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LAKE STURGEON (*ACIPENSER FULVESCENS*) SAMPLING TECHNIQUES ON THE UPPER MISSISSIPPI RIVER, USA

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ABSTRACT

Lake sturgeon were an important commercial fish in the upper Mississippi River and Great Lakes region during the late 1800's. Because of the high market demand and mismanagement for sturgeon they were soon overexploited. These factors along with deteriorating water quality, habitat destruction, and the building of dams which inhibit upstream movements to spawning areas reduced or extirpated their populations over much of their native range.

In an effort to reestablish populations in the Mississippi and Missouri Rivers and to produce a self sustaining population, the Missouri Department of Conservation began obtaining fertilized eggs and rearing and stocking lake sturgeon in 1984. More than 286,000 lake sturgeon have been stocked since this time. Fish from the first stockings should now be reaching sexual maturity creating a population with varying age classes. Research is now needed to better manage this species for future success. In order to study these animals the first step is to develop the most effective and efficient sampling methods.

In this study I used standard gill nets, hobbled gill nets, trotlines and hoop nets to determine the best gear at catching lake sturgeon during different river conditions.
All sampling was conducted from March 2005 to November 2006 in Pool 24 of the Mississippi River.

Over the two years 567 gear sets were deployed capturing 319 lake sturgeon. Sizes ranged from 192 mm/0.1 kg to 1218 mm/14.65 kg. Gill nets had significantly higher catch rates than hoop nets and trotlines. The dam, tailwaters, and wing dike

habitats had significantly higher catch rates than the channel border, side channel and main channel habitats, but they were not significantly different from each other.

A General Linear Model (GLM) was preformed ($\alpha = 0.05$) to compare habitat and gear type using temperature, discharge, and depth as covariates. This test resulted in an R-squared value of 0.17. It showed that gear type ($p < 0.0001$), habitat ($p = 0.0017$) and temperature ($p = 0.0128$) all had significant impacts on catch rates, but depth ($p = 0.2544$) and discharge ($p = 0.6848$) did not.

Gill nets caught more fish across length classes than any other gear type. Hoop nets caught some of the smallest lake sturgeon but they had relatively low catch rates. The largest lake sturgeon that were captured in gill nets was during the months of March, July, August and September and the smallest were in April. Trotlines captured the largest sturgeon during the month of September and the smallest in the month of April. Trotlines did not catch any lake sturgeon smaller than 300 mm.

A linear regression ($p = 0.010$) showed mesh size had a positive linear relationship to fork length and resulted in an R-squared value of 0.3889. A t-test showed that the hobbled gill nets had significantly higher catch rates when compared to standard non-hobbled gill nets. There was no significant difference between standard non-hobbled gill nets and trotlines.

Straight 8/0 hooks caught larger fish than circle 11/0 hooks. A t-test found this not to be a significant difference ($p = 0.062$), but with a difference of 100 mm this could be considered biologically significant. Circle hooks had a higher mean catch per unit of effort than straight hooks, but again a paired t-test found this not to be significant ($p = 0.1189$).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Lake sturgeon (*Acipenser fulvescens*) are found in three drainages of the North American continent: the Hudson Bay, the Great Lakes, and the Mississippi River drainage basins. The presence of sturgeons in the fossil records dates back to well over 175 million years and shows that sturgeons have remained relatively unchanged through time. (Choundhury and Dick 1998; Krieger and Fuerst 2002).

Sturgeons (family Acipenseridae) are a primitive fish located only in the northern hemisphere (Pflieger 1997). A majority of the species live in marine environments, with most freshwater species retaining andronomy to some degree. All species of sturgeons spawn in freshwater (Birstein and Bemis 1997). These fish have a heterocercal tail in which the backbone extends into the upper fork of the caudal fin. They also have rows of primitive plate-like scales called scutes. Underneath the head are a row of four barbels that they use to find food by dragging on the benthic substrate. Once they find food they use their telescoping mouth to vacuum up benthic invertebrates and fish (Pflieger 1997).

Lake sturgeon have a cone shaped snout. They are yellowish brown in color and have smooth, unfringed barbels. The lake sturgeon's belly is absent of scutes and the lower lip has two lobes. This species of sturgeon requires 10 to 20 years to reach sexual maturity and then only spawn every 2 to 5 years (Pflieger 1997). They can live to nearly 150 years in age and reach excesses of 2.4 meters (8 ft.) in length and weights of nearly 136 kilograms (300 lbs). Lake sturgeon also exhibits migratory behavior and may travel up to 322 kilometers (200 miles) in unrestricted waters to spawning grounds (McKinley et al. 1998).

Lake sturgeon were an important commercial fish in the upper Mississippi River and Great Lakes region during the late 1800's. Because of the high market demand and mismanagement for sturgeon, they were soon overexploited. These factors along with plummeting water quality, habitat destruction, and the building of dams which inhibit upstream movements to spawning areas reduced or extirpated their populations over much of their native range (Williams et al. 1989). The historic population size of lake sturgeon is unknown, but estimates can be made from commercial fishing data. In the years from 1975 to 1999 harvestable sized lake sturgeon abundance in Black Lake, Michigan declined nearly 66% (Baker and Borgeson 1999). Lake Erie sturgeon harvest declined 80%, from about 2,300,000 kilograms to less than 455,000 kilograms between 1885 and 1895 (Harkness and Dymond 1961). It is estimated that the population size of lake sturgeon is about 1% of the abundance prior to the 19th century (Tody 1974). Lake sturgeon are now a state endangered species in Missouri.

Even though most populations are on the decline, some management strategies have had success in improving lake sturgeon stocks. Such strategies include the placement of rock and gravel substrates in rivers to produce habitat and spawning locations in the Lake Winnebago tributaries (Kempinger 1988; LaHaye et al. 1992). Studies have also shown that populations can become more abundant when there are sufficient numbers of mature fish along with adequate habitat (Folz and Meyers 1985). Thus, increasing the numbers of reproducing adults and improving their spawning habitat will likely increase the density of lake sturgeon.

In an effort to reestablish lake sturgeon populations in the Mississippi and Missouri rivers and to produce a self-sustaining population, the Missouri Department of

Conservation (MDC) started obtaining fertilized eggs from the Wisconsin Department of Natural Resources in 1983 (Todd 2007). In August and November 1984, MDC stocked 12,179 lake sturgeon in Mark Twain Lake, a tributary lake to the Mississippi River. Another 11,136 were stocked in the lake from 1985 to 1986. Since the initial stocking, lake sturgeon have been released at four sites on the Mississippi River (Figure 1). As of December 2004 in Missouri, nearly 286,000 lake sturgeon have been stocked in the Mississippi River and its tributaries. Reestablishment efforts have had some success in that encounters with lake sturgeon by anglers and commercial fisherman are now more frequent than prior to the stockings (Todd 2007).

A majority of the research that has been conducted on lake sturgeon has been implemented in the Great Lakes and Hudson Bay drainages from Michigan to Wisconsin and into Canada (Williams et al. 1989). Little research has been conducted on lake sturgeon in the Mississippi River. Fish from the original stockings in 1984 are now reaching the age of sexual maturity. A population with varying age classes due to subsequent stockings should now be present. Research is now needed on the upper Mississippi River to better manage this species for future success. In order to study populations of these animals, the first step is to develop the most effective and efficient sampling methods to use in the pooled portion of the Mississippi River.

The sampling gears targeting this species have included gill nets, trotlines, hoop nets, trammel nets, electrofishing, trap nets, and many others. Published literature on the most effective sampling methods are nonexistent and most studies have adopted commercial fishing strategies to use for their research. Many of the methods implemented in lakes and small tributaries may not be effective in large rivers.

In this study I used standard gill nets, hobbled gill nets, trotlines and hoop nets deployed in Pool 24 of the Mississippi River to determine the best gear at catching lake sturgeon during different river conditions (i.e. water temperature and discharge).

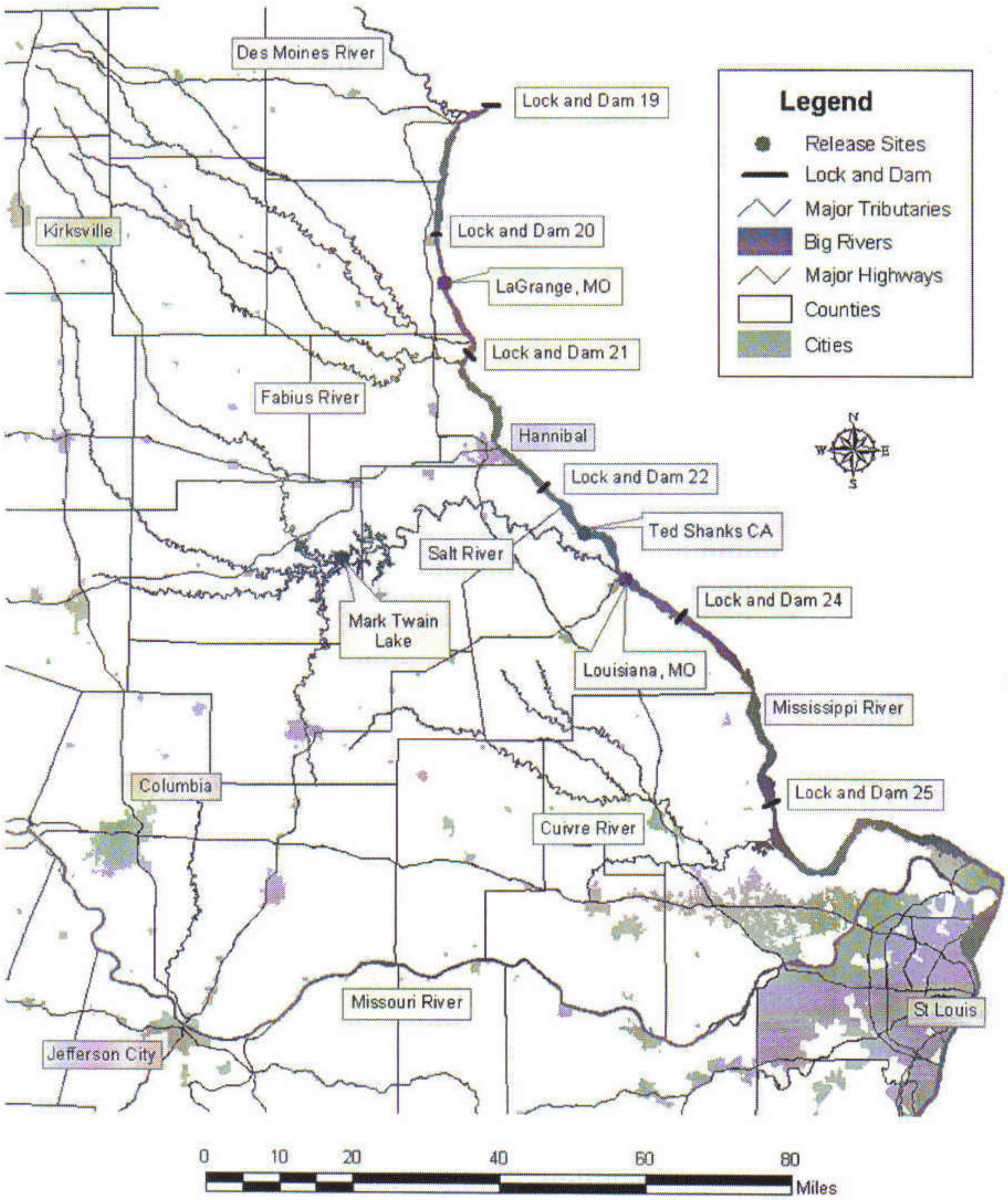

Figure 1. Lake sturgeon release sites on the Mississippi river and its tributaries (Todd 2007).

MATERIALS AND METHODS

Study Location

All sampling was conducted from March 2005 to November 2006 in Pool 24 of the Mississippi River. Pool 24 is located 6.4 kilometers (4 miles) downstream of Hannibal, Missouri. It is a 41.8 kilometer (26 mile) pool confined between Lock and Dam 22 at Saverton, Missouri and Lock and Dam 24 at Clarksville, Missouri.

