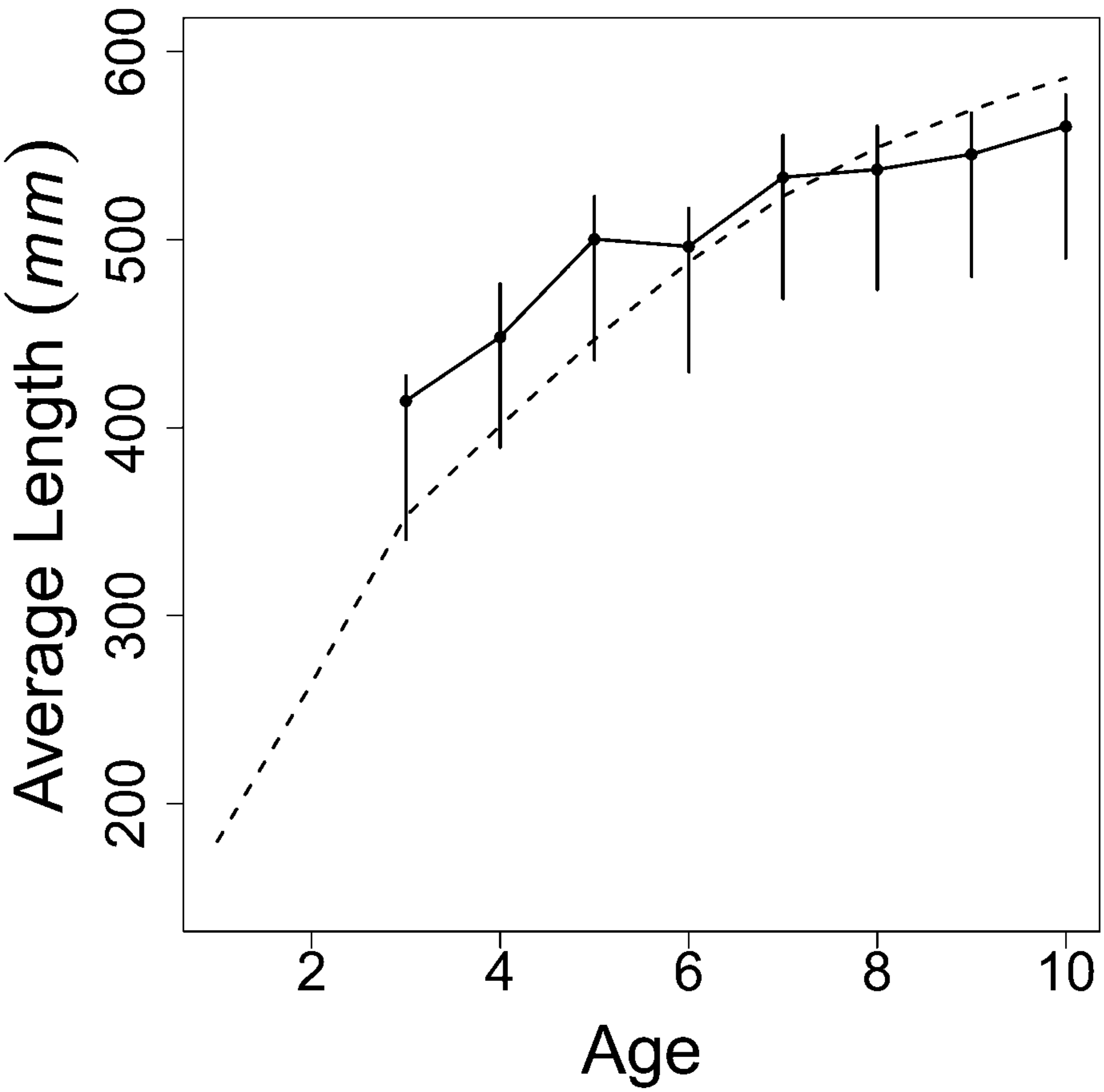


Figure 8. Growth rates of Walleye, and associated 95% confidence intervals (vertical lines), in Brevoort Lake (solid line) relative to state of Michigan average growth rates (dashed line).



