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Mark-Recapture Study of the Spring 2009 Walleye Population in the Woman Chain of Lakes Cass County, MN

By

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Abstract

A mark-recapture study of the walleye population in the Woman Chain of lakes in northern Cass County, Minnesota was conducted to provide precise estimates of spawning stock biomass, to verify estimates of walleye abundance derived from Anderson's (1998) gillnet catchability model, and to provide fisheries managers with additional insight to spawning movements and habitat use. Mature fish were tagged with individually numbered t-bar anchor tags during the spawning period from 18 April 2009 to 7 May 2009, and recapture sampling was conducted with gillnets fished throughout the chain during 1 - 17 June 2009. We did not find evidence of walleyes spawning anywhere in the chain other than the Boy River between Child Lake and Bungey Bay. A geographically stratified Petersen study design was followed, but stratification turned out to be unnecessary due to complete mixing of tagged fish throughout the chain after spawning. The pooled Petersen population estimate of walleyes ≥ 13 in for the entire chain was 9,149 fish (95% confidence interval 8,162-10,135), or an average density of 1.5 fish/acre. Fall 2008 population estimates calculated using Anderson's (1998) gillnet selectivity model were consistently lower than the 2009 spring Petersen estimates, and the discrepancy increased with increasing minimum lengths of fish included in the estimates. The estimates from the gillnet selectivity model probably were biased low.

Introduction

The Woman Chain of lakes is the site of a major walleye spawn-taking operation by the Minnesota Department of Natural Resources (DNR), and Woman Lake is one of four spawn-take lakes in an ongoing federal-aid research project evaluating the traditional policy of stocking back 10% of the fry (F-26-R, Minnesota, Study 644). A mark-recapture study of the walleye population in the Woman Chain was initiated to provide precise estimates of spawning stock biomass needed for Study 644. It would also allow for verification of estimates of walleye abundance derived from Anderson's (1998) catchability model, and provide fisheries managers with additional insight to spawning movements and habitat use.

Study Area

The Woman Chain (defined as Child Lake, Little Woman Lake, the Boy River between Child Lake and Woman Lake, Woman Lake, and Girl Lake) comprises approximately 6,264 acres in northern Cass County, Minnesota (46.95° N, 94.28° W). The Boy River flows through the chain from a small marshy inlet on Child Lake down to a small dam at the outlet on the east end of Girl Lake, and there is also a marshy connection to Black Water Lake through a small culvert (Figure 1). It appeared unlikely that substantial numbers of adult fish would move in or out of the chain through the small inlets or dammed outlet, so we considered the chain a geographically closed system.

Methods

Mature fish were tagged with individually numbered Hallprint Model TBA-1 t-bar anchor tags during the spawning period from 18 April 2009 to 7 May 2009. Tags were inserted at the base of the soft dorsal fin; virtually all females and 33% of males were double-tagged to minimize complete tag loss and allow estimation of the tag loss rate. We determined the sex of tagged fish by extrusion of gametes. Fish were captured at the Boy River spawning trap during the normal spawn-taking procedure; we also attempted to capture as many fish as possible using up to 100 trap nets at many locations throughout the chain, and by nighttime electrofishing in Woman Lake and the Boy River between Child and Woman lakes.

Recapture sampling was conducted with gillnets fished throughout the chain during 1 - 17 June 2009. Nets were 300' X 6' monofilament with 100' panels of 1.5", 2.0", and 2.5" bar mesh. Most net sets were of short duration during twilight and nighttime to maximize catch rates and minimize mortality. Dissection of 167 untagged fish that died in the nets allowed us to estimate sex and maturity ratios of all untagged fish. Sex and maturity ratios of all 640 untagged fish captured during the recapture period were assumed to be the same as the sample that was dissected, pooled over all recapture strata. We assumed there was no recruitment of unmarked fish due to growth between marking and recapture periods; in support of this assumption, measured lengths of recaptured fish at the time of recapture averaged 3.7 mm smaller than at the time of marking (probably due to measurement error).