Macrohabitats

Pool 24 is located in the Upper Mississippi River and offers a wide range of habitats. For this study, I chose to use a broad habitat classification system based on a modified version developed by Wilcox (1993). The modified version for this study focuses on seven broad macrohabitats (Figure 2).

The Wing Dike (WD) habitat is an area that surrounds a wing dike up to 92 meters upstream or downstream. This covers any gear set placed directly off the wing dike. This classification also includes L-dikes, chevrons and kicker dikes which are extensions of a reveted bank into the river. The Main Channel (MC) habitat is the navigational channel and is located between the navigational buoys, which is the area for barge traffic. Channel Border Open (CBO) habitat is free of wing dikes and is the area between the main channel habitat and the shore. In contrast Channel Border Diked (CBD) habitat is the area between the wing dike habitats and is also located between the main channel habitat and the shore. The Side Channel (SC) habitat is the area behind and in between the river islands. This habitat included connected (water flowing through) and non-connected (no water flow) side channels. Tailwater (TW) habitat is the area directly below the dam gates and is an area of turbulent water. The Dam (DM) habitat is located next to the tailwaters and is below the earthen portion of the dam. This area only experiences down river flow during high river stages. During normal and low flow times an eddy is created below the earthen portion which creates an area of deposition.

Gear Types

Gill Nets – Monofilament gill nets 91.4 m (300 ft) long and 2.4m (8 ft) tall were used. Each net had a different bar mesh size which included: 6.4, 7, 7.6, 8.9, 10.2, 11.4, and 12.7 cm (2.5, 2.75, 3, 3.5, 4, 4.5, and 5 inches respectively). Experimental gill nets derived from a modified version used in a study on the St. Louis River (Schram et al. 1999) were also used. These 91.4 m (300 ft) nets consisted of six 15.2 m (50 ft) alternating panels of three different bar mesh sizes, 5.1, 7.6, and 10.2 cm (2, 3 and 4 inches respectively). Some non-experimental gill nets were also hobbled. A hobbled gill net is a gill net that has had the lead line and the float line tied closer together. This creates a pocket or "C" shape with the net allowing a portion to lie slightly parallel to the bottom. Hobbled gill nets used included 2.5 m (8 ft) tall nets hobbled to 1.3 m (4 ft) and 4.9 m (14 ft) nets down to 2.4 m (8 ft) in different bar mesh sizes.

Nets were fished overnight and less than 24 hours when water temperatures were below 12.8 ˚C. When temperatures rose above 12.8 ˚C, short-term sets were utilized. During summer temperatures above 26.7 ˚C, nets were not allowed to fish more than three hours. These guidelines reduced stress and mortality.

A crew of two or three people set gill nets parallel to river current in randomly

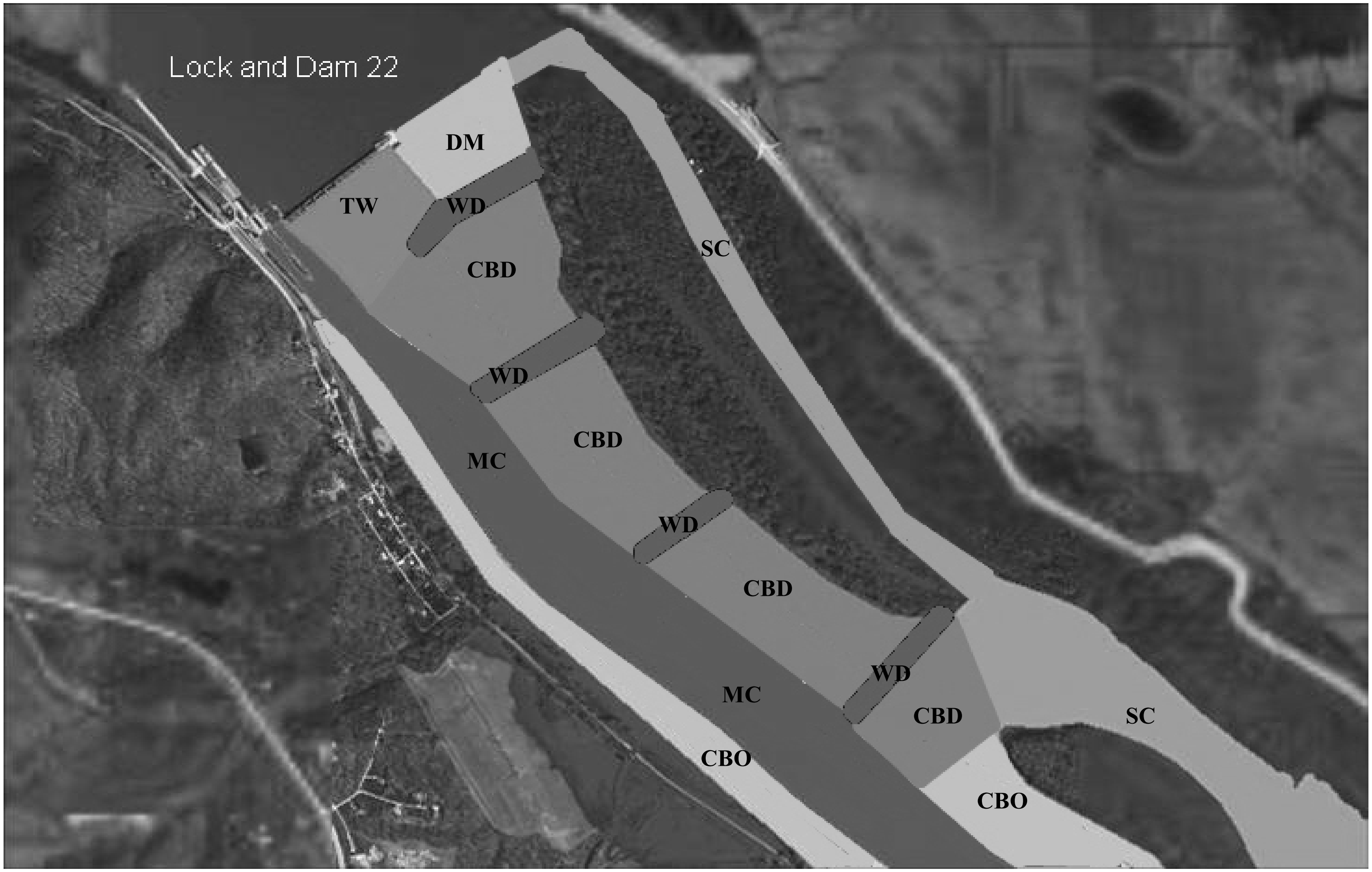

Figure 2. Habitat Classification for the Upper Mississippi River. **DM** = Dam, **TW** = Tailwaters, **WD** = Wing Dike, **CBD** = Channel Border Diked, **MC** = Main Channel, **SC** = Side Channel, **CBO** = Channel Border Open.

chosen habitats using a large sand anchor. The anchor had a 12.2 m (40 ft) line attached to the lead line on the upstream end, and on the downstream lead line a weight was attached. Large floats were attached to the float line at both ends of the gill net. Depth measurements were recorded at the upstream and downstream ends of the net along with a GPS coordinate at the middle. Catch per unit of effort (CPUE) of gill nets was calculated as lake sturgeon per hour (lksg/hr).

Trotlines- All trotlines were constructed by hand and were based on a modified version from a study done on the St. Clair River (Thomas and Haas 1999). A 0.64 cm (1/4 in) diameter main line with a length of 91.4 m (300 ft) was used. The first dropper line was set about 7.5 m (25 ft) from each end. Two brass brads were crimped over the main line with about 5 cm (2 in) of space between them in order to keep the dropper from moving down the line. Each dropper line was spaced about 3.05 m (10 ft) apart on the main line resulting in 25 hooks. A small steel ring was tied at each end to allow for anchor and float attachment.

Droppers were removable and constructed of a 46 cm (18 in) #36 nylon twine. A standard trotline snap with a barrel swivel was tied on one end. Two different hook types were evaluated. The first type was a standard 8/0 straight "J" hook and the second type was an 11/0 circle "C" hook. Each trotline consisted of 12 circle and 13 straight hooks.

Three different bait types were used during this study. First were large Canadian night crawlers (*Lumbricus terrestris*) purchased from a local bait shop. Second was cut gizzard shad (*Dorosoma cepedianum*) captured from the Mississippi River during electrofishing. The third type of bait used was "pickled squid sturgeon bait" purchased from Gilmore Fish Smokehouse in Dallesport, WA. This bait type is used in capturing green sturgeon (*Acipenser medirostris*) and white sturgeon (*Acipenser transmontanus*) in the northwest (T. Hill, U S Fish and Wildlife Service 2005, personal communication).

One advantage of the trotline is that it could be set in areas that are very difficult or impossible to set other gear types. Trotlines were deployed in randomly chosen habitats and could be set either parallel or perpendicular to the current and at deep or shallow depths. They could also be set during high river discharge, when there were large amounts of debris, or when other gear types are unfavorable. Depth was recorded at both the upper and lower ends of the trotline as well as a GPS coordinate in the middle of the set.

Trotlines were allowed to fish overnight when water temperatures were below 24˚C. When water temperatures rose above 24˚C, 3 to 5 hour sets were implemented to reduce stress and mortality. During this period multiple sets per day with the same line could be used. The CPUE was calculated as lake sturgeon per hour.

Hoop nets**-** Hoop nets used for this study were selected from the Missouri Department of Conservation inventory. They were constructed of # 15 twine with a mesh of 3.81 cm (1.5 in). The mouth measured 91.44 cm (36 in) in diameter and each hoop net was 2.44 m (8 ft) in total length.

Hoop nets were set parallel to river current in randomly chosen habitats. A large sand anchor with a 12.2 m (40 ft) lead line was attached to the cod end and a float with the same length of rope was attached to the top of the downstream hoop. After the sand anchor was set the hoop net was fed off the bow of the boat as the driver controlled rate of deployment. A single depth was recorded at the bottom end of the net along with a

GPS coordinate. The nets were fished overnight and CPUE was recorded as lake sturgeon per hour.

Information recorded for each gear set included; date and time of set, date and time of retrieval, river mile, GPS coordinate, habitat type, upper and lower depths, and discharge and temperature at the time of deployment.

All lake sturgeon were weighed and measured. Weight was taken to the nearest gram and fork length to the nearest millimeter. The fish were then checked for a coded wire tag and a PIT (passive integrated transponder) tag. Coded wire tags are implanted into hatchery reared fish and the location of these in the fish's body designates when and where the fish were released during stockings. The PIT tags are implanted beneath the dorsal fin of all lake sturgeon in Missouri upon capture. The tags contain a microchip that has a unique identification number. Each time a fish is recaptured with this type of tag, information such as length, weight and location can be compared to previous captures of that individual sturgeon. Genetic tissue samples were taken from the caudal fin and sent to Andrea Drauch of Purdue University for analysis.

Data Analysis

Statistical analysis was performed using *SAS 9.0* software (SAS Inc., Cary, North Carolina). A nonparametric Kruskal-Wallis test with Dunn's multiple comparison post hoc test and Bonferroni correction (Zar 1999) was used to evaluate differences in CPUE among gear types (experiment-wise alpha = 0.05) (all gill net mesh sizes combined). For the previous test, both hobbled and non-hobbled gill nets were combined, but later a t-test was used to compare CPUE of non-hobbled and hobbled gillnets. A nonparametric

Kruskal-Wallis with a Dunn's post hoc test was used to compare CPUE between the different habitat types. A General Linear Model (GLM) was performed to compare CPUE of each gear type and habitat using temperature, depth and discharge as covariates. A length frequency histogram was created to compare the sizes of lake sturgeon captured for each gear type. Linear regression was used to determine if there was a correlation of gill net mesh size to fork length. I used a t-test to compare mean lengths of lake sturgeon captured by the two trotline hook types and a paired t-test to compare the CPUE of the two hook types (Zar 1999).

RESULTS

During this study 319 lake sturgeon were captured, 36 of these being recaptures (twelve recaptures PIT tagged prior to this study) (Appendix A). Over the two years, 567 gear sets were deployed (Table 1). Lake sturgeon captured ranged in sizes from 192 mm/0.1 kg to 1218 mm/14.65 kg.

