Reducing the Incidental Catch of Lake Trout in Large-mesh Gill-net Fisheries for Lake Whitefish

By

Samuel B. Michaels
Fisheries Biologist

Brian Brost
Data Analyst

William P. Mattes
Great Lakes Section Leader

Great Lakes Indian Fish & Wildlife Commission
P.O. Box 9
Odanah, Wisconsin 54861
(715) 682-6619

Project Report 13-2
USFWS Great Lakes Fish and Wildlife Restoration Act
Grant # 30181-A-G016 (F10AP00080)

April 2013

ACKNOWLEDGMENTS

We would like to thank the U.S. Fish and Wildlife Service Great Lakes Fish and Wildlife Restoration Act program and the Lake Superior and Lake Superior Technical Committees of the Great Lakes Fisheries Commission for supporting this project. We thank Mike Plucinski, Great Lakes Technician; Sara Weed, Clara Smoniewski, Acorn Armagost, Scott Braden, Amber Mealman, GLIFWC interns; Tim Wilson and Ed Leoso, Bad River Natural Resources Department; and Matt Symbal and the Red Cliff Natural Resource Department for their contributions to this project. Also, we thank Neil Kmiecik for editing this report.

SUMMARY

This pilot study was conducted to determine whether standard gill nets modified to fish four (4) feet off the bottom would reduce by-catch of lake trout while maintaining an economically viable catch of lake whitefish. A total of 41 gangs, each comprised of equal footage of the modified gill net (MGN) and standard gill net (SGN), were deployed during 2009 – 2011 in Keweenaw Bay, Lake Superior. A hierarchical, generalized linear mixed model (GLMM) was used to determine whether the catch of lake trout and lake whitefish differed by gear type. Compared to the SGNs, the MGNs reduced catch of lake trout by 68% and the catch of lake whitefish by 50%. A 50% reduction (i.e. an estimated 49,418 pounds) in catch of whitefish, the target species, would affect the economic viability of the tribal fishery. A 68% reduction in catch of lake trout (i.e. an estimated 31,151 pounds) could be beneficial if a need existed that outweighed the cost of the reduced whitefish catch. However, such a need does not exist in Michigan management units MI-2 through MI-5 within 1842 ceded territory waters of Lake Superior where lake trout populations are recovered and tribal harvest of lake trout is effectively managed to stay within the tribal quota.

LIST OF FIGURES

FIGURE **PAGE**

LIST OF TABLES

TABLE **PAGE**

LIST OF APPENDICES

APPENDIX **PAGE**

INTRODUCTION

Lake Superior hosts numerous gill-net fishermen who target commercially important species such as lake whitefish *Coregonus clupeaformis*, lake trout *Salvelinus namaycush namaycush*, and cisco *Coregonus artedi*. Lake whitefish (or whitefish) is the species most often targeted by tribal commercial fishermen. During 2011, reported catch of whitefish by tribal commercial fishermen in Michigan 1842 ceded territory waters (Management Units MI-2 through MI-5) of Lake Superior was 643,139 round pounds or 87% of the total catch (Mattes 2011). Harvest of lake trout is regulated by a quota in each Management Unit in Lake Superior but whitefish harvest is not. As a result of the quotas, and effort limitations in some areas, by-catch of lake trout can be a concern for tribal gill-net fishermen targeting whitefish. Modifying gill nets so they fish off the bottom has been suggested as a way to reduce lake trout by-catch.

The Great Lakes Indian Fish and Wildlife Commission (GLIFWC) routinely conducts gill net surveys in Michigan waters of Lake Superior for lake trout and lake whitefish during fall, and for siscowet *Salvelinus namaycush siscowet* during spring and summer. These surveys provided GLIFWC staff an opportunity to conduct a pilot-project to assess the effects of modified gill nets on reducing the catch of lake trout while maintaining an economically sustainable catch of whitefish.

