A Population Assessment of Lake Sturgeon in upper St. Croix River, Minnesota and Wisconsin 2003-2011

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Executive Summary

Due to the importance of lake sturgeon both locally and regionally, an intensive survey of the upper St. Croix River lake sturgeon population was conducted by the Minnesota and Wisconsin Departments of Natural Resources from 2003 through 2011. The goals of this survey were to assess the status and demographics of lake sturgeon in the upper St. Croix River.

A total of 724 lake sturgeon were captured during this survey ranging in length from 10-66 in (Total length). Lake sturgeon capture tally histories were used to assess population demographics. Annual population estimates of lake sturgeon $\geq$21 in ranged from 284-947 fish. Annual survival was estimated at a constant 59%. However, goodness of fit testing suggested underdispersed data and caution should be used in the application of these analyses.

Density estimates suggested the upper St. Croix River lake sturgeon population was below the recommended lower limits of a self-sustaining population. Estimates of survival were also much lower than other lake sturgeon populations.

Management recommendations include 1) Continue to not allow angling harvest of lake sturgeon in the upper St. Croix River and consider a brief catch and release season, 2) Evaluate possible improvements to fish passage in tributaries, 3) Consider sampling methods to assess lake sturgeon recruitment, 4) Continue monitoring of age, growth, and density, and 5) Conduct outreach to anglers and local lake and river groups.

Introduction

Lake sturgeon Acipenser fulvescens are considered threatened throughout much of their historic range due to overharvest, habitat loss and fragmentation by dams (WSCS 2005). The waters of Wisconsin collectively possess one of the largest self-sustaining populations of lake sturgeon in the world (WDNR 2000).

With a life strategy of slow growth and late maturation, lake sturgeon are particularly sensitive to stressors such as environmental change, barriers to fish passage, and over-exploitation. Female lake sturgeon become sexually mature at approximately 25 years and 55 in (Becker 1983). Once reaching maturity, females will typically spawn every 4-6 years. Male lake sturgeon typically reach sexual maturity at approximately 15 years and 45 in and then spawn every year or every other year.

Wisconsin's lake sturgeon management plan (WDNR 2000) recommends managing for densities of Age 2+ fish at 250 fish/mile in inland rivers and 1.5 fish/acre in lake systems (combination in flowages). It also recommends populations should be ideally represented by males up to 40 years of age and females up to 70 years of age.

This study focused on the lake sturgeon population in the upper St. Croix River. The boundaries of the study area were roughly the border of Minnesota and Wisconsin downstream to the St. Croix Falls dam, a distance of approximately 70 river miles (Figure 1). A companion study by Bass (2012) focused on size structure and growth of lake sturgeon the upper St. Croix River. Further details on the study area as well as a brief history of lake sturgeon management in the upper St. Croix River were also provided in that report.

Frequent incidental captures of lake sturgeon in the upper St. Croix River spurred angler interest for an open season. The objectives of this study were to assess the status and demographics of lake sturgeon in the upper St. Croix River to assist in management decisions.

Methods

Between 2003-2011, lake sturgeon were captured by Minnesota and Wisconsin DNR fisheries crews in the upper St. Croix River primarily by angling with night crawlers. Each sturgeon captured was measured to the nearest 0.1 in and weighed. All sturgeon were tagged with an individually numbered Carlin disc dangler tag at the base of the dorsal fin. Beginning in 2006, lake sturgeon were marked with both a Carlin disc dangler tag and a passive integrated transponder (PIT) tag that was injected near the base of the pectoral fin.

Lake sturgeon capture histories were tallied and imported into Program MARK version 6.1. Goodness of fit testing was conducted using program RELEASE within program MARK. Estimates of density, survival (Φ), probability of capture (p), and probability of entry into the population (pent) were assessed using the POPAN Jolly-Seber model. For this study, survival estimates (Φ) included both fish that had survived and fish that had not permanently emigrated out of the study area (i.e. had not traveled below the dam at St. Croix Falls). Probability of entry included both fish that had recruited to the sampling gear and fish that had immigrated into the study area.

Models with either time dependent (year) or constant (.) survival, recapture probability, and probability of entrance parameters were tested for fit. Akaike's information criterion corrected for sample size (AIC_C) was used to assess the most parsimonious model for POPAN Jolly-Seber analysis.