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Appendix A

Figure A1. Length frequency histogram of Northern Pike captured in the Fall Walleye Index Netting survey.

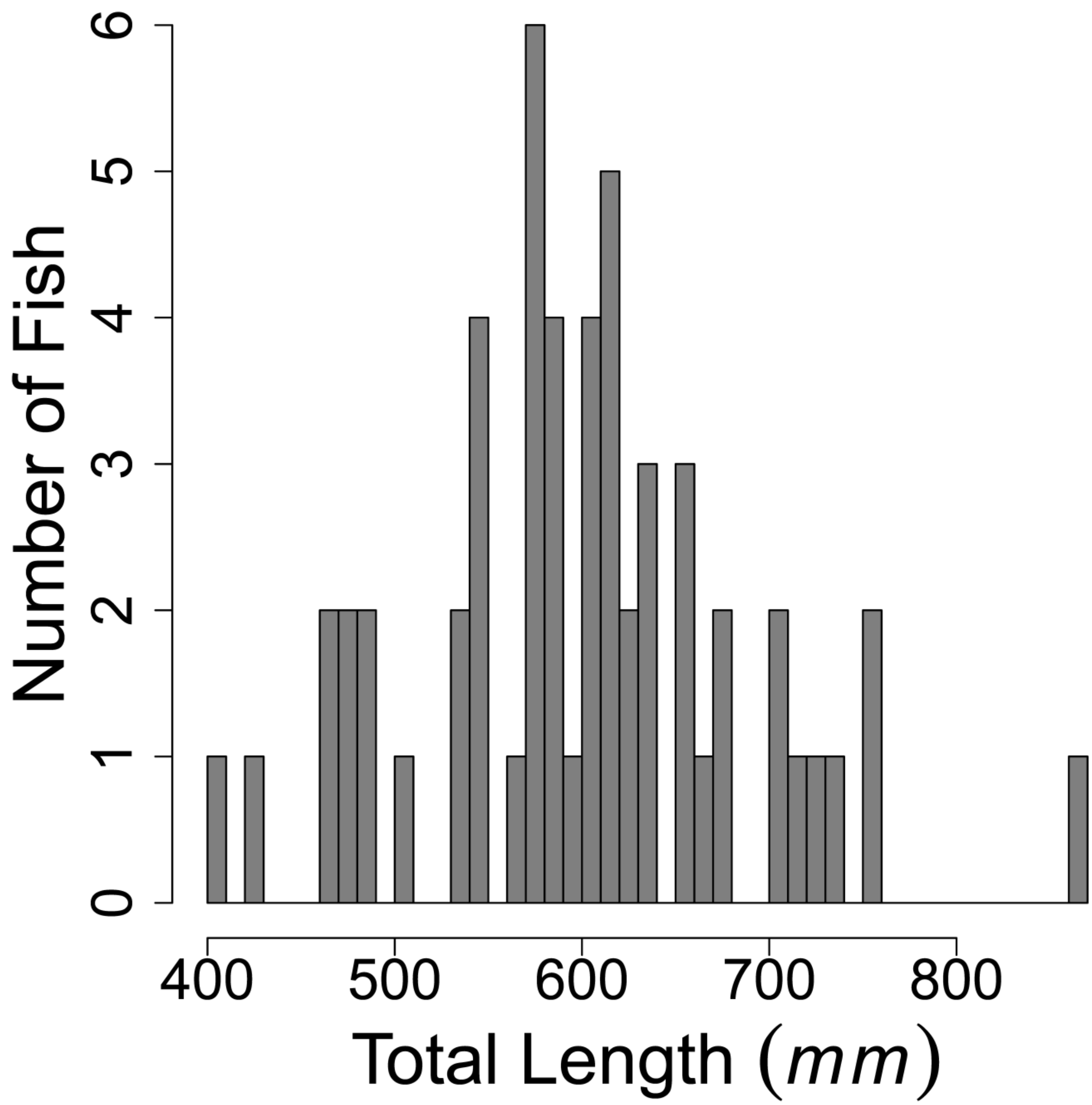

Figure A2. Relative weight (W_R) of Northern Pike captured in the Fall Walleye Index Netting survey.