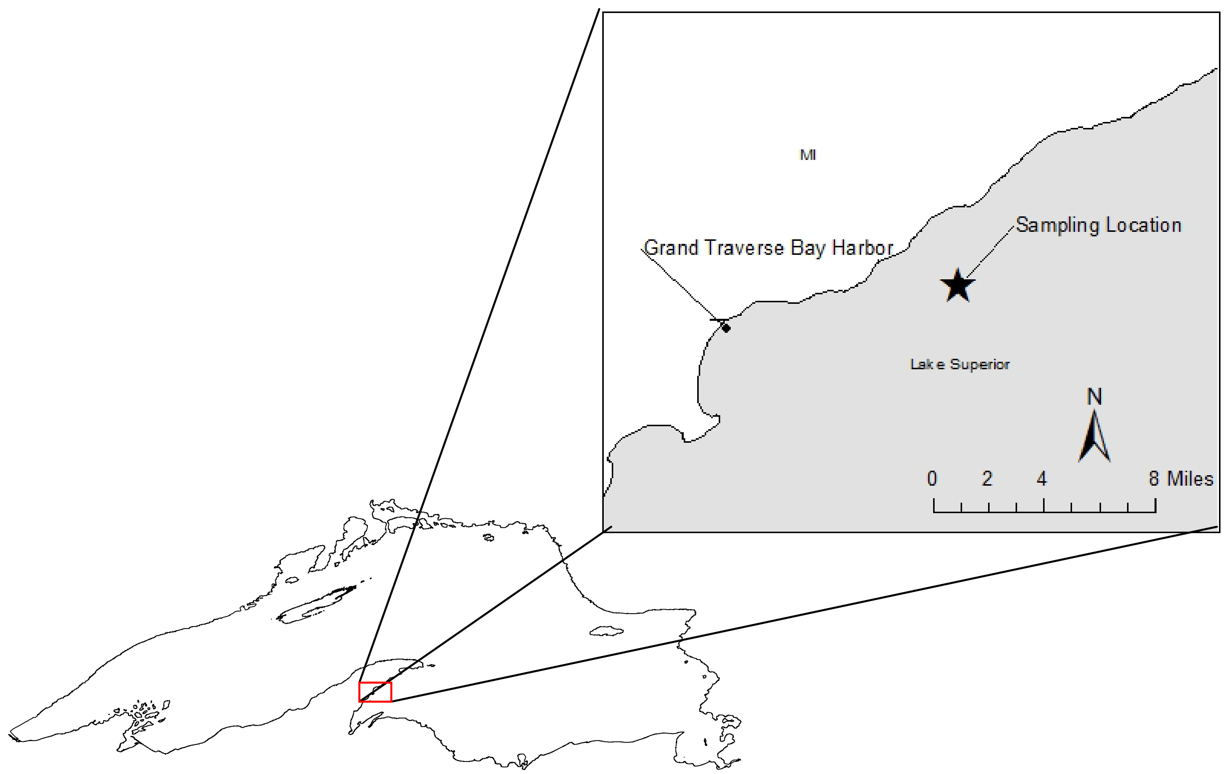
The objectives of the study were to 1) estimate the change in catch rate of lake trout associated with modifications made to a typical monofilament large-mesh gill net, 2) estimate the catch rate of lake whitefish associated with the modifications, 3) estimate the absolute change in lake trout harvest associated with the modifications, 4) estimate the absolute change in lake whitefish harvest associated with the modifications.

METHODS

Sampling was conducted in Keweenaw Bay, Lake Superior, approximately 7 miles northeast of Grand Traverse Bay Harbor (Management unit MI-4, Statistical grid 1225) (Figure 1) during November 2009 and June, July, and October 2010 and June and July 2011 (Appendix A). Standard bottom-set gill nets (SGNs) and modified gill nets (MGNs) were used throughout the study.