Catch curve analysis was used to determine lake sturgeon mortality. The descending limb of a catch curve regression was used to estimate total annual mortality (Ricker 1975). Age analysis was performed by age group rather than year class. Use of this method assumed that recruitment and survival did not vary at age over time.

Lake sturgeon age classes 3-17 provided the strongest predictive power (r^2) and were included in the catch curve regression.

Results

A total of 724 lake sturgeon were sampled in the upper St. Croix River during this survey, ranging in length from 10-66 in (Figure 2). Of the 724 lake sturgeon captured, 89 (12%) were greater than 40 in. 88 lake sturgeon (17%) were captured more than once during the course of this study (Figure 3).

Lake sturgeon were fully vulnerable to our sampling at approximately 21 in. Therefore, only lake sturgeon $\geq$21 in (N=565) were included in population analyses. Excluding fish captured more than once in the same year, the recapture rate of these fish was 13% (Table 1).

Overall goodness of fit testing using program RELEASE suggested a slight underdispersion (lower variability within the data than expected) of our lake sturgeon data (c-hat = 0.8 for test 2 and 3 combined). However, closer examination uncovered more substantial underdispersion within test3.sm (c-hat = 0.35) and test 2 (c-hat = 0.29). Cooch and White (2006) generally described test 3 as the "survival test" and test 2 as the "recapture test". Underdispersion is typically caused by insufficient data and without a universally accepted method of correcting this issue (Cooch and White 2006), application of these results should be used with caution.

Five Jolly-Seber open population models were tested (Table 2). The most parsimonious model was one that used constant Φ and time dependent p and pent. Due to the very high weight of this model (>95%), all open population demographic calculations were based on this model only. Annual population estimates ranged from 284-947 fish (4.1-13.5 fish/river mile; Table 3). Annual estimated survival from this model was 0.59 (S.E. = 0.053, 95% CI=0.49-0.69). Annual estimates of p and pent showed much variation (Table 3).

Catch curve analysis estimated total instantaneous mortality (Z) for age classes 3-17 at 0.1848 (r^2=0.76; Figure 4). Total annual mortality (A) for lake sturgeon was calculated to be 16.9%, with annual survival of 83.1%.

Discussion

Results from this survey suggest the lake sturgeon population of the upper St. Croix River was below the recommended lower limits of a self-sustaining population. Welsh et al. (2010) characterized self-sustaining lake sturgeon populations in the Great Lakes as having a minimum of 750 sexually mature fish. With a substantial portion of population estimates comprised of juvenile fish, it was very unlikely that the upper St. Croix River lake sturgeon population exceeded 750 sexually mature fish during this study. Also, the Wisconsin lake sturgeon management plan recommends managing for densities of Age 2+ lake sturgeon at 250 fish/mile. With 70 river miles included in this study, population estimates were well below that target.

Movement of fish out of the study area may have impacted survey results. However, only one fish that was tagged in the upper St. Croix River was recaptured below the St. Croix Falls dam. With over 700 lake sturgeon tagged in the upper St. Croix River and significant sampling below the St. Croix Falls dam, permanent emigration out of the study area does not appear to be substantial.

Movements of fish into tributaries of the upper St Croix were documented, particularly into the Kettle and Namekagon Rivers. The average distance moved for four fish captured in more than one river of the upper St. Croix River system was 28.1 miles. Also, a long term marking study of lake sturgeon in the Namekagon and St. Croix Rivers calculated the mean distance traveled between captures as 55.8 miles, with a range of 0-112 miles (Johannes 1980). Consideration should be given to assessing lake sturgeon demographics throughout the upper St. Croix River system.

Estimated survival calculated from the catch curve analysis (0.83) were very similar to values for lake sturgeon reported in other studies (0.8 in the lower Kettle River, Dieterman et al. 2010; 0.85 in the St. Mary's River, Bauman et al. 2011). Estimated survival calculated by Jolly-Seber analysis was quite low and may have been impacted by insufficient sample size, as suggested by the goodness of fit testing. Also, fish movement out of the study area may have contributed to the low survival estimate.

