Spring 2019

Size and Age Structure of Introduced Populations of Blue Catfish (Ictalurus furcatus) in Two Kansas Reservoirs and Implications for Management

Ernesto Flores
Fort Hays State University, e_flores@mail.fhsu.edu

SIZE AND AGE STRUCTURE OF INTRODUCED POPULATIONS OF

BLUE CATFISH (*ICTALURUS FURCATUS*) IN

TWO KANSAS RESERVOIRS AND

IMPLICATIONS FOR MANAGEMENT

being

A Thesis Presented to the Graduate Faculty

of Fort Hays State University in

Partial Fulfillment of the Requirements for

The Degree of Master of Science

by

Ernesto Flores

B.S., Fort Hays State University

Date 5/29/2019

Approved ______________________
Major Professor

Approved ______________________
Chair, Graduate Council

This thesis for

Master of Science degree

by

Ernesto Flores
has been approved by

____
Chair, Supervisory Committee

____
Supervisory Committee

____
Supervisory Committee

____
Supervisory Committee

____
Chair, Department of Biological Sciences

ABSTRACT

The introduction of a new fish species into an aquatic ecosystem can bring about many challenges for fisheries managers. Questions might arise for the manager regarding the initial sportfish survival rate, grow rate, reproduction and recruitment, and what kind of impact will the introduction have on the already established populations found in the water body. A new population of fish is often protected using length limit regulations, allowing biologists to gain insight on whether the population will be self-sustaining or in need of periodic stockings. Age and growth information is used to understand population dynamics, estimate annual mortality and recruitment, and generate insight on which abiotic and biotic factors might influence growth rates; often associated with survival, the faster you grow the less susceptible you are as an individual to being consumed. Growth rate determination requires the extraction of hard structures from individual fish within a robust sample of the population. Selection of hard structures used for aging a fish species depends on the structure's ability to provide accurate and precise age estimation. Otoliths have emerged as the hard structure of choice to generate precise age estimates but require sacrificing individuals. I chose to use pectoral fin rays to estimate ages of Blue Catfish *(Ictalurus furcatus)* from two water bodies in Kansas to estimate whether pectoral fin rays generate usable data and minimize unnecessary mortality associated with the harvest of otoliths.

The Blue Catfish was introduced in Wilson Reservoir in 2006 and Lovewell Reservoir in 2010 with a shared management goal of establishing trophy fisheries. In 2016, I collected pectoral fin rays from 116 individuals from Lovewell Reservoir and 165 Blue Catfish from Wilson Reservoir and sectioned them with a novel approach that

allowed me to conduct an age and growth analysis for both populations. The objective was to estimate the trophy potential of these populations based on growth rates.

The Wilson Reservoir population of Blue Catfish had 5 of 11-year classes were represented in the sample; All 7 years since the initial stocking were represented in Lovewell Reservoir samples. Only the Blue Catfish in Lovewell Reservoir has begun to recruit naturally and produce individuals surpassing the minimum length limit of 889 mm. The population in Wilson Reservoir exhibit slower growth rates compared to Lovewell Reservoir and individual growth rates slow down after fish reach 520 mm. Under current conditions, the Blue Catfish population at Lovewell Reservoir is likely more suitable for trophy management, due to natural reproduction and higher growth rates compared to the Wilson Reservoir population. However, Blue Catfish populations oftentimes take decades to realize trophy potential. Therefore, further analysis is needed to determine the underlying factors that lead to relatively poor growth of Blue Catfish at Wilson Reservoir.

ACKNOWLEDGEMENTS

I thank Kansas Department of Wildlife, Parks, and Tourism (KDWPT) and Fort Hays State University's Department of Biological Sciences for the support, experience, and funding that made this project possible. I thank the Ellsworth District Fisheries Biologist Bryan Sowards and Glen Elder District Fisheries Biologist, Scott Waters, and KDWPT research biologists Jeff Koch and Ben Neely for their advice, guidance, and time spent collecting data during the course of this project. I also thank the fisheries research staff at Emporia for their help in completing this project and analyzing results. I thank my Committee members, Mr. Mark Eberle, Dr. Mitchell Greer, Dr. Brian Maricle, Mr. Bryan Sowards, and especially thank my Advisor, Dr. William Stark for his patience, guidance, encouragement, and mentoring throughout my years at Fort Hays State University; and all the time he spent reviewing and editing this manuscript to complete my Master's degree. I thank all KDWPT employees, Jared Ireland, Grayson Fabrizius, Jared Engelbert, Vanessa Salazar, and Allison Hullinger, who spent their time helping collect data while working on this project. I thank my family for all their support, especially my mother, Santa Guzman, my brothers, Angel and Pedro, and all of my colleagues for all the support I was given to be able to finish graduate school and move forward with life. I was truly blessed to be able to work with all the people that are mentioned above. Thanks to all.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

Recreational anglers over the age of 16 numbered 35.8 million in 2016 in the United States; which was an increase of 8% from 2011. Anglers in the United States spent $46.1 billion on equipment, licenses, travel, and other expenditures related to fishing in 2016. A portion of this total is made available to the natural resource agencies of each state through the Dingell-Johnson Act passed in 1950. These funds facilitate the enhancement and conservation of sport fisheries by supporting investigations of sportfish populations, sportfish stockings, enhancement of facilities for public use, and habitat improvements for sport fisheries (American Sportfish Association 2013; USFWS 2015).

In Kansas, an estimated 400,000 anglers over the age of 16 participated in fishing activities for a combined 4.2 million days in 2011 (USFWS 2012). On average, each angler fished 10 days and spent $520 on fishing related activities and, in total, spent over $200 million on fishing related expenditures in 2011 (USFWS 2012). The Kansas Department of Wildlife, Parks and Tourism (KDWPT) manages 303 impoundments for public use that vary in size from one to 15,000 acres. The largest reservoirs are part of the network of impoundments managed by federal agencies such as the who control water levels.

The primary functions of these federal reservoirs are flood control, water supply, irrigation for agriculture, and recreation. Impoundments in Kansas vary in magnitude from F.I.S.H access ponds, which are leased from private landowners for public fishing access, community fishing lakes, state fishing lakes, and large federal reservoirs. These public waters are managed by biologists with different management tools to provide a variety of outdoor recreational angling opportunities throughout the state of Kansas.

Biologists within (KDWPT) rely on adaptive strategies to manage the fisheries within these abiotically diverse impoundments. Adaptive management is a structured decision-making process that involves assessing fish populations, setting goals, defining objectives, and executing management decisions that can then be evaluated and modified in response to changing conditions (Arlinghaus et al. 2016). Understanding the natural history of a fishery, abiotic and biotic variables, human impacts on sportfish, in combination with temporally relevant sampling, allow biologists to achieve management objectives that develop healthy and sustainable fisheries. Appropriate sampling of these fish populations allows managers to identify trends in population dynamics that trigger different management actions (e.g. stocking, regulations, and habitat enhancement). These management actions are designed to achieve a balance of fishery conservation and angler use.

Age information is one of the most useful types of data biologists can collect and is frequently used to document recruitment classes, estimate growth rates, and estimate annual mortality, all of which potentially influence management decisions (Campana, 2001). Both biotic and abiotic variables influence growth of fishes and include water temperature, forage availability, surface elevation, water quality indices, and angler harvest (Zale et al. 2012)

Age information combined with growth data can be used to answer questions regarding sportfish management as well as effects of intentional or accidental species introductions. For example, Kwak et al. (2006) evaluated growth and mortality rates of introduced Flathead Catfish *(Polydictis olivaris)* in river systems to compare growth rates between native and introduced populations finding that fish in the Northeast Cape Fear, Neuse, and Lumber rivers grew faster than native populations, similar to native reservoir populations, and slower than other introduced populations in other riverine systems.

Marshall et al. (2009) investigated the sex-specific growth rates of Channel Catfish *(Ictalurus punctatus)*, Blue Catfish, and Flathead Catfish in Lake Wilson, Alabama to generate accurate population assessments. The three catfish populations were managed with an 864-mm restrictive-length limit, where liberal harvest was allowed for individuals below the limit and only one individual could be harvested above the limit. They concluded that the harvest restriction on larger catfish would indeed protect larger fish of both sexes if growth rates were similar. However, males grew faster and much larger than females. Liberal harvest of catfish below the 864-mm restrictive-length limit might disproportionately remove female catfish from the population while protecting a higher proportion of males. By lowering the restrictive-length limit based on these data, smaller slow growing females would be less susceptible to exploitation.

This type of information often referred to as age and growth is collected by biologists by a variety of ways; recapture of individuals of known age or, more simply, inferred from length-frequency histograms. However, robust samples of hard structures from individuals throughout the population's length distribution are used most often in thorough age and growth assessments (Spurgeon et al 2015; Quist and Isermann 2017). There are a variety of hard structures that have been used to estimate the age of fish including scales, fin rays, otoliths, and cleithral and opercular bones (DeVries and Frie 1996; Quist and Isermann 2017). Age estimates from hard structures are obtained by counting the total number of seasonal bands, or annuli, deposited within a hard structure (e.g. otoliths, pectoral spines, and scales). Annuli formation results from accumulations of calcium carbonate during periods of differential growth (typically annual or daily) on hard structures. Periods of slow growth produce dense opaque bands on a hard structure. Periods of rapid growth produce more translucent zones (Chambers and Miller 1995; Helfman et al. 2009; Quist et al. 2012; Spurgeon et al 2015; Buckmeier et al. 2017). Because fish exhibit indeterminate growth, hard structures can contain a complete record of age and growth rates for individuals (Helfman et al. 2009).

The accuracy and precision of age estimates can differ depending on the hard structure selected for the study and the target species from which age and growth estimates will be calculated. Schramm and Doerzbacher (1985) reported that scales did not provide reliable age estimates of Black Crappie *(Pomoxis nigromaculatus)* in the southeastern United States. (Quist and Isermann 2017) suggested that otoliths are the most accepted hard structure when aging Centrachid species. Graham (1999) used pectoral spines rather than otoliths to age Blue Catfish from Missouri waters and sectioned otoliths have been verified and used for Largemouth Bass *(Micropterus salmoides)* age and growth studies (Miller and Storck 1982). Selecting the hard structure that generates the most precise and accurate age estimate is critical but often dependent on many factors, such as the perceived value of individual fish, or the time required to collect the structures (Yates et al. 2016; Quist and Isermann 2017).

Scales are easily obtained and their collection causes little apparent harm to the individual. However, age estimates are less accurate, less precise, and produce a wider range of estimated ages than other hard structures (McInery 2017). Otoliths generally provide the most precise and accurate age estimates, but they require euthanizing the fish to obtain the hard structure. Calcified fin rays have been used to estimate age of marine and freshwater fishes, and the collection is non-lethal. Accordingly, calcified rays can be an excellent alternative when assessing a population with unknown dynamics, especially in ictalurid catfishes (Fischer and Koch 2017).

Age is estimated from hard structures by counting visible annuli. Growth can be estimated by measuring the distances from the focus, or center of structure, to the outer edge of each annulus along a single axis (Devries and Frie 1996: Quist et al 2012) (Figure 1). The distances can be used to generate back-calculated length-at-age with the Fraser Lee method which was used for this project (Devries and Frie 1996). The Fraser Lee method uses the linear relationship between total length of an individual and hard structure radius to determine length-at-age with the y-intercept varying in value by allowing the assumption that a fish is already a certain length before the first scale forms. By knowing length at the time of capture and the radius of the hard structure, length-at-age can be estimated proportionally by measuring the distance from the focus to each individual annulus. Distances are averaged for each age class and used to estimate a mean back-calculated length for the entire population (Devries and Frie 1996).