We used a geographically stratified Petersen study design (Schwarz and Taylor 1998) and analyzed the data with computer program SPAS (Arnason et al. 1996); this is similar to recent Mille Lacs population estimates (Schwarz 2009). Marking strata sampled during the spawning period were Child Lake, the Boy River between Child and Woman lakes including the spawning trap and Little Woman Lake, Bungey Bay, the SW main basin of Woman Lake, the NE main basin of Woman Lake, Broadwater Bay, and Girl Lake. Tagged fish were released in the same strata where they were captured. Recapture strata sampled in June were the same as marking strata except we did not sample the Boy River or Little Woman Lake. The validity of assumptions required for potential pooling of strata was examined using the "Complete Mixing" and "Equal Proportions" chi-square tests that were generated by SPAS (Arnason et al. 1996).

Tag loss was estimated and population estimates were adjusted using the methods of Seber (1982), assuming each tag of a double-tagged fish was independent of the other and had the same probability of loss. Since there was undoubtedly a lack of demographic closure due to natural and fishing mortality between marking and recapture periods (the walleye angling season opened on 9 May 2009), the abundance estimates represented the population at the time of marking, not at the time of recapture (Arnason et al. 1996). We did not adjust population estimates for possible mortality of marked fish due to handling and tagging.

Biomass estimates were calculated as follows. Each tagged fish was assigned an estimated weight using the equation $W = (1.65 \text{ X } 10^{-6})L^{3.27}$, where W = weight in grams and L = total length in millimeters. For each segment of the population, the mean weight of all tagged fish was then multiplied by the population estimate and converted to pounds. The length-weight

equation was derived from regression analysis of fish measured and weighed during pooled 2007-2008 Woman Lake fall gillnet assessments. Using a length-weight equation based on pooled sexes of fall-captured fish probably underestimates biomass of spring pre-spawn fish, especially females, because the weight of the ripe gonads is not included.

Anderson's (1998) gillnet selectivity (q_abg) model was used to calculate alternative population estimates for comparison with the mark-recapture estimates. The q_abg estimates were based on 2008 fall gillnet catches of walleyes ≥ 15 inches in Woman Lake only, but were expanded to the acreage of the entire Woman Chain. Confidence intervals of the q_abg population estimates were calculated using bootstrap methods described by Haddon (2001), where population estimates calculated from individual net catches served as the pool for resampling.

Results and Discussion

A total of 2,364 mature walleyes ≥ 13 in TL were tagged and of these, 218 were recaptured (Table 1). Examining Table 1, it is apparent that fish tagged in the Boy River and Bungey Bay dispersed throughout the chain between the marking period in late April-early May and the recapture period in June. Primarily for this reason, each subset of the population passed at least one of the SPAS chi-squared tests ($P > 0.05$; Table 2), suggesting stratification was unnecessary (Arnason et al. 1996). In addition, preliminary calculations of both stratified and pooled estimates revealed little difference except for greater precision of the pooled estimates. Therefore, we only present pooled estimates for the entire chain.

Pooled Petersen estimates for various segments of the walleye population of the entire chain during the 2009 spawning period are listed in Table 3. We tagged 36% of the estimated population of mature fish; therefore, 95% confidence limits are reasonably precise (± 10-15%). The estimated probability of loss of each tag between marking and recapture periods was 2.8%, so the estimated probability of a double-tagged fish losing both tags was 2.8% ·2.8% = 0.077%. Since a lower proportion of males than females were double-tagged, some subsets of the population for which abundance estimates were calculated had a higher probability of complete tag loss than others, but even in the worst case (mature males) adjustment for tag loss only reduced the population estimate by 1.7%.

Fall 2008 population estimates calculated using Anderson's (1998) gillnet selectivity model were substantially lower than the 2009 spring mark-recapture estimates; the discrepancy increased from -30% for fish ≥ 15 in to -57% for fish ≥ 21 in (Figure 2). Any mortality of marked fish due to handling and tagging would inflate the mark-recapture estimates by approximately the same percentage as the mortality rate, but visual observations in the shallow, clear Boy River where the great majority of fish were tagged and released indicated short-term mortality due to handling and tagging was negligible, consistent with other studies (Pierce and Tomcko 1993; Scholten et al. 2002; Schwarz 2009). In addition, if a substantial percentage of tagged walleyes had died shortly after moving out of the Boy River into the lakes, the public