Annual probability of entrance estimates showed much variation across sampling years. These results suggest that annual recruitment may have been inconsistent during this study. However, inconsistent sampling effort has been found to impact these estimates (Bauman et al. 2011). Similar to their findings, the year with the lowest number of fish captured in this study (2005) also had one of the lowest pent estimate.

Little information is known on lake sturgeon angling catchability and hooking mortality. During this study, 17% of marked lake sturgeon were recaptured at least one time and a total of 37 lake sturgeon in this study were captured multiple times in one year, suggesting high catchability. In a study in the Kettle River using similar methods but over a longer time period (20 years) and smaller section of river (22 miles), 49% of lake sturgeon were captured multiple times, with one fish captured 12 times. Kozfkay and Dillon (2010) estimated that each white sturgeon in a stretch of Snake River in Idaho open to catch and release angling was hooked an average of 7.7 times in one year. Delayed hooking mortality for white sturgeon caught by anglers in the Fraser River, British Columbia, was estimated at 2.6% (Roubichaud et al. 2006). With potential illegal harvest and unknown levels of delayed hooking mortality, efforts to allow angling opportunities for lake sturgeon should proceed cautiously. To mitigate the potential impacts of high water temperature on delayed mortality, a brief catch and release season during cooler water temperatures in the fall may be considered.

Conclusions and Management Recommendations

1. We recommend continuing closing the upper St. Croix lake sturgeon population to angler harvest. The population has not met any of the parameters established for stable, self-sustaining populations. The potentially high angling catchability of lake sturgeon and possible hooking mortality may add to already high estimates of mortality. A brief catch and release season during cooler water temperatures in the fall may be considered.
2. Efforts to improve fish passage in the upper St. Croix River basin should be evaluated. Lake sturgeon have shown resilience to genetic impacts due to their long generation time (Wozney et al. 2011). However, reconnecting the upper St. Croix River population to other isolated populations in the basin would insure maintenance of genetic diversity as well as link critical habitat for both populations.
3. Methods to assess lake sturgeon recruitment are lacking. Wading and haul-seine surveys have proven effective to sample age-0 lake sturgeon in areas characterized by low current velocity and high water clarity (Benson et al. 2005). Use of these methods for the upper St. Croix River should be explored.
4. Continued monitoring of age, growth, and density is needed to document any population changes. Other sampling gear such as setlines should be considered to increase the number of lake sturgeon captured.
5. Outreach to anglers and local lake and river groups should continue. Opportunities to educate the public about this unique fish are critical to lake sturgeon recovery.

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Table 1. Capture frequency of lake sturgeon ≥ 21 in captured in the upper St. Croix River from 2003 to 2011. R(i) is the total number of lake sturgeon captured during that year. j is the number of fish initially captured in the i^{th} year recaptured in later years. For example, a total of 33 lake sturgeon ≥ 21 in were initially marked in 2003. There were eight recaptures of those fish in later sampling (five in 2004, two in 2005, and one in 2007).

i	R(i)	j	2004	2005	2006	2007	2008	2009	2010	2011	Total
2003	33		5	2	0	1	0	0	0	0	8
2004	113			7	3	6	1	1	1	0	19
2005	34				1	1	0	1	0	0	3
2006	82					6	3	1	0	0	10
2007	90						15	3	2	0	20
2008	89							10	2	0	12
2009	72								2	0	2
2010	41									1	1
2011	11										NA

Table 2. Models used either constant (.) or time varying parameters (year) for apparent survival (Φ), probability of recapture (p), and probability of entrance (pent). Corrected Akaike values (AIC_C), ΔAIC_C (=$AIC_{C(i)}$ - $AIC_{C(min)}$), Akaike weights ($AIC_C w_i$), model likelihood, and number of parameters (K) displayed for each model.

Model	**AIC_C**	**ΔAIC_C**	**AIC_C weight**	**Model likelihood**	**K**
Φ(.), p(year), pent(year)	653.248	0.00	0.95626	1.0000	16
Φ(year), p(year), pent(year)	661.009	7.76	0.01974	0.0206	24
Φ(year), p(year), pent(.)	661.115	7.87	0.01872	0.0196	19
Φ(year), p(.), pent(year)	663.671	10.42	0.00522	0.0055	17
Φ(.), p(.), pent(year)	672.392	19.14	0.00007	0.0001	9

Table 3. Annual estimates of population size, probability of recapture (p), and probability of entrance (pent) derived from the model Φ(.), p(year), pent(year). Annual survival was estimated at 0.59 (S.E. = 0.05).

