CHAPTER TWO

EVALUATION OF CHANNEL CATFISH ICTALURUS PUNCTATUS AGE/LENGTH STRUCTURE IN THE SAN JUAN RIVER FROM 2002 TO 2011

Abstract

The impact of non-native fish species on native fish communities is a subject that has caused concern in many regions in the United States and across the globe. When non-native channel catfish were introduced in the 1890's it was not known what their impact would be on the native species. The success of the channel catfish populations was associated with the decline of native fishes and brought about the establishment of the San Juan River Recovery and Implementation Program. This program has been dedicated to mitigating the direct effects of the non-native species introduction through direct removal efforts, monitoring, and research projects to determine the characteristics of the interactions between species. This study evaluated the population structure of the sampled channel catfish population in the San Juan River, New Mexico to determine if the channel catfish are exhibiting a compensatory response to electroshock removal efforts. The population structure of channel catfish in 2002 have been compared to the channel catfish population in 2011 to determine if significant differences in length at age have occurred over time. Channel catfish were sampled using standard electrofishing practices and calcified structures were analyzed to determine age. These data were compared to calcified structures of channel catfish in 2002 to determine if differences occurred in length at age. There was a difference in length at age for all age classes of

channel catfish compared between 2002 and 2011. In all cases the channel catfish in 2011 were significantly larger than their 2002 counterparts at the same age. In addition, the presence of a large number of juvenile channel catfish in the 2011 sample, in contrast to 2002, suggests that many young are being produced and surviving in the system. This information may be important from a management prospective because it may suggest that removal efforts are not reducing the population size of channel catfish and resource availability can support many juvenile channel catfish.

Introduction

Although the introduction of channel catfish to the San Juan River system in the late 1800's was not viewed as a harmful act, the residual effects of the non-native species interactions are now thought to be responsible for the decline of the native fish species. In the San Juan River system channel catfish are of particular concern due to their omnivorous nature and may compete with native species for the same resources such as macro-invertebrates (Brooks et al. 2000). Monitoring studies of adult fish in the San Juan River demonstrated that channel catfish accounted for the largest percentage of large bodied fish in the system (i.e. 47.6% of total catch) (Ryden 2010). Due to the endangered status of two native species in the San Juan River, a recovery program was established to mitigate the effects of the non-native channel catfish.

Since 2001 efforts have been aimed at removal and monitoring of the channel catfish and other non-native species in the San Juan River. Although the San Juan River Recovery and Implementation Program has been successful at removing a large number of non-native species, populations of native fishes such as the razorback sucker and

Colorado pikeminnow have not recovered. Wild populations of razorback sucker and Colorado pikeminnow continued to decline and the last razorback sucker taken from the upper portion of the Colorado River basin was in 1995 (Mueller 2006a).

Due to the lack of information regarding the population structure of the non-native species the recovery program has found it difficult to quantify the effect that non-native species removal efforts have had on non-native populations. In particular an assessment of length at age would be advantageous in that it will allow the removal team to account for the reduction of particular year classes of fish. If management personnel were able to determine the number of fish from each spawning year that had been removed they may have a clearer picture of their success at reducing the overall population of channel catfish. Pitlo (1997) observed that as the numbers of large catfish declined, the population became highly dependent on newly recruited fish, resulting in large fluctuations in catch and dependence on the strength of individual year-classes. This appears to be occurring within the two uppermost intensive removal sections where the majority of fish collected in 2009 comprised of the 2002/2003 cohorts and ranging from 400-475 mm TL. However, though the measurable channel catfish recruitment (i.e. increased juvenile catch rates) in upper Sections of the San Juan River has not been documented since 2002, an increase in juvenile abundance in down-stream sections of the river suggest reproductive potential is still high (Davis et al. 2009). Pitlo's 1997 research on the age structure of a commercial catfish fishery noted many key components representative of an exploited fishery. Overharvest of this fishery resulted in (1) declines in yield (2) increases in the proportion of small fish in the commercial harvest, (3) a narrow range of age groups represented in the fishery, (4) high dependence on single year-classes, and (5) high mortality rates. Shifts in age structure of a non-commercial fishery, where MSY is not the end goal, can affect the ability of management to remove these individuals from the system, and will likely result in the resurgence of a large number of spawning adults in years with favorable environmental conditions, and subsequent production of many young in the following years.

Examples in the literature suggest that fish populations exhibit compensatory responses to exploitation. When evaluating non-native lake trout predation on Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri)*, (Ruzycki et al. 2003) determined that the harvesting techniques were only successful at removing larger lake trout. This exploitation of the larger size class of fish was sought after by management officials in order to reduce the overall age structure of lake trout in the system. Research conducted in a high mountain California lake also demonstrated a resurgence of non-native fishes after gill netting removal efforts failed to capture individuals < 110mm (Britton 2006).

These data suggest that the techniques used in non-native fish removal can exclude younger age classes thus causing an overall shift in the available ages of the invasive species in the system.

In the San Juan River, shifts in size structure of channel catfish have been observed upstream (Davis 2005) and on a river-wide scale (Ryden 2005) after the initiation of nonnative removal. This study quantifies the current age and size structure of the sampled San Juan River channel catfish population in 2011 and compares these data to the sampled population collected in 2002 to determine if differences exist in length at age.