Gill nets had the highest catch rates with hoop nets being the lowest (Figure 3). A nonparametric Kruskal Wallis test was used on these data because of the large number of gear sets with zero catch which skewed the data and violates the assumption of normality. This test rejected the null hypothesis that gill nets, trotlines and hoop nets all had the same catch per unit of effort ($p < 0.001$, df = 2). Gill nets had significantly higher catch rates than trotlines and hoop nets, but there was no significant difference in catch rates between trotlines and hoop nets. A nonparametric Kruskal-Wallis test showed that the dam, tailwater, and wing dike habitats had significantly higher catch rates than the channel border, main channel and side channel habitats (Table 2).

In an effort to create a model that better predicts catch rates a GLM test was performed ($\alpha = 0.05$) to compare CPUE of each habitat and gear type using temperature, discharge, and depth as covariates. This test resulted in an R- squared value of 0.17, F value = 4.68, df = 22. Although this is weak it did show that gear type ($p < 0.0001$), habitat ($p = 0.0017$) and temperature ($p = 0.0128$) all had significant impacts on catch rates, but depth ($p = 0.2544$) and discharge ($p = 0.6848$) did not. Temperature showed a positive relationship to CPUE, so as temperature increased CPUE increased. The Tukey post hoc tests supported the Kruskal-Wallis tests stating CPUE for gillnets were

Table 1. Number of samples for each gear type within each habitat during 2005 and 2006 combined (All mesh sizes combined).

	Channel Border Diked (CBD)	Channel Border Open (CBO)	Dam (DM)	Main Channel (MC)	Side Channel (SC)	Tailwaters (TW)	Wing Dike (WD)	**Total**
Gill nets (GN)	4	12	47	2	2	18	56	**141**
Hobbled Gill nets (HGN)	2	5	57	1	2	7	39	**113**
Trotlines (TL)	13	32	39	8	10	30	73	**205**
Hoop nets (HN)	13	35	26	0	5	7	22	**108**
Total	**32**	**84**	**169**	**11**	**19**	**62**	**190**	***567***

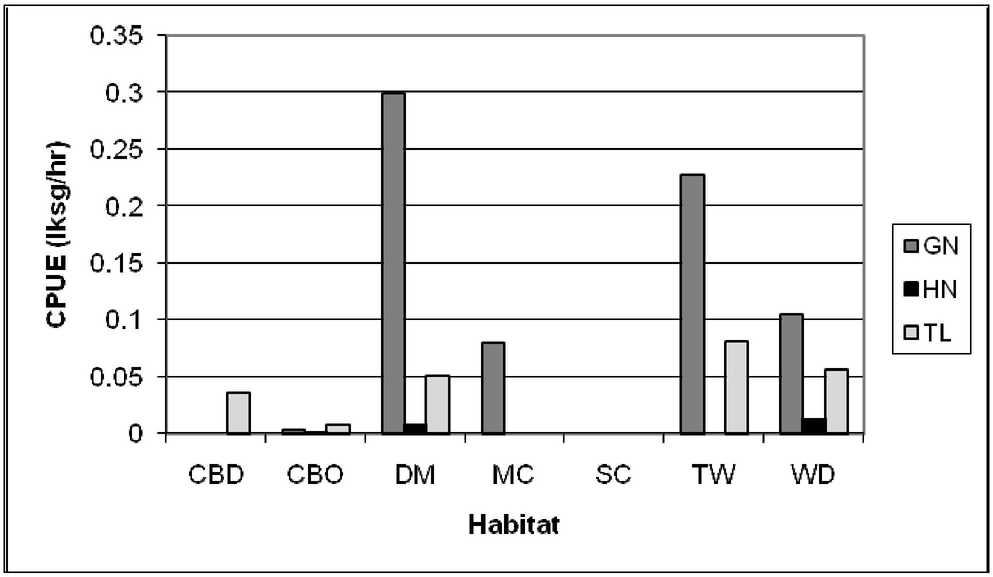

Figure 3. Catch per unit of effort (CPUE) for each habitat by each gear type. CPUE is displayed as lake sturgeon per hour (lksg/hr) (CBD = Channel Border Diked, CBO = Channel Border Open, DM = Dam, MC = Main Channel, SC = Side Channel, TW= Tailwaters, WD = Wing Dikes) (GN = gill net, HN = hoop net, TL = trotline) (All mesh sizes and gill net types combined).

Table 2. Mean CPUE (lake sturgeon per hour) in each habitat. Same letters indicate no significant difference.

Habitat Type	Mean CPUE
Dam	0.075 [a]
Tailwater	0.040 [a]
Wing Dike	0.038 [a]
Channel Border Diked	0.015 [b]
Channel Border Open	0.004 [b]
Main Channel	0.005 [b]
Side Channel	0.000 [b]

significantly different than the other two gear types and the dam, tailwater and wing dike habitats had significantly higher CPUE than the other habitats.

Temperature profiles for the two years showed that the water temperatures were warmer on average in 2005 than in 2006 with the biggest difference being in the late summer and fall (Figure 4). Gill nets had good catch rates throughout the temperature range with the highest catch rates between 12 to 17 ˚C (Figure 5). Trotlines had their highest CPUE between 23 and 26 ˚C.

In 2005, three flood pulses were recorded with two in the spring and one in the fall. In contrast 2006 only produced one flood pulse for the entire year which occurred during the spring (Figure 6). Gill nets had the greatest catch rates during high discharge and trotlines during low discharge (Figure 7), but these results are likely an artifact of the temperature relationship since discharge was found not to have a significant impact on CPUE.

Gill nets caught more fish across length classes than any other gear type (Figure 8). Hoop nets caught some of the smallest lake sturgeon but they had relatively low catch rates throughout. Trotlines did not catch any fish smaller than 300 mm. A bimodal distribution of length classes in the population was also observed.

On average the largest lake sturgeon captured in gill nets were during July, August, September and March and the smallest were in April (Figure 9). Most lake sturgeon caught in gill nets were captured in the month of October and the fewest in July and August (Figure 10).

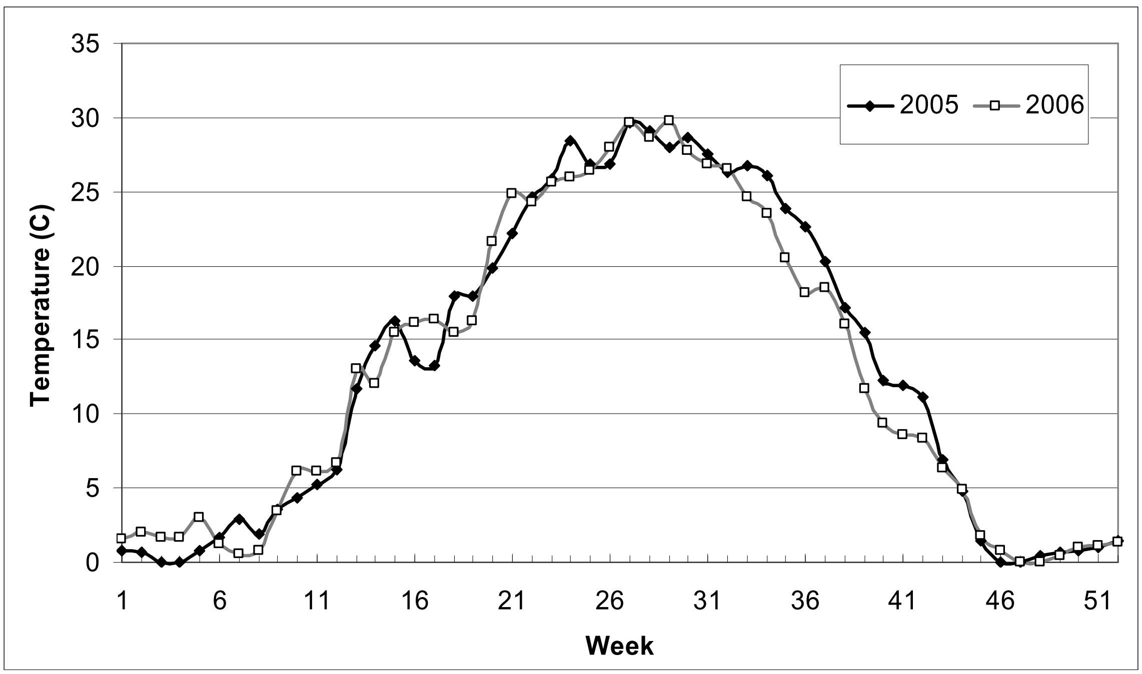

Figure 4. Average weekly temperature profile (˚C) of the Mississippi River at Lock and Dam 22 for 2005 and 2006.

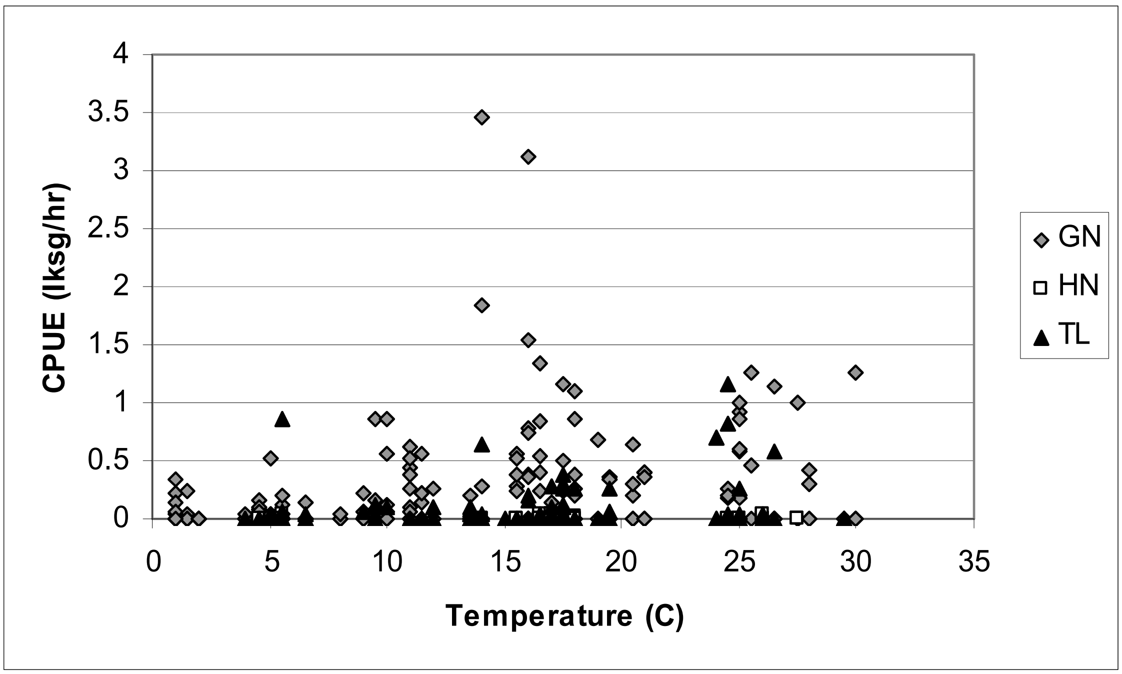

Figure 5. Catch per unit of effort (CPUE) at water temperature for each gear type. CPUE is displayed as lake sturgeon per hour. (GN = Gill net, HN = Hoop net, TL = Trotline) (All mesh sizes and gill net types combined).

