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STATUS OF THE 2011 AND 2012 LAKE STURGEON SPAWNING POPULATION IN THE BAD AND WHITE RIVERS, WISCONSIN

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Lake Superior

CONSERVING AMERICA'S fisheries U.S. Fish & Wildlife Service

Great Lakes RESTORATION

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On the cover:

Ashland Fish and Wildlife Conservation Office fish biologist Joshua Schloesser (left) and Bad River fishery technician Kris Arbuckle (right) holding a 36.3 kg (80 lb) lake sturgeon caught while making the spawning run up the Bad River, Wisconsin.

INTRODUCTION

The lake sturgeon is important to the ecology of Lake Superior and culturally to the people of the region. Since 1994, the USFWS Ashland Fish and Wildlife Conservation Office has collaborated with the Bad River Natural Resources Department to conduct research projects and monitor the status of lake sturgeon populations in the Bad and White rivers. The Bad River lake sturgeon population is one of the largest on Lake Superior and is genetically distinct from other populations (Welsh et al. 2008). The Bad River population supports a tribal subsistence and state regulated sport-fish fishery and therefore, should be continually monitored to ensure this population remains sustainable.

In 2010, a comprehensive report by the USFWS estimated the spawning run size and developed biological models to better understand the characteristics and demographics of this population to improve management (Schloesser and Quinlan 2011). Additional spawning run assessments were planned for 2011 and 2012 to improve these biological and demographic models and continue mark recapture population estimates on the Bad River population.

On a Great Lakes wide scale, there is a need to develop a rapid survey process to improve the understanding of the current status of lake sturgeon populations to promote effective rehabilitation projects (Holey et al. 2000). Auer and Baker (2007) conducted a research project on the use of a fixed-location split-beam hydroacoustic survey to assess spawning lake sturgeon and determined it was a feasible technique. To date, this assessment tool has not been used by management agencies, but holds promise with additional research.

This report is a summary of the Bad River spawning assessment activities that occurred in cooperation with the Bad River Natural Resources Department during 2011 and 2012. In both years, a gill net assessment was conducted with the objective to assess the size of the lake sturgeon spawning run in the Bad and White rivers and to collect additional biological data that will contribute to future population models. During 2012, an experimental fixed-location hydroacoustic unit was deployed to test the feasibility of this assessment technique on the Bad River and to compare the findings presented in Auer and Baker (2007). The intention of conducting a hydroacoutsic assessment in conjunction with a mark-recapture survey was to validate both assessment techniques.

METHODS

Gill Netting

Each year, two gill nets were set across each river perpendicular to the current and spaced approximately 75 m apart so as to maximize encounters with migrating lake sturgeon. The gill nets set at the Bad River site were 61 m long and 2.4 m tall with 25.4 cm stretch multifilament mesh. Gill nets set in the White River were the same dimensions except they were only 30.5 m long because the river was narrower. The sampling methods were the same in both years.

All gill nets were checked daily and captured lake sturgeon were measured for total and fork length (mm), girth (mm), and weight (g). If gametes were expelled from the fish with light

pressure applied to the abdomen, sex was determined. Each fish was given a uniquely numbered t-bar anchor tag inserted at the base of the dorsal fin, as well as a passive integrated transponder (PIT) tag inserted at the base of the skull (the dorsal posterior of the right side of the head).

The body condition and condition of the gonads (e.g., ripe, hard, or spent) were inspected to determine if the fish was migrating towards or away from the spawning grounds. Fish with bruises, scrapes, or a concave abdomen were indications that the fish had already spawned. Fish determined to be spent were released approximately 1 rkm downstream of the gill nets to return to Lake Superior. Fish that were unblemished and "fresh", or with hard gonads were released approximately 1 rkm upstream of the nets to continue the assumed upstream migration towards the spawning grounds. After fish were processed, gill nets were cleaned of debris, repaired, and immediately reset in the same locations.