Materials and methods

Field protocols

Three sections of the San Juan River are electro shocked multiple times during the course of a year for non-native fish removal (NNFR). These sections are: PNM to Hogback (River Mile (RM) 167.5-159), Hogback Diversion to Shiprock Bridge (RM 158.8–147.9) and Shiprock Bridge to Mexican Hat, Utah (RM 147.9–52.9). During the summer months (June-August) channel catfish removed from these sections were sampled. Channel catfish were collected using raft-mounted electrofishing gear (pulsed direct current ~1.2 volts/cm). Electrofishing surveys were conducted during daylight hours when stunned fish will be most visible. Attempts were made to net all fish stunned near the front and sides of the raft (anode) with a 10ft long dip net. Channel catfish collected during the sampling efforts were held in oxygenated live wells aboard the removal vessels. When live well became crowded fish were removed from the boats and euthanized in MS-222 solution. Following the treatment of MS-222 multiple samples were taken from each fish. For each channel catfish sampled, the location, date, total length (TL), weight and sex were recorded. Fish were sampled one at a time and each fish received a unique identification number. Total length was measured to the nearest 1mm using a 1000mm measuring board. Whole body weight was measured to the nearest 5 grams using a range of spring scales. Gonads were removed from the female fish, fixed in a 10% formalin solution and stored in 500ml plastic bottles. These ovary samples were shipped to the Bozeman Fish Technology Center for further inspection in a laboratory setting. Histologies were later conducted on these ovaries. Pectoral fins were collected for each fish using a pair of pliers to disarticulate the fin rays. Samples were placed in a paper envelope marked with the fish's identification number. Otoliths were removed using a hacksaw and sawing from the dorsal to the ventral portion of the catfish cranium. The cut was made at the posterior end of the operculum after which the otoliths were removed with a pair of small tweezers. Otoliths will be placed in small paper envelopes marked with the identification number for individual fish. Pectoral spines will be evaluated in the laboratory to determine age and yearly growth of fish. Although scales can be used to age many fish species studies have found them to underestimate age in individuals older than 4 years (Cazorla 2011). In addition channel catfish do not have scales but rather a thick protective skin therefore this method of aging was rules out. After samples have been collected during a removal trip, all samples will be properly packaged and shipped to the Bozeman Fish Technology Center for further analysis.

Laboratory Protocols

Pectoral spines were sectioned below the basal groove using an 8000 series cordless Dremel tool with a #426 reinforced cutting wheel. Once sections were made they were placed into individual ziplock bags labeled with the identification number for that fish. Sections were laid out next to a standard 3 x 1" frosted microscope slide labeled with the identification number for each fish. Once the sections were laid out they were mounted onto the microscope slides with tweezers and Loctite® instant mix epoxy. When the epoxy had dried slides were placed into slide boxes and arranged in order. Slides were then taken to the Bozeman Fish Technology Center where digital images were taken. A Leica® DM 2000 microscope with an attached RT KE Spot digital camera was used to obtain the images. The light was supplied by the base lamp of the microscope and magnification was set to 5x for all samples. The light intensity varied for each sample based on the thickness of the spine section. Digital images were saved based on the unique identification number on a 500 GB external hard drive. Spines were aged based on the annuli that form like tree rings within the spine. For each spine section age was determined by counting the number of annuli from the middle to the perimeter of each spine. These ages were recorded in an excel spreadsheet without any associated length or weight data to ensure there was no bias. Two blind readers then aged the appropriate number of spines for each length class and recorded their ages in an excel spreadsheet. Once ages were established an age length key was constructed to quantify the length/age association of the channel catfish population in the San Juan River, NM. Spines collected in 2002 were treated in the same manner as spines from 2011 with the difference that they were already mounted on slides. Digital images were taken and pectoral spines were aged in the same manner as previously mentioned. Water temperature was also taken into consideration as it can have a large impact on channel catfish growth. The range of temperatures adequate for channel catfish growth is between 23.8-32.2°C (Swann 1997), and optimum growth for channel catfish has been determined to occur at 29.4°C (Wellborn 1988). Average monthly temperature data was collected Shiprock, NM from 2002 to 2011.

<u>Statistical Methods</u>

A power analysis was conducted using the statistical program “R,” to determine the number of samples needed to have 95% confidence to detect a difference of 15mm between age at length from 2002 and 2011 samples. Based on the standard error of the

2002 data, which was 21.15, the number of spines needed for 95% confidence in each group is 27. This was not an issue as there were adequate numbers of samples within each length category, therefore distribution of total lengths in the sampled population in 2011 allowed for comparisons with the sampled population in 2002.

Using the statistical program "R," length/frequency histograms were constructed for all individuals sampled in 2002 and 2011 respectively. Boxplots were created to evaluate the variance and spread of the data between genders and years. The spread of the data was evaluated to determine if the data was normally distributed. Levene's test was then conducted to determine if variances were equal between genders and years. If spreads seemed different based on preliminary analysis, a Welch's two-sample t-test was conducted to determine if the presumed differences were statistically different.

To determine if differences existed between the condition factors of the fish sampled in 2002 and 2011 an analysis of covariance was conducted. When evaluating condition factor for the sampled channel catfish population in 2002 and 2011, an ANCOVA was conducted to assess if differences existed between years. Due to the fact that body forms change in a curvilinear manner with respect to increasing length the data would be more difficult to analyze than data in a linear form (Guy and Brown 2007). However, a simple solution is to logarithmically transform the data so that a linear regression can be applied to the data and comparisons between years will be easier to assess. In this manner weight is considered the dependent (W_s) variable, length is the independent variable (L), $\beta(0)$ is the overall intercept, $\beta(y)$ is the adjustment for year and $\beta(1)$is the slope of the line. The resulting equation is: $\log_{10}(W_s)=\beta(0) + \beta(y) + \beta(1)[\log_{10}(L)]$.

Age/length keys were constructed for 2002 and 2011 based on the proportional distributions of lengths for an estimated age. These tables are essentially contingency tables that were constructed in “R” to evaluate the differences in groups. Each length group is associated with a probability of age and all samples within a row represent a single age class. To determine if differences exist in length at age between 2002 and 2011 two sided t-tests were conducted with total length as the response variable and year and age as the explanatory variables. Data was imported into the statistical program NCSS and Aspin-Welch unequal variance t-tests were run on all age categories between and within years. Twelve age categories were compared between years, however, some ages could not be compared across years due to extremely low sample sizes at the largest and smallest lengths.