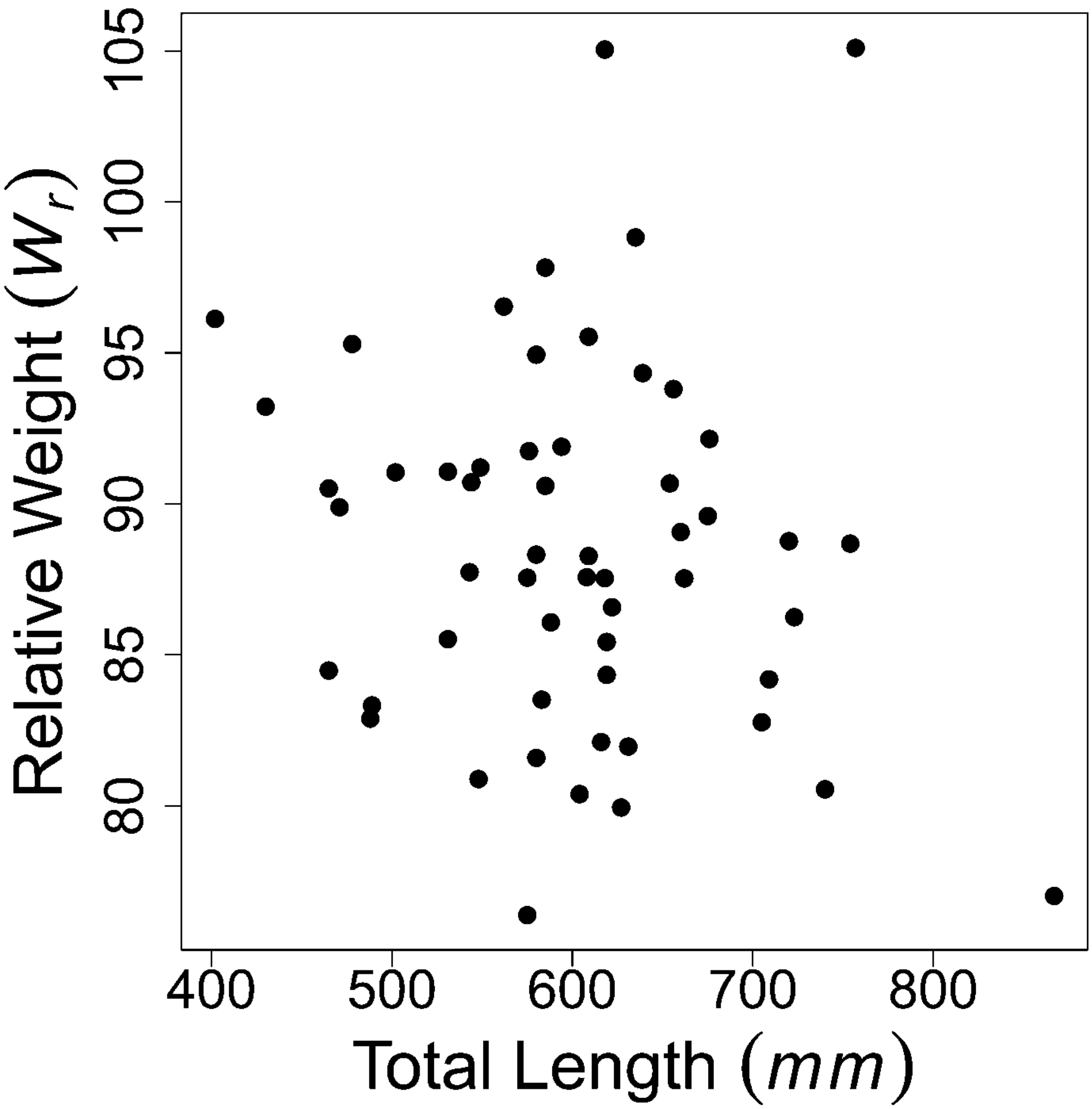

Figure A3. Length frequency histogram of Spottail Shiner captured in the Fall Walleye Index Netting survey.