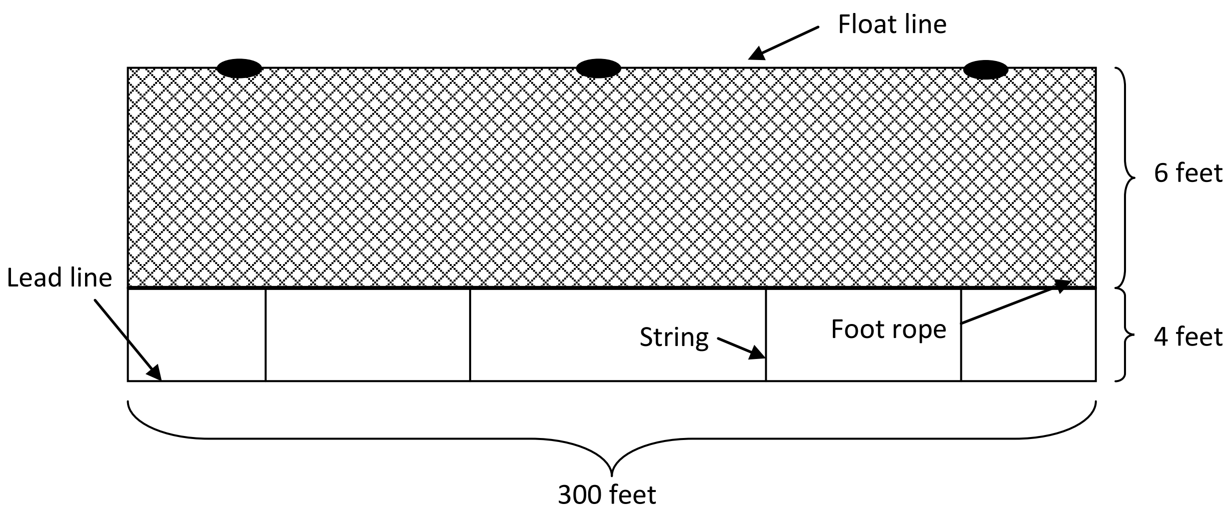
Modified gill nets were constructed with an extra foot rope, which was attached to the lead line with a series of strings, which measured four feet in length. The addition of the foot rope allowed an approximate four-foot suspension of the gill net mesh from the lake bottom (Figure 2). This modification was intended to permit the passage of demersal fish such as lake trout without reducing net capture efficiency for whitefish.

Figure 1. Sampling location of GLIFWC's modified gill net study.



A gill net gang was comprised of six alternating panels of 300 feet of MGN and 300 ft of SGN for a total length of 1,800 feet per gang (900 feet of standard and 900 feet of modified gill net). All nets measured six feet in height and were constructed of 4.5 inches stretched monofilament mesh. A total of 41 gangs (73,800 feet) was deployed; average depth per gang ranged from 42 to 277 feet (Appendix A). Each gang was typically soaked overnight for approximately 20 hours and lifted the following morning; however nine gangs throughout the study period were soaked for two nights due to adverse weather conditions. Live fish were counted and measured for each net type prior to being released back into the water. Dead fish were counted, weighed and measured for each net type, and aging structures were extracted for age determination.

Figure 2. Depiction of a modified gill net used during GLIFWC's modified gill net study.



A hierarchical, generalized linear mixed model (GLMM) was used to estimate the number of lake trout and whitefish caught as a function of independent predictor variables. Models for each species were developed separately. A GLMM allows for response variables with non-normal distributions (e.g., a Poisson distribution for count data), and accounts for correlated data through the introduction of random effects (Gelman and Hill 2007; Bolker et al. 2009). The generalized linear mixed model that we used had the form:

$$y_{ijk} = Poisson\left(e^{X_{ijk}\beta+\alpha_j+\gamma_k+\varepsilon_i}\right),$$

where y_{ijk} is the total number of lake trout or whitefish caught in net type i (MGN or SGN) in gang j on date k, X_{ijk} is a matrix of predictors, β is a vector of model coefficients, and α and γ are random effects for gang and date, respectively. ε is an overdispersion parameter. The random effects describe the difference between the overall intercept (i.e. β_0) and the intercept for the respective gang or date. Both random effects were modeled as normally distributed with mean zero and unknown variance.