Due to bias that may exist in age estimation of a single reader it is important to validate ages by quantifying the amount of bias and precision that exists between readers. Ideally, validation is a comparison between fish of a known age relative to the estimated ages of the samples collected from a population, allowing for an estimation of accuracy. Due to the fact that fish of known ages were not available for the population of channel catfish that were sampled for this study, a measure of bias and precision between agers was more appropriate for this study (Campana 2001 and Campana et al 1995). An age difference plot, and age bias graph were used to assess the bias between agers based on the methods of validation suggested by Campana et al. (1995). To quantify a level of precision, the coefficient of variation was calculated and was used as a measure of precision between agers. Based on the fact that this study did not evaluate any fish of a known age it is more appropriate that this method be referred to as age estimation rather than age determination. This type of graph is a comparison of assigned ages from two different readers to establish variance and covariance and ultimately determine precision for the aging of these samples. Although other methods exist for estimating precision in aging calcified structures, including percent agreement and average percent error, it has been suggested that the use of the coefficient of variation calculation is statistically more rigorous than the other methods (Campana et al. 1995).

Results

In 2011 we were able to capture and sample 440 channel catfish in 535 minutes of electroshocking lending to a catch per unit effort of .82fish/min or 49.38fish/hr. In 2002 data was collected from 116 males (51.2%) and 106 females (48.8%). In 2011 data was collected from 229 males (52.3%) and 209 females (47.7%). The distribution of the sampled fish includes 23 fish from the fish ladder at RM 166.6, 104 fish from Shiprock bridge to Montezuma Creek, 260 fish from PNM to Hogback and 268 fish from Hogback to Shiprock bridge. All of the fish sampled in 2002, 217 fish, were from PNM to Hogback. All of the fish from both years were sampled between the months of April and August, however, the fish sampled in April, 199 fish, were collected in 2002. The additional 18 fish sampled in 2002 were collected in June. In 2011 109 fish were collected in June and 329 fish were collected in August. Of the fish collected, 20 pectoral spines used to age fish were either damaged in the field or in the laboratory while attempting to obtain spine sections. Ten of these fish were from the 2002 sampling season and 10 were from the 2011 sampling season.

In 2002, male total length ranged from 259 mm to 540 mm with an average length of 383.6mm (±5.39 SE). Total length for females in the same year ranged from 257 mm to 499 mm with an average total length of 381.6mm (±5.74 SE). Total length for males in 2011 ranged from 83mm to 650mm with an average total length of 328.5 (±6.22 SE). In 2011, female total length ranged from 180mm to 581mm with an average total length of 336.4 (±6.47 SE). Histograms of fish total length based on year illustrated that the data was normally distributed within years (Figure 3). Boxplots of gender and year showed that the spread of the data was different between years but that the variance was equal between genders (Figure 4). Further evaluations of distributions determined that the data was normally distributed within years but that large differences in distribution exist between years. The Levene's test to determine whether differences exist in variance between gender and year demonstrated overwhelming evidence that there was a significant difference in variance between genders and years ($p<.0001$, $F=13.59$ from a two-sided t-test with 3 and 651 df). An additional Levene's test to evaluate the variances that existed between only genders gave further evidence for differences in variances between years ($p<.92$, $F=.011$ from a two-sided t-test with 1 and 653 df). Results from the Welch's two sample t-test suggest that there is a difference in the 2002 and 2011 male populations ($p<.0001$, $t=6.45$ from a two-sided t-test with 322 df, 95% confidence interval 36.92-69.34). Likewise the Welch's t-test for the female populations in 2002 and 2011 also exhibited overwhelming evidence for differences in the populations ($p<.0001$, $t=5.45$ from a two-sided t-test with 298 df, 95% confidence interval 30.14-64.20).

When evaluating if differences exist in total length at age between 2002 and 2011, some differences existed that made comparisons between years impossible for some ages. For instance, in 2011, 18 age one and 140 age 2 fish were collected during sampling, however, in 2002 no fish of these ages were collected. Length at age comparisons were conducted for ages three through ten base on an adequate number of samples for comparisons. Length at age for all age compared (3-10) were significantly smaller between pre and post removal years (Figures 9 and 10). Age three fish were significantly smaller prior to removal efforts in 2002 than in 2011 ($t=-1.79$, $p<.01$). Although a significant difference exists in the total length at age 3 the sample sizes were very different (i.e. 2 fish in 2002 and 149 fish in 2011). Age four and five fish were also significantly smaller between pre and post removal efforts ($t=4.1$-6.6, $p<.01$). Age six and seven fish were also significantly smaller between pre and post removal efforts ($t=3.5$-5.5, $p<.01$). Age eight and nine fish were significantly smaller between pre and post removal efforts ($t=3.8$-5.1, $p<.01$). Although sample size was smaller in age 10 fish (i.e. combined 8 fish from both years), fish were again smaller pre removal versus post removal efforts ($t=1.2$. $p<.01$). Age 11 and 12 fish were not compared between years due to the low sample sizes for these age classes (i.e. 3 age 11 fish and 1 age 12 fish. In all cases where significant differences were observed in total length at age, the fish sampled in 2011 were larger at age then in 2002.