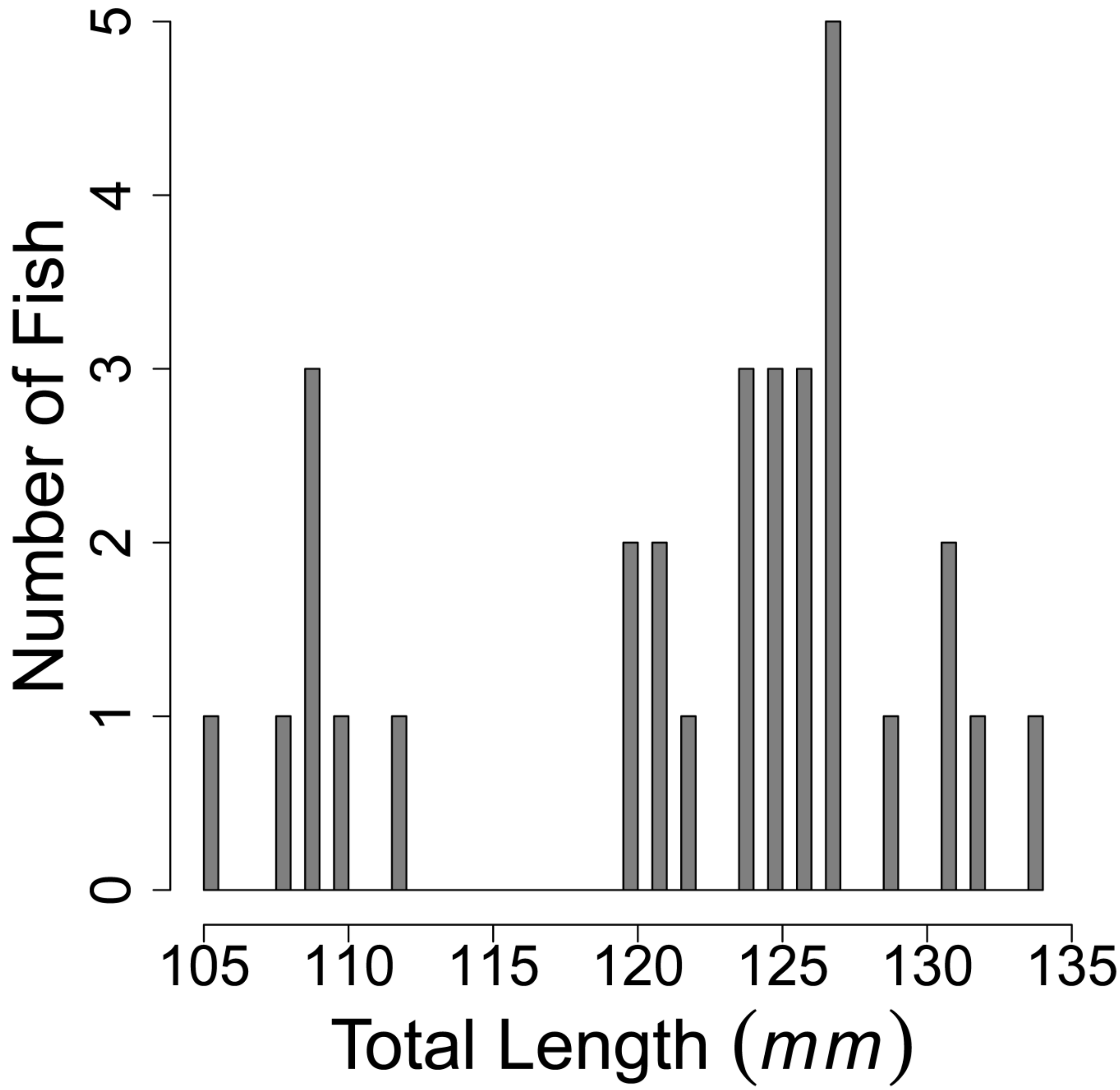

Figure A4. Length frequency histogram of Rock Bass captured in the Fall Walleye Index Netting survey.