Population size was estimated using the POPAN formulation of the Jolly-Seber model implemented through Program MARK. Individual capture histories were compiled using a series of 1's or 0's at each sampling occasion to indicate whether the fish was captured (1) or not captured (0). The POPAN model estimates apparent survival between sampling occasions (φ), capture probability (p), probability of entry (PENT) into the study area from a larger super-population, and abundance (N; Schwarz and Arnason 1996). For these modeling purposes, φ was referred to as the proportion of the population that remains in the study area and $1 - \varphi$ equals the probability of a lake sturgeon that returned to Lake Superior, out of our effective study area. Likewise, PENT refers to the probability of a lake sturgeon entering into the effective study area from Lake Superior after the first sampling occasion.

Assumptions of the Jolly-Seber class of models specify that animals retain their tags throughout the experiment, tags are identified correctly, sampling is instantaneous, marked and unmarked animals have equal survival probabilities, catchability is the same for marked and unmarked animals at each sampling occasion, and the study area is constant (Seber 1982). Program RELEASE was used to test for violations of assumptions; equal survival probability among all animals (Test 3) and for equal probability of recapture among all animals (Test 2).

Model parameters were estimated as constant (.), group (g; separate Bad River and White River), time (t; each sampling occasion), and group by time interaction ($g*t$). The candidate set of models included all formulations for φ (., g, t, $g*t$), p (., g), PENT (., g, t, $g*t$), and N (g). A logical biological hypothesis would support a t or $g*t$ model to represent the migratory behavior (φ and PENT parameters) of spawning lake sturgeon, but concerns of estimating too many parameters prompted the need to fit constant and group models as well (even though they do not make much biological sense). Candidate models were ranked using Akaike Information Criterion corrected for small sample sizes (AICc; Burnham and Anderson 2002). The top models and candidate models with an AICc value ≤ 2 of the top model were considered to be equally well supported by the data (Burnham and Anderson 2002). All candidate models contributing some weight (w_i) of evidence they support the data were used in a model averaging procedure to derive final parameter estimates.

Hydroacoustics

The hydroacoustic sampling equipment was housed in a portable trailer and powered by a bank of batteries that was recharged daily by a propane powered generator. The sampling site was located approximately 100 m upstream of the Government Road bridge because of easy access, the proper channel morphology to fit the acoustic beam, and a consistent laminar flow to prevent fish milling behavior. Our assessment was fixed-location using the Hydroacoustic Technology Inc. (HTI) model 241 split-beam echo sounder. The transducer was split-beam operating at 200 kHz with a 4 × 10° elliptical-beam. Pulse width was set at 0.2 ms and transmitted at a rate of 10 pulses per second, similar to the settings used by Auer and Baker (2007). All data collected were viewed using HTI program Echoscape. To determine the target strength of lake sturgeon, spent fish in a range of lengths were released directly upstream of the acoustic beam to calibrate a known sized fish against the measured target strength from the hydroacoustic equipment. The goal was to develop this relationship to improve species differentiation during data analysis.