Five independent variables were examined for their effect on the number of lake trout and whitefish caught: net type, season, month, mean net depth (depth at the two ends of the net averaged), and net soak time (number of nights set). Month and season were not included in the same model due to collinearity. Depth, a continuous variable, was scaled to mean zero and unit variance prior to model fitting. Preliminary graphs showed a slight quadratic relationship between depth and whitefish catch, the significance of which we explored by including a quadratic term for depth ($depth^2$) in the whitefish model.

Models were fit under a Bayesian framework in WinBUGS, as implemented from R statistical software (R Core Development Team 2012) using the R2WinBUGS package (Sturtz et al. 2005). Models were simplified by removing coefficients that had a 95% Bayesian credible interval that overlapped zero (on the log scale), which indicates an ambiguous effect for that parameter. Model adequacy was assessed by examining residual plots for patterns, and by calculating a Bayesian *p*-value from the posterior predictive distribution (Gelman and Hill 2007). The posterior predictive check was performed by comparing model fit for the actual data to model fit for ideal data sets generated under the parameter estimates obtained from the analysis of the observed data. Model fit was quantified using a sum-of-squares discrepancy measure. The Bayesian *p*-value, calculated as the proportion of discrepancy measures for the ideal data sets that are greater than the measure for the actual data set, should be near 0.5 for a well-fitting model; values near 0 or 1 indicate lack of fit.

In order to estimate the absolute change in harvest of lake trout and whitefish associated with the gill net modification, we used equation:

$$X = t / 1 + p\text{, where}$$

X = estimated catch of fish in the MGN
t = total number of fish commercially harvested with gill nets in MI-4 during 2010
p = proportional difference in catch by gear type

RESULTS

A total of 199 lake trout and 108 whitefish were captured in the standard gill nets compared to 66 lake trout and 52 whitefish in the modified gill nets. Mean CPE (number/gang) for lake trout was 4.9 in the SGNs and 1.6 in the MGNs while mean CPE for whitefish was 2.6 in the SGNs and 1.3 in the MGNs (Table 1) (Appendix A).

Table 1. Total catch and CPE of lake trout and whitefish by standard gill nets (SGN) and modified gill nets (MGN).

		Standard Gill Net			Modified Gill Net			
	Species	Total Catch	CPE (number/ gang)	SD	Total Catch	CPE (number/ gang)	SD	Estimated Percent Decrease*
Objective 1	Lake trout	199	4.9	±7.0	66	1.6	±2.7	68%
Objective 2	Lake whitefish	108	2.6	±3.0	52	1.3	±1.5	50%

*Percent decrease between SGN and MGN CPE's as estimated by the GLMM.

A hierarchical, generalized linear mixed model (GLMM) was used to determine whether the catch of lake trout and lake whitefish differed by gear type. The best-fit model for describing lake trout catch included net type and season (Table 2) (Figure 3). The best-fit model for describing lake whitefish catch included variables for net type, depth, and depth^2 (the quadratic term for depth), and number of nights. The Bayesian p-value was 0.53 for the lake trout catch model and 0.47 for the lake whitefish catch model. As noted in the methods section, the Bayesian p-value should be near 0.5 for a well-fitting model, while values near 0 or 1 indicate lack of fit.

Model results indicated that catch of lake trout was 211% (95% CI: 124%, 339%) greater in SGN's than in MGN's. For whitefish, catch was 101% (95% CI: 33%, 213%) greater in SGNs than in MGNs. In other words, when compared to the SGNs, the MGNs reduced catch of lake trout by 68% and catch of whitefish by 50% (Table 1).