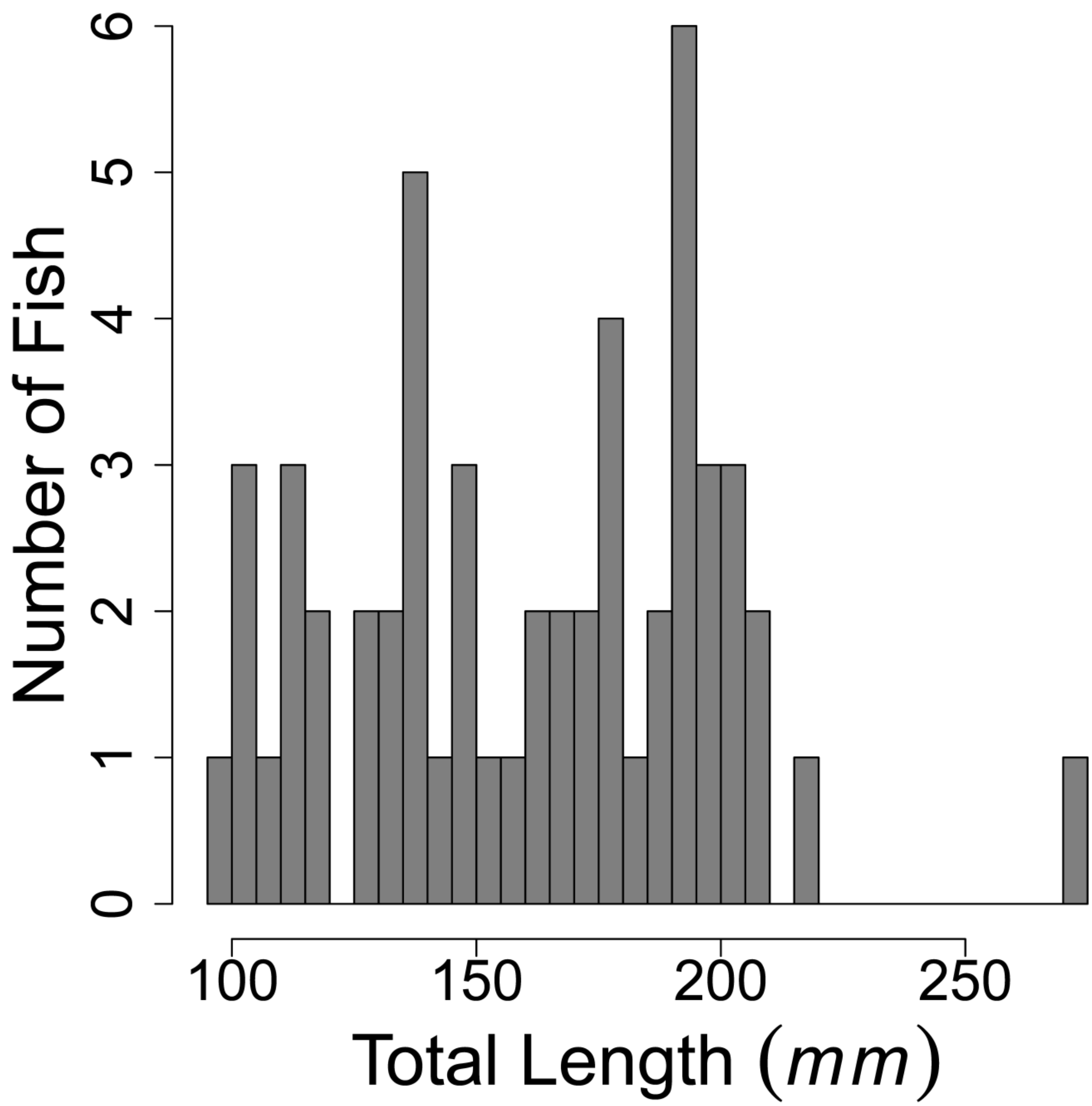

Figure A5. Relative weight (W_R) of Rock Bass captured in the Fall Walleye Index Netting survey.