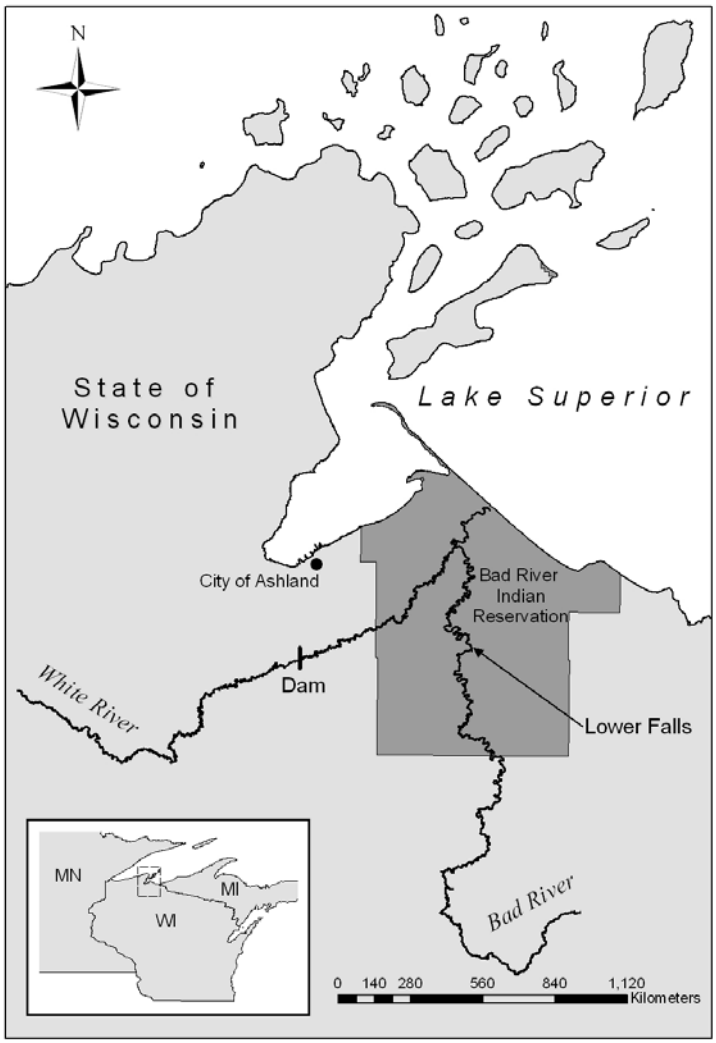

Figure 1.—Location of lake sturgeon spawning areas immediately below the lower falls of the Bad River and the dam on the White River, Wisconsin.

RESULTS

The Bad and White rivers were sampled from April 20 to May 14 in 2011 for a total of 17 sampling nights. A total of 148 lake sturgeon were handled, including fish captured multiple times, with 109 caught in the Bad River and 39 in the White River. Excluding recaptured fish, 132 individuals were handled during this survey. The POPAN model used to estimate population size had a goodness-of-fit test that indicated our data did not violate the assumption of equal probability of recapture among all animals (P = 0.8879). However, the assumption of equal survival probability among all animals could not be evaluated due to sparse data and few recaptured marked fish. This serves as a warning that the model results should be used with caution as the data structure may not fit the assumptions of the model well.

The candidate models that ranked highest were the simplest models (i.e., least number of estimated parameters), where φ, *p*, and PENT varied as either a constant or group function (Table 1). The top four approximating models incorporated either constant or a group effect for φ, *p*, and PENT, contributing 60% of the weight to the model averaged estimates. The estimated adult lake sturgeon population size for the Bad River was 557 (274-839) and 186 (40-331) for the White River in 2011 (Table 3).

In 2012, both rivers were sampled from April 11 to May 4 for a total of 23 sampling nights. A total of 274 lake sturgeon were handled, including fish captured multiple times, with 212 caught in the Bad River and 62 in the White River. Excluding those recaptured fish, 235 individuals were handled during the 2012 survey. Similar to 2011, goodness-of-fit tests on the 2012 POPAN model did not violate the assumption of equal probability of recapture among all animals (P = 0.9952), but the assumption of equal survival probability among all animals could not be evaluated due to sparse data. Much like in 2011, few recaptures during the survey period limit the models utility and caution should be taken when interpreting population size estimates.

The 2012 candidate models with the fewest number of parameters ranked highest where φ, *p*, and PENT varied as either a constant or group function (Table 2), similar to what was observed in 2011. The top eight models accounted for >99% of the weight of the model averaged parameter estimates. Incorporating a *t* or *g*t* effect into models was not well supported for the 2012 data. The estimated adult lake sturgeon population size for the Bad River was 1,170 (657-1,684) and 147 (66-229) for the White River (Table 3).

The hydroacoustic unit collected data from April 11 to May 12, 2012, but continuous data collection was interrupted by low battery power shut downs and computer program lock ups. The monitoring location initially appeared adequate, but after installation a small sandbar was identified in front of the acoustic beam. This sand bar likely caused interference with the acoustic beam and limited detection capabilities of fish near the river bottom. Most fish detected were within 10 m of the transducer, leaving most of the river "unmonitored". For this reason, lake sturgeon upstream and downstream movements were not tracked. Also, results from the target strength calibration exercise were not presented due to low sample sizes and concerns of inaccuracy with the hydroacoustic beam being partially blocked by the sandbar. These data will be combined with future research for a more robust analysis.