Back-calculated lengths gathered from either method can be used to estimate growth from length-at-age. A commonly used growth model is the von Bertalanffy growth model (Helfman et al. 2009). This model describes fish growth as it relates to age, with the assumption that fish growth decreases with age and reaches an asymptote (Helfman et al. 2009). The von Bertalanffy growth model can provide insights into growth rates within a population, compare growth between populations, and estimate the effect of angling mortality on a population (Helfman et al. 2009).

Many federal reservoirs in Kansas are near the end of their expected lifespan and are at or transitioning towards a eutrophic state. These productive waters are thought to be ideal conditions to establish Blue Catfish fisheries because of the recent success at Milford Reservoir (Goeckler et al. 2003, J. Reinke, KDWPT, personal communication). Prior to 2002, only two federal reservoirs in Kansas had Blue Catfish intentionally introduced outside of riverine introductions. Since then, 12 federal reservoirs and La Cygne Lake have been stocked with Blue Catfish in an attempt to replicate the success seen with the population of Blue Catfish in Milford Reservoir despite this population longevity. Despite the Blue Catfish population's popularity with anglers at Milford Reservoir, and the establishment of populations in most other federal reservoirs in Kansas, a paucity of age and growth information has been summarized for this species in Kansas. In fact, only one reservoir has been sampled for age and growth information and that information is now outdated (Goeckler et al. 2003).

Blue Catfish were introduced in Wilson and Lovell reservoirs in 2006 and 2010, respectively. The objective of these introductions was to decrease the abundance of invasive White Perch *Morone americana* in Wilson Reservoir and over abundant Gizzard Shad *dorosoma cepedianium* population in Lovewell reservoir. An additional objective for both reservoirs was to develop trophy Blue Catfish fisheries. Accordingly, in the absence of population demographic data, an 889-mm minimum-length limit was implemented to protect Blue Catfish from harvest and increase the probability of establishing high profile Blue Catfish fisheries.

The initial stocking in Wilson Reservoir occurred in October 2006 at rate of 2 fish per acre, or approximately 18,000 intermediate sized individuals ranging from 146 – 219 mm. Subsequently, Blue Catfish were stocked every year except in 2009 and 2015 but at a minimum of 1 fish per acre (B. Sowards, KDWPT, personal communication). As mentioned, the introduction of Blue Catfish was, in part, an attempt to reduce the number of White Perch in the reservoir. The White Perch is designated as an aquatic nuisance species in Kansas and current management efforts are focused on control rather than eradication (C. Steffen, KDWPT, Personal communication).

Lovewell Reservoir was stocked with Blue Catfish at 1 fish per acre, or 3,000 individuals, annually from October of 2010, through 2014; except in 2013 when the rate was 0.33 fish per acre. The goal, in part, was a top down control of abundant Gizzard Shad (S.Waters, KDWPT, personal communication).

Despite repeated stockings and allocation of department resources, the status of Blue Catfish populations in Wilson and Lovewell reservoirs are mostly unknown. Furthermore, standard sampling techniques have yet to be established to produce usable demographic data. Such information is necessary to thoroughly evaluate both populations and gain insight into how Blue Catfish populations respond to environmental conditions.

The objectives of this project were to (1) characterize the age structure of Blue Catfish population in Wilson and Lovewell reservoirs, (2) estimate Blue Catfish growth in both Wilson and Lovewell reservoirs, (3) Generate recommendations for management of Blue Catfish populations in both reservoirs.

METHODS

Study sites:

Wilson Reservoir impounds the Saline River in west-central Kansas approximately 77 km east of Hays, Kansas and 98 km west of Salina, Kansas. The watershed area is 4972 km^2 with a predominant agriculture landscape surrounding the reservoir. Elevation at conservation pool is 462 m above sea level. The reservoir has a surface acreage of 3,658 ha with a mean depth is 9 m. The water level is managed by the Army Corps of Engineers and the fisheries are managed by KDWPT.

Wilson Reservoir is classified as mesotrophic, a median Secchi depth of 173 cm and mean chlorophyll-a concentration of 4.48 ppb (Kansas Department of Health and the Environment Bureau of Surface Water Sampling Report for Station LM01500; B. Sowards, KDWPT, personal communication). The reservoir historically maintains a stable water level, relative to other impoundments in west-central Kansas, although recently the surface elevation decreased three meters (2009 -2015) due to an extended drought period (Figure 2). Established sport fish populations include White Bass *Morone chrysops*, Striped Bass *Morone saxatilis*, Walleye *Sander vitreus*, Largemouth Bass *Micropterus salmoides*, Smallmouth Bass *Micropterus dolomieu*, and Channel Catfish *Ictalurus punctatus,* and Blue Catfish were introduced in 2006.

Lovewell Reservoir impounds the White Rock Creek in the Republican River basin in North-Central Kansas and is located 29 km northeast of Mankato, Kansas and approximately 11 km downstream from The Kansas-Nebraska border. The reservoir has a watershed area of 893 km^2 with much of the watershed surrounded by agriculture. The reservoir's elevation at conservation pool is 482 m above sea level. The surface area is

1,208 ha, maximum depth is 9.5 m, and mean depth of 4.4 m. Lovewell reservoir is a hyper-eutrophic (chlorophyll-a concentration = 25.95 ppb; Kansas Department of Health and the Environment Bureau of Water, 2011), turbid, and windswept. The water level is managed by the Bureau of Reclamation and this reservoir experiences water level fluctuations due to influx and irrigation draw downs. Established sportfish populations include Black Crappie *Pomoxis nigromaculatus*, White Crappie *Pomoxis annularis*, Bluegill *Lepomis macrochirus*, White Bass, Hybrid Striped Bass *(Morone chrysops x Morone saxatilis)*, Walleye, and Channel Catfish. Blue Catfish was introduced in 2010 and subsequently stocked every October until 2015 (Waters 2016).

Sample methods:

The newly established populations of Blue Catfish in Lovewell and Wilson reservoirs have not been evaluated or characterized due to difficulties associated with collecting a sufficient sample size without a targeted effort. Standard sampling protocols adopted by KDWPT prescribed annual sampling during the months of October-November to assess sportfish populations by using experimental monofilament gill nets (24.3 m' long x 1.8 m' deep, with 8, 3 m' panels of varying mesh sizes). However, this method often yields low catch rates for Blue Catfish (Dumont and Schlechte 2004; Buckmeier and Schlechte 2009: B. Sowards, KDWPT, personal communication). Accordingly, KDWPT has explored additional sampling methods in an effort to collect larger samples that represented a broad range of lengths and ages, and minimized overall capture bias inherent when using only one sampling technique (Bodine and Shoup 2010).

I attempted to collect 5 individuals per 1-cm length group. Several sampling gears were used to meet this requirement. Both random and targeting techniques were used to increase sample size. It was evident that collecting a sufficient sample of Blue Catfish at Wilson Reservoir, versus Lovewell Reservoir, would be more difficult. Therefore, I used a wide array of sampling gears during this project.

Wilson Reservoir Collections:

In addition to the experimental gill nets described above, I used low-frequency electrofishing and float lines to sample Blue Catfish from 8 June through 31 October 2017. I used a Midwest Lake Electrofishing ©Infinity HC-80 control box (80 amp and 600 volts maximum) with settings at 15 pulses per second, 15 percent duty cycle, and maximum amperage ranging from 15 to 20. Midwest Lake Electrofishing Company retrofitted the unit on to a 5-m Coffelt boat hull. The unit was designed to more effectively sample Wilson Reservoir than traditional units because water conductivity generally exceeds 2,500 µS and requires higher amperage to induce electrotaxis. Electrofishing was conducted for 5 minutes at each designated sample site. Two chase boats were used to assist in collection when fish surfaced at relative long distances from the electrofishing boat. Low-frequency electrofishing with similar settings has been used effectively to sample Blue Catfish populations throughout the range of species (Bodine et al. 2013). This technique has been shown to be the most efficient gear for collecting Blue Catfish and collects individuals in relation to their abundance from 200 - 1000 mm (Bodine and Shoup 2010, Bodine et al. 2013). However, likely due to high water conductivity, this gear has been inefficient at collecting Blue Catfish at Wilson Reservoir (B. Sowards, personal communication).

I used float lines in conjunction with a project to evaluate their effectiveness in sampling Blue Catfish populations, especially larger individuals, in high conductivity environments (B. Sowards, KDWPT, personal communication). Float lines consisted of a 5 x 30 x 30 cm wooden float, and 9.14 m of 1.65-mm diameter weed-trimmer line anchored by 2.2-kg cement weights. Fixed swivels were placed 1.5 meters above the anchor weight; 7/0 circle hooks were attached to the weed trimmer line by barrel swivels with leaders constructed from 45-kg test monofilament line. Each float-line was designed to fish one hook per float. Float lines were deployed in the upper end of Wilson Reservoir from 8 June through 18 June, 2017 within standard sampling grids used by KDWPT to randomly assign the sample locations (Figure 3 A&B). This stratified, random sampling regime allowed me to focus efforts in areas known to have a higher relative abundance of Blue Catfish.

Float lines were fished overnight with freshly caught Common Carp *Cyprinus carpio* as bait. Common Carp was selected due to higher hook retention versus other species, especially Gizzard Shad. Prior field trials suggested higher catch rates when Common Carp, compared to Gizzard Shad, was used as bait.

Lovewell Reservoir Collections:

Blue Catfish were collected from Lovewell Reservoir from 21 May through 31 October 2016. I used a Smith-Root electrofisher equipped with a Honda GX 160, 5.5 horsepower generator set to low-frequency, pulsed DC (15 pulses-per-second and 2-3 mean amperes) to sample Blue Catfish. Water conductivity was near optimal (~700 µS) and, therefore, capture of Blue Catfish was efficient at Lovewell Reservoir

To minimize gear-associated biases and to promote collection of individuals across all length and age groups, float-lines were deployed in June 2016 as described above with individual total length (TL) not differing significantly from the sample gathered by electrofishing. Experimental monofilament gill nets were deployed to sample Blue Catfish during annual sampling in October 2016 to supplement samples obtained with low-frequency electrofishing and float-lines. All techniques used to sample Blue Catfish from both reservoirs were designed to collect fish across a broad size range.

Data collection:

I recorded total length to the nearest millimeter and mass in grams from all captured Blue Catfish. Pectoral spines were extracted to estimate age of individuals and to avoid euthanizing fish. Pectoral spines were excised by hand or, for larger individuals, plyers to relax the spine against the fish and rotate the spine counter-clockwise until the articulate process was dislocated, and the spine removed. The pectoral spine was inspected, cleaned, and deposited in a coin envelope labeled with an identification number, TL, and mass. Individuals were monitored after removing the spine and then released.