probably would have reported tagged fish floating or washed up on the lakeshores. Therefore, we believe the q_abg estimates are biased low. Part of the discrepancy may be due to small samples of gillnet fish ($n \leq 42$) available to calculate the q_abg estimates in Woman Lake, but we suspect the q_abg model also systematically underestimated abundance. The q_abg model was originally parameterized using walleye population data obtained from Lake Mille Lacs (Anderson 1998), therefore differences in walleye behavior between Mille Lacs and Woman Lake could cause walleyes to encounter gill nets at different rates in the two lakes. Another source of uncertainty in the q_abg model that could result in bias was caused by the small sample sizes of large walleyes in the dataset used to develop the model originally. Subsequent Petersen mark-recapture estimates of the walleye population of Lake Mille Lacs itself also resulted in higher abundance estimates than those obtained by the q_abg model. Consequently, it was not unexpected for the q_abg abundance estimates for the Woman Chain to be lower than the Petersen estimates, especially in light of the high proportion of large walleyes in the gill net catch (Charles Anderson, Minnesota DNR, personal communication).

We had expected to find lake spawning sites during the marking period. However, despite setting up to 100 trap nets repeatedly at various locations throughout the chain and electrofishing at night on what appeared to be typical rocky shoal walleye spawning habitat in the main part of Woman Lake (Scott and Crossman 1973; Becker 1983), we only found concentrations of mature walleyes associated with the Boy River at the upstream end of the chain. In addition, we occasionally attempted to collect walleye eggs from potential spawning locations using fine-mesh dip nets. Although sampling effort was low and did not follow a systematic sampling design, we were able to collect walleye eggs easily from the Boy River and the river mouth in Bungey Bay, but did not find any on the rocky shoals in the main part of Woman Lake. The trapnetting, electrofishing, and egg sampling results suggest little or no lake spawning in 2009. However, the fact that we only captured 36% of the estimated population of mature fish during the spawning period despite extremely intensive sampling effort in the Boy River and Bungey Bay leaves open the possibility that either a substantial portion of the population spawned in unknown locations, or that not all mature fish actually attempted to spawn in 2009.

The 2009 walleye population estimate of the Woman Chain was lower and the average weight was smaller than when previous mark-recapture estimates were made in 1996-1997 (Table 4); however, the 1996-1997 population estimates had large standard errors and the recapture samples were primarily based on angler creel survey sampling of Woman Lake only, with no adjustment for emigration of marked fish to Child or Girl lakes (Gustafson 1998). Gustafson (1998) considered emigration negligible based on a low proportion of voluntary angler tag returns from outside of Woman Lake itself, but this assumption does not account for the possibility of lower targeted walleye angling effort, catch rate, or tag reporting rate on Child and Girl lakes than on Woman Lake. In 2009, 12.6% of gillnet recaptures of fish tagged in the Boy River came from Child and Girl lakes (Table 1). If behavior of marked fish in 1996-1997 was actually similar to that in 2009, the population estimates reported by Gustafson (1998) were

inflated by approximately the same percentage as the percentage of emigrants – possibly 10% or more. Given the large standard errors of the 1996-1997 population estimates and the questionable assumption of no emigration from Woman Lake itself, it is unclear whether population density of the entire chain was actually much, if any, lower in 2009 than in 1996-1997.

Woman, Ten Mile, Big Sand, and Whitefish are all Class 22 lakes (Schupp 1992) that have had mark-recapture walleye population estimates (Table 4). Sizes of fish included in the estimates are not totally consistent among lakes, but close enough for comparisons. Ten Mile Lake is just a few miles west of the Woman Chain, and its estimated walleye density in 1995 was about the same as the Woman Chain in 1996. The densities found in Big Sand Lake in the early 1990s were substantially higher and average weights were smaller than in the Woman Chain in 2009. However, the estimated density in the Whitefish Chain in 2005 was close to the Woman Chain in 2009. This is interesting because the Whitefish Chain is similar in many ways to the Woman Chain, including a major spawning run up the Pine River inlet (Knapp 2006). So, although the overall Woman Chain densities seem low, they may not be unusual for a river-spawning population in a lake chain with some connected lakes or bays (e.g., Child Lake, Broadwater Bay) that are inhabited by walleyes at times, but probably are not optimal adult walleye habitat for much of the year and therefore result in decreased average density estimates.