Table 1.—Candidate models for the 2011 mark-recapture population estimate ranked according to lowest AICc values. Apparent survival (φ), capture probability (*p*), probability of entry (PENT), and population size (N) were modeled as a constant probability (.), function of group (*g*; Bad and White rivers), time (*t*), and a group by time interaction (*g***t*).

Model	AICc	Delta AICc	AICc Weights	Model Likelihood	Number of Parameters
{ φ (.), *p*(.), PENT(.), N(g)}	341.7634	0	0.28913	1	5
{ φ (g), *p*(.), PENT(.), N(g)}	343.6653	1.9019	0.11171	0.3864	6
{ φ (.), *p*(.), PENT(g), N(g)}	343.7059	1.9425	0.10947	0.3786	6
{ φ (.), *p*(g), PENT(.), N(g)}	343.9119	2.1485	0.09875	0.3415	6
{ φ (.), *p*(.), PENT(t), N(g)}	344.3408	2.5774	0.07969	0.2756	20
{ φ (t), *p*(.), PENT(.), N(g)}	344.5505	2.7871	0.07176	0.2482	20
{ φ (t), *p*(.), PENT(g), N(g)}	345.6262	3.8628	0.04191	0.145	21
{ φ (g), *p*(.), PENT(g), N(g)}	345.8674	4.104	0.03715	0.1285	7
{ φ (.), *p*(g), PENT(g), N(g)}	345.9022	4.1388	0.03651	0.1263	7
{ φ (g), *p*(g), PENT(.), N(g)}	346.1161	4.3527	0.0328	0.1134	7
{ φ (g), *p*(.), PENT(t), N(g)}	346.9193	5.1559	0.02195	0.0759	21
{ φ (.), *p*(g), PENT(t), N(g)}	346.9369	5.1735	0.02176	0.0753	21
{ φ (t), *p*(g), PENT(.), N(g)}	347.3959	5.6325	0.0173	0.0598	21
{ φ (g), *p*(g), PENT(g), N(g)}	347.5951	5.8317	0.01566	0.0542	8
{ φ (t), *p*(g), PENT(g), N(g)}	348.3888	6.6254	0.01053	0.0364	22
{ φ (g), *p*(g), PENT(t), N(g)}	350.5356	8.7722	0.0036	0.0125	22
{ φ (.), *p*(.), PENT(g*t), N(g)}	355.9471	14.1837	0.00024	0.0008	36
{ φ (g), *p*(.), PENT(g*t), N(g)}	359.5108	17.7474	0.00004	0.0001	37
{ φ (.), *p*(g), PENT(g*t), N(g)}	359.6128	17.8494	0.00004	0.0001	37
{ φ (g), *p*(g), PENT(g*t), N(g)}	363.2233	21.4599	0.00001	0	38
{ φ (t), *p*(.), PENT(t), N(g)}	366.9098	25.1464	0	0	35
{ φ (t), *p*(g), PENT(t), N(g)}	370.1494	28.386	0	0	36
{ φ (g*t), *p*(.), PENT(.), N(g)}	380.538	38.7746	0	0	36
{ φ (g*t), *p*(.), PENT(g), N(g)}	382.2689	40.5055	0	0	37
{ φ (g*t), *p*(g), PENT(.), N(g)}	383.3238	41.5604	0	0	37
{ φ (g*t), *p*(g), PENT(g), N(g)}	385.2196	43.4562	0	0	38
{ φ (t), *p*(.), PENT(g*t), N(g)}	389.8234	48.06	0	0	51
{ φ (t), *p*(g), PENT(g*t), N(g)}	394.2162	52.4528	0	0	52
{ φ (g*t), *p*(.), PENT(t), N(g)}	412.5302	70.7668	0	0	51
{ φ (g*t), *p*(g), PENT(t), N(g)}	417.1725	75.4091	0	0	52
{ φ (g*t), *p*(.), PENT(g*t), N(g)}	471.0372	129.2738	0	0	67
{ φ (g*t), *p*(g), PENT(g*t), N(g)}	477.883	136.1196	0	0	68