Age and Growth:

Pectoral spines were placed in a freezer to prevent bacterial growth and later cleaned of remaining tissue prior to sectioning. Each spine was sectioned by using a Buehler® Isomet ™ low-speed saw with a standard chuck. I sectioned pectoral spines by using a transect-cut similar to Buckmeier et al. (2002) between the articulate process and distal groove (Figure 4). The spine was then mounted on a microscope slide using cyanoacrylate. The slide was mounted on a slide chuck and then cut to a thickness of 15 μm (Figure 5 a-d). Each slide was screened on a stereo microscope with magnification set to capture the entire spine image. Slides that produced low quality images were not used in this study. Acceptable slides were immersed in mineral oil to further enhance contrast and viewed under an Olympus BX51 compound microscope with an Olympus DP71 camera and Microsuite Basic Edition software. A digital photograph was recorded of each section (Figure 1).

Age was estimated from each pectoral spine section. Three independent readers viewed the same image of each section. If all estimates agreed, the section was included in the sample. When the initial estimates disagreed, the section was viewed again by all readers, a consensus age was assigned, and the section was included in the sample. When a consensus could not be reached, the section was eliminated from the study.

The pectoral spine sections were viewed and measured using R statistical software with the RfishBC package (Ogle 2018). Measurements were recorded from the focus or lumen of the pectoral spine to the outer edge of each annulus and to the outer edge of the structure. Growth measurements were assigned by calculating distance between each annulus on the pectoral spines. These distances were then used to generate back-calculated lengths-at-age for individual fish. Multinomial logistic regression models were used to estimate proportions of aged fish from both populations and generate age-length keys to assign ages to Blue Catfish samples that were not aged. Von Bertalanffy growth models were created for both populations to visualize and compare growth rates between populations.

RESULTS

Wilson Reservoir

Size Structure:

I collected 170 Blue Catfish that ranged from 210 to 840 mm (Figure 6). No fish were collected between 280- and 510-mm TL. Approximately 90 percent of the sample was collected by using float lines with no fish collected less than 520 mm TL. Low-frequency electrofishing and gill-nets were used to sample Blue Catfish in Wilson reservoir with mixed results. The majority of small fish ranging from 200-250 mm were collected using low frequency electrofishing.

Age Structure:

I collected pectoral spines from 170 Blue Catfish. After removing damaged spines and unreadable slides, ages were assigned to 165 individuals. Initial agreement was 86% among three independent readers and a consensus age was determined for the remaining 21 fish. The oldest fish collected was age-11 and the youngest was age-1. The majority of the sample comprised individuals from Ages 8–11, but Ages 2–7 were not observed in this sample (Figure 7). Collection of a few age-1 fish suggests that natural recruitment occurred in Wilson Reservoir post drought period; upon further review, these fish were agreed to be stocked fish from 2016.

Growth:

Estimated lengths-at-age were determined by using back-calculation. Age-1 fish had an estimated mean length-at-age of 184 mm TL while Age-11 fish were estimated at 660 mm TL. Blue Catfish from Wilson Reservoir typically grew to approximately 499 mm, on average, by Age 5, but slowed substantially until they reached their maximum age of 11. Fish grew to an estimated mean length of 660 mm in 11 years (Table 1) and were 229 mm TL less than the 889-mm (35 inch) minimum length-limit restriction.

Lovewell Reservoir

Size structure:

I collected 146 Blue Catfish that ranged from 220 to 860 mm; 50, 10-mm length groups had at least one individual, and 13 had a minimum of 5 individuals per length group (Figure 8). The most effective means of capture for Blue Catfish at Lovewell Reservoir was low frequency electrofishing. Float lines and experimental gill nets were also used to sample Blue Catfish in Lovewell Reservoir to eliminate gear bias. Ultimately, LFE allowed us to obtain the most representative sample from this location.

Age structure:

I collected pectoral spines from 146 Blue Catfish, but only 116 were of sufficient quality to estimate age. Initial agreement among three readers was 88%. However, a consensus age estimate was reached in all 14 cases where initial readings diverged. The oldest fish collected was estimated at Age-10 and the youngest was age-1. The Blue Catfish was introduced in 2010, and fish were sampled in 2016, therefore the three, age-10 individuals might be a result of natural reproduction prior to the initial stocking by KDWPT (Figure 9). Age-1 fish in our sample are the first evidence of natural recruitment since stocking began in 2010.

Growth:

Blue Catfish in Lovewell Reservoir had an estimated mean length-at-age ranging from of 189 mm TL at age-1 and 791 mm TL at age-10. Fish grew to 659 mm TL, on average, by age-6 and continued to exhibit faster growth than those sampled from Wilson

Reservoir. Because age-10 individuals were likely the result of immigration from another source, we excluded those individuals in a second analysis. Mean back-calculated length of age-1 and age-6 fish, excluding the age-10 individuals, was192 mm TL and 666 mm TL, respectively. Back-calculated growth was almost identical to the estimated mean length-at-age when the three Age-10 fish were included (Table 2).

Age-length keys were generated to estimate annual mortality for both populations. Inadequate samples prohibited calculation of annual mortality estimates.

Von Bertalanffy growth models were generated from back-calculated lengths generated by using the Fraser-Lee Method and R statistical software. Graphs were generated to illustrate differences in growth rates between Blue Catfish populations from Wilson and Lovewell reservoirs (Figure 10 and 11).

DISCUSSION

Fisheries biologists have a shared goal to conserve natural resources in Kansas for present and future appreciation. Management of the resource is focused on three main goals: balancing fish populations, enhancing fish habitat, and maintaining a positive relationship with the public (McMullin and Pert 2010). Objectives of this research were to 1) characterize two populations of recently introduced Blue Catfish, 2) investigate sampling techniques, and 3) provide management recommendations to improve population structure of both Blue Catfish populations. One of the most useful tools for gaining insight into a population is to identify age structure and growth rates. This information can be used to generate management recommendations for both populations and develop a more thorough understanding of Blue Catfish population dynamics in Kansas.

I collected information from Blue Catfish populations for Lovewell and Wilson reservoirs in 2016 and 2017, respectively. I collected the samples with a variety of gear types to ensure sufficient sample sizes across the associated length distributions of the respective populations.

Wilson and Lovewell reservoirs were selected as the study sites for this project based on their proximity in space, similar time periods since initial introduction, and discrepancy in productivity. The Blue Catfish was also introduced to reduce the density of White Perch in Wilson Reservoir and decrease density of Gizzard Shad in Lovewell Reservoir; the development of a trophy Blue Catfish fishery at both locations was a shared secondary objective. However, periodic stockings of Blue Catfish have occurred at both reservoirs and unrefined sampling protocols resulted in an inability to truly evaluate the populations. The need to evaluate populations, especially larger individuals within the populations, is critical for understanding and managing for the trophy potential of these populations. Determining how to effectively sample and manage Blue Catfish populations will improve management efforts in the future (Neely 2018, KDWPT, personal communication). Float line sampling, for instance, has improved our ability to sample populations where LFE and experimental gill nets are limited and analyze larger Blue Catfish that typically go unnoticed in these young Blue Catfish populations.

Historically, both otoliths and pectoral spines have been used to estimate age of Channel Catfish and Flathead Catfish, despite questions about their validity (Sneed 1951; Marzolf 1955; Mayhew 1969; Prentice and Whiteside 1975; Turner 1982; Crumpton et al. 1987). The technique used to section pectoral spines from Wilson and Lovewell reservoirs for this study was not validated because there were no known-age individuals in either population. Pectoral spines were the hard structure selected to age these individuals to avoid sacrificing fish in recently established populations.

Wilson Reservoir

Age Structure:

The Blue Catfish population in Wilson Reservoir, exhibited slower growth and did not attain as large of a maximum size as Blue Catfish in Lovewell Reservoir despite being stocked five years earlier in Wilson Reservoir. Blue Catfish were stocked at a minimum of one fish per acre every year since 2006 except for in 2009 and 2015, when no fish were stocked. Accordingly, absent natural recruitment, we would not expect Age 2 and Age 8 fish in our sample (Table 2). In total, I collected five out of 11 possible age classes (Ages -1, 8, 9, 10, and 11) (Figure 7). Age-1 fish were initially thought to be the first evidence of natural recruitment in Wilson Reservoir where mature Blue Catfish, however stocking records corresponding with that ag Age-8 fish in our sample might be the result of natural recruitment because no stockings occurred in 2009. However, it is possible that their ages were underestimated, as is common with age information derived from pectoral spines of individuals older than age-5 (Homer et al. 2015).

Reproduction of Blue Catfish has been observed in at least one Kansas reservoir as early as age-3 (Lundgren 2017). Similarly, Blue Catfish reached maturity between 350 and 662 mm TL in Louisiana and Kentucky (Henderson 1972; Hale 1987; Hale and Timmons 1989). Back-calculated length at age-3 from Blue Catfish at Wilson Reservoir was 357 ± 38.1 mm, within the range reported for Louisiana and Kentucky. These age-8 individual fish could have resulted from aging error despite age estimates of Blue Catfish from Lovewell Reservoir matching stocking data during those years.

Blue Catfish stocked from 2010 through 2015 (Ages 2-7) were not observed in samples from Wilson Reservoir. The sample distribution across total length could have resulted from sampling bias across the three selected gear types. Approximately 90% of individuals were captured using float-lines because low-frequency electrofishing and experimental gill-nets were inefficient at sampling Blue Catfish in Wilson Reservoir. The use of float-lines to target larger Blue Catfish has been used historically in fisheries where conditions render LF electrofishing and gill-nets ineffective.

Alternatively, fish Ages 2–7 might be absent due to extreme environmental conditions that were observed from 2010 to 2015. Wilson Reservoir experienced a reduction in rocky shoreline and riverine habitat associated with a decrease in surface elevation (Figure 2) during the protracted drought from 2010 to 2015. Fish stocked in

2010 through 2014 were stocked at similar rates, unit weight, and mean length to those earlier year classes that had successful recruitment (Appendix 1). Wilson Reservoir is classified as a Mesotrophic Reservoir with a stable water level where Chlorophyll-a levels average 4.48 µg/L (Kansas Department of Health and Environment, 2018). The decrease in surface elevation of 3.1 m (Figure 2) over five years in a low productivity environment might have negatively affected the recruitment or other aspects of reproduction of Blue Catfish in Wilson Reservoir. Other indications of negative affects might be observed in the reduced condition indices such as relative weight (Wr) observed in top predator populations including Striped Bass, over the same time period (Table 3). The mean Wr for Striped Bass from stock through preferred size-groups declined and remained at values that were a cause for concern until an influx of water filled Wilson Reservoir to conservation pool. Striped Bass across these size ranges are comparable to the size structure observed for Blue Catfish in Wilson Reservoir. The lack of shallow or littoral zone cover for young-of-the-year might have been responsible for the poor condition, relative abundances, and lack of recruitment for Blue Catfish as well as other top pelagic predators such as the Striped Bass.

Lovewell Reservoir

Age Structure:

Blue Catfish were stocked in 2010 through 2014 and were sampled in 2016. As such, expected age classes in my sample ranged from 1 to 6 years, contingent on the evidence of natural recruitment and periodic stocking records. Records indicated fish were stocked at a rate of 1 fish per acre with variable unit weight, mean length, and mean weight, from 2010 through 2014. Blue Catfish were not stocked in 2015 and 2016. I collected 5 individuals that were age-1 (Figure 9) suggested Blue Catfish naturally reproduced and successfully recruited. The largest year class was age-6 (60/116 individuals) which were stocked in 2010 at a rate of 1 per acre with a mean length of 200 mm TL per fish. Blue Catfish were stocked in 2013 at a rate of 0.33 fish per acre (1,000 fish) and resulted in one of the smallest year classes represented in the sample (4/116). All other stockings into Lovewell Reservoir were stocked at a minimum of 1 per acre or 3,000 individuals and appeared to produce stronger year-classes based on my samples (Appendix 2).