Management Recommendations

The population of walleyes ≥ 13 inches in the Woman Chain during the spawning season of 2009 was characterized by a relatively low density and large average size compared to other Class 22 lakes, suggesting a recent history of limited recruitment. However, lake survey gillnetting has indicated a strong 2006 year class that should begin contributing to the fishery in the near future (Calub Shavlik, Minnesota DNR Walker Area fisheries office, personal communication). Therefore the population may already be shifting to a higher density and lower average size, which should moderate immediate concerns about inadequate recruitment.

The current q_abg model probably underestimates walleye abundance in the Woman Chain. Consequently, this bias should be taken into account when using the results of the model.

Since we tagged 36% of the estimated population of mature fish in 2009, there should be many recaptures in the Boy River spawning trap in 2010. It should be possible to use the 2010 spawning run sample for another pooled Petersen estimate of the 2009 spawning population after adjusting for a full year of recruitment and tag loss. It should also be possible to get 2009-2010 annual mortality estimates for comparison to those reported by Gustafson (1998). Considering the relative ease of marking and recapturing a large proportion of the adult walleye population in the Woman Chain during annual operation of the spawning trap on the Boy River, consideration should be given to continuing to mark and recapture fish at the trap for several years in order to obtain exceptionally good data on walleye abundance, survival, and movement that could be useful for managing not only the Woman Chain, but also other walleye fisheries in Minnesota.

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References

Anderson, C. S. 1998. Partitioning total size selectivity of gill nets for walleye (*Stizostedion vitreum*) into encounter, contact, and retention components. Canadian Journal of Fisheries and Aquatic Sciences 55:1854-1863.

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences 2106.

Becker, G. C. 1983. Fishes of Wisconsin. The University of Wisconsin Press, Madison.

Gran, J. 1997. Lake survey report for Ten Mile Lake (Div. of Waters No. 11-413) 1995. Minnesota Department of Natural Resources, Section of Fisheries, Walker.

Gustafson, S. P. 1998. Population dynamics of adult walleye in Woman Lake, Cass County, Minnesota. Minnesota Department of Natural Resources, Section of Fisheries, Completion Report for Federal Aid Project F-29-R(P)-17, Study IV, Job 429, St. Paul.

Haddon, M. 2001. Modelling and quantitative methods in fisheries. Chapman & Hall/CRC, Boca Raton, Florida.

Jacobson, P. C. 1994. Population dynamics of large walleye in Big Sand Lake. Minnesota Department of Natural Resources, Section of Fisheries, Investigational Report 436, St. Paul.

Knapp, M. L. 2006. Mark-recapture study of the Pine River walleye stock on the Whitefish Chain of Lakes, Crow Wing County, Minnesota, 2005-2006. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Section of Fisheries, Completion Report for F-29-R-25, Area 212, Study 4, Job 719, St. Paul.

Pierce, R. B., and C. M. Tomcko. 1993. Tag loss and handling mortality for northern pike marked with plastic anchor tags. North American Journal of Fisheries Management 13:613-615.

Scholten, G. D., D. A. Isermann, and D. W. Willis. 2002. Retention and survival rates associated with the use of t-bar anchor tags in marking yellow perch. Proceedings of the South Dakota Academy of Science 81:35-38.

Schupp, D. H. 1992. An ecological classification of Minnesota lakes with associated fish communities. Minnesota Department of Natural Resources, Section of Fisheries, Investigational Report 417, St. Paul.

Schwarz, C. J. 2009. Analysis of the mark-recapture studies for walleye in Mille Lacs, Minnesota: 2008 report -- Work performed under Contract B12818 for the Department of Natural Resources, State of Minnesota. Simon Fraser University, Department of Statistics and Actuarial Science, Burnaby, British Columbia.

Schwarz, C. J., and C. G. Taylor. 1998. Use of the stratified-Petersen estimator in fisheries management: estimating the number of pink salmon (*Oncorhynchus gorbuscha*) spawners in the Fraser River. Canadian Journal of Fisheries and Aquatic Sciences 55:281-296.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184, Ottawa.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, second edition. MacMillan, New York, New York.

Table 1. Numbers of walleyes tagged and recaptured in the Woman Chain during spring 2009. Numbers in parentheses represent total numbers of walleyes captured during the recapture period. Tagging zones of three recaptured fish were unknown because tag numbers were not recorded. These fish were assigned to the Boy R. tagging zone for the purpose of the stratified population estimates.