Year	**Population Estimate (95% CI)**	**p (95% CI)**	**pent (95% CI)**
2004	478 (260-696)	0.24 (0.14-0.37)	NA
2005	284 (140-427)	0.12 (0.06-0.21)	0.00
2006	947 (516-1378)	0.09 (0.05-0.14)	0.34 (0.19-0.53)
2007	562 (256-869)	0.16 (0.09-0.28)	0.00
2008	436 (219-653)	0.20 (0.12-0.33)	0.05 (0.00-0.32)
2009	437 (198-677)	0.16 (0.09-0.28)	0.08 (0.02-0.23)
2010	530 (118-943)	0.08 (0.03-0.17	0.12 (0.03-0.38)

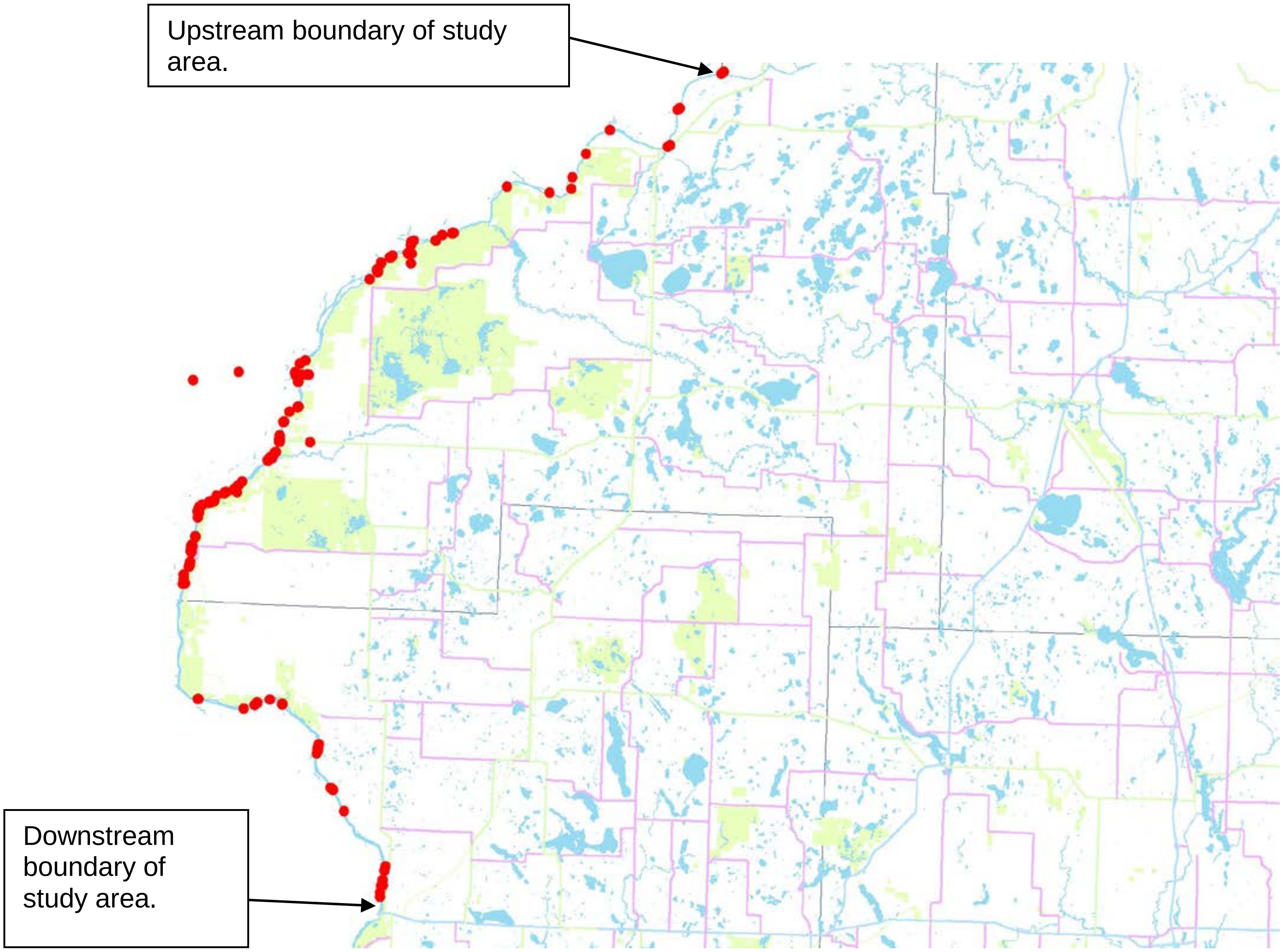

Figure 1. Map depicting lake sturgeon capture locations (each red dot represents one captured fish; two dots not in St. Croix represent fish captured in the Snake River) on the St. Croix River, 2003-2011.

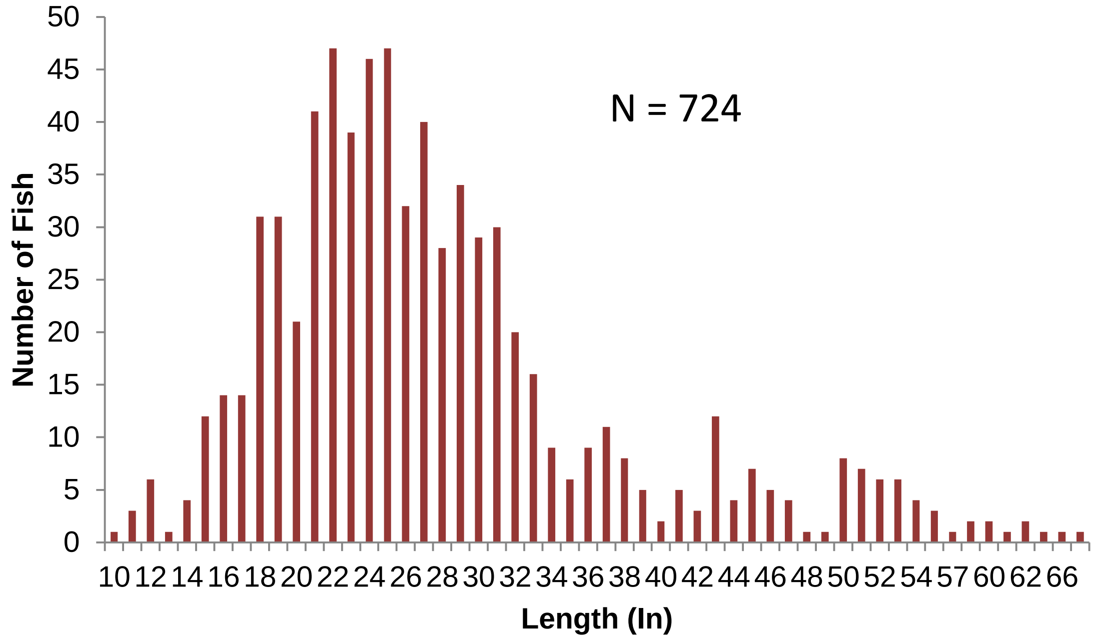

Figure 2. Length frequency of all lake sturgeon captured in St. Croix River, 2003-2011.