The size of stocked fish might also influence year-class strength. The average length of individuals stocked in Lovewell Reservoir ranged between 175 and 210 mm TL in 2010, 2012, and 2014 and resulted in the strongest year-classes. In 2011, Blue Catfish were stocked at 1 per acre but average total length was only 120 mm, and resulted in a relatively weak year-class in the sample. Although this observation is not reported elsewhere, it might suggest that both stocking density and a minimum average total length of 200 mm might be necessary to produce reliable year-classes of Blue Catfish in Lovewell or other reservoirs (Appendix 2).

Back-Calculated Growth: Wilson and Lovewell Reservoirs

Blue Catfish in Wilson Reservoir (Table 1) had an estimated mean length-at-age of 660 mm TL at Age 11 while in Lovewell Reservoir that mean length was attained by Age 6 (Table 2). The Blue Catfish in Lovewell Reservoir grew faster than those from Wilson Reservoir based on the von Bertalanffy growth model and exhibited distinct year classes relative to the Wilson Reservoir population (Figure 12).

The difference in growth might be explained by the higher productivity of Lovewell Reservoir (chlorophyll-a (25.95 μg/L) compared to Wilson Reservoir (4.48 μg/L; Kansas Department of Health and Environment Bureau of Surface Water Sampling Report for Station LM014001). Additionally, the water level at Lovewell Reservoir was stable relative to Wilson Reservoir where water levels varied dramatically, especially during years with missing year classes. Blue Catfish in Wilson Reservoir might experience greater intraspecific- and inter-specific competition because of reduced water levels and elimination of littoral habitats (Figure 2).

The objectives of this project were to (1) characterize the age structure of Blue Catfish population in Wilson and Lovewell reservoirs, (2) estimate Blue Catfish growth in both Wilson and Lovewell reservoirs, (3) Generate recommendations for management of Blue Catfish populations in both reservoirs. These objectives presented several challenges. First, it became clear early in the investigation that the use of experimental gill-nets, as prescribed in the standard sampling protocol for KDWPT, would not provide sufficient sample sizes. Accordingly, low-frequency electrofishing and float lines were used to augment samples. The high-water conductivity and paucity of smaller individuals less than 500 mm in Wilson Reservoir made electrofishing inefficient, therefore the majority of samples were collected using float lines. Although I used experimental gill nets and float lines at Lovewell Reservoir, low-frequency electrofishing was the most efficient technique and provided reasonable sample size for age determination. All three techniques were used to eliminate capture bias and collect a representative sample.

The next challenge was to characterize the age structure captured from hard structures. Pectoral spines were sectioned and aged by a panel of three readers.

Agreement among readers in both populations was 86 and 87 percent. I detected 5 of a possible eleven 11 classes in the samples from Wilson Reservoir. A review of stocking records and abiotic conditions in the reservoir revealed some associations with recruitment and year-class strength. Those fish that were introduced into Wilson Reservoir at a rate of 1 per acre and a total length of at least 175 mm were present in my samples. Fish stocked that met only one of these requirements during extended periods of drought or no inflow into the reservoir were absent; this suggests that stocking rates and conditions within the reservoir play important roles in the successful establishment of strong year-classes.

In samples from Lovewell Reservoir all 6 year-classes were represented which indicated successful stockings. There were also indications of natural recruitment. Year-classes that established as the result of stocking a minimum of 1 fish per acre and that averaged greater than 175 mm TL comprised 88 percent of the samples (102/116 individuals).

Blue Catfish at Lovewell Reservoir grew faster compared to the Wilson Reservoir population and showed evidence of natural recruitment by age-4. The population of Blue Catfish in Lovewell Reservoir should be monitored into the future to determine if the harvest regulation should remain at minimum length limit of 889 mm and a creel limit of 5/day. Under the current restrictive limit, it is highly unlikely that this fishery will become overexploited because virtually all individuals are protected. However, Boxrucker and Kuklinski (2006) suggested that the liberal harvest of smaller individuals is needed to reduce the potential of density-dependent growth factors affecting the population negatively. This is currently not an issue at Lovewell Reservoir due to the proximity in time since the first reported stocking, however, this should be taken into consideration when monitoring the population into the future.

Blue Catfish grew at a slower rate in Wilson Reservoir and I detected no evidence of natural recruitment. The slower growth and apparent large overlap in total length among year-classes might result from competition between and within species. The intensity of these interactions were likely exacerbated by reduced water levels and loss of associated shallow habitats that resulted in poor forage abundance during the recent drought (2010–2015). Although conditions appear unfavorable for the Blue Catfish population at Wilson Reservoir, the comparison of growth rates between other populations throughout the Blue Catfish distribution shows that growth rates from Lovewell and Wilson reservoirs fall within the range of other populations documented by (Graham 1999). Both populations are considered to young populations that are susceptible to other variables as the population ages and establishes in the reservoir.

This project provides a baseline of population characteristics that describe different outcomes when introducing Blue Catfish. The population of Blue Catfish in Lovewell Reservoir should be monitored to evaluate recruitment and young-of-the-year fish densities as a means of determining if the population is self-sustaining. Electrofishing and float lines also can be used to evaluate whether the minimum length limit of 889 mm TL with a limit of 5 fish per day are effective minimizing the risk of exploitation. The Blue Catfish population in Wilson Reservoir should be evaluated for the next 3 years in the absence of annual stockings to gain insight on natural reproduction and recruitment, or lack thereof, since the reservoir has filled and has a relatively stable water level. Another post-evaluation could come in the form of changing the current minimum length limit of 35 inches (889 mm) and five fish per day creel limit to encourage the harvest of smaller individuals ranging from 559 – 711 mm to improve growth rates and decrease inter-specific competition in a reservoir that has multiple predatory sportfish populations competing for a limited forage base (Sowards, personal communication).

Although the Blue Catfish populations in Lovewell and Wilson Reservoir differ, these outcomes are invaluable in describing how populations establish in Kansas impoundments. If possible, Blue Catfish should be stocked at a minimum of 200 mm in TL at a rate of at least 1 fish per acre during stable water level periods to give the best probability to establish this sportfish population. Information obtained from this research demonstrate two potential outcomes of stocking Blue Catfish under varying conditions; these results are valuable to not only provide baseline information for both of these federal impoundments, but also inform fisheries managers in Kansas, and throughout the distribution of Blue Catfish, about the potential trends in size structure and growth of newly introduced populations.

LITERATURE CITED

Arlinghaus, R., S.J. Cook, S.G., Sutton, A.J. Danylchuk, W. Potts, K. Dem, F. Freire, J. Alos, E.T., Silva, I.G., Cows, R. Van Anrooy. 2016. Recommendations for the future of recreational fisheries to prepare the social-ecological system to cope with change. Fisheries Management and Ecology 23: 177-186.

Bodine, K. A. and D.E. Shoup. 2010. Capture Efficiency of Blue Catfish Electrofishing and the Effects of Temperature, Habitat, Reservoir Locations on Electrofishing-Derived Length Structure Indices and Relative Abundance. North American Journal of Fisheries Management 30: 613-621.

Bodine, K.A., D.E. Shoup, J. Olive, Z.L. Ford, R. Krogman, and T. J. Stubbs. 2013. Catfish sampling techniques: where we are now and where we should go. Fisheries 38:529-546.

Boxrucker, J and K. E. Kuklinski. 2006. Abundance, growth, and mortality of selected Oklahoma Blue Catfish population: implantation for management of trophy fisheries. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 60:152-156.

Buckmeier, D. L., E. R. Irwin, R. K. Betsill, and J. A. Prentice. 2002. Validity of otoliths and pectoral spines for estimating ages of Channel Catfish. North American Journal of Fisheries Management 22:934-942.

Buckmeier, D. L., and W. J. Schlechte. 2009. Capture efficiency and size selectivity of channel catfish and blue catfish sampling gears. North American Journal of Fisheries Management 29:404–416.

Buckmeier, D. L., P. C. Sakaris, & D. J. Schill. (2017). Validation of annual and daily increments in calcified structures and verification of age estimates. In M. C. Quist, & D. Isermann (Eds.), Age and growth of fishes: Principles and techniques (pp. 33–80). Bethesda, MD: American Fisheries Society

Campana, S. E. 2001. Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods. Journal of Fish Biology 59:197-242.

Chambers, R. C., and T. J. Miller. 1995. Evaluating fish growth by means of otolith increment analysis: special properties of individual-level longitudinal data. Pages 155-175 *in* D. H. Secor, J. M. Dean, and S. E. Campana, editors. Recent developments in otolith research. University of South Carolina Press, Columbia.

Crumpton, J. E., M. M. Hale, and D. J. Renfro. 1987. Aging of three species of Florida catfish utilizing three pectoral spine sites and otoliths. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 38(1984):335–341.

Devries, D. R., and R. V. Frie. 1996. Determination of age and growth. Pages 483-512 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, second edition. American Fisheries Society, Bethesda, Maryland.

Dumont, S. C., and W. Schlechte. 2004. Use of resampling to evaluate a simple random sampling design for general monitoring of fishes in Texas reservoirs. North American Journal of Fisheries Management 24:408–416.

Fischer, J.R., J.D. Koch. 2017. Fin Rays and Spines. Pages 173-183 in M.C. Quist and D.A. Iserman, editors. Age and Growth of Fishes: principles and techniques. American Fisheries Society, Bethesda Maryland.

Goeckler, J.M., M.C. Quist, J.A. Reinke, and C.S., Guy. 2003. Population characteristics and evidence of natural reproduction of Blue Catfish in Milford Reservoir, Kansas. Kansas Academy of Science, Transactions 106, p. 149–154

Graham, K. 1999. A Review of the Biology and Management of Blue Catfish. American Fisheries Society 24: 37-49.

Hale, R. S. 1987. Commercial catch analysis, spawning season, and length at maturity of blue catfish in Kentucky Lake, Kentucky-Tennessee. Master’s thesis. Murray State University, Murray, Kentucky

Hale, R. S., and T. J. Timmons. 1989. Comparative age and growth of blue catfish in the Kentucky portion of Kentucky Lake between 1967 and 1985. Transactions of the Kentucky Academy of Science 50(1-2):22–26

Helfman, G. S., B. B. Collette, D. E. Facey, and B. W. Bowen. 2009. The diversity of fishes: biology, evolution, and ecology, second edition. Wiley-Blackwell, West Sussex, UK.

Henderson, G. G. 1972. Rio Grande blue catfish study. Texas Parks and Wildlife Department, Federal Aid in Fisheries Restoration Project F-18-R-7, Job 11, Progress Report, Austin

Homer, M.D., Peterson, J.T., Jennings, C.A. 2015. Evaluation of Three Aging Techniques and Back-calculated Growth for Introduced Blue Catfish from Lake Oconee, Georgia. Southeastern Naturalist 14(4): 740-756.