Condition indices are often used to assess the general health, community structure and even environmental influences on fish populations (Guy and Brown 2007). An analysis of condition factor was conducted on the channel catfish sampled in the San Juan River in 2002 and 2011. The ANCOVA demonstrated that after accounting for differences in length, there are significant differences in weight between the years of 2002 and 2011($p<.03$, $t=2.33$ from an ANCOVA with 633 df). In addition the graph of these data (Figure 7) demonstrates the variability of these data points from 2002 and

2011. Channel catfish sampled in 2011 were heavier in weight at a given length then channel catfish in sampled in 2002.

Data from water temperature analysis suggests that in 2002 water temperatures were higher for all months than in subsequent years. In addition since temperature data has been recorded on the river water temperatures have never reached the optimal growth temperatures suggested for channel catfish. Water temperatures have fluctuated from 2002-2011 with the greatest variations occurring between the months of April through June. However, a trend towards lower or higher water temperatures over the course of the last 10 years is not apparent in the data. In 2002, channel catfish were sampled in April with an average water temperature of 15 °C and in 2011 channel catfish were sampled in June and August with average monthly water temperatures of 16 ^{o}C and 23.8 ^{o}C respectively. Since the water temperature is significantly higher in August of 2011 than in April of 2002, there is a possibility that some of the differences observed in length at age and condition factor are confounded by the increased growth during months of warmer water temperatures.

Water temperature also plays a role in capture efficiency when sampling with electrofishing gear. A study evaluating this phenomenon determined that capture efficiency was significantly higher in water temperatures of 18 °C or higher (Bodine and Shoup 2010). Based on these data the August sampling trip should have a higher capture rate than the April and June sampling as the water temperature was at 23.8 ^{o}C in August. There were over 3 times more fish captured in August than in June of 2011, however different portions of the river were sampled in June and August and therefore confound an accurate assessment of capture efficiency. However, based on the CPUE of the San

Juan River Recovery and Implementation Program removal rafts that operated on all sections of the river throughout the summer the CPUE for PNM to Hogback diversion increased from 1fish/hr. to 13fish/hr. Due to the increase in capture efficiency in the later summer months there is a possibility that the lack of age 1 and 2 channel catfish in the 2002 sampled population is a direct result of lower water temperatures effecting the strength of the electrical current and there for capture efficiency.

Discussion

Results from the analysis of the sampled channel catfish population suggest that differences exist in the population structure between 2002 and 2011. Males and females from the sampled populations in 2002 and 2011 exhibit similar population structure with respect to total length within a given year. However, the total length distributions of male and female catfish between years are significantly different. The length frequency histograms (Figure 3) illustrate the distributions of total lengths for the sampled population.

The age structure of the sampled channel catfish population was also different from 2002 to 2011. The most obvious difference is the fact that 158 channel catfish of age 1 or 2 were collected in 2011 and no fish of this age class were collected in the sample from 2002. An evaluation of the distribution of age one and two fish showed that there were 87 collected in August and 71 in June. This distribution shows that the collection of younger age individuals (age one and two fish) was not based on water temperature increasing capture efficiency of smaller fish in August as opposed to June in 2011.

When comparing the channel catfish length at age between 2002 and 2011 many differences were observed. For all age classes compared (i.e. 3-12) between 2002 and 2011 the length at age for the channel catfish were significantly different. However, the shift that was expected from a compensatory response to removal of larger fish was not observed. I hypothesized that the channel catfish length at age would decrease over the years due to exploitation of the >300 mm fish through electrofishing removal efforts. However, the opposite effect seems to be developing in the San Juan River system. All age length categories compared suggest that the fish in the system now are larger at age then they were in 2002. This data was supported by the findings in the 2011 San Juan River Recovery and Implementation Program Report (Duran et al. 2012). The report suggests that the mean total length of all fish removed in 2011 (341 mm ± 6.4) was significantly lower than in than the previous year (427 mm ± 8.1). This decrease in mean total length was attributed to the decrease of large adults captured in 2011. In addition, although the mean total length for channel catfish was different in 2002 than in 2011 the distribution of total lengths creates some degree of overlap within a given age category. Therefore, although the mean total length is an important metric to take into account the age/length structure of the channel catfish may be more telling of the changes in the sampled population.

Another comparison was made in the San Juan River Recovery and Implementation report as to the number of juvenile and sub-adult channel catfish observed in the river system. The report suggest that an increase in juvenile and sub-adult abundance was observed in all sections of the San Juan River in 2011 compared to previous years. This observation strengthens the argument that the increase of age 1 and 2 fish observed in

2011 as compared to 2002 is a result of differences in the population structure of the channel catfish and not owing to the capture efficiency tied to differences in water temperature between months (Duran et al. 2012)

Due to time and funding constraints otolith preparation and aging was not conducted. These samples were to be compared with pectoral spines to determine if these hard parts were consistent with one another with respect to age. However, many papers have evaluated the efficacy of aging fish using otoliths and pectoral spines. One study evaluated the age estimates derived from sagittal otoliths and pectoral spine sections and found that for over 90% of the samples ages were consistent (Buckmeier et al 2002). Another paper evaluating the precision of age estimations between pectoral spines and otoliths determined that the average percent error when aging otoliths and spines was 8.4% with a coefficient of variation of 11.4. In addition the slope of the age bias plots was not different than one which is an indication that there were similar age assignments between structures (Colombo et al. 2010). The data was so compelling in the previous mentioned article that the authors saw fit to suggest the use of pectoral spines over otoliths as an aging structure. For these reasons I feel confident that the use of pectoral spine sections as an age estimator in channel catfish is an adequate and appropriate methodology.