Table 2.—Candidate models for the 2012 mark-recapture population estimate ranked according to lowest AICc values. Apparent survival (φ), capture probability (*p*), probability of entry (PENT), and population size (N) were modeled as a constant probability (.), function of group (*g*; Bad and White rivers), time (*t*), and a group by time interaction (*g***t*).

Model	AICc	Delta AICc	AICc Weights	Model Likelihood	Number of Parameters
{ φ (.), *p*(g), PENT(.), N(g)}	603.7954	0	0.44514	1	6
{ φ (.), *p*(g), PENT(g), N(g)}	605.5016	1.7062	0.18967	0.4261	7
{ φ (g), *p*(g), PENT(.), N(g)}	605.6007	1.8053	0.1805	0.4055	7
{ φ (g), *p*(g), PENT(g), N(g)}	607.6106	3.8152	0.06607	0.1484	8
{ φ (g), *p*(.), PENT(.), N(g)}	608.1248	4.3294	0.0511	0.1148	6
{ φ (.), *p*(.), PENT(.), N(g)}	609.3366	5.5412	0.02788	0.0626	5
{ φ (g), *p*(.), PENT(g), N(g)}	609.6524	5.857	0.0238	0.0535	7
{ φ (.), *p*(.), PENT(g), N(g)}	611.3822	7.5868	0.01002	0.0225	6
{ φ (g), *p*(.), PENT(t), N(g)}	614.1893	10.3939	0.00246	0.0055	27
{ φ (g), *p*(g), PENT(t), N(g)}	614.6352	10.8398	0.00197	0.0044	28
{ φ (t), *p*(g), PENT(.), N(g)}	617.0857	13.2903	0.00058	0.0013	27
{ φ (.), *p*(.), PENT(t), N(g)}	618.1305	14.3351	0.00034	0.0008	26
{ φ (.), *p*(g), PENT(t), N(g)}	619.1922	15.3968	0.0002	0.0004	27
{ φ (t), *p*(g), PENT(g), N(g)}	619.3417	15.5463	0.00019	0.0004	28
{ φ (t), *p*(.), PENT(.), N(g)}	621.8503	18.0549	0.00005	0.0001	26
{ φ (t), *p*(.), PENT(g), N(g)}	624.3105	20.5151	0.00002	0	27
{ φ (t), *p*(g), PENT(t), N(g)}	656.0945	52.2991	0	0	48
{ φ (t), *p*(.), PENT(t), N(g)}	662.023	58.2276	0	0	47
{ φ (.), *p*(g), PENT(g*t), N(g)}	663.2421	59.4467	0	0	49
{ φ (g), *p*(g), PENT(g*t), N(g)}	665.817	62.0216	0	0	50
{ φ (g), *p*(.), PENT(g*t), N(g)}	666.4485	62.6531	0	0	49
{ φ (g*t), *p*(g), PENT(.), N(g)}	666.8994	63.104	0	0	49
{ φ (.), *p*(.), PENT(g*t), N(g)}	667.6862	63.8908	0	0	48
{ φ (g*t), *p*(.), PENT(.), N(g)}	669.0011	65.2057	0	0	48
{ φ (g*t), *p*(.), PENT(g), N(g)}	671.975	68.1796	0	0	49
{ φ (g*t), *p*(g), PENT(g), N(g)}	673.2656	69.4702	0	0	50
{ φ (t), *p*(g), PENT(g*t), N(g)}	715.8648	112.0694	0	0	70
{ φ (g*t), *p*(g), PENT(t), N(g)}	717.8472	114.0518	0	0	70
{ φ (g*t), *p*(.), PENT(t), N(g)}	718.6682	114.8728	0	0	69
{ φ (t), *p*(.), PENT(g*t), N(g)}	720.5451	116.7497	0	0	69
{ φ (g*t), *p*(g), PENT(g*t), N(g)}	797.1417	193.3463	0	0	92
{ φ (g*t), *p*(.), PENT(g*t), N(g)}	798.6056	194.8102	0	0	91