Catch of lake trout was 289% (95% CI: 12%, 1,168%) higher during the fall than during the summer. Depth influenced whitefish catch with catch decreasing 20% (95% CI:-54%, 30%) for each 57-foot increase (equivalent to one standard deviation) in depth, and decreased 44% (95% CI: -66% to -14%) with each unit increase in depth^2. The number of soak nights influenced whitefish catch with catch increasing 326% (95% CI: 33%, 1,667%) for two-night sets.

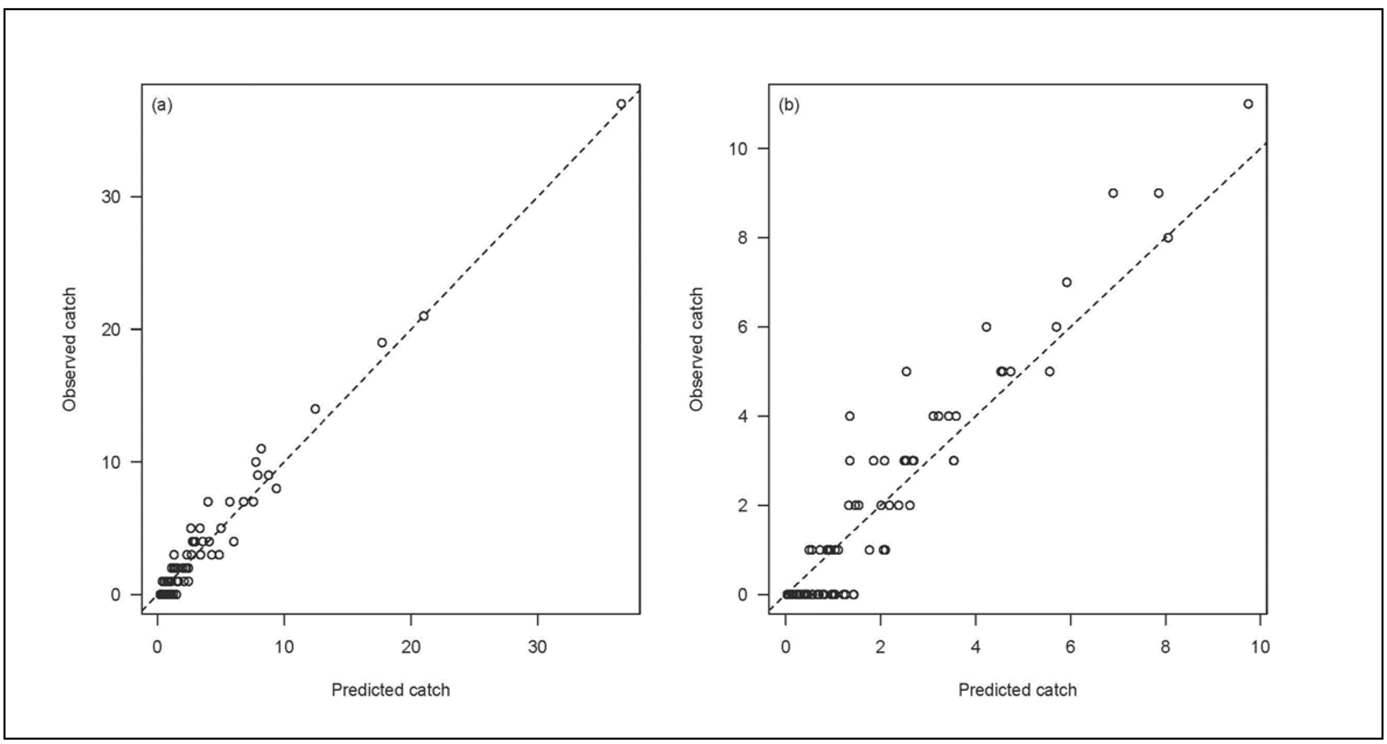
Table 2. Model coefficients and estimates* for the generalized linear mixed model used to estimate lake trout (LAT) and whitefish (LWF) catch.