CHAPTER FOUR

CONCLUSIONS

The findings of this study suggest that differences do exist in the length at age of channel catfish sampled in the San Juan River in 2011 when compared to 2002. However, the compensatory response of smaller size at age that was hypothesized for the population was not observed in the sampled population. The sampled population in 2011 did have a higher abundance of juvenile and sub-adult fish than in 2002, however, all age classes were larger in length for a given age in 2011 than in 2002. This data suggests that the hypothesized effects of electroshocking removal efforts are not causing a selective pressure towards smaller individuals. In fact the opposite effects was observed as the sampled channel catfish population in 2011 was longer at a given age than before removal efforts were established in 2001. Although the presence of larger adult channel catfish has decreased in the sampled population in the San Juan River, the emergence of so many juveniles should be of some concern. This increase in abundance of younger fish suggests that the channel catfish are successfully reproducing in the river system. In addition, the larger size at age of the sampled channel catfish in 2011 compared to 2002 suggests that resource availability is not an issue for this species at the moment. The fluctuations observed in the mean total length of channel catfish sampled from 2001 to 2011 suggest that there is not a general trend towards larger or smaller mean total length across years. Although mean total length was given as a function of all catfish captured and removed, the presence or absence of large adult channel catfish seems to be the driving factor in the overall mean total length of channel catfish reported (Duran et al. 2012). Since the reproductive potential for channel catfish was determined to be beyond the 400 mm mark, the absence of large adults does not seem to suggest a lack of reproductive potential. Since the size at age of channel catfish has increased, when compared to 2002, these fish maybe more fecund than in previous years. This increase in fecundity at a younger age may account for the increase in juvenile abundance observed over the years. My suggestion is that the fluctuations observed in the abundance of large adult channel catfish, illustrated by increases and decreases in mean total length, may not explain the fluctuations observed with increased juvenile abundance. I believe that further studies should be conducted to systematically address the biotic and abiotic factors that could be driving these fluctuations in length at age and condition factor. Comparisons should be made to the length at maturity table provided by this paper to determine if the reproductive potential of channel catfish differs from year to year and how this relationship could be tied to juvenile or large adult abundance for a given year.

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Figures and Tables

2002 Age/Length Key								
	Length							# Fish
Age	0-100	101-200	201-300	301-400	401-500	501-600	601-700	
1	*	*	*	*	*	*	*	0
2	*	*	*	*	*	*	*	0
3	*	*	50.0%	50.0%	*	*	*	2
4	*	*	25.0%	75.0%	*	*	*	16
5	*	*	10.3%	76.9%	12.8%	*	*	39
6	*	*	3.6%	76.4%	16.4%	3.6%	*	55
7	*	*	*	48.1%	48.1%	3.8%	*	52
8	*	*	*	34.6%	61.5%	3.8%	*	26
9	*	*	*	33.3%	66.7%	*	*	9
10	*	*	*	20.0%	40.0%	40.0%	*	5
11	*	*	*	*	100.0%	*	*	2
12	*	*	*	*	100.0%	*	*	1
							Total	207

Figure(1) Age Length Key for sample population of the San Juan River, NM 2002. Values are given as percentage of the sampled population within a length/age category. *Denotes a value of zero or that no individuals of length x were of age y.

2011 Age/Length Key								
	Length							# Fish
Age	0-100	101-200	201-300	301-400	401-500	501-600	601-700	
1	*	38.9%	61.1%	*	*	*	*	18
2	*	2.1%	88.6%	9.3%	*	*	*	140
3	*	*	22.8%	75.8%	0.7%	0.7%	*	149
4	*	*	*	80.0%	16.0%	4.0%	*	25
5	*	*	*	*	87.5%	12.5%	*	8
6	*	*	*	14.3%	78.6%	7.1%	*	14
7	*	*	3.4%	10.3%	58.6%	27.6%	*	29
8	*	*	*	3.8%	69.2%	26.9%	*	26
9	*	*	*	*	46.7%	46.7%	6.7%	15
10	*	*	*	*	33.3%	33.3%	33.3%	3
11	*	*	*	*	*	100.0%	*	1
12	*	*	*	*	*	*	*	0
							Total	428

Figure(2) Age Length Key for sample population of the San Juan River, NM 2002. Values are given as percentage of the sampled population within a length/age category. *Denotes a value of zero or that no individuals of length x were of age y.