Table 3.—Model averaged parameter estimates and 95% confidence intervals for apparent survival (φ), capture probability (*p*), probability of entry (PENT), and population size (N) of the 2011 and 2012 lake sturgeon population assessment on the Bad and White rivers.

	Bad River		White River	
	Estimate	95% C.I.	Estimate	95% C.I.
2011				
φ	0.9531	0.1090-0.9997	0.9483	0.1134-0.9996
p	0.027	0.0117-0.0613	0.0276	0.0110-0.0676
PENT	0.0574	0.0218-0.1605	0.0569	0.0202-0.1662
N	557	274-839	186	40-331
2012				
φ	0.9693	0.8007-0.9960	0.9782	0.7307-0.9986
p	0.0159	0.0086-0.0293	0.037	0.0182-0.0739
PENT	0.0355	0.0225-0.0516	0.0343	0.0229-0.0529
N	1,170	657-1,684	147	66-229

DISCUSSION

The lake sturgeon assessments that have occurred on the Bad River over the last 3 spawning seasons indicate this population may be one of the largest in Lake Superior (Holey et al. 2000; Schloesser and Quinlan 2011). The lake sturgeon rehabilitation plan for Lake Superior identified populations with 1,500 spawning adults as self-sustaining (Auer 2003). The evidence of annual spawning runs reaching an approximate size of 750-1,300 individuals (approximately 850 during 2010; Schloesser and Quinlan 2011) combined with the intermittent spawning strategy of lake sturgeon indicates the Bad and White rivers meet the definition of self-sustaining. However, this does not mean conservation efforts are not necessary. Lake sturgeon are still a vulnerable species to over-harvest and sensitive to environmental degradation, so measures should be taken to ensure the population remains sustainable.

Achieving adequate numbers of recaptured fish was problematic over the last two sample seasons leading to models that were fit to sparse data. Sparse data and the failure to meet model assumptions mean care should be taken when interpreting models results. The low recapture rate observed during both years will have a tendency to increase the population size estimate and increase the spread between 95% confidence intervals. We estimated a net saturation point of roughly 10 fish per 61 m of gill net in the Bad River and 6-7 fish per 30.5 m of gill net in the White River. It appears that during peak spawning periods, the nets become saturated and allow other migrating fish to easily pass through the netting location, which may contribute to low recapture rates. Additionally, during high flows or in large debris loads, the fish can avoid capture, decreasing the chance of recapturing fish. In the future, additional nets could be added to the paired design to overcome net saturation and increase capture probabilities.

In this report we did not update the biological models, but plan to incorporate data from 2010, 2011, 2012, and future surveys to refine previously developed biological models (Schloesser and Quinlan 2011) to better understand the population demographics. A thorough understanding of lake sturgeon biology in Lake Superior is currently lacking in all populations, making this study even more important in the broader context of Great Lakes lake sturgeon management. Surveys conducted consecutively over multiple years has the benefit of estimating spawning periodicity, which is necessary to estimate total adult population size (including spawners and non-spawners) versus annual spawning run size that has traditionally been done.

We approached the 2012 hydroacoustic assessment as experimental and a "learning season" due to staff inexperience with hydroacoustic monitoring techniques. The sampling location was chosen due to ease of access and because it had the right bathymetric profile to "fit" the acoustic beam. Minor movements to better position the transducer will hopefully eliminate the problems encountered with a sandbar and provide a higher quality of data. During the 2013 season, it is the intent to work with a trained HTI professional who will provide additional training in field setup, system diagnosis, and data analysis. The data collected to calibrate lake sturgeon size and target strength will be combined with additional work in 2013 for a more robust analysis.

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