Species	Coefficient **	Mean	Standard Deviation	2.5% Confidence Interval	97.5% Confidence Interval
LAT	b.0	-7.58E-01	0.392	-1.58E+00	-0.0395
	b.net type	1.14E+00	0.170	8.04E-01	1.4782
	b.season	1.36E+00	0.600	1.16E-01	2.5404
LWF	b.0	-1.73E+00	0.976	-3.77E+00	0.10032
	b.net type	6.99E-01	0.228	2.86E-01	1.14187
	b.depth	-2.27E-01	0.261	-7.75E-01	0.26578
	b.depth^2	-5.83E-01	0.238	-1.09E+00	-0.1515
	b.nights	1.45E+00	0.666	2.85E-01	2.87185

* Mean, standard deviation, and confidence interval estimates are in log scale.

** b.0 = intercept; b.net type = coefficient for effect of standard gill net on catch; b.season = coefficient for effect of season on catch; b.depth = coefficient for effect of depth on catch; b.depth^2 = quadratic term for depth; b.nights = coefficient for effect of nights set on catch.

Figure 3. Observed vs. model-predicted numbers of (a) lake trout and (b) whitefish caught in MGNs and SGNs.



Total effort with 4.5 inch mesh in the tribal commercial gill net fishery in management unit MI-4 of Lake Superior was reported to be 1,190,000 feet during 2011 (Mattes 2011). Total reported harvest of lake trout with 4.5 inch mesh was 45,810 pounds while total reported harvest of whitefish was 98,840 pounds (Table 3). If 1,190,000 feet of MGNs had been fished instead of the SGNs, an estimated 14,659 pounds of lake trout and 49,422 pounds of whitefish would have been harvested. In other words, if MGNs had been used instead of SGNs, 31,151 fewer pounds of lake trout and 49,418 fewer pounds of whitefish would have been harvested by tribal commercial fishermen in MI-4.

Table 3. Reported harvest and effort in 4.5 inch mesh standard gill nets in MI-4* during 2011 compared to estimated harvest in modified gill nets based on the same effort fished.

			Reported harvest in standard gill nets **		Estimated harvest in modified gill nets		Absolute change in harvest	
	Species	Effort (ft)	Round Pounds	Number	Round Pounds	Number	Round Pounds	Number
Objective 3	Lake trout	1,190,000	45,810	13,882	14,659	4,442	-31,151	-9,440
Objective 4	Whitefish	1,190,000	98,840	32,947	49,422	16,474	-49,418	-16,473

* In 2011, the TAC for lake trout was 50,000 fish and the tribal quota was 25,000 fish (Mattes 2011).

**Reported harvest was in dressed pounds. To convert to round pounds, dressed pounds was multiplied by 1.25 for lake trout and 1.17 for whitefish. To convert to number of fish, round pounds was divided by an average weight of 3.3 pounds for lake trout and 3.0 pounds for whitefish. (Mattes 2011).

DISCUSSION

The number of lake trout (66 fish) and whitefish (52 fish) caught in the modified gill nets as constructed and fished in this study, was substantially lower than the number caught in the standard gill nets (199 and 108, respectively) (Table 1). Catch of lake trout was reduced by 68% but catch of whitefish was reduced by 50%, a reduction that would not be economically sustainable.

At the depths fished in this study (average: 151 feet; range: 42-277 feet) the magnitude of the reduction in the modified gill net catch for whitefish (50% or an estimated 49,418 pounds) would affect the economic viability of the tribal fishery (Tables 1 and 3, Appendix A). A 68% reduction in catch of lake trout (i.e. an estimated 31,151 pounds) could be beneficial if a need existed that outweighed the economic loss of the reduced whitefish catch. However, such a need does not exist in Michigan management unit MI-4 or in the other Michigan management units that are within the 1842 ceded territory (Mattes 2011). Lake trout populations in these management units (MI-2 through MI-5) are considered recovered and tribal harvest (whether by-catch, targeted harvest, or both) is effectively managed by a quota and closed seasons. For example, in MI-4 during 2011, reported catch in 4.5 inch stretch mesh was 13,882 lake trout, about half of the tribal lake trout quota of 25,000 fish (Mattes 2011).