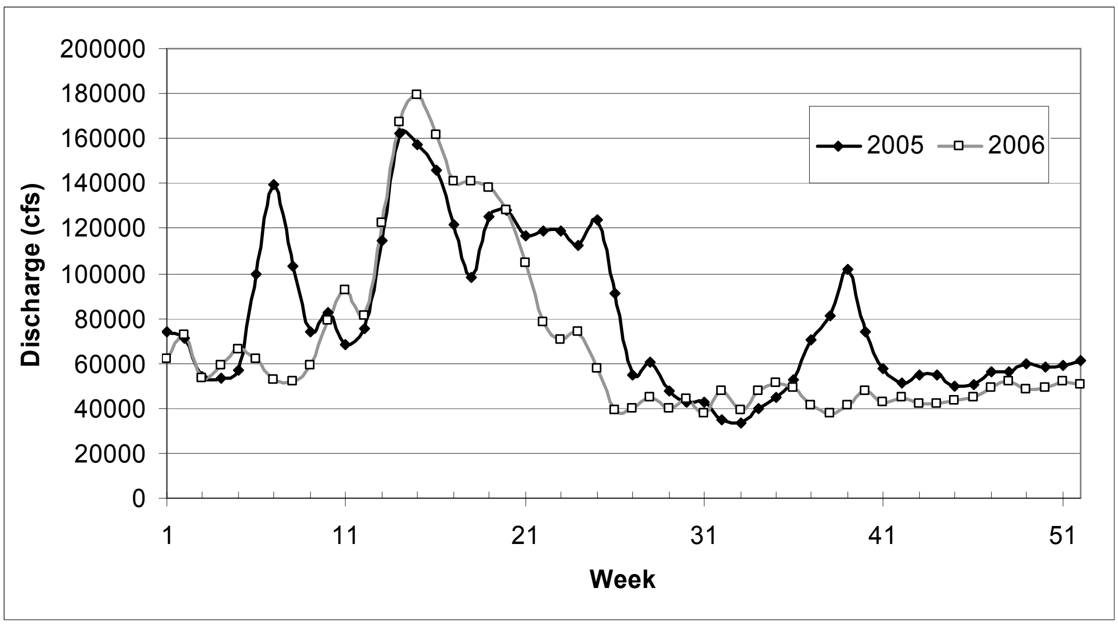

Figure 6. Mean weekly discharge profile in cubic feet per second (cfs) of the Mississippi River at Lock and Dam 22 during 2005 and 2006.

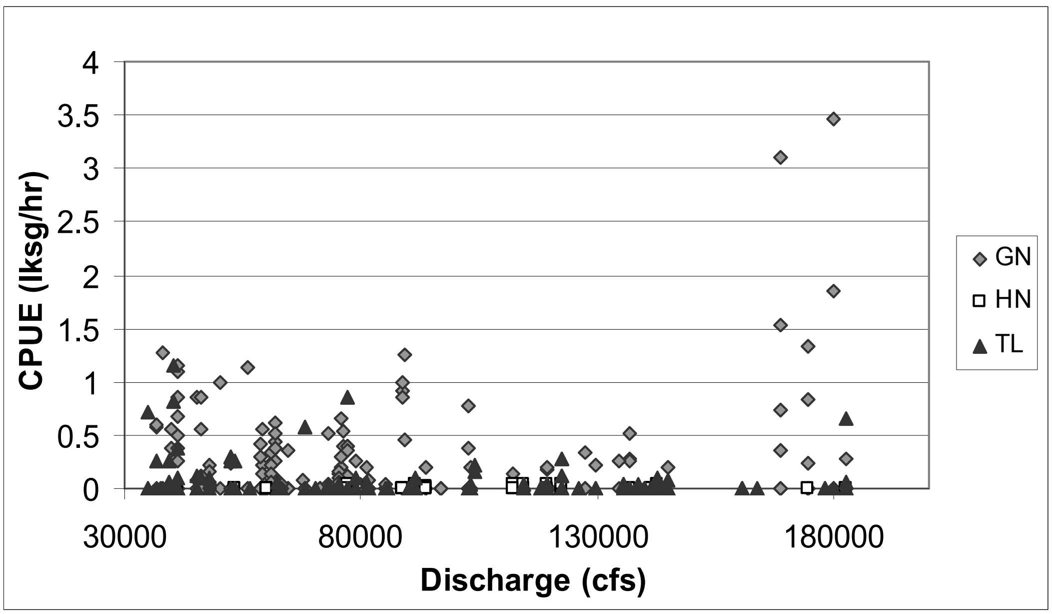

Figure 7. Catch per unit of effort (CPUE) at discharge (cfs) for each gear type (CPUE is displayed as lake sturgeon per hour). (GN = gill net, HN = hoop net, TL = trotline) (All mesh sizes and gill net types combined).

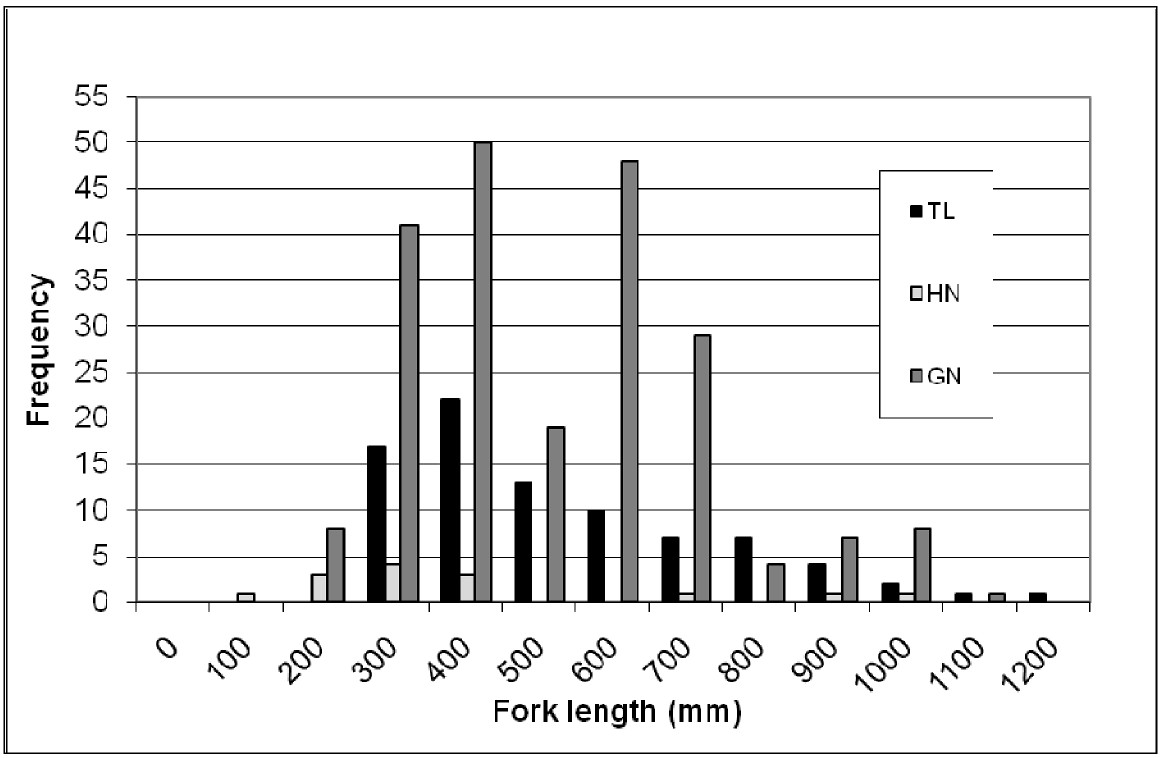

Figure 8. Length frequency of lake sturgeon captured by each gear type during 2005 and 2006 combined (GN =Gill net, HN = Hoop net, TL = Trotline) (All mesh sizes and gill net types combined).

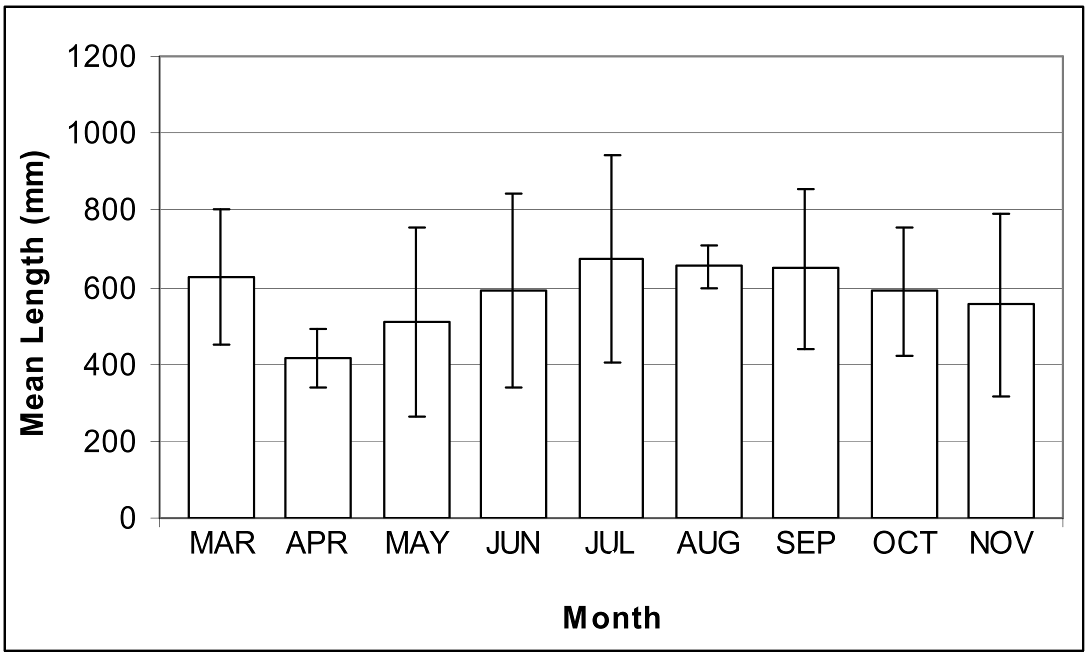

Figure 9. Mean fork length (mm) of lake sturgeon captured with gill nets by month for 2005 and 2006 combined. (Error bars are standard deviation) (All mesh sizes and gill net types combined).

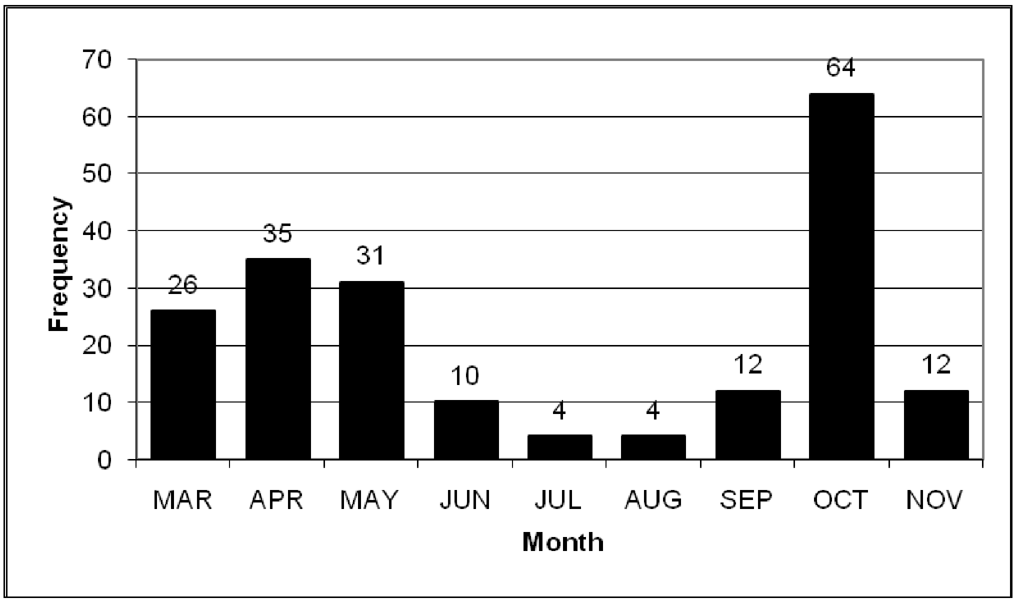

Figure 10. Frequency of lake sturgeon captured with gill nets by month during 2005 and 2006 combined (All mesh sizes and gill net types combined).

Trotlines captured their largest sturgeon on average during the month of September and the smallest in the month of April (Figure 11). The greatest frequency of sturgeon captured on trotlines occurred during the months of April and May with the fewest in August (Figure 12). The largest lake sturgeon on average captured in hoop nets was during the month of March (Figure 13). Hoop nets captured a low frequency of lake sturgeon throughout the sampling year (Figure 14).

The highest CPUE for lake sturgeon with gill nets was in the month of April. Trotlines had their highest CPUE during the months of August and September (Figure 15).