Kansas Department of Health and Environment Bureau of Water. 2011. Water Quality Standards White Paper.

Kansas Department of Health and Environment. Bureau of Surface Water Sampling Report a. Wilson Reservoir.

Kansas Department of Health and Environment. Bureau of Surface Water Sampling Report b. Lovewell Reservoir.

Kwak, J.K., W.E. Pine III, D. S. Waters. 2006, Age, Growth, and Mortality of Introduced Flathead Catfish in Atlantic Rivers and a Review of Other Populations. North American Journal of Fisheries Management 26: 73-87.

Lundgren, S. Progress and Management report for Big Hill Reservoir. Kansas Department of Wildlife, Parks, and Tourism.

Marshall, M.D., M.J. Maceina, M.P. Holley. 2009. Age and Growth Variability between Sexes of Three Catfish Species in Lake Wilson, Alabama. North American Journal of Fisheries Management. 29:5, 1283-1286.

Mayhew, J. K. 1969. Age and growth of the Flathead Catfish in the Des Moines River, Iowa. Transactions of the American Fisheries Society 98:118-121.

Marzolf, R.C., 1955. Use of pectoral spines and vertebrae for determining age and rate of growth of the channel catfish. J Wildl Manage 19:243-249.

McMullin, S. L., and E. Pert. 2010. The process of fisheries management. Pages 133-155 *in* W. A. Hubert and M. C. Quist, editors. Inland fisheries management in North America, third edition. American Fisheries Society, Bethesda, Maryland.

Miranda, L.E. and J. Boxrucker. 2009. Warmwater fish in large standing waters. Pages 29-42 *in* S.A. Bonar, W.A. Hubert, and D.W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Miller, S. J., T. Storck. 1982. Daily Growth Rings in Otoliths of Young-of-the-Year Largemouth Bass. Transactions of the American Fisheries Society 111: 527-530.

McInery, M.C., 2017. Scales. Pages 127-147 in M.C. Quist and D.A. Iserman, editors. Age and Growth of Fishes: principles and techniques. American Fisheries Society, Bethesda Maryland.

Neely, B. Personal Communication. Kansas Department of Wildlife, Parks, and Tourism.

Ogle, D.H., RFishBC. 2018. R Package version 0.1.1.9000, htpp://derekogle.com/RfishBC.

Pope, K.L., R.M. Neumann, and S.D. Bryan. 2009. Warmwater fish in small standing waters. Pages 13-27 *in* S.A. Bonar, W.A. Hubert, and D.W. Willis, editors. Standard methods for sampling North American freshwater fishes. American Fisheries Society, Bethesda, Maryland.

Prentice, J. A., and B. G. Whiteside. 1974. Validation of aging techniques for largemouth bass and channel catfish in central Texas farm ponds. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 28:414-428

Quist, M. C., J. L. Stephen, S. T. Lynott, J. M. Goeckler, and R. D. Schultz. 2010. Exploitation of Walleye in a Great Plains reservoir: harvest patterns and management scenarios. Fisheries Management and Ecology 17:522-531.

Quist, M.C. and D.A. Isermann, editors. 2017. Age and growth of fishes: principles and techniques. American Fisheries Society, Bethesda, Maryland.

Quist, M. C., M. A. Pegg, and D. R. Devries. 2012. Age and growth. Pages 677-731 *in* A. V. Zale, D. L. Parrish, and T. M. Sutton, editors. Fisheries techniques, third edition. American Fisheries Society, Bethesda, Maryland.

Reinke. J. Progress and Management Report for Milford Reservoir. Kansas Department of Wildlife, Parks, and Tourism.

Schramm, H. L., Jr., and J. F. Doerzbacher. 1985. Use of otoliths to age black crappie from Florida. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 36(1982): 95-105.

Sneed, K. E. 1951. A method for calculating the growth of Channel Catfish, *Ictalurus lacustris punctatus*. Transactions of the American Fisheries Society 80:174-183.

Steffen, C. Personal Communication. Kansas Department of Wildlife, Parks, and Tourism.

Sowards, B. J. Progress and Management report for Wilson Reservoir. Kansas Department of Wildlife, Parks, and Tourism.

Spurgeon, J.J., M. J. Hamel, K. L. Pope, M. A. Pegg. 2015. The Global Status of Freshwater Fish Age Validation Studies and a Prioritization Framework for Further Research. Reviews in Fisheries Science & Aquaculture 23: 329-345.

Turner, P. R. 1982. Procedures for age determination and growth rate calculations of flathead catfish. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 34(1980):253–262.

U.S. Fish and Wildlife Service. 2015. 2011 National survey of fishing, hunting, and wildlife-associated recreation: national overview. Washington, DC.

U.S. Fish and Wildlife Service. 2012. 2011 National survey of fishing, hunting, and wildlife-associated recreation: state overview. Washington, DC.

U.S. Fish and Wildlife Service. 2013. Dingell-Johnson Sport Fish Restoration.

Waters, S.W. Progress and Management report for Lovewell Reservoir. Kansas Department of Wildlife, Parks, and Tourism.

Yates, J. R., C. J. Watkins, M.C. Quist. 2016. Evaluation of Hard Structures Used to Estimate Age of Common Carp. Northwest Science 90(2): 195-205.

Zale. A. V., D.L. Parrish., T.M. Sutton. Editors. 2012. Fisheries Techniques, Third Edition. American Fisheries Society, Bethesda, Maryland.

Table 1.) – Mean back-calculated lengths and standard deviation for Blue Catfish from Wilson Reservoir generated from pectoral spines.

Age	Total	Mean Back-Calculated Total Length (mm)	Mean Standard Deviation (mm)
1	165	184	33.7
2	153	285	41.8
3	153	357	38.1
4	153	430	40.5
5	153	499	43.4
6	153	552	47.4
7	153	587	48.5
8	153	612	50.6
9	138	628	51.2
10	93	649	55.4
11	14	660	57
	165	184-660	46.1

Table 2.) – Mean back-calculated lengths and standard deviation for Blue Catfish from Lovewell Reservoir generated from pectoral spines.

Age	Total	Mean Back-Calculated Total Length (mm)	Mean Standard Deviation (mm)
1	116	189	33.8
2	111	345	39.4
3	84	458	48.8
4	80	537	49.3
5	65	603	54.1
6	62	659	55.9
7	3	588	4.2
8	3	652	3.8
9	3	726	6.5
10	3	791	21.7
	116	189-791	31.8

Table 3.) – Condition indices (Mean Relative Weight) for Striped Bass from Wilson Reservoir sampled during drought years using experimental gill-nets: Stock-sized Stripe Bass are 300 mm (12 inches), quality 510 mm (20 inches), and preferred 760 mm (30 inches). Drought conditions persisted from 2012 through 2016.

Condition Index for Striped Bass	**2012**	**2013**	**2014**	**2015**	**2016**
Wr S-Q (12-20 inches)	92.66	94.91	81.59	88.15	93.21
Wr Q-P (20-30 inches)	75.8	73.64	67.25	69.77	91.36

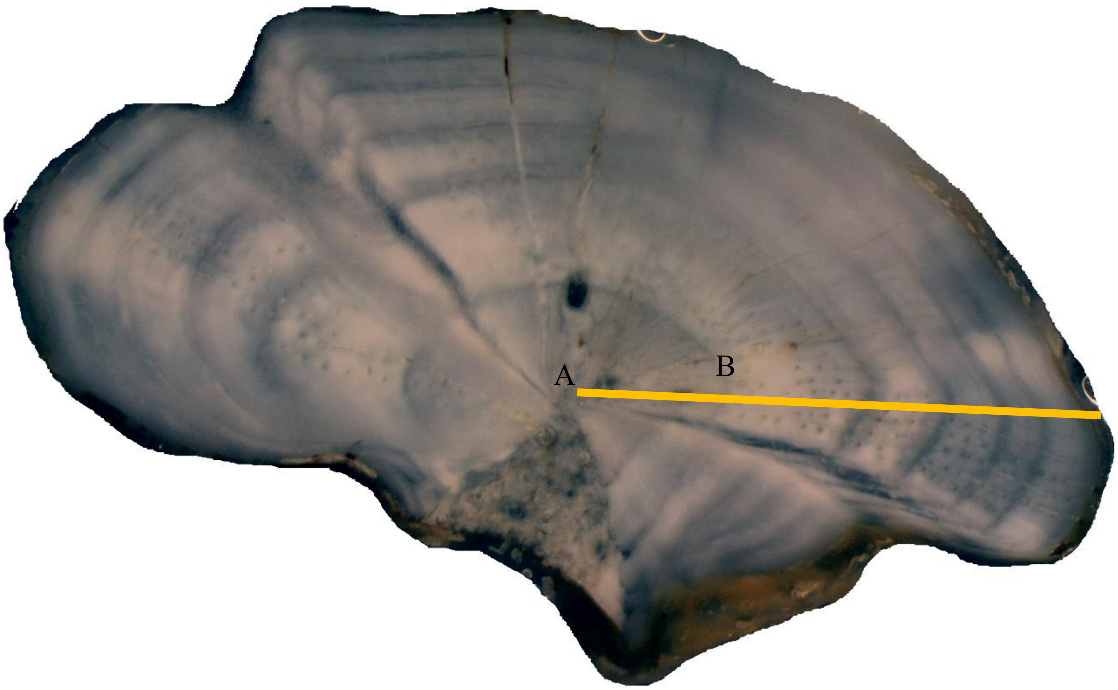

Figure 1.) – Image of a sectioned, pectoral spine of a Blue Catfish. The image was captured with a Olympus BX51 microscope and Olympus DP71 camera. Yellow line depicts a transect used to measure distances from the focus (A) to the edge of the structure and between annuli (B)

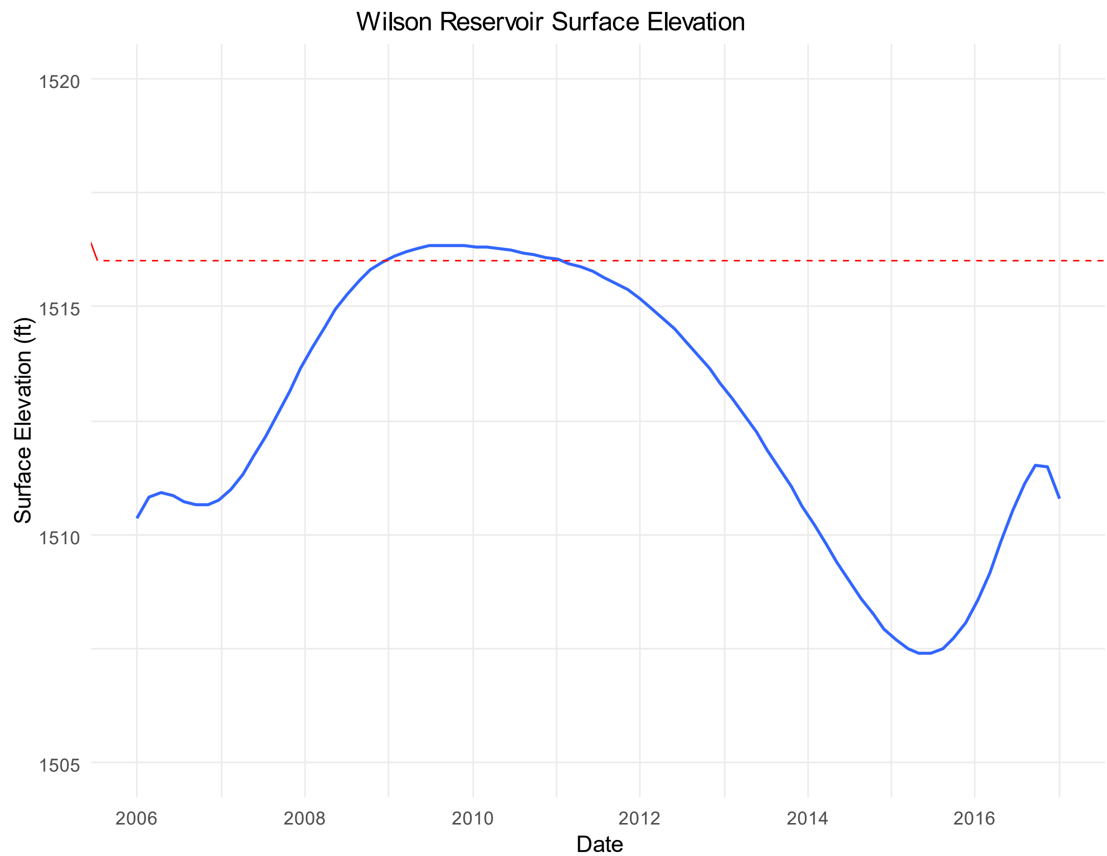

Figure 2.) – Wilson Reservoir surface elevation in feet from 2006 to 2017.