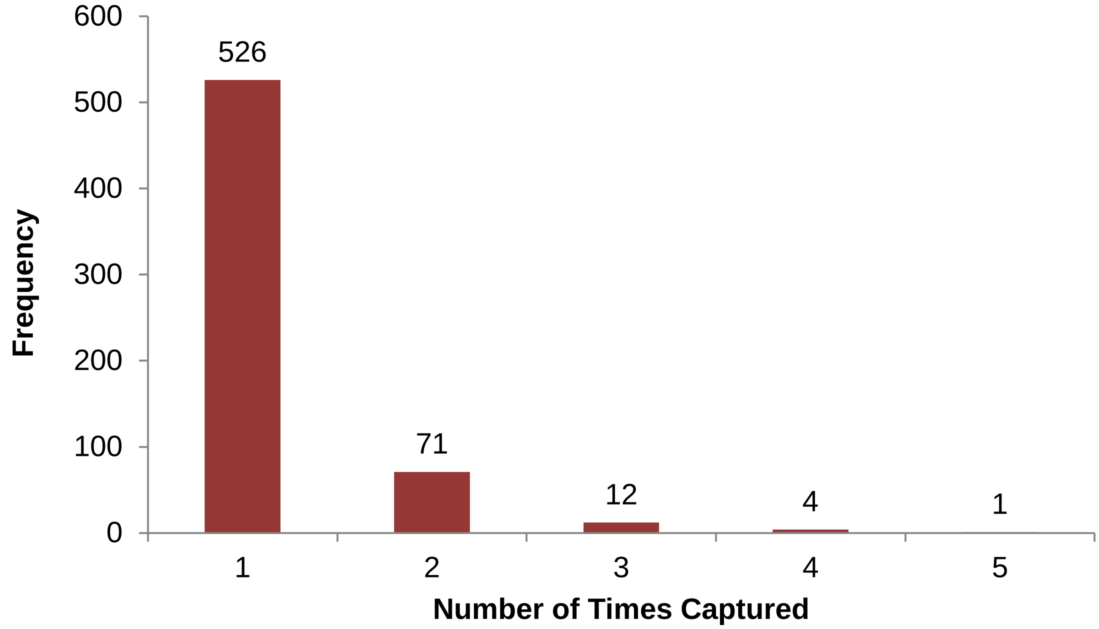

Figure 3. Frequency of capture for lake sturgeon sampled from St. Croix River, 2003-2011.

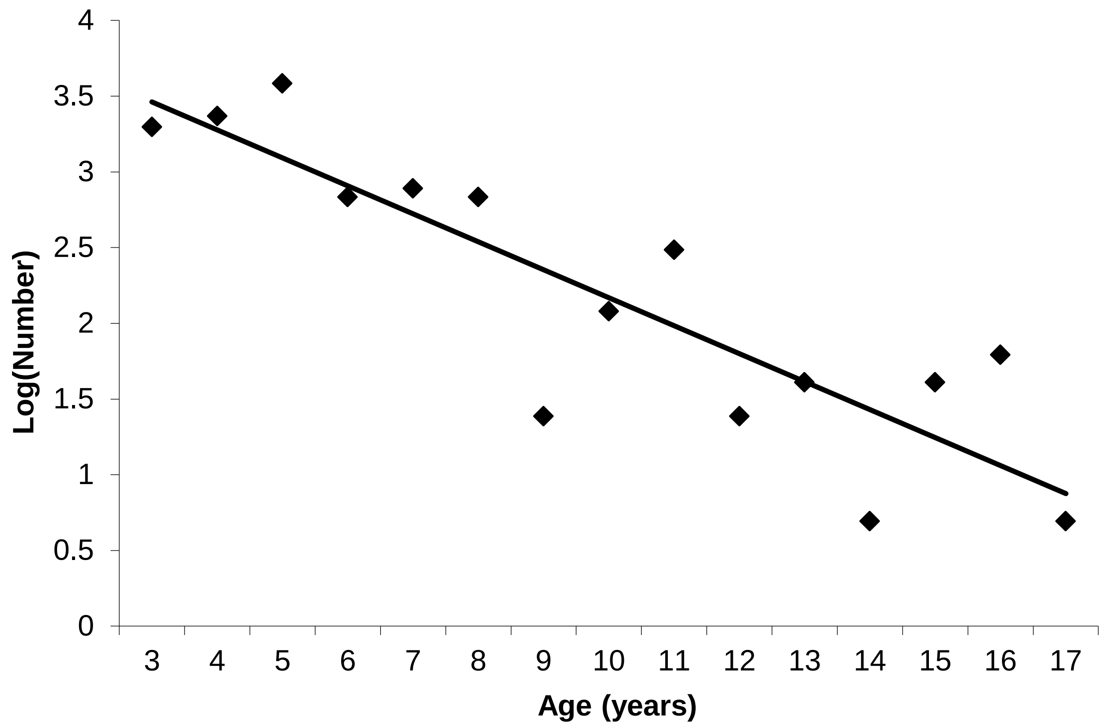

Figure 4. Catch curve for lake sturgeon sampled from St. Croix River, 2003-2011.