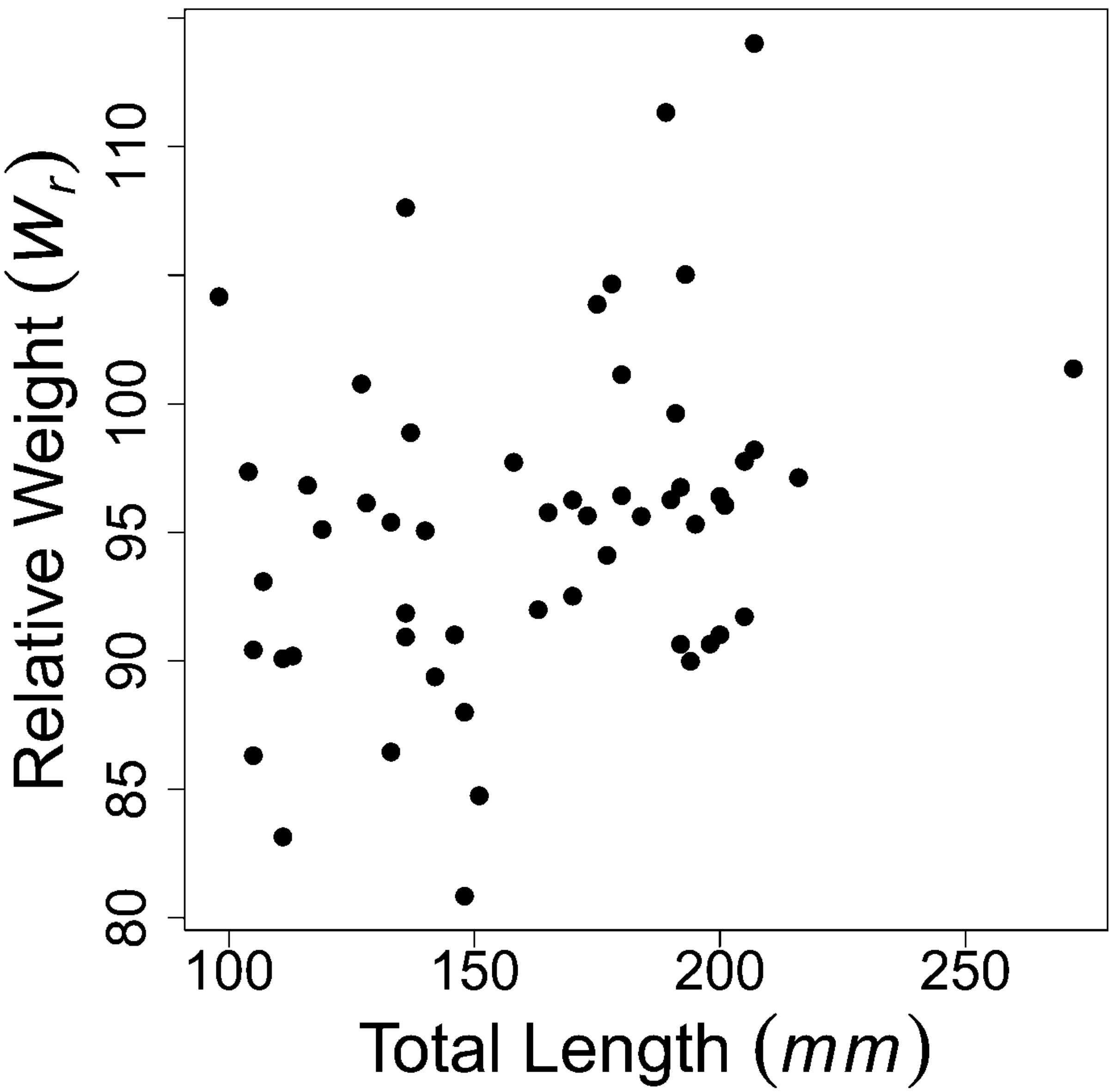

Figure A6. Length frequency histogram of White Sucker captured in the Fall Walleye Index Netting survey.