>= 13 in

		Number recaptured per zone					
Tagging zone	Number tagged	Child L.	Bungey Bay	Woman SW	Woman NE	Broadwater Bay	Girl L.
Boy R.	1973	8	20	45	77	18	15
Child L.	51	5	0	0	0	0	1
Bungey Bay	292	0	3	6	12	2	1
Woman SW	21	0	0	0	0	0	0
Woman NE	17	0	0	1	0	1	0
Broadwater Bay	4	0	0	0	0	0	0
Girl L.	6	0	0	0	0	0	0
Unknown	0	0	0	0	1	2	0
Totals	2364	13(47)	23(52)	52(253)	90(361)	23(86)	17(55)

>= 14 in

		Number recaptured per zone					
Tagging zone	Number tagged	Child L.	Bungey Bay	Woman SW	Woman NE	Broadwater Bay	Girl L.
Boy R.	1954	8	20	45	77	18	15
Child L.	51	5	0	0	0	0	1
Bungey Bay	287	0	3	6	11	2	1
Woman SW	21	0	0	0	0	0	0
Woman NE	15	0	0	1	0	1	0
Broadwater Bay	4	0	0	0	0	0	0
Girl L.	6	0	0	0	0	0	0
Unknown	0	0	0	0	1	2	0
Totals	2338	13(47)	23(49)	52(240)	89(347)	23(85)	17(54)

>= 15 in

		Number recaptured per zone					
Tagging zone	Number tagged	Child L.	Bungey Bay	Woman SW	Woman NE	Broadwater Bay	Girl L.
Boy R.	1879	8	19	45	72	18	15
Child L.	51	5	0	0	0	0	1
Bungey Bay	279	0	2	6	12	2	1
Woman SW	20	0	0	0	0	0	0
Woman NE	13	0	0	0	0	1	0
Broadwater Bay	4	0	0	0	0	0	0
Girl L.	5	0	0	0	0	0	0
Unknown	0	0	0	0	1	1	0
Totals	2251	13(41)	21(42)	51(206)	85(315)	22(78)	17(53)

Table 1. Continued.

>= 17 in

Tagging zone	Number tagged	Number recaptured per zone: Child L.	Bungey Bay	Woman SW	Woman NE	Broadwater Bay	Girl L.
Boy R.	1684	5	19	40	66	17	15
Child L.	50	5	0	0	0	0	1
Bungey Bay	267	0	2	5	11	2	1
Woman SW	19	0	0	0	0	0	0
Woman NE	8	0	0	0	0	0	0
Broadwater Bay	4	0	0	0	0	0	0
Girl L.	5	0	0	0	0	0	0
Unknown	0	0	0	0	1	1	0
Totals	2037	10(30)	21(35)	45(161)	78(263)	20(68)	17(36)

>= 19 in

Tagging zone	Number tagged	Number recaptured per zone: Child L.	Bungey Bay	Woman SW	Woman NE	Broadwater Bay	Girl L.
Boy R.	1424	5	15	36	61	14	15
Child L.	46	5	0	0	0	0	1
Bungey Bay	252	0	1	5	10	1	1
Woman SW	17	0	0	0	0	0	0
Woman NE	4	0	0	0	0	0	0
Broadwater Bay	4	0	0	0	0	0	0
Girl L.	5	0	0	0	0	0	0
Unknown	0	0	0	0	1	0	0
Totals	1752	10(23)	16(28)	41(144)	72(236)	15(51)	17(34)

>= 21 in

Tagging zone	Number tagged	Number recaptured per zone: Child L.	Bungey Bay	Woman SW	Woman NE	Broadwater Bay	Girl L.
Boy R.	929	4	8	23	44	6	13
Child L.	38	3	0	0	0	0	1
Bungey Bay	187	0	1	4	8	1	1
Woman SW	13	0	0	0	0	0	0
Woman NE	3	0	0	0	0	0	0
Broadwater Bay	3	0	0	0	0	0	0
Girl L.	3	0	0	0	0	0	0
Unknown	0	0	0	0	0	0	0
Totals	1176	7(16)	9(19)	27(88)	52(161)	7(26)	15(24)

Table 1. Continued.