To compare the difference in CPUE of standard gill nets to hobbled gill nets a t-test was performed. This test showed that the hobbled gill nets had significantly higher catch rates when compared to standard non-hobbled gill nets (df = 253, t value = 2.14, $p = 0.013$) (Figure 16). In the earlier test when all gillnets where combined they were found to have significantly higher catch rates than trotlines, so a nonparametric Kruskal-Wallis test ($\alpha = 0.05$) was performed again breaking up gill nets into the two types. A Dunn's post hoc test with Bonferroni correction showed no significant difference between standard non-hobbled gill nets and trotlines. Hobbled gill nets did have significantly higher catch rates than both trotlines and non-hobbled gill nets.

The 6.4 to 7.6 cm (2.5 to 3 in) bar mesh gill nets captured the widest size ranges of lake sturgeon (Figure 17). A linear regression showed mesh size had a positive linear relationship to fork length ($p = 0.010$) and resulted in an R-squared value of 0.3889.

No lake sturgeon were captured on gizzard shad or pickled squid, thus all trotline data is based on Canadian night crawlers as bait. Straight 8/0 hooks caught larger fish than circle 11/0 hooks (Figure 18). A t-test found this not to be a significant difference (df = 54, t = -1.89, p value = 0.062). Circle hooks did have higher CPUE than straight hooks (Figure 19), but again a paired t-test found this not to be statistically significant (df = 43, t = 1.59, p value = 0.1189).

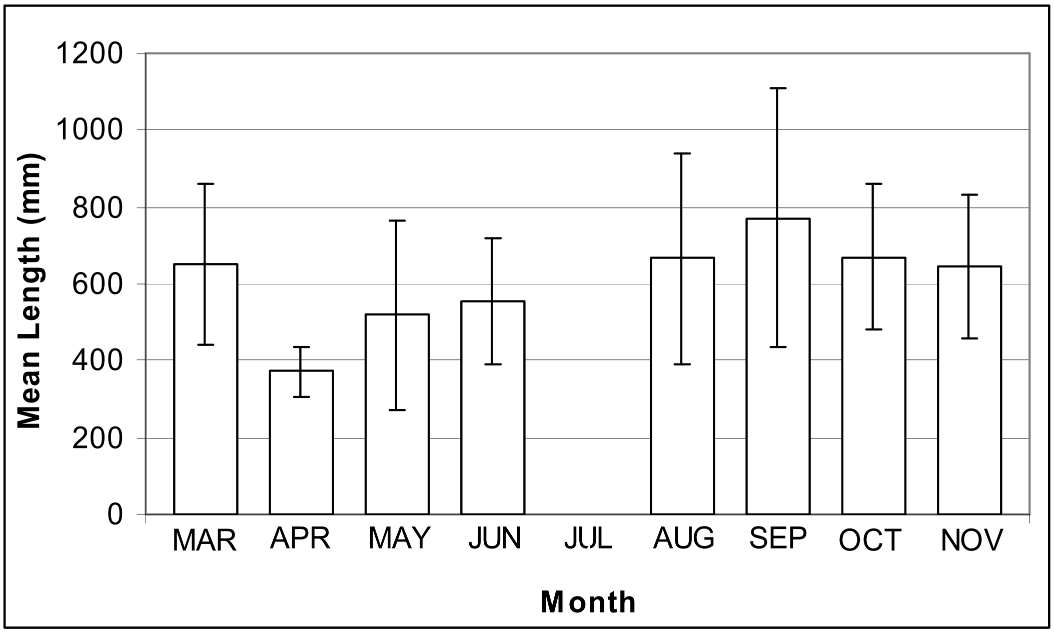

Figure 11. Mean fork length (mm) of lake sturgeon captured with trotlines by month for 2005 and 2006 combined. (Error bars are standard deviation).

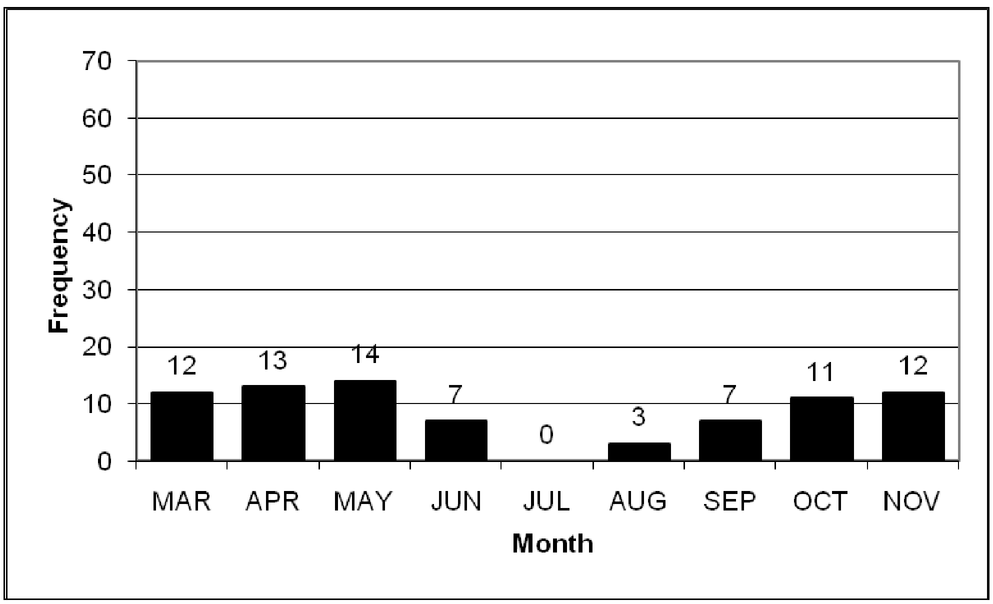

Figure 12. Frequency of lake sturgeon captured with trotlines by month for 2005 and 2006 combined.

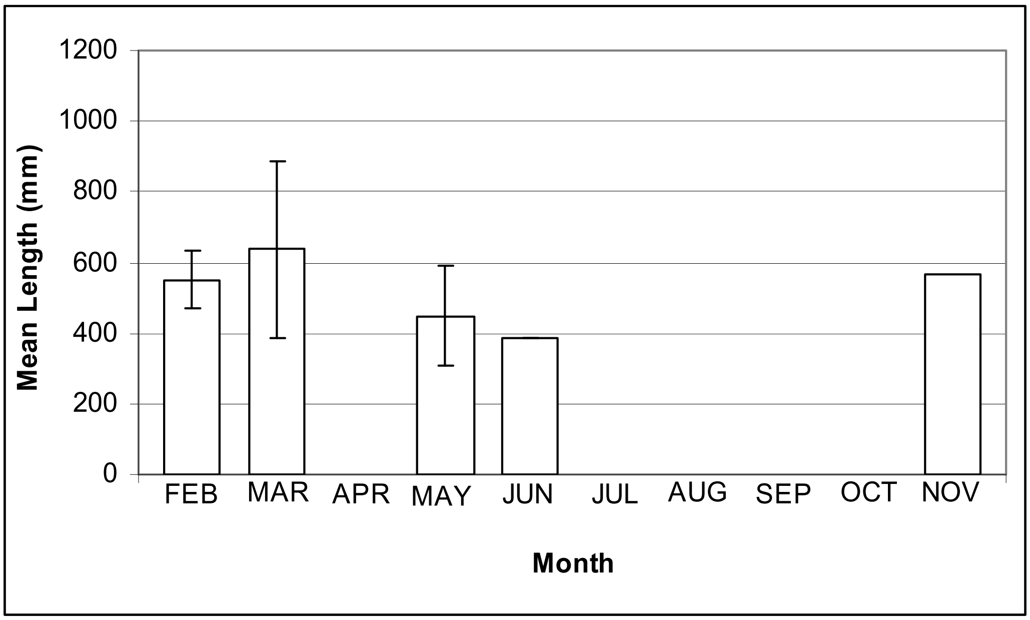

Figure 13. Mean fork length (mm) of lake sturgeon captured with hoop nets by month for 2005 and 2006 combined. (Error bars are standard deviation).

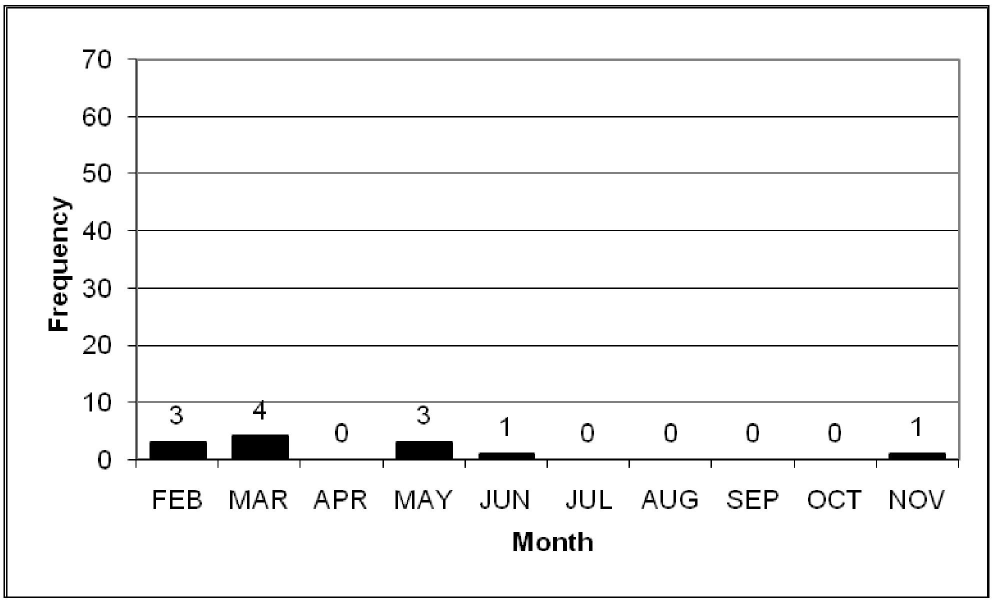

Figure 14. Frequency of lake sturgeon captured with hoop nets by month for 2005 and 2006 combined.

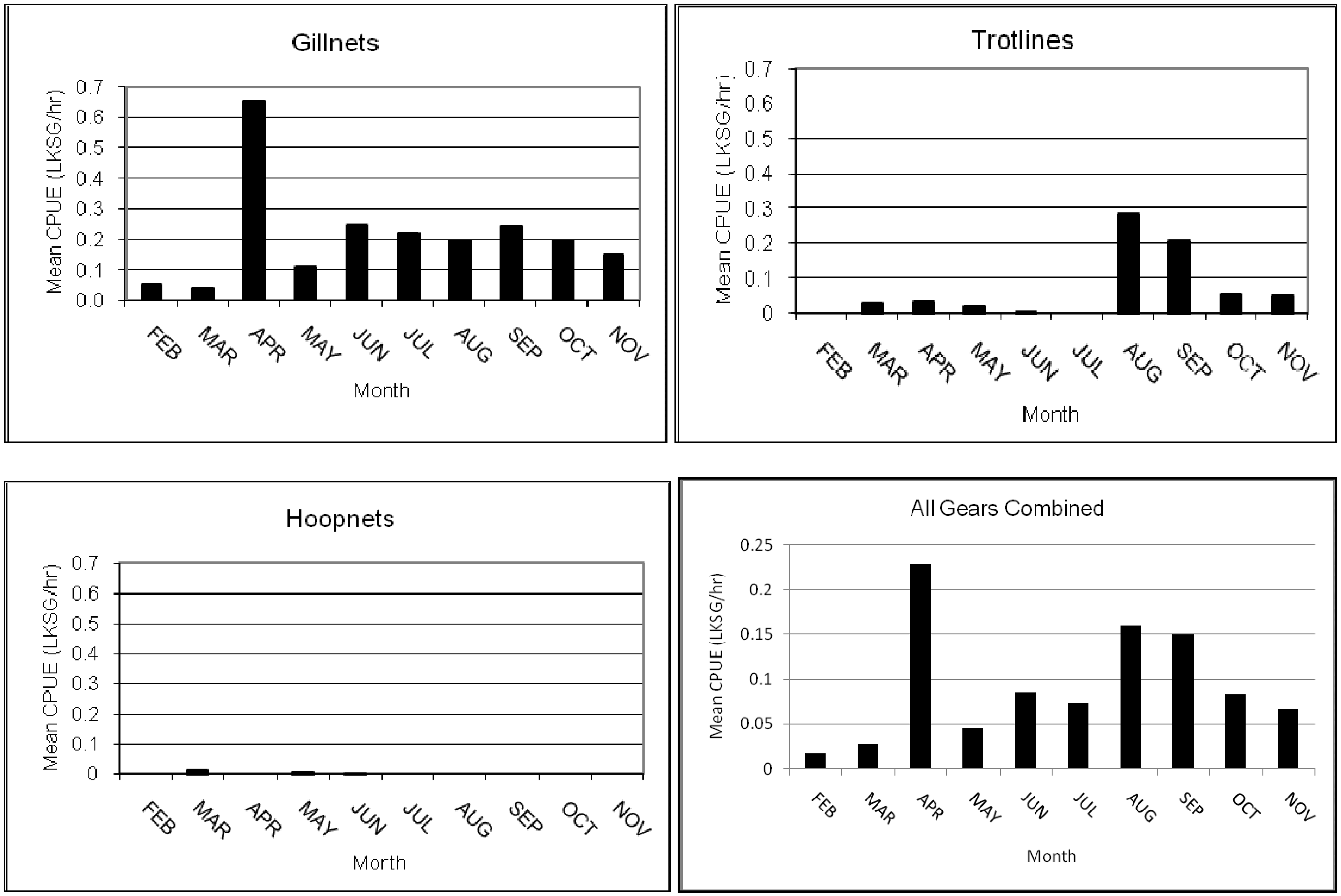

Figure 15. Mean monthly catch per unit of effort (CPUE = lake sturgeon per hour) for each gear type for 2005 and 2006 combined (All gill net types combined).