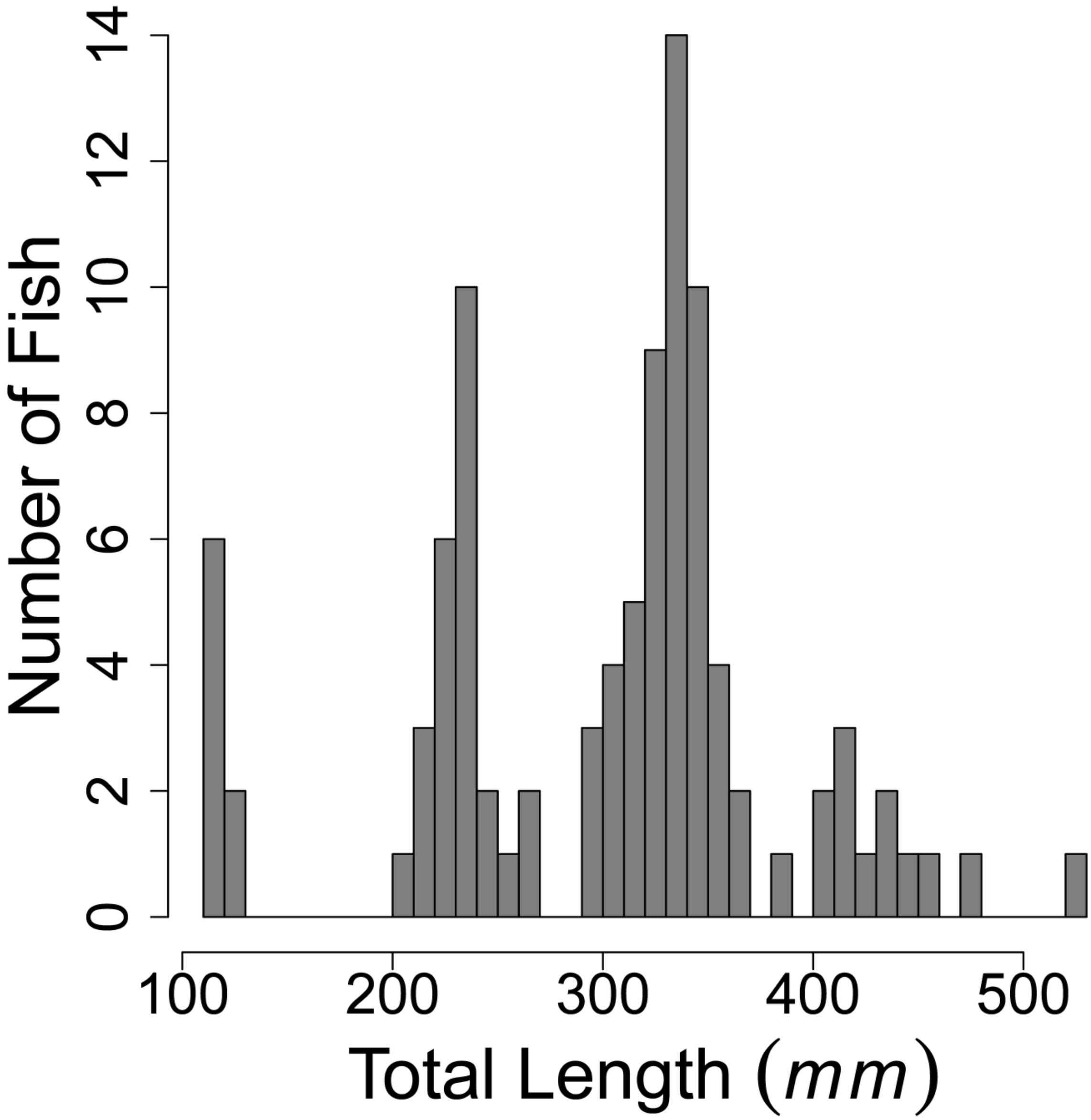

Figure A7. Relative weight (W_R) of White Sucker captured in the Fall Walleye Index Netting survey.