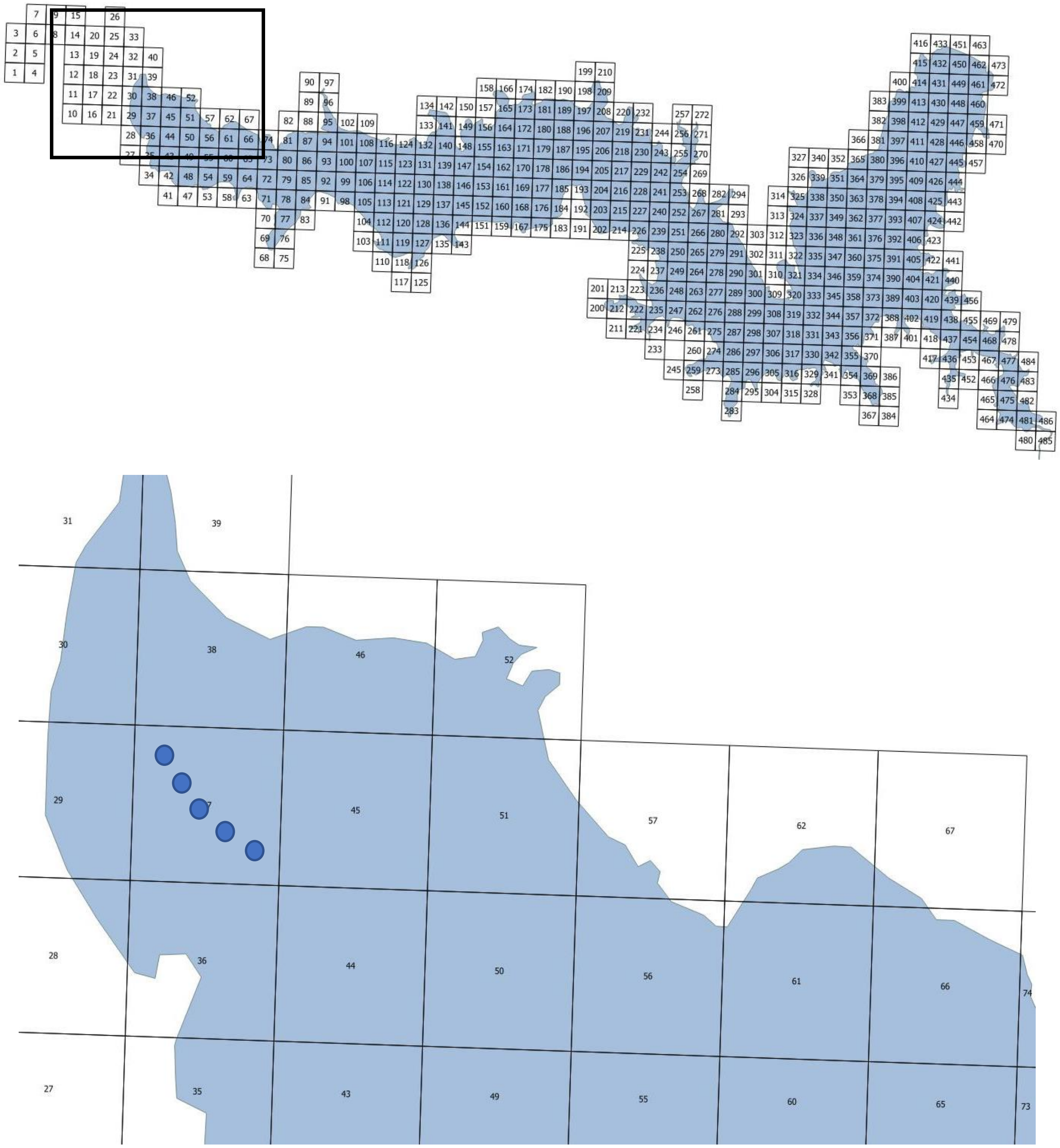

Figure 3A.) – Wilson Reservoir with sample grids used by KDWPT. Each sample grid is approximately 11ha and were used as a baseline area for deploying 5 float-lines per sampling grid. Figure 3B.) – Float-lines were generally deployed following the distinct river channel in Wilson Reservoir with a minimum of 5 float-lines per sampling grid. In total, 6 grids were sampled daily over a period of 10 days for a total of 300 float-lines over the course of the project.

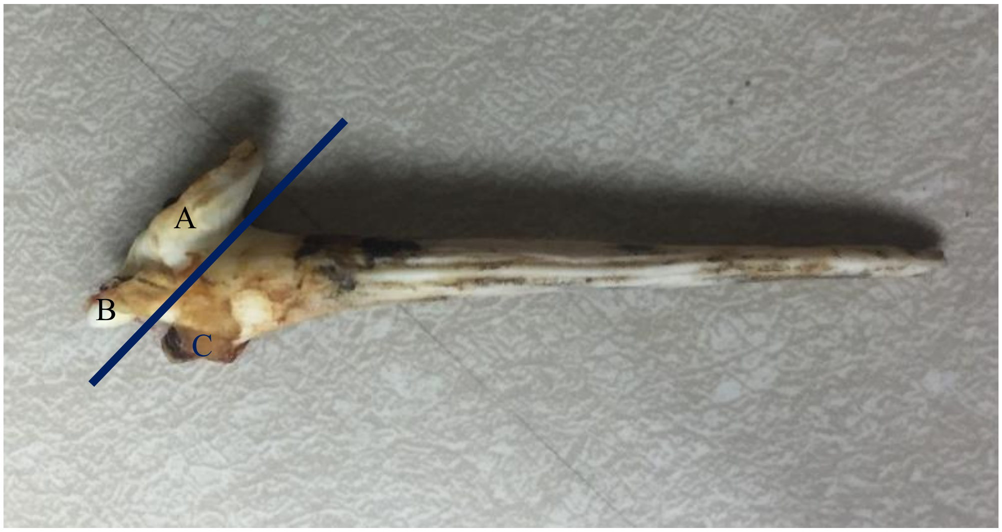

Figure 4.) Pectoral spine of a Blue Catfish indicating anatomical orientation. The line indicates the axis of first cross-section using the Buehler low-speed saw. Inserts: A. Dorsal Articular Process. B. Anterior Articular Process. C. Ventral Articular Process.

Figure 5A.) Pectoral Spine oriented and placed in a Buehler low-speed saw chuck prior to the first cross section. Figure 5B.) Pectoral spine placed on microscope slide after the initial cross section. Figure 5C.) Final section of the pectoral spine using a slide mount chuck approximately 15 micrometers thick. Figure 5D.) Finished product used to capture an image for this individual under an Olympus BX51 microscope with an Olympus DP71 camera with Microsuite Basic Edition software.

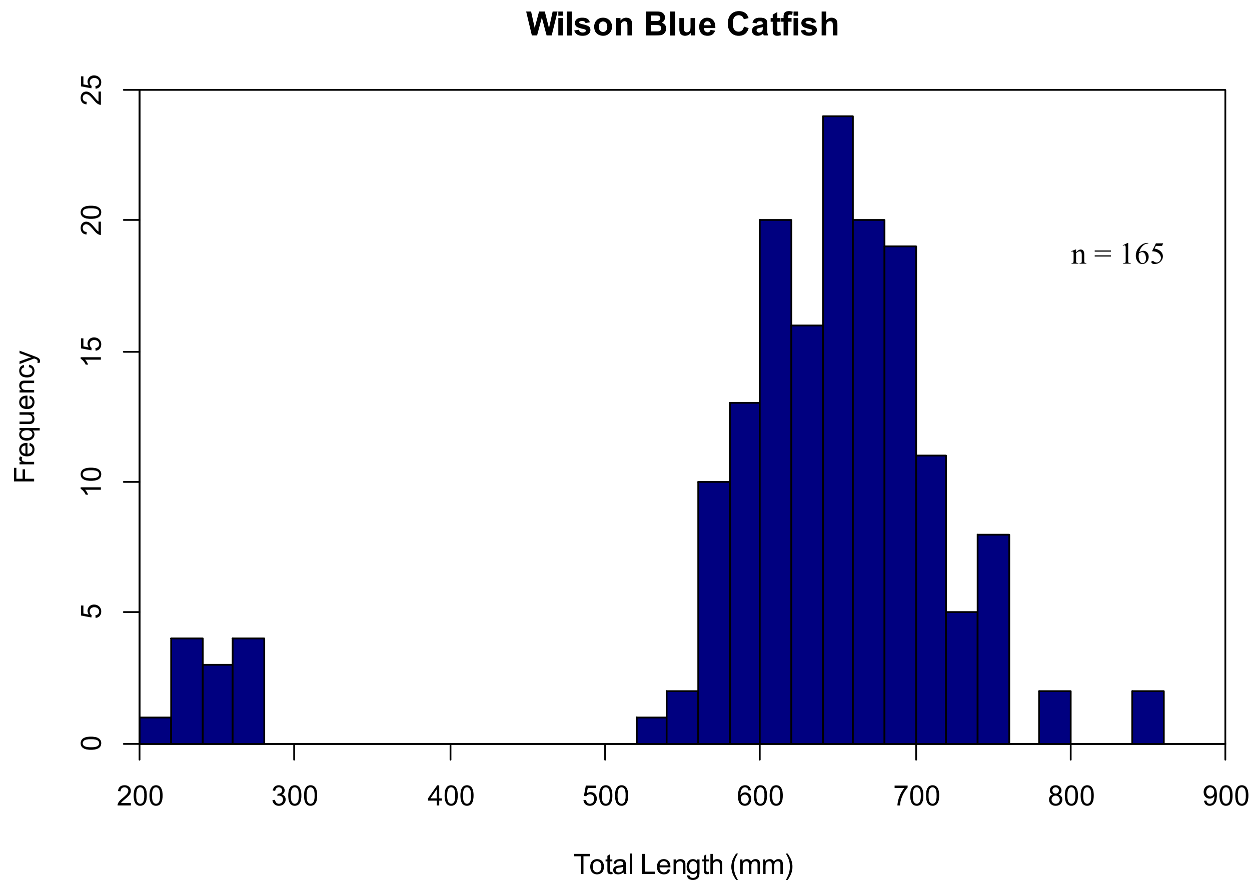

Figure 6.) –Length frequency histogram of a sample of aged Blue Catfish form Wilson Reservoir. Total number of fish caught on the y axis and total length (mm) on the x axis. Columns are organized into 20-mm increments.