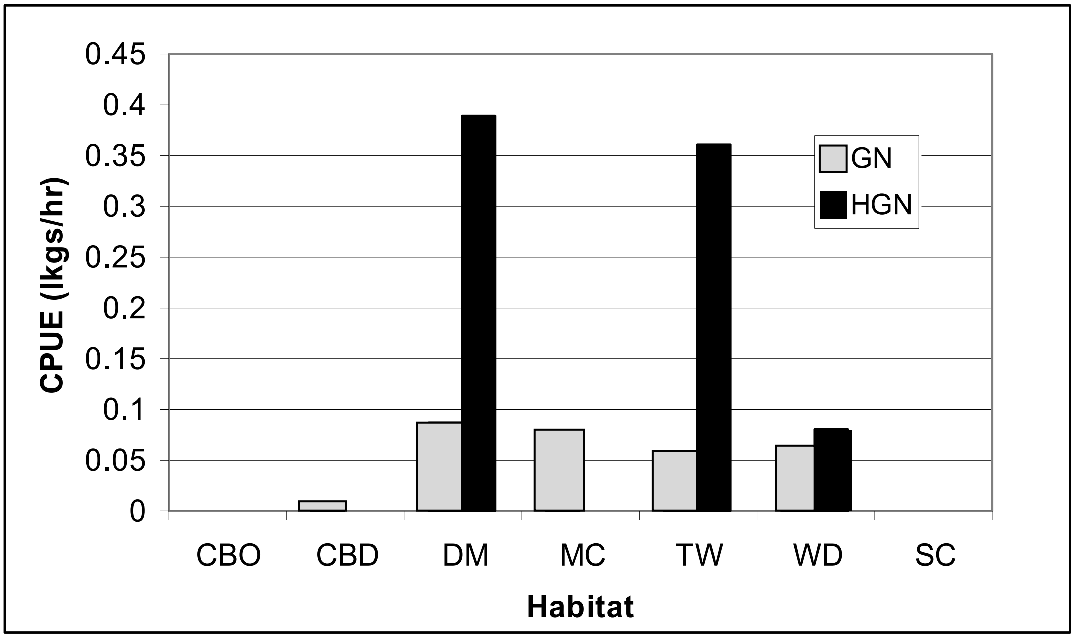

Figure 16. Catch per unit of effort (CPUE = lake sturgeon per hour) of hobbled gill nets (HGN) and non-hobbled gill nets (GN) for each habitat type. (CPUE is displayed as lake sturgeon per hour) (CBD = Channel Border Diked, CBO = Channel Border Open, DM = Dam, MC = Main Channel, SC = Side Channel, TW= Tailwaters, WD = Wing Dikes).

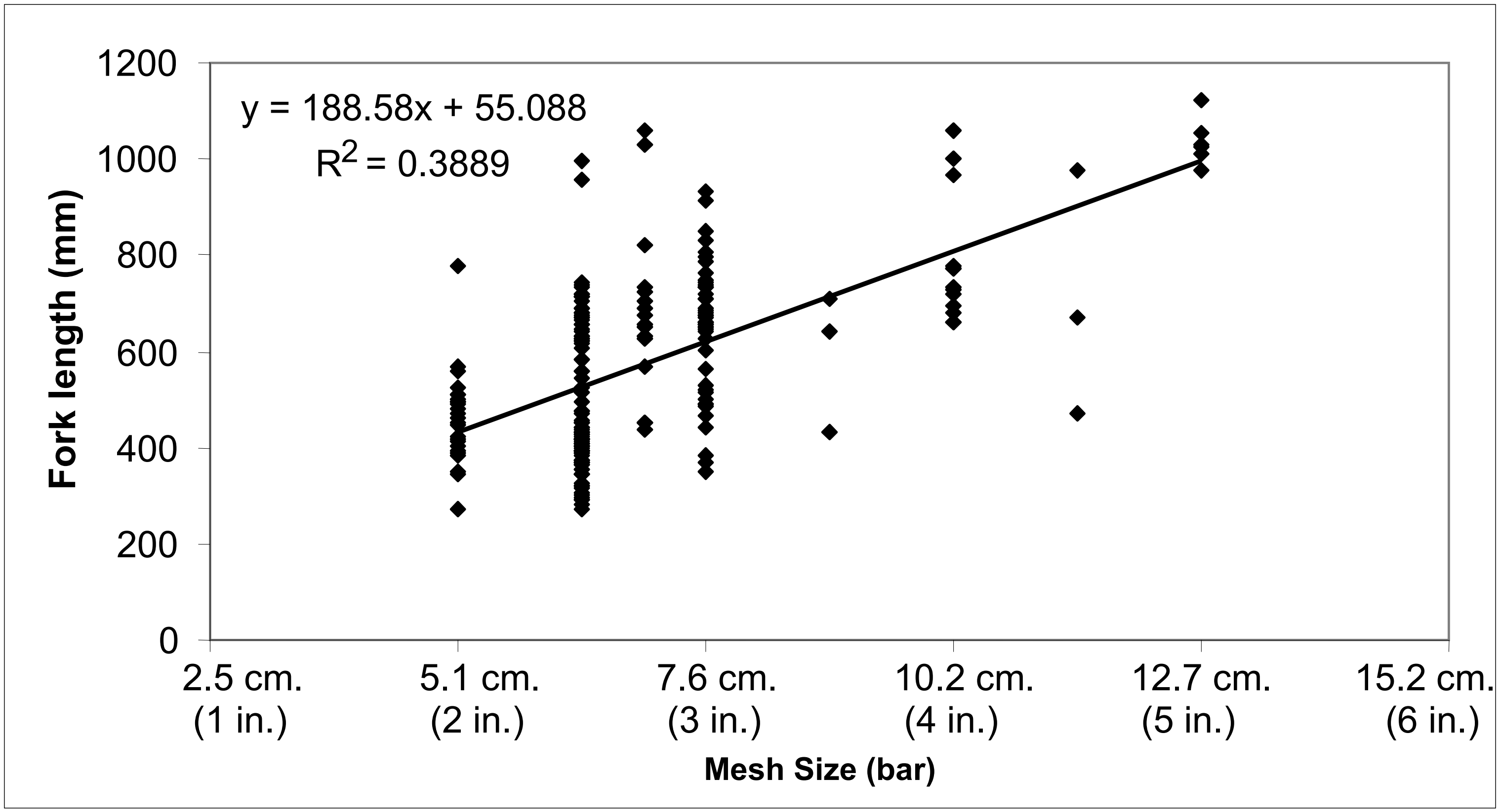

Figure 17. Linear regression of fork length (mm) to bar mesh size (cm) for all lake sturgeon captured in gill nets during 2005 and 2006 combined.

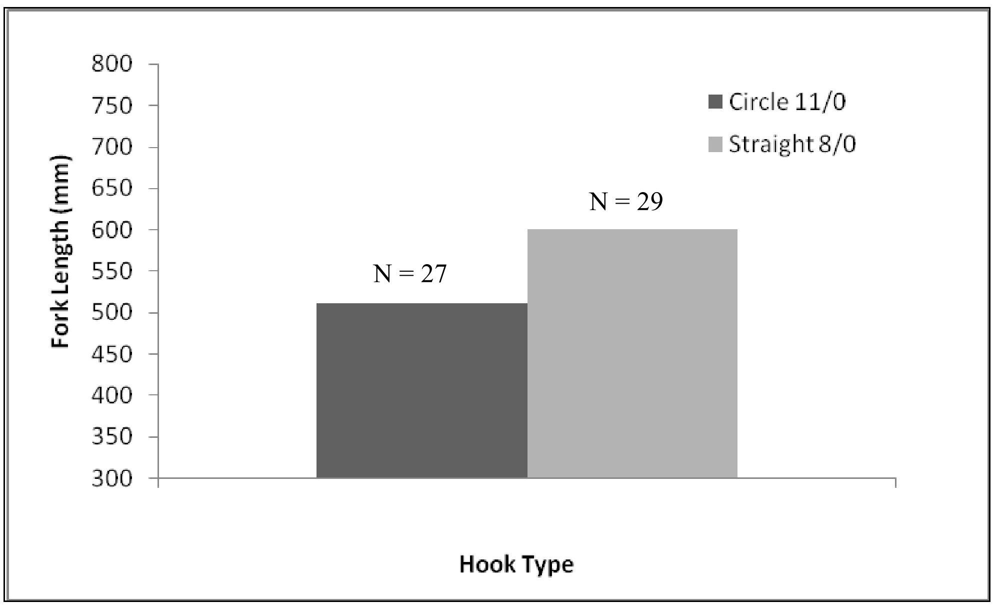

Figure 18. Mean fork length (mm) of lake sturgeon captured on trotlines for each hook type during 2005 and 2006 combined (df = 54, t = -1.89 p = 0.064, α = 0.05).

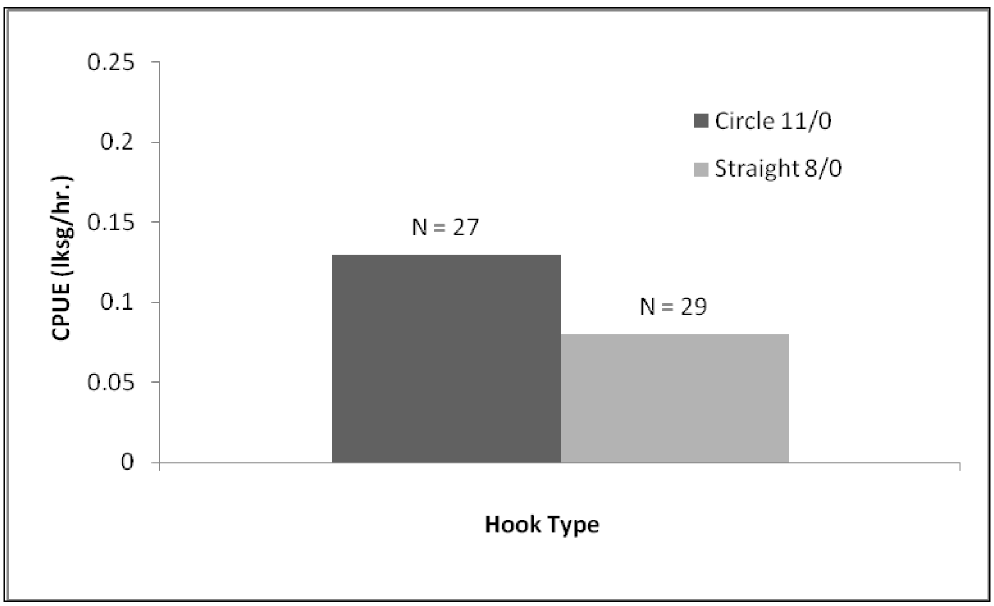

Figure 19. Catch per unit of effort (lake sturgeon per hour) of trotlines for each hook type during 2005 and 2006 combined (df = 43, t = 1.59, p = 0.1189, α = 0.05).