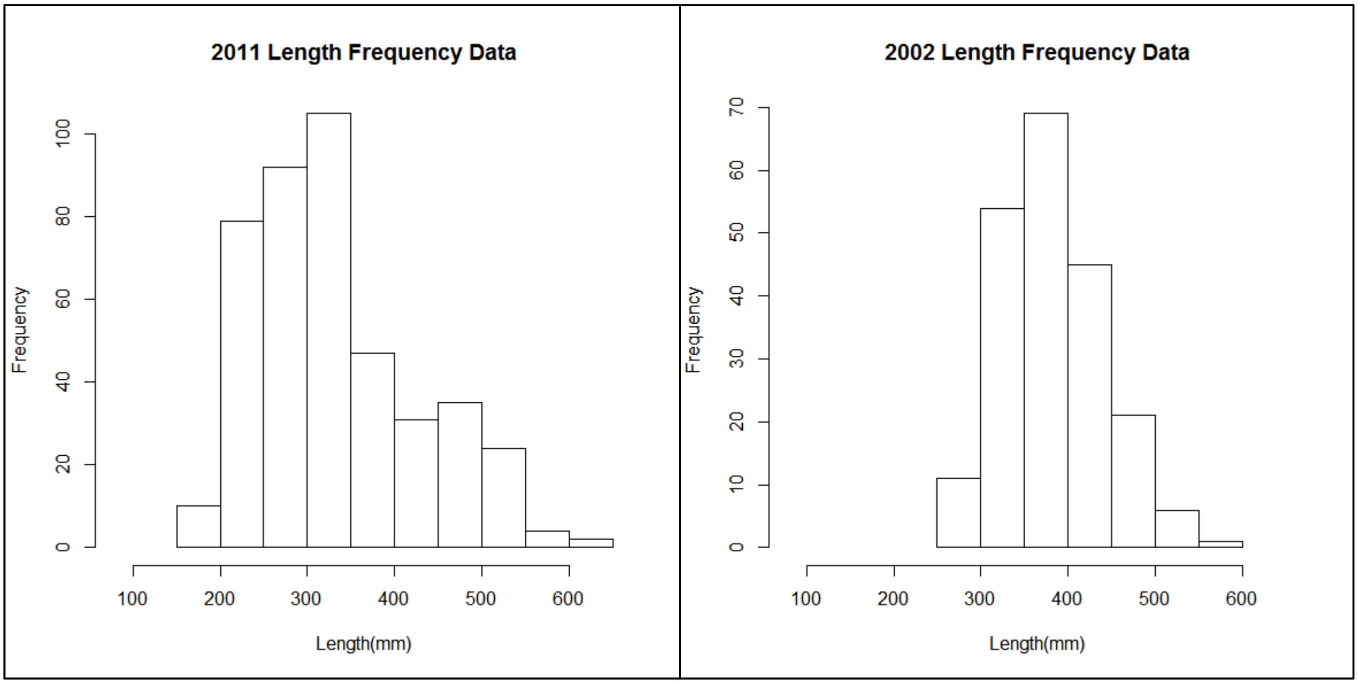

Figure (3): Length/Frequency histograms for channel catfish (*Ictalurus punctatus*) sampled in the San Juan River, NM in 2011 and 2002 respectively.

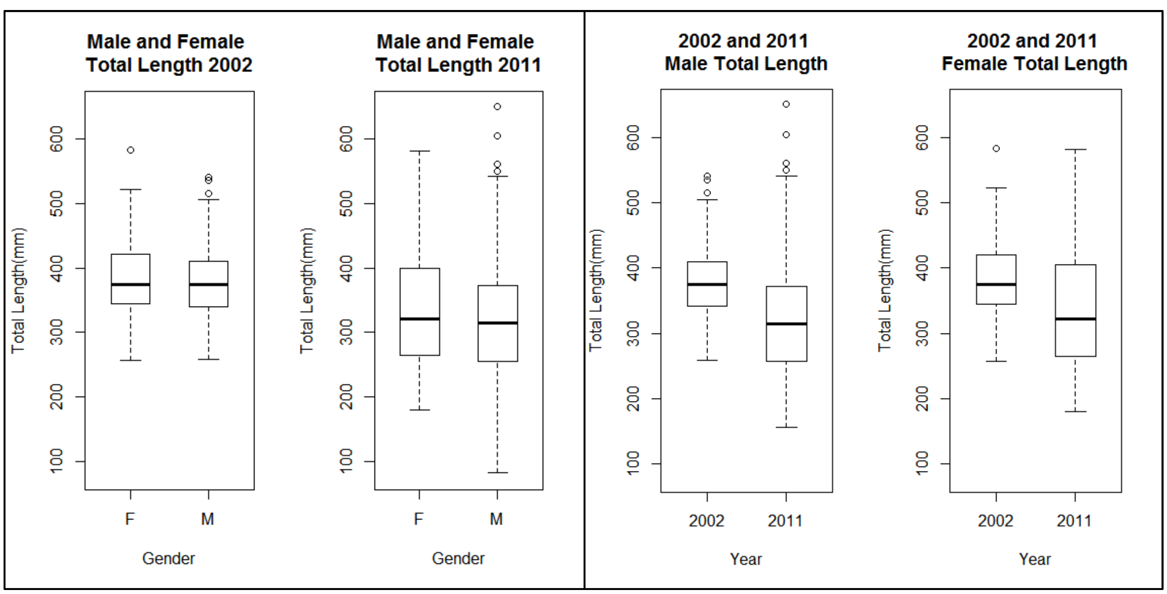

Figure (4): Boxplots of total lengths(mm) for channel catfish collected in 2002 and 2011 based on gender. The figure illustrates the mean total lengths and spread of the data collected.

Maturation Data for 2011 Based on Length							
	Length						#Fish
Stage	0-100	101-200	201-300	301-400	401-500	501-600	
1	*	*	*	*	*	*	0
2	*	5.1%	55.1%	37.8%	2%	*	98
3	*	*	37.1%	48.6%	5.7%	8.6%	35
4	*	*	8%	44%	36%	12%	25
5	*	*	*	*	*	*	0
6	*	*	*	*	70%	30%	20
7	*	*	*	20%	*	80%	5
8	*	*	*	*	85.7%	14.3%	7
9	*	*	*	*	*	*	0

Figure(5): Table of length and maturity for the sampled channel catfish population in the San Juan River 2011. Values are given as percentage of the sampled population within a length/maturity stage category. *Denotes a value of zero or that no individuals of length x were of stage y.

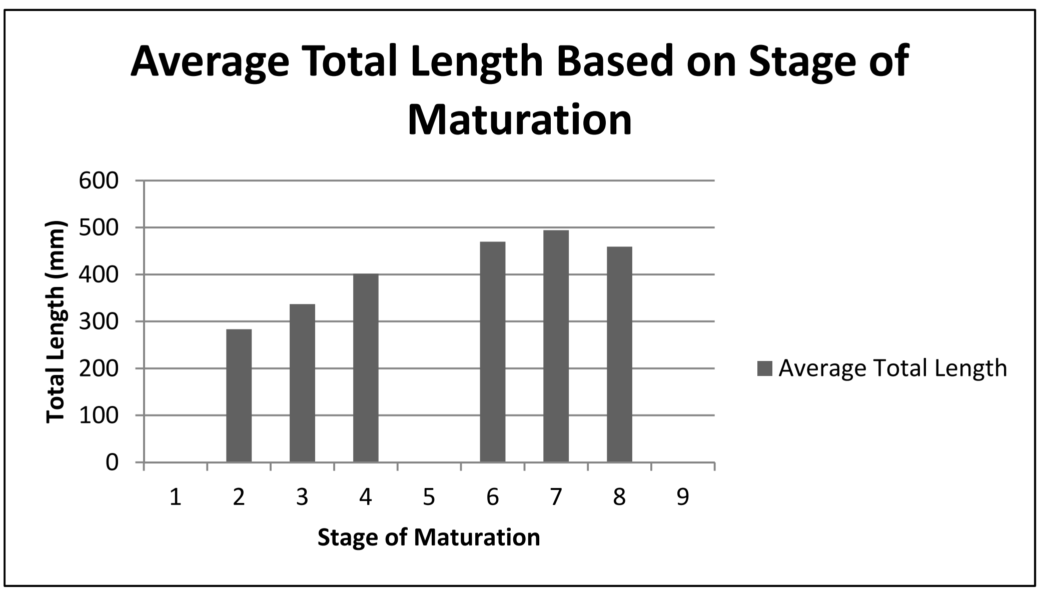

Figure (6): Graph of average total lengths calculated for stage of maturity. Stages 1, 5 and 9 do not have values as the samples were staged based on the highest level of maturation observed.