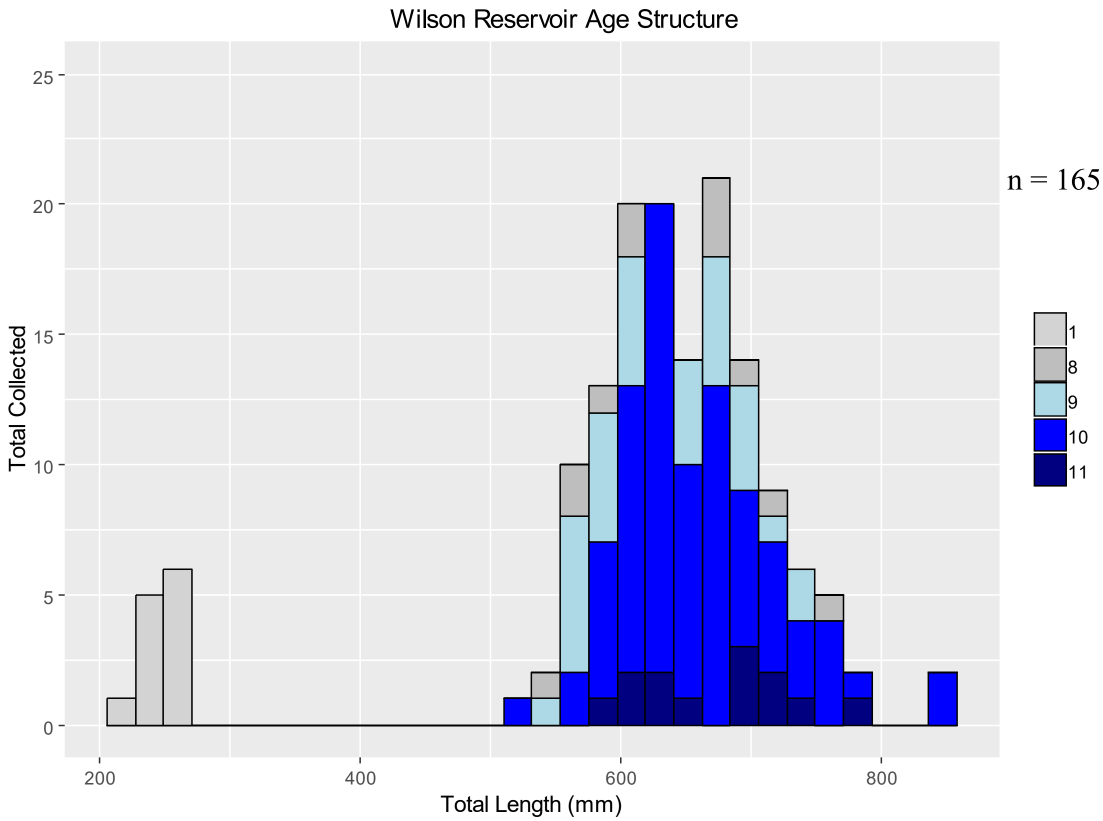

Figure 7.) – Wilson Reservoir age frequency histogram. Each year class is depicted by a different color illustrating different age classes within the population.

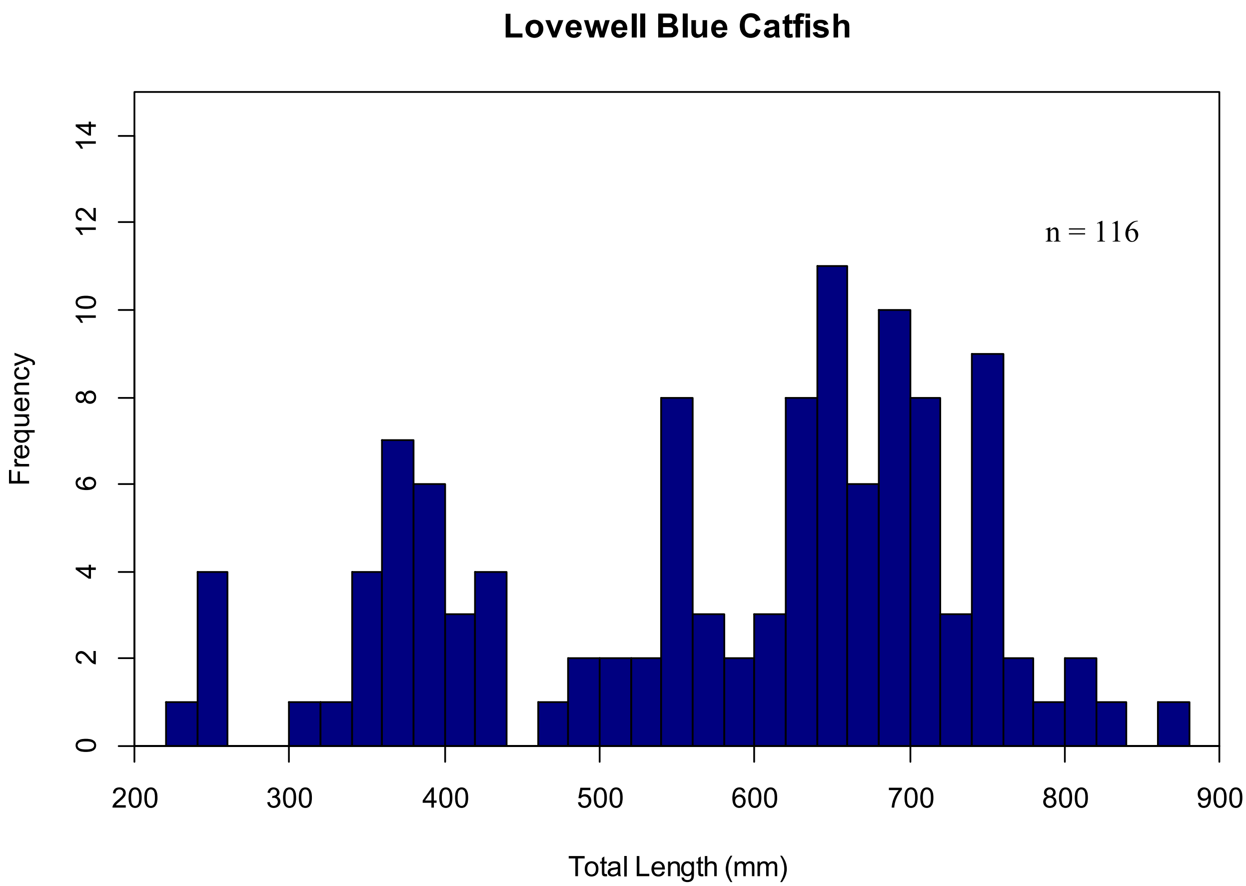

Figure 8.) – Lovewell Reservoir length frequency histogram of aged individuals. Total number of fish caught on the y axis and total length (mm) on the x axis. Columns are organized into 20 mm increments.

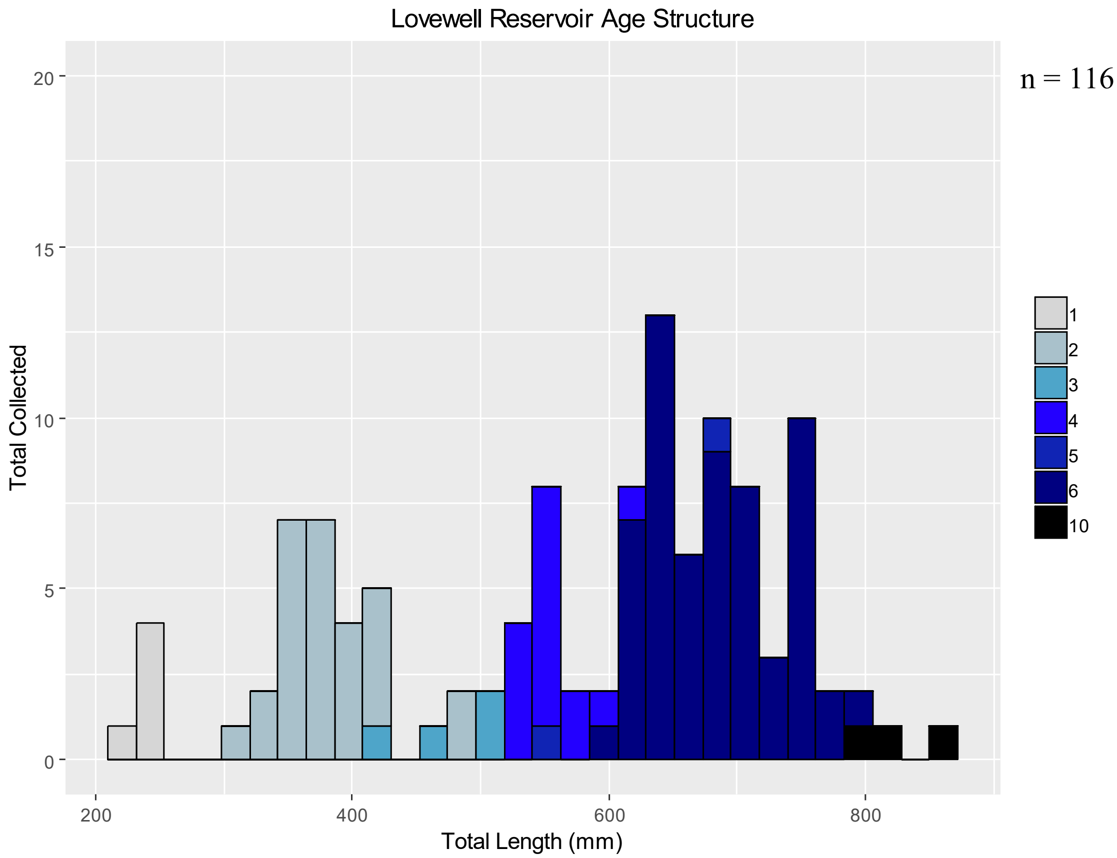

Figure 9.) – Lovewell Reservoir age frequency histogram generated in R statistical software. Each year class is depicted by a different color illustrating different age classes within the population.