Ebener (2011) conducted a study using modified gill nets to determine if incidental catch of lake trout could be minimized so that tribal commercial harvest of whitefish in an area of Lake Huron could be increased. Modified gill nets used in his study fished three feet off the bottom, were 21 feet in height, 250 feet long, and fished at depths from 20 to 110 feet. He reported that the modified gill nets reduced catch of lake trout and whitefish by 26% and 5%, respectively, and that the reduction in catch for both species increased as depth increased. In GLIFWC's study, catch of whitefish was influenced by depth but catch of lake trout was not (Table 2). Ebener (2011) stated that for depths less than 75 feet, MGNs caught 22% fewer lake trout and 1% fewer whitefish, and at depths greater than 75 feet, MGNs caught 41% fewer lake trout and 16% fewer whitefish. He concluded that the tribal whitefish fishery could be expanded to permit fishing with only the modified nets in water > 75 feet with minimal risk to the lake trout populations in that area.

Although not deemed a viable alternative in this study for the reasons mentioned above, the use of modified gill nets in commercial fisheries targeting whitefish may be of benefit in some circumstances. For example, in areas where lake trout are being rehabilitated and at some depths, lake trout catch may be minimized by modified gill nets and thereby provide an opportunity for increased harvest of whitefish. Also, in areas where gill net effort for whitefish is limited by lake trout catch rates and quotas (i.e. Wisconsin waters of Lake Superior), the use of modified gill nets might reduce lake trout catch rates at some depths and thus allow an increase in effort for whitefish.

LITERATURE CITED

Ebener, M. P. Modifying Commercial Gill Nets to Reduce the Incidental Catch of Lake Trout: Results from the Bay Mills Small Boat Zone Study 2009-2010. Administrative Report 11-03.Chippewa Ottawa Resource Authority. Sault Ste. Marie, Michigan, USA.

Bolker, B.M., M.E. Brooks, C.J. Clark, S.W. Geange, J.R. Poulsen, M.H.H. Stevens, and J.S. White. 2009. Generalized Linear mixed models: a practical guide for ecology and evolution. Trends in Ecology and Evolution 24:127-135.

Gelman, A. and J. Hill. 2007. Data analysis using regression and multilevel/hierarchical models. Cambridge University Press.

Mattes, W. P. Biological and commercial catch statistics from the Chippewa inter-tribal gill net fishery within Michigan waters of Lake Superior during 2011. Administrative Report 12-15. Great Lakes Indian Fish and Wildlife Commission, Odanah, Wisconsin, USA.

R Core Development Team 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Sturtz, S., U. Ligges, and A. Gelman. 2005. R2WinBUGS: A Package for Running WinBUGS from R. Journal of Statistical Software 12:1-16.

Appendix A. Catch of lake trout (LAT) and lake whitefish (LWF) by net type, date, gang, season, and depth during 2009 – 2011 modified gill net study.