All mature fish

Tagging zone	Number tagged	Number recaptured per zone: Child L.	Bungey Bay	Woman SW	Woman NE	Broadwater Bay	Girl L.
Boy R.	1977	8	20	45	77	18	15
Child L.	51	5	0	0	0	0	1
Bungey Bay	294	0	3	6	12	2	1
Woman SW	22	0	0	0	0	0	0
Woman NE	17	0	0	1	0	1	0
Broadwater Bay	4	0	0	0	0	0	0
Girl L.	6	0	0	0	0	0	0
Unknown	0	0	0	0	1	2	0
Totals	2371	13(34)	23(41)	52(177)	90(258)	23(62)	17(40)

Mature females

Tagging zone	Number tagged	Number recaptured per zone: Child L.	Bungey Bay	Woman SW	Woman NE	Broadwater Bay	Girl L.
Boy R.	888	4	8	16	34	6	12
Child L.	31	3	0	0	0	0	1
Bungey Bay	224	0	2	4	8	1	1
Woman SW	18	0	0	0	0	0	0
Woman NE	3	0	0	0	0	0	0
Broadwater Bay	4	0	0	0	0	0	0
Girl L.	4	0	0	0	0	0	0
Unknown	0	0	0	0	0	1	0
Totals	1172	7(19)	10(20)	20(90)	42(136)	8(30)	14(27)

Mature males

Tagging zone	Number tagged	Number recaptured per zone: Child L.	Bungey Bay	Woman SW	Woman NE	Broadwater Bay	Girl L.
Boy R.	1089	4	12	29	43	12	3
Child L.	20	2	0	0	0	0	0
Bungey Bay	70	0	1	2	4	1	0
Woman SW	4	0	0	0	0	0	0
Woman NE	14	0	0	1	0	1	0
Broadwater Bay	0	0	0	0	0	0	0
Girl L.	2	0	0	0	0	0	0
Unknown	0	0	0	0	1	1	0
Totals	1199	6(15)	13(21)	32(87)	48(122)	15(32)	3(13)

Table 2. Chi-squared test statistics for assumptions of pooled Petersen estimates, based on the data in Table 1. The "complete mixing" statistics test the assumption that recapture probabilities are constant across strata; the "equal proportions" statistics test the assumption that the expected ratio of marked to unmarked is constant across strata.

	Complete mixing			Equal proportions		
Segment of population	χ^2	df	*P*	χ^2	df	*P*
≥ 13 in	4.19	6	0.65	13.29	5	0.02
≥ 14 in	4.59	6	0.60	13.65	5	0.02
≥ 15 in	3.95	6	0.68	11.30	5	0.05
≥ 17 in	5.23	6	0.51	17.77	5	0.00
≥ 19 in	6.38	6	0.38	14.95	5	0.01
≥ 21 in	3.70	6	0.72	11.50	5	0.04
All mature fish	4.33	6	0.63	10.91	5	0.05
Mature females	4.36	6	0.63	12.57	5	0.03
Mature males	NA	6	NA	6.36	5	0.27

Table 3. Pooled Petersen estimates of the walleye population in the entire Woman Chain during the 2009 spawning period. Estimates are adjusted for 2.8% loss of one tag and 0.077% loss of two tags.

		95% normal confidence limits			95% normal confidence limits			
Segment of population	N	Lower	Upper	Biomass (lb)	Lower	Upper	N/ac	lb/ac
All fish ≥ 13 in	9,149	8,162	10,135	30,771	27,452	34,088	1.5	4.9
All fish ≥ 14 in	8,749	7,809	9,689	29,682	26,493	32,871	1.4	4.7
All fish ≥ 15 in	7,817	6,974	8,660	27,265	24,325	30,206	1.2	4.4
All fish ≥ 17 in	6,239	5,555	6,923	23,234	20,687	25,781	1.0	3.7
All fish ≥ 19 in	5,238	4,635	5,841	21,050	18,627	23,473	0.8	3.4
All fish ≥ 21 in	3,340	2,882	3,799	15,680	13,530	17,835	0.5	2.5
All mature fish	6,578	5,919	7,237	22,068	19,858	24,279	1.1	3.5
Mature females	3,714	3,147	4,280	16,724	14,171	19,273	0.6	2.7
Mature males	2,909	2,532	3,286	6,495	5,653	7,336	0.5	1.0

Table 4. Comparisons of Woman Chain spring walleye population estimates with similar lakes or chains in Minnesota. The 1996-1997 estimates reported by Gustafson (1998) were assumed to represent the entire Woman Chain.