DISCUSSION

The five highest catch rates for lake sturgeon were with hobbled gill nets of 6.35 cm (2.5 in) bar mesh, which were all set in the month of April. This was during high flow (91,000-145,000 cfs) and cooler temperatures (12.8-18.3˚C). These fish had an average fork length of 395 mm. The months of March, April and May seem to be the best time of year to catch these smaller sturgeon. Although hoop nets had low catch rates, they did catch some of the smallest lake sturgeon during this same time period.

Seven out of the largest 10 lake sturgeon were captured during the months of September and November. The largest was captured on a trotline in the tailwaters of Lock and Dam 22. In the month of September 2006 discharge was low (36,000-46,000 cfs). Larger lake sturgeon would congregate below the dam during this period allowing us to capture them. We utilized short-term three to four hour trotline and gill net deployments. Setting these short duration gear sets produced a high CPUE even though the frequency of catch was small. To limit stress and mortality, the use of these short-term trotline sets should be used in warmer water temperatures (above 24˚C) instead of gill nets.

Length frequencies for lake sturgeon (Figure 7) show a bimodal distribution in the population with a weak length class between 550 mm and 650 mm. This could be due to weak stocking years or low survival rates for these year classes. One needs to look at year classes rather than size classes to get a better understanding of this observation.

Gill nets ranged from 6.4 cm (2 in) to 12.7 cm (5 in) bar mesh. The linear regression (Figure 15) shows that the potential for catching smaller or larger sizes of lake sturgeon has not been reached. The addition of a smaller 2.54 cm (1 in) and larger mesh size, 13.97 cm (5.5 in) or 15.24 cm (6 in), is needed to ensure that a representative portion of the population is being sampled.

Fork length of sturgeon captured on trotlines for the two hook types (Figure 16) shows that straight 8/0 hooks captured larger sturgeon than the circle 11/0 hooks. Even though this was found not to be statistically significant ($p = 0.062$), with a higher sample size of lake sturgeon this may become significant. The difference in mean fork length of lake sturgeon between the two hooks was approximately 100 mm, which could represent a biologically significant difference.

Sampling efforts were low in the main channel habitat. This habitat type proved difficult to sample due to barge traffic and safety concerns during deployment and retrieval of gear in strong currents. The main channel habitat has been shown to be utilized by lake sturgeon during telemetry studies (Knights et al. 2002). Trammel nets may be a solution to sample these areas, but concerns for safety when sampling in extreme flows makes this undesirable most times of the year.

If targeting lake sturgeon greater than 800 mm, I recommend using a combination of 10.2 (4 in) to 12.7 cm (5 in) hobbled gill nets and trotlines in late August through early November in the tailwaters and dam habitat. This is when water temperatures are between 18 and 27 ˚C and discharge is typically low. Short-term gill net sets should be used when water temperatures are above 12.8 ˚C. Trotlines should not be left overnight if water temperatures are above 24 ˚C.

For lake sturgeon less than 800 mm, hobbled gill nets of 6.4 to 7.6 cm (2.5 to 3 in) bar mesh should be used. Gill nets should be set during the months of April and May in the dam and wing dike habitats. This is when water temperatures are between 10 to 17

˚C and either preceding or during the spring increase in discharge. Trotlines should be set in the months of April and May. This is the period of time during the spring increase in discharge and temperature when fish become more active. Hoop nets can also be used during times when gill net deployments are not possible (high flows and debris). These nets should be set in wing dike habitats, preferably towards the dike tip. This acts as a current break and an area of refuge for sturgeon to go before maneuvering around a dike.

In order to sample a broad size range of the population, I recommend the use of experimental hobbled gill nets with multiple mesh sizes and trotlines deployed in the above manners.

This study was conducted to investigate three common gear types. Because of the wide variety and variations of these gears, further investigation could be performed. (i.e. different hook types and sizes, larger or smaller mesh gill nets). Other gear types that may be utilized include drifted trammel nets, multifilament gill nets, and benthic otter trawls. Because sturgeon have sharp scutes, the multifilament mesh may hold onto sturgeon more effectively. As the stocked population of lake sturgeon age, a greater number of fish will be at reproductive maturity. The benthic otter trawl is very effective at capturing small fishes and may give indication if and when recruitment is occurring, the ultimate goal in the recovery of the lake sturgeon in the Mississippi River.

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APPENDIX A – CATCH SUMMARY

Table 3. All lake sturgeon captured during 2005 and 2006 in Pool 24 of the Mississippi River. (TL = Trotline, GN = Gillnet, HN = Hoop net, EGN = Experimental gillnet, HGN= Hobbled gillnet) (CBD = Channel Border Diked, CBO = Channel Border Open, DM = Dam, MC = Main Channel, SC = Side Channel, TW = Tailwaters, WD = Wing Dikes)

Capture Date	Length (mm)	Weight (Kg)	Cap/Recap	Habitat	Gear type
3/8/2005	652	2.05	Capture	WD	GN
3/8/2005	656	2.03	Capture	WD	GN
3/9/2005	796	4.37	Capture	WD	GN
3/9/2005	912	5.71	Capture	WD	GN
3/9/2005	465	0.65	Capture	WD	GN
3/9/2005	520	1.01	Capture	WD	GN
3/9/2005	748	3.36	Capture	WD	GN
3/9/2005	515	1.11	Recapture	CBO	GN
3/15/2005	850	4.7	Capture	WD	GN
3/16/2005	500	0.84	Capture	WD	GN
3/16/2005	765	3.7	Capture	WD	GN
3/21/2005	570	1.2	Capture	WD	TL
3/22/2005	350	0.2	Capture	DM	GN
3/23/2005	370	0.32	Capture	WD	GN
3/23/2005	490	0.8	Capture	WD	GN
3/23/2005	490	0.77	Capture	WD	GN
3/23/2005	516		Capture	WD	GN
3/23/2005	530	1.1	Capture	WD	GN
3/23/2005	659	2	Capture	WD	GN
3/23/2005	660	2.02	Capture	WD	GN
3/23/2005	670	2.2	Capture	WD	GN
3/23/2005	710	2.75	Capture	WD	GN
3/23/2005	785	2.95	Capture	WD	GN
3/23/2005	830	4.1	Capture	WD	GN
3/23/2005	850	4.98	Capture	WD	TL
3/23/2005	675	1.8	Recapture	DM	GN
3/29/2005	486	0.99	Capture	WD	GN
3/29/2005	564		Capture	WD	GN
3/29/2005	732	3.1	Capture	WD	GN
3/29/2005	568	1.12	Capture	WD	TL
3/30/2005	660	2.25	Capture	WD	GN
5/4/2005	310	0.24	Capture	DM	GN
5/4/2005	330	0.24	Capture	DM	GN
5/4/2005	330	0.23	Capture	DM	GN
5/4/2005	460	0.59	Capture	DM	GN
5/4/2005	512	1.16	Capture	DM	GN
5/10/2005	232	0.1	Capture	DM	HN
5/10/2005	316	0.16	Capture	WD	HN
5/10/2005	436	0.52	Capture	CBO	HN
5/10/2005	364	0.25	Capture	DM	TL
5/10/2005	424	0.43	Capture	DM	TL
5/11/2005	290		Capture	DM	HGN
5/11/2005	1010	8.5	Capture	WD	HN
5/11/2005	330	0.14	Capture	DM	HN
5/11/2005	430	0.58	Capture	DM	HN
5/16/2005	362	0.28	Capture	DM	GN
5/16/2005	670	1.95	Capture	DM	GN
5/17/2005	602	1.53	Recapture	DM	TL
5/18/2005	208	0.19	Capture	WD	HN
5/18/2005	364	0.25	Capture	DM	HN
5/18/2005	968	7.06	Capture	DM	HN
5/18/2005	330	0.21	Capture	DM	TL
5/18/2005	338	0.22	Capture	DM	TL
5/18/2005	364	0.23	Capture	DM	TL
5/18/2005	380	0.28	Capture	DM	TL
5/19/2005	404	0.37	Capture	DM	TL
5/20/2005	682	2.46	Capture	DM	TL

Table 3: (Continued)

Capture Date	Length (mm)	Weight (Kg)	Cap/Recap	Habitat	Gear type
6/22/2005	752	1.38	Capture	WD	HN
6/22/2005	400	0.31	Capture	TW	TL
7/28/2005	648	1.7	Recapture	DM	GN
7/29/2005	650	1.85	Capture	WD	GN
8/15/2005	582	1.18	Capture	TW	GN
8/15/2005	608	1.26	Capture	TW	GN
8/15/2005	630	1.64	Capture	TW	GN
8/15/2005	958	5.82	Capture	TW	GN
8/30/2005	639	1.61	Capture	TW	GN
8/30/2005	710	2.67	Capture	TW	GN
10/3/2005	604	1.7	Recapture	DM	GN
10/5/2005	282	0.13	Capture	TW	GN
10/5/2005	663	3.19	Capture	WD	GN
10/5/2005	678	2.11	Recapture	WD	GN
10/5/2005	727	2.62	Recapture	WD	GN
10/6/2005	557	1.17	Capture	DM	GN
10/6/2005	656	1.48	Capture	DM	HGN
10/6/2005	679	2.3	Capture	DM	HGN
10/12/2005	356	0.06	Capture	DM	HGN
10/12/2005	356	0.28	Capture	DM	HGN
10/12/2005	584	1.2	Capture	DM	HGN
10/20/2005	559	1.01	Capture	WD	EGN
10/20/2005	441	0.53	Capture	WD	GN
10/20/2005	628	1.38	Capture	WD	GN
10/20/2005	370	0.32	Capture	DM	TL
10/20/2005	450	0.48	Capture	DM	TL
10/20/2005	450	0.42	Capture	WD	TL
10/20/2005	482	0.59	Capture	WD	TL
10/20/2005	592	1.3	Capture	WD	TL
10/20/2005	682	2.28	Capture	DM	TL
10/20/2005	607	1.96	Recapture	WD	TL
10/27/2005	422	0.45	Capture	WD	GN
10/27/2005	630	1.71	Capture	WD	GN
10/27/2005	743	2.47	Capture	WD	GN
10/27/2005	880	5.45	Capture	WD	GN
10/27/2005	442	0.56	Capture	WD	TL
10/27/2005	499	0.71	Capture	WD	TL
10/27/2005	674	2.01	Recapture	WD	GN
11/2/2005	350	0.23	Capture	WD	EGN
11/2/2005	390	0.37	Capture	WD	EGN
11/2/2005	470	0.54	Capture	WD	EGN
11/2/2005	500	0.73	Capture	WD	EGN
11/2/2005	526	0.9	Capture	WD	EGN
11/2/2005	1060	7.85	Capture	DM	GN
11/2/2005	1060	8.08	Capture	DM	GN
11/2/2005	386	0.29	Capture	WD	GN
11/2/2005	650	1.67	Capture	WD	GN
11/2/2005	632	0.9	Capture	DM	HGN
11/2/2005	773	2.07	Recapture	WD	EGN
11/2/2005	674	2.25	Recapture	WD	GN
11/2/2005	686	2.15	Recapture	WD	GN
11/3/2005	416	0.38	Capture	WD	EGN
11/3/2005	448	0.55	Capture	WD	EGN
11/3/2005	450	0.58	Capture	WD	EGN
11/3/2005	480	0.57	Capture	WD	EGN
11/3/2005	490	0.65	Capture	WD	EGN
11/3/2005	496	0.7	Capture	WD	EGN
11/3/2005	510	0.79	Capture	WD	EGN
11/3/2005	566	1.48	Capture	WD	EGN
11/3/2005	315	0.05	Capture	DM	HGN
11/3/2005	557	0.99	Capture	DM	HGN
2/13/2006	968	6.4	Capture	WD	EGN

Tab1e 3: (Continued)