Age	Number at Age	Mean TL (mm)	SD	Minimum	Maximum
1	*	*	*	*	*
2	*	*	*	*	*
3	2	281.5	34.6	257	306
4	16	329.4	32.7	280	384
5	39	347.8	42.0	259	436
6	55	373.5	47.4	297	535
7	52	402.9	52.4	316	540
8	26	410.9	44.7	330	522
9	9	430.4	57.7	320	497
10	5	473.0	76.1	377	582
11	2	429.5	31.8	407	452
12	1	499	0	499	499
total	**207**				

Table (1) Mean total length at age of channel catfish sampled in the San Juan River, NM 2002

Age	Number at Age	Mean TL (mm)	SD	Minimum	Maximum
1	18	203.6	19	156	226
2	140	256.3	30	180	333
3	149	325.9	36	228	523
4	25	385.3	48	322	512
5	8	449.8	36	409	530
6	14	438.5	38	379	512
7	29	455.8	63	283	581
8	26	476.0	46	379	579
9	15	516.7	46	457	650
10	3	536.7	58	499	604
11	1	555.0	0	555	555
12	*	*	*	*	*
total	**428**				

Table (2) Mean total length at age of channel catfish sampled in the San Juan River, NM 2011

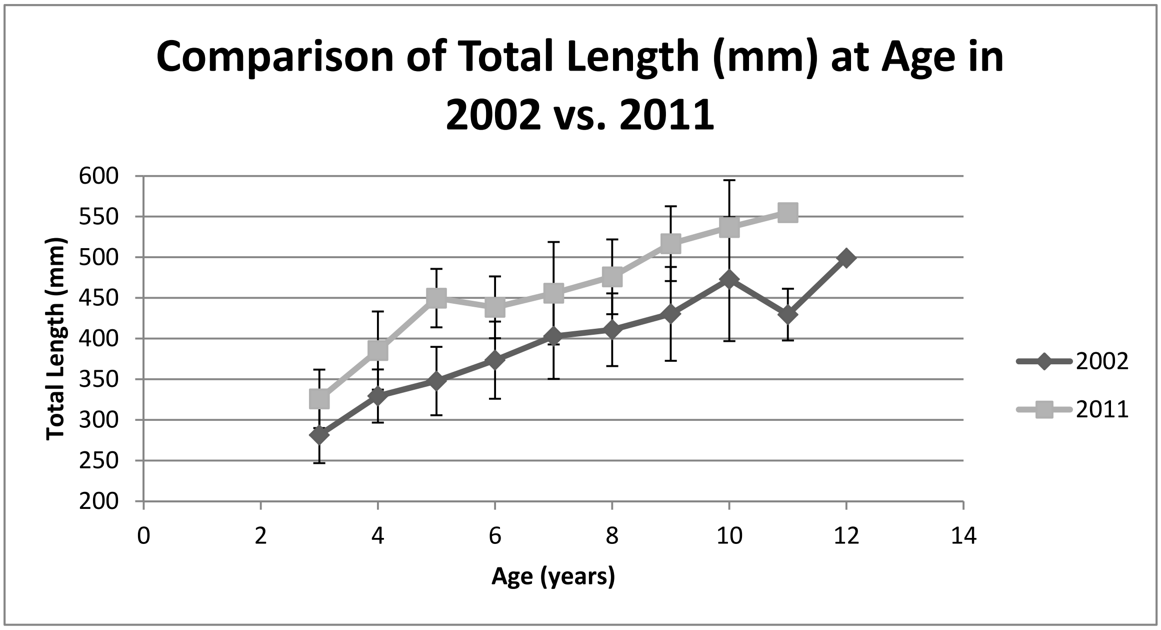

Figure (9): Comparison of mean total length (mm) at age for channel catfish sampled in 2002 and 2011. Mean total lengths at age were smaller for between pre and post removal years (2002-2011).

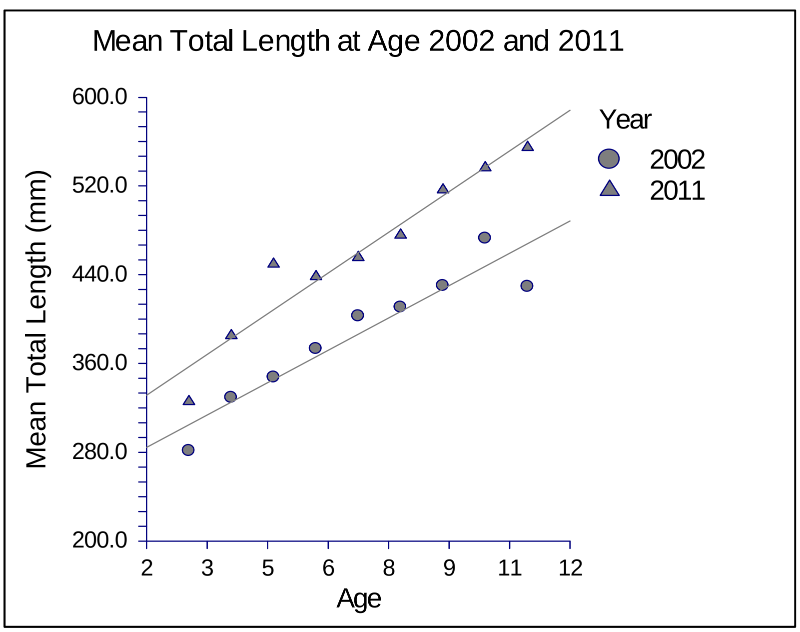

Figure (10): Linear regression of channel catfish mean total length at age. Differences can be observed in the position and slopes of the lines between pre and post removal efforts in 2002 and 2011 respectively.