Lake or chain	Year	Size	N/ac	lb/ac	Mean weight (lb)
Woman Chain	2009	≥ 13 in	1.5	4.9	3.4
		≥ 14 in	1.4	4.7	3.4
		≥ 15 in	1.2	4.4	3.5
		≥ 17 in	1.0	3.7	3.7
	1997[1]	≥ 13 in	2.0	5.1	2.6
	1996[1]	≥ 13 in	2.6	6.7	2.6
Ten Mile[2]	1995	> 13.8 in	2.2	NA	NA
Big Sand[3]	1992	> 13.8 in	4.1	12.5	3.0
	1991	> 13.8 in	4.3	12.1	2.8
Whitefish Chain[4]	2005	≥ 16 in	1.4	NA	NA

[1] Gustafson (1998) estimates from creel survey, adjusted to the acreage of the entire chain.
[2] Gran (1997), cited by Gustafson (1998); average of reported estimates.
[3] Jacobson (1994).
[4] Knapp (2006); average of estimates from creel and gillnet samples; not corrected for tag loss.

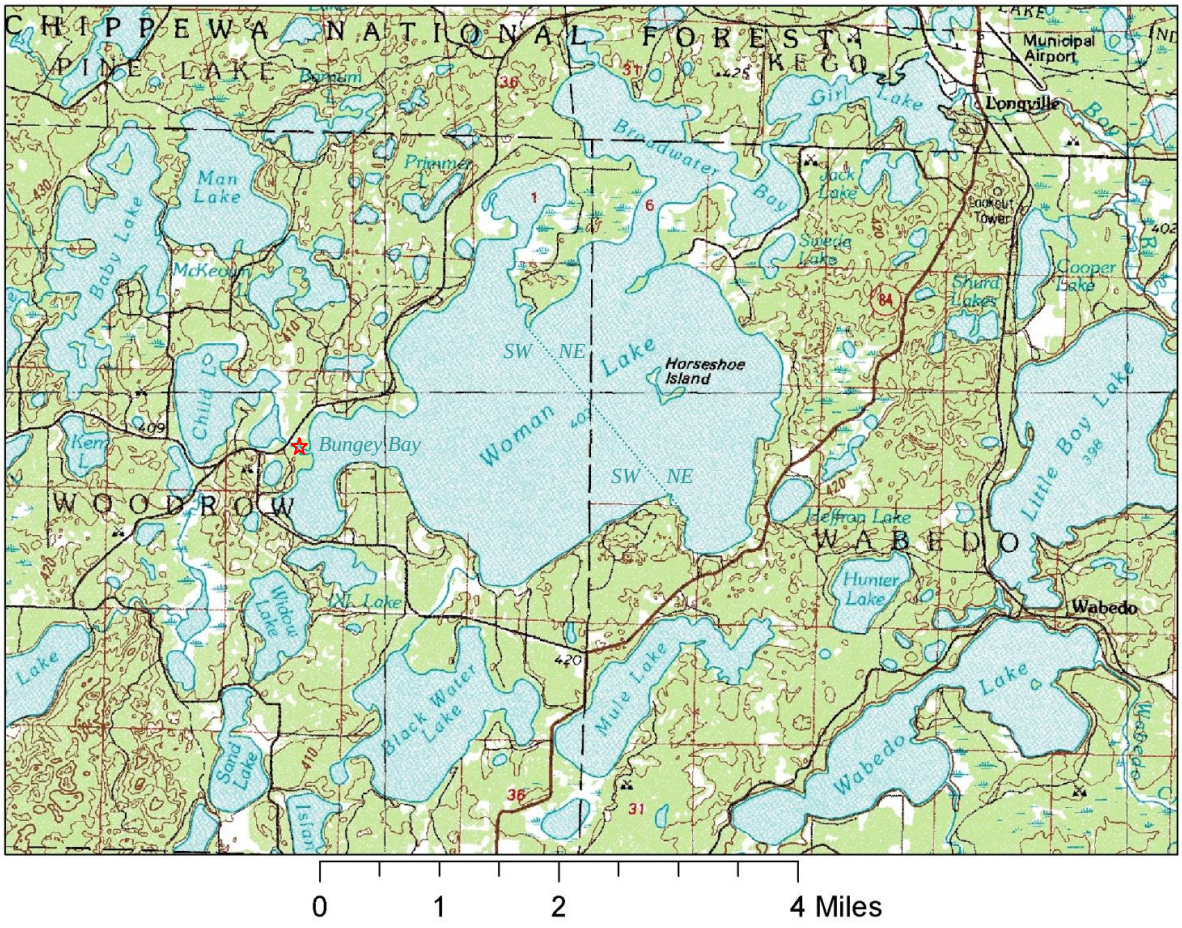

Figure 1. Map of the Woman Chain of lakes and vicinity in northern Cass County, Minnesota (46.95° N, 94.28° W). The location of the walleye spawning trap is indicated by the star between Bungey Bay and Child Lake. The stratum boundary between SW and NE Woman Lake is indicated by a dotted line.

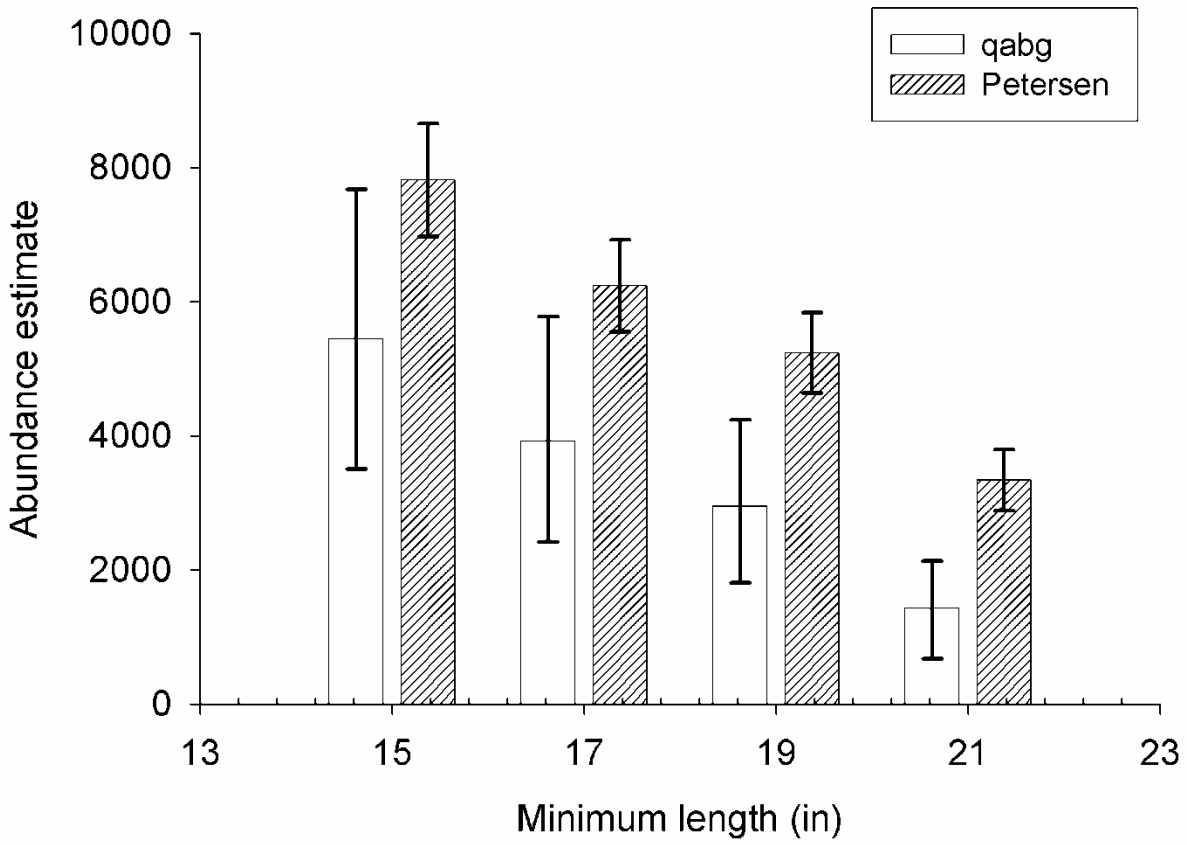

Figure 2. Comparison of fall 2008 Woman Chain walleye population estimates from Anderson's (1998) gillnet selectivity (q_abg) model with spring 2009 Petersen mark-recapture population estimates. Error bars represent 95% confidence limits.