Capture Date	Length (mm)	Weight (Kg)	Cap/Recap	Habitat	Gear type
2/13/2006	497	0.8	Capture	WD	EGN
2/13/2006	512	0.77	Capture	WD	EGN
2/13/2006	1002	7.76	Capture	TW	GN
2/13/2006	645	1.87	Recapture	WD	EGN
2/13/2006	662	2.19	Recapture	WD	EGN
2/13/2006	774	3.57	Recapture	WD	EGN
2/28/2006	415	0.46	Capture	WD	EGN
2/28/2006	424	0.46	Capture	WD	EGN
2/28/2006	779	3.38	Recapture	WD	EGN
3/1/2006	346	0.3	Capture	MC	EGN
3/28/2006	270	0.56	Capture	WD	EGN
3/28/2006	718	2.32	Capture	WD	EGN
3/28/2006	219	0.11	Capture	TW	GN
3/28/2006	466	0.56	Capture	WD	HN
3/28/2006	696	2.37	Capture	WD	TL
3/28/2006	734	2.66	Recapture	WD	EGN
3/28/2006	1054	7.4	Recapture	TW	GN
3/28/2006	770	3.71	Recapture	WD	TL
3/28/2006	810	3.44	Recapture	WD	TL
3/29/2006	750	2.95	Recapture	WD	TL
3/30/2006	1012	7.68	Capture	TW	HGN
4/18/2006	394	0.35	Capture	DM	HGN
4/18/2006	365	0.26	Capture	DM	TL
4/18/2006	367	0.21	Capture	DM	TL
4/18/2006	500	0.38	Capture	TW	TL
4/19/2006	295	0.19	Capture	DM	HGN
4/19/2006	301	0.2	Capture	DM	HGN
4/19/2006	323	0.18	Capture	DM	HGN
4/19/2006	325	0.22	Capture	DM	HGN
4/19/2006	343	0.27	Capture	DM	HGN
4/19/2006	368	0.34	Capture	DM	HGN
4/19/2006	368	0.33	Capture	DM	HGN
4/19/2006	370	0.36	Capture	DM	HGN
4/19/2006	374	0.36	Capture	DM	HGN
4/19/2006	389	0.33	Capture	DM	HGN
4/19/2006	389	0.37	Capture	DM	HGN
4/19/2006	410	0.47	Capture	DM	HGN
4/19/2006	417	0.45	Capture	DM	HGN
4/19/2006	417	0.41	Capture	DM	HGN
4/19/2006	420	0.44	Capture	DM	HGN
4/19/2006	435	0.46	Capture	DM	HGN
4/19/2006	441	0.54	Capture	DM	HGN
4/19/2006	443	0.47	Capture	DM	HGN
4/19/2006	451	0.61	Capture	DM	HGN
4/19/2006	458	0.57	Capture	DM	HGN
4/19/2006	344	0.22	Recapture	DM	HGN
4/25/2006	689	1.89	Capture	DM	GN
4/25/2006	306	0.19	Capture	DM	HGN
4/25/2006	392	0.39	Capture	DM	HGN
4/25/2006	394	0.38	Capture	TW	HGN
4/25/2006	413	0.43	Capture	TW	HGN
4/25/2006	417	0.44	Capture	DM	HGN
4/25/2006	432	0.52	Capture	DM	HGN
4/25/2006	471	0.56	Capture	TW	HGN
4/25/2006	477	0.74	Capture	DM	HGN
4/25/2006	523	0.94	Capture	DM	HGN
4/26/2006	272	0.12	Capture	DM	HGN
4/26/2006	292	0.18	Capture	DM	HGN
4/26/2006	320	0.21	Capture	DM	HGN
4/26/2006	366	0.31	Capture	DM	HGN
4/26/2006	372	0.33	Capture	DM	HGN
4/26/2006	383	0.41	Capture	DM	HGN

Table 3: (Continued)

Capture Date	Length (mm)	Weight (Kg)	Cap/Recap	Habitat	Gear type
4/26/2006	392	0.39	Capture	DM	HGN
4/26/2006	404	0.49	Capture	DM	HGN
4/26/2006	416	0.43	Capture	DM	HGN
4/26/2006	421	0.48	Capture	DM	HGN
4/26/2006	434	0.48	Capture	DM	HGN
4/26/2006	476	0.71	Capture	DM	HGN
4/26/2006	544	0.98	Capture	DM	HGN
4/26/2006	433		Recapture	DM	HGN
5/2/2006	473	0.22	Capture	TW	GN
5/2/2006	669	1.81	Capture	TW	GN
5/2/2006	429	0.51	Capture	WD	HGN
5/2/2006	703	2.26	Recapture	DM	HGN
5/9/2006	308	0.17	Capture	DM	HN
5/15/2006	978	6.75	Capture	DM	TL
5/15/2006	370	0.34	Capture	DM	TL
5/15/2006	713	2.97	Capture	CBD	TL
5/15/2006	832	3.93	Capture	WD	TL
5/15/2006	581	1.2	Recapture	CBD	TL
5/16/2006	935	6.49	Capture	DM	EGN
5/16/2006	422	0.37	Capture	DM	TL
5/16/2006	758	2.8	Capture	DM	TL
5/22/2006	474	0.71	Capture	WD	TL
5/23/2006	316	0.16	Capture	WD	TL
5/23/2006	330	0.19	Capture	TW	TL
5/23/2006	448	0.61	Capture	DM	TL
5/24/2006	384	0.18	Capture	DM	EGN
5/28/2006	432	0.5	Capture	DM	GN
5/31/2006	1120	10.52	Capture	TW	GN
5/31/2006	975	6.53	Capture	TW	GN
5/31/2006	470	0.64	Recapture	WD	TL
6/5/2006	808	3.65	Capture	DM	EGN
6/5/2006	422	0.46	Capture	CBO	TL
6/7/2006	1000	8.38	Capture	DM	EGN
6/7/2006	404	0.3	Capture	DM	EGN
6/7/2006	710	2.29	Capture	DM	EGN
6/7/2006	346	0.27	Capture	DM	HGN
6/7/2006	396	0.44	Capture	DM	HGN
6/7/2006	628	1.4	Capture	DM	HGN
6/7/2006	670	2.1	Capture	DM	HGN
6/7/2006	408	0.27	Recapture	DM	HGN
6/7/2006	642	1.72	Recapture	DM	HGN
6/8/2006	996	6.74	Capture	DM	HGN
6/8/2006	402	0.36	Capture	DM	HGN
6/8/2006	419	0.21	Capture	DM	HGN
6/8/2006	426	0.43	Capture	DM	HGN
6/8/2006	620	2	Capture	DM	HGN
7/18/2006	1026	8.9	Capture	TW	GN
7/18/2006	366	0.28	Recapture	TW	GN
8/29/2006	412	0.46	Capture	TW	TL
8/29/2006	680	2.18	Capture	TW	TL
9/5/2006	462	0.19	Capture	WD	EGN
9/5/2006	680	2.45	Capture	DM	HGN
9/5/2006	688	1.85	Capture	DM	HGN
9/5/2006	1218	14.65	Capture	TW	TL
9/8/2006	376	0.11	Capture	DM	HGN
9/8/2006	1188	12.65	Capture	TW	TL
9/8/2006	960	5.34	Capture	WD	TL
9/8/2006	374	0.28	Capture	TW	TL
9/8/2006	510	0.72	Capture	TW	TL
9/8/2006	594	1.02	Capture	TW	TL
9/8/2006	780	1.42	Capture	WD	TL
9/8/2006	852	2.93	Capture	WD	TL

Table 3: (Continued)

Capture Date	Length (mm)	Weight (Kg)	Cap/Recap	Habitat	Gear type
9/12/2006	358	0.15	Capture	WD	TL
9/12/2006	874	4.19	Capture	WD	TL
9/28/2006	380	0.07	Capture	WD	TL
9/28/2006	488	0.38	Capture	WD	TL
9/28/2006	606	1.08	Capture	WD	TL
9/28/2006	690	1.8	Capture	WD	TL
9/28/2006	894	4.09	Capture	WD	TL
9/28/2006	690	1.9	Recapture	DM	HGN
9/29/2006	450	0.33	Capture	WD	TL
9/29/2006	662	1.83	Capture	TW	TL
10/2/2006	680	1.93	Capture	DM	GN
10/2/2006	732	2.09	Capture	DM	GN
10/2/2006	742	2.48	Capture	DM	GN
10/2/2006	366	0.31	Capture	DM	HGN
10/2/2006	382	0.29	Capture	CBD	TL
10/2/2006	422	0.1	Capture	CBD	TL
10/2/2006	440	0.22	Capture	WD	TL
10/2/2006	458	0.92	Capture	CBD	TL
10/2/2006	502	0.6	Capture	CBD	TL
10/2/2006	504	0.33	Capture	CBD	TL
10/2/2006	508	0.68	Capture	DM	TL
10/2/2006	738	2.61	Capture	CBD	TL
10/2/2006	800	2.93	Capture	CBD	TL
10/3/2006	640	1.52	Capture	DM	GN
10/3/2006	656	1.94	Capture	DM	GN
10/3/2006	658	1.24	Capture	DM	GN
10/3/2006	720	2.21	Capture	DM	GN
10/3/2006	1030	7.7	Capture	DM	GN
10/3/2006	616	1.32	Capture	WD	HGN
10/3/2006	740	2.35	Capture	WD	HGN
10/3/2006	712	2.06	Recapture	WD	HGN
10/5/2006	384	0.28	Capture	WD	TL
10/5/2006	412	0.39	Capture	WD	TL
10/5/2006	412	0.37	Capture	WD	TL
10/5/2006	518	0.76	Capture	WD	TL
10/5/2006	526	0.73	Capture	WD	TL
10/5/2006	794	2.95	Recapture	WD	TL
10/6/2006	624	1.03	Capture	DM	HGN
10/6/2006	670	1.6	Capture	DM	HGN
10/6/2006	720	2.46	Capture	DM	HGN
10/13/2006	392	0.26	Capture	WD	EGN
10/13/2006	676	1.74	Capture	DM	HGN
10/13/2006	712	2.32	Capture	DM	HGN
10/16/2006	800	2.93	Capture	TW/DM	GN
10/16/2006	584	1.3	Capture	DM	HGN
10/16/2006	400	0.22	Capture	WD	TL
10/16/2006	472	0.51	Capture	WD	TL
10/19/2006	642	1.7	Recapture	DM	GN
10/19/2006	782	2.76	Recapture	DM	GN
10/20/2006	552	1.05	Capture	SC/WD	HGN
10/24/2006	740	2.38	Capture	WD	GN
10/24/2006	392	0.33	Capture	WD	HGN
10/24/2006	408	0.25	Capture	DM	HGN
10/24/2006	450	0.5	Capture	WD	HGN
10/24/2006	656	1.76	Capture	DM	HGN
10/24/2006	668	1.83	Capture	DM	HGN
10/24/2006	716	1.99	Capture	DM	HGN
10/24/2006	736	2.54	Capture	DM	HGN
10/24/2006	356	0.21	Capture	WD	TL
10/24/2006	626	1.27	Capture	WD	TL
10/24/2006	978	5.9	Recapture	WD	HGN
10/31/2006	696	2.05	Capture	WD	GN

Table 3: (Continued)

Capture Date	Length (mm)	Weight (Kg)	Cap/Recap	Habitat	Gear type
10/31/2006	776	3.31	Capture	WD	GN
10/31/2006	404	0.21	Capture	DM	HGN
10/31/2006	496	0.64	Capture	DM	HGN
10/31/2006	626	1.51	Capture	DM	HGN
10/31/2006	720	2.47	Capture	DM	HGN
10/31/2006	1058	8.14	Capture	CBO	TL
10/31/2006	920	5.5	Capture	CBO	TL
10/31/2006	920	5.33	Capture	CBO	TL
11/1/2006	590	1.25	Capture	CBO	TL
11/2/2006	744	2.32	Capture	DM	HGN
11/2/2006	496	0.54	Capture	TW	TL
11/2/2006	1006	6.3	Capture	CBO	TL
11/2/2006	732	2.4	Recapture	DM	GN
11/3/2006	726	2.74	Capture	DM	HGN