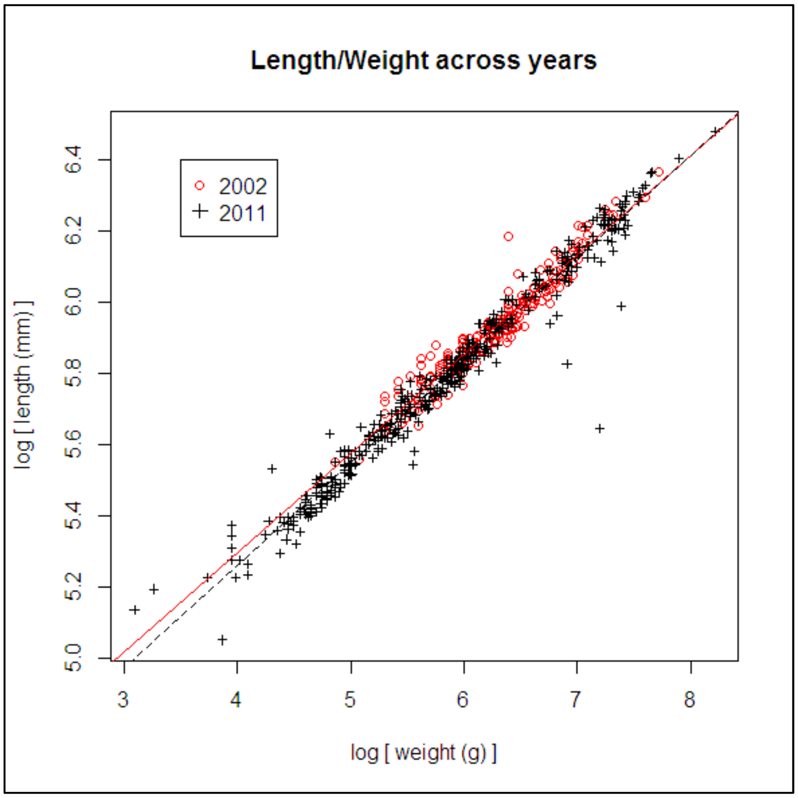

Figure (7): Graph of log relationship of weight and total length from channel catfish sampled on the San Juan River in April 2002 and June and August 2011.

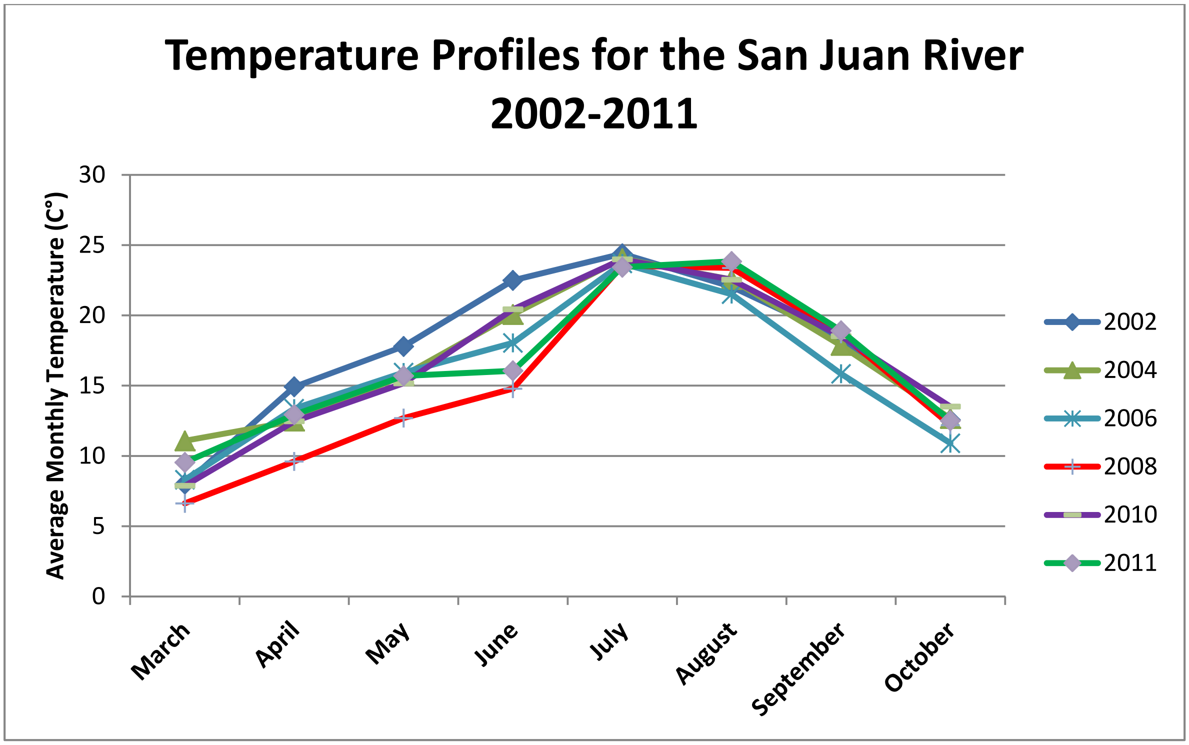

Figure (8): Graph of temperature profiles for the San Juan River, NM from 2002 to 2011. Temperatures are average monthly water temperatures for the San Juan River.