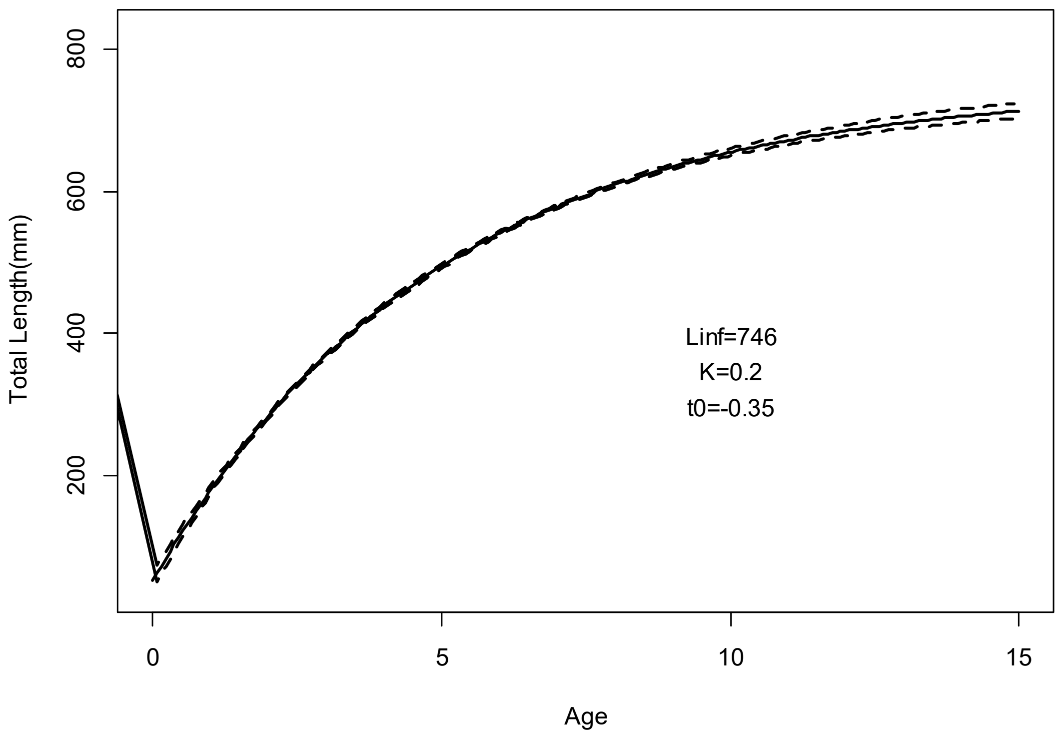

Figure 10.) – von Bertalanffy growth curve for Blue Catfish collected from Wilson Reservoir generated in R statistical software.

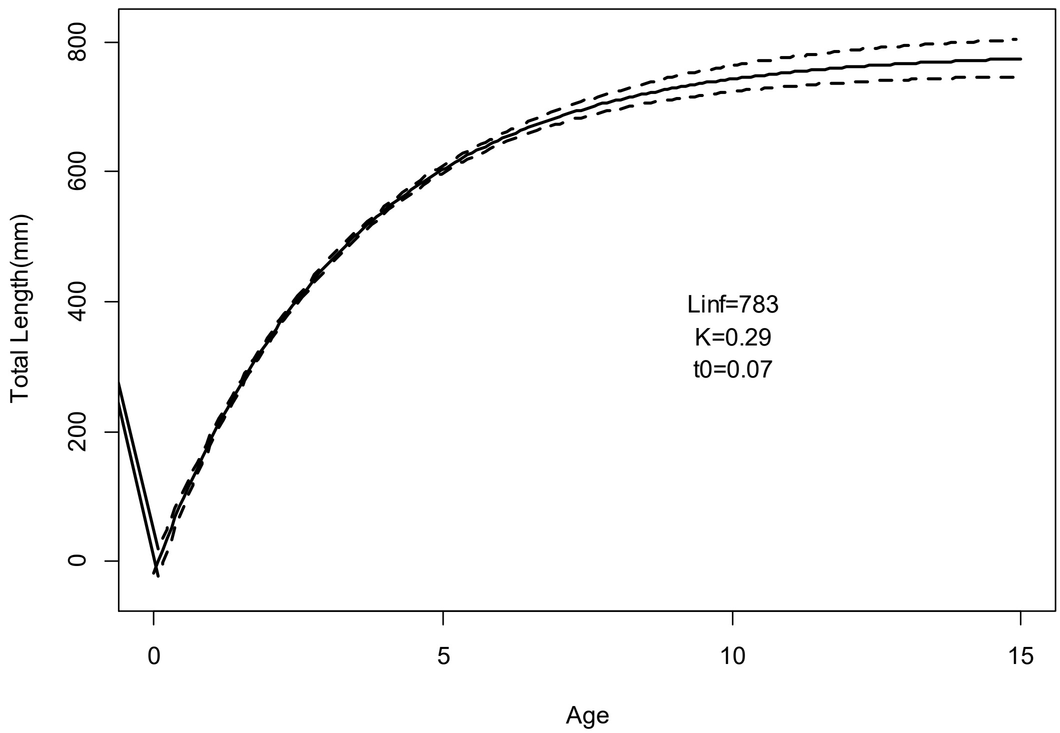

Figure 11.) – von Bertalanffy growth curve generated for Lovewell Reservoir using R statistical software.

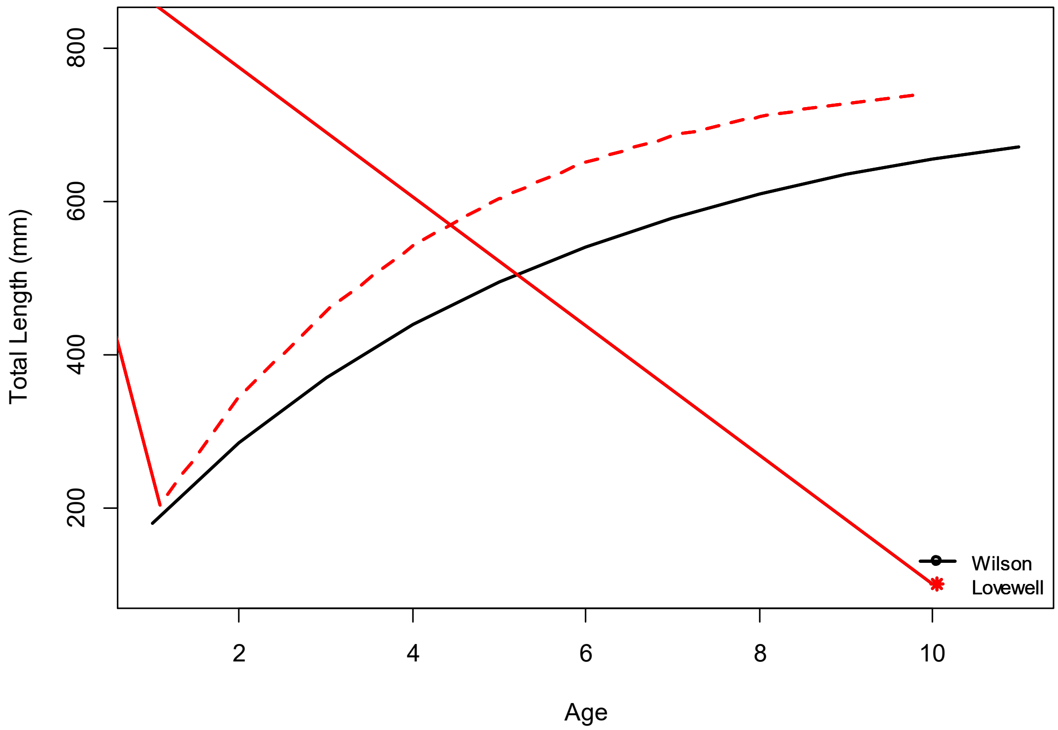

Figure 12.) – von Bertalanffy growth comparing growth rates between Lovewell and Wilson Reservoir. Red line depicts faster growth from Lovewell Reservoir compared to the black line depicting growth rates from Wilson Reservoir

Wilson Reservoir Stocking Rates					
Date Stocked	Number	Unit Weight	Mean Weight	Mean Length	Age
October 2006	2/acre	13.51/pound	N/A	169 mm	11
October 2007	1/acre	5.8/pound	N/A	219 mm	10
October 2008	2/acre	14.1/pound	N/A	164 mm	9
October 2009	0	0	0	0	8
October 2010	1/acre	8.98/pound	N/A	N/A	7
October 2011	1/acre	21.8/pound	N/A	146 mm	6
October 2012	1/acre	7.55/pound	N/A	197 mm	5
October 2013	1/acre	10.55/pound	N/A	N/A	4
October 2014	1/acre	13.42/pound	N/A	N/A	3
October 2015	0	0	0	0	2
October 2016	1/acre	19.7/pound	N/A	N/A	1

Appendix 1.) – Stocking records for Blue Catfish stocked in Wilson Reservoir. Units are described as number per acre stocked, average number of individuals per pound, mean weight (g) per individuals, mean length per individual (mm), and expected age in 2017 with no evidence of natural recruitment. 2017 with no evidence of natural recruitment.

Lovewell Reservoir Stocking Rates					
Date Stocked	Number	Unit Weight	Mean Weight	Mean Length	Age
October 2010	1/acre	9/pound	50.4 grams	200 mm	6
October 2011	1/acre	21.8/pound	20.8 grams	120 mm	5
October 2012	1/acre	7.55/pound	60.1 grams	210 mm	4
October 2013	0.33/acre	10.55/pound	43.0 grams	190 mm	3
October 2014	1/acre	13.42/pound	33.8 grams	175 mm	2
October 2015	0	0	0	0	1
October 2016	0	0	0	0	0

Appendix 2.) – Stocking records for Blue Catfish in Lovewell Reservoir. Units are the date stocked, number of fish stocked per acre, number of individuals per pound, mean weight (g) of each individual, mean length (mm) of each individual, and predicted age of each stocking with no evidence of natural recruitment.

Fort Hays State University
FHSU Scholars Repository
Non-Exclusive License Author Agreement

I hereby grant Fort Hays State University an irrevocable, non-exclusive, perpetual license to include my thesis ("the Thesis") in *FHSU Scholars Repository*, FHSU's institutional repository ("the Repository").

I hold the copyright to this document and agree to permit this document to be posted in the Repository, and made available to the public in any format in perpetuity.

I warrant that the posting of the Thesis does not infringe any copyright, nor violate any proprietary rights, nor contains any libelous matter, nor invade the privacy of any person or third party, nor otherwise violate FHSU Scholars Repository policies.

I agree that Fort Hays State University may translate the Thesis to any medium or format for the purpose of preservation and access. In addition, I agree that Fort Hays State University may keep more than one copy of the Thesis for purposes of security, back-up, and preservation.

I agree that authorized readers of the Thesis have the right to use the Thesis for non-commercial, academic purposes, as defined by the "fair use" doctrine of U.S. copyright law, so long as all attributions and copyright statements are retained.

To the fullest extent permitted by law, both during and after the term of this Agreement, I agree to indemnify, defend, and hold harmless Fort Hays State University and its directors, officers, faculty, employees, affiliates, and agents, past or present, against all losses, claims, demands, actions, causes of action, suits, liabilities, damages, expenses, fees and costs (including but not limited to reasonable attorney's fees) arising out of or relating to any actual or alleged misrepresentation or breach of any warranty contained in this Agreement, or any infringement of the Thesis on any third party's patent, trademark, copyright or trade secret.

I understand that once deposited in the Repository, the Thesis may not be removed.

Thesis: Size and Age Structure of Introduced populations of Blue Catfish (Ictalurus Furcatus) in Two Kansas Reservoirs and Implications for management.

Author: Ernesto Flores and William J. Stark

Signature: [signature]

Date: 5/28/19