	Standard Gill Net						Modified Gill Net					
Date	Gang	LAT catch	LWF catch	Season	Depth (ft)	Effort (ft)	Gang	LAT catch	LWF catch	Season	Depth (ft)	Effort (ft)
11/4/2009	1	5	0	FALL	115.5	900	1	0	3	FALL	115.5	900
11/4/2009	2	2	3	FALL	114.5	900	2	0	0	FALL	114.5	900
11/4/2009	3	0	0	FALL	98	900	3	0	0	FALL	98	900
11/5/2009	4	19	2	FALL	84	900	4	3	5	FALL	84	900
11/5/2009	5	37	1	FALL	110.5	900	5	14	2	FALL	110.5	900
11/5/2009	6	21	0	FALL	111.5	900	6	7	1	FALL	111.5	900
6/22/2010	7	0	3	SUMMER	98	900	7	0	0	SUMMER	98	900
6/22/2010	8	1	9	SUMMER	95	900	8	1	2	SUMMER	95	900
6/22/2010	9	0	5	SUMMER	128	900	9	0	3	SUMMER	128	900
6/23/2010	10	4	6	SUMMER	107.5	900	10	0	0	SUMMER	107.5	900
6/23/2010	11	0	3	SUMMER	97	900	11	1	1	SUMMER	97	900
6/23/2010	12	3	1	SUMMER	139.5	900	12	3	3	SUMMER	139.5	900
6/24/2010	13	2	1	SUMMER	78	900	13	0	0	SUMMER	78	900
6/24/2010	14	0	1	SUMMER	51.5	900	14	1	0	SUMMER	51.5	900
6/24/2010	15	0	0	SUMMER	42	900	15	1	0	SUMMER	42	900
7/13/2010	16	1	0	SUMMER	228.5	900	16	0	0	SUMMER	228.5	900
7/13/2010	17	3	0	SUMMER	251.5	900	17	0	0	SUMMER	251.5	900
7/13/2010	18	3	0	SUMMER	101	900	18	3	0	SUMMER	101	900
7/14/2010	19	0	1	SUMMER	167.5	900	19	0	0	SUMMER	167.5	900
7/14/2010	20	2	0	SUMMER	130	900	20	0	1	SUMMER	130	900
7/20/2010	21	2	0	SUMMER	276.5	900	21	1	0	SUMMER	276.5	900
7/20/2010	22	2	0	SUMMER	234.5	900	22	1	0	SUMMER	234.5	900
7/20/2010	23	3	0	SUMMER	185	900	23	1	0	SUMMER	185	900
10/12/2010	24	4	0	FALL	201	900	24	5	4	FALL	201	900
10/12/2010	25	8	0	FALL	176.5	900	25	7	0	FALL	176.5	900
10/12/2010	26	1	0	FALL	106.5	900	26	0	1	FALL	106.5	900
10/13/2010	27	5	1	FALL	213.5	900	27	1	0	FALL	213.5	900
10/13/2010	28	3	2	FALL	170.5	900	28	2	1	FALL	170.5	900
10/13/2010	29	9	4	FALL	176	900	29	4	2	FALL	176	900
10/14/2010	30	4	0	FALL	263.5	900	30	0	0	FALL	263.5	900
10/14/2010	31	9	7	FALL	135.5	900	31	2	3	FALL	135.5	900
10/14/2010	32	7	4	FALL	170	900	32	4	0	FALL	170	900
6/15/2011	33*	7	3	SUMMER	132.5	900	33*	1	0	SUMMER	132.5	900
6/15/2011	34*	10	11	SUMMER	148	900	34*	1	3	SUMMER	148	900
6/15/2011	35*	4	4	SUMMER	215	900	35*	0	3	SUMMER	215	900
6/17/2011	36*	11	6	SUMMER	130	900	36*	2	1	SUMMER	130	900
6/17/2011	37*	2	5	SUMMER	155	900	37*	0	4	SUMMER	155	900
6/17/2011	38*	2	9	SUMMER	170	900	38*	0	2	SUMMER	170	900
7/13/2011	39*	0	8	SUMMER	155.5	900	39*	0	5	SUMMER	155.5	900
7/13/2011	40*	1	5	SUMMER	187.5	900	40*	0	0	SUMMER	187.5	900
7/13/2011	41*	2	3	SUMMER	230	900	41*	0	2	SUMMER	230	900
Total		199	108			36,900		66	52			36,900
Average Depth (ft)					150.8						150.8	

* Gang had a two-night soak time.