FOOD HABITS OF BLUE CATFISH (ICTALURUS FURCATUS) INTRODUCED INTO LAKE OCONEE, GEORGIA

by

GEOFFREY EARL MITCHELL

(Under the Direction of Cecil A. Jennings)

ABSTRACT

Blue Catfish are native to the Coosa river drainage in northwest Georgia, but were discovered outside this range (in Lake Oconee) in 1997. In Lake Oconee, their abundance and growth rates have increased dramatically, but their food habits are unknown. Therefore, food habits of Blue Catfish were determined by examining the stomachs of 808 specimens from Lake Oconee's upper and lower regions during all seasons from summer 2012 to summer 2013. Stomach contents were analyzed using the Index of Relative Importance. The dominant seasonal prey item was Asian Clams (*Corbicula fluminea;* 98%) during the summer, Asian Clams (46%) in the fall, Mayflies *(Ephemeroptera*; 23%) in the winter, and Mayflies (84%) in the spring. The results show that the diet of introduced Blue Catfish in Lake Oconee, Georgia, is omnivorous. More importantly, the results also show that they are not preying intensely on native bi-valves and fishes.

INDEX WORDS: Diet, index of relative importance, Lake Oconee

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# CHAPTER ONE

# INTRODUCTION AND LITERATURE REVIEW

## INTRODUCTION

The Blue Catfish (*Ictalurus furcatus*), a member of the Ictaluridae family, is one of the largest freshwater fishes in North America (Graham 1999). The Blue Catfish's native range historically has spanned from the Ohio River drainage into Belize (Graham 1999). Because of this species large size, it represents an important species for commercial, recreational, and predator-control purposes such as controlling invasive snails (Ledford et al. 2006) within the United States (Graham 1999; Michalet and Dillard 1999; USDI and USDC 2001); as a result, it has experienced wide-spread introduction nationally (Graham 1999; Higgins 2006). Blue Catfish are native to the Coosa river drainage in northwest Georgia (Glodeck 1979), but recently have been discovered outside of this range (Homer and Jennings 2011). Blue Catfish were first discovered in the Oconee River system about 18 years ago; they were documented in Lake Sinclair in 1996 and Lake Oconee in 1997 (Homer and Jennings 2011; Fig 1). In Lake Oconee, their abundance and growth rate have increased dramatically (Homer and Jennings 2011; Fig 2).

Because of its introduction into many water bodies, this species can have negative effects on native aquatic communities (Wilcove et al. 1998; Lodge et al. 2000; Jelks et al. 2008). For example, increases in Blue Catfish population sizes have been correlated with declines of native White Catfish (*Ictalurus catus*) via predation in the Chesapeake Bay watershed (Schloesser et al. 2010) and in Lake Oconee, a large reservoir in central Georgia (Homer and Jennings 2011; Fig. 2). Literature pertaining to the feeding ecology of either native or introduced Blue Catfish populations is minimal, and research examining the dynamics between introduced Blue Catfish populations and their native prey species is needed to determine introduced Blue Catfish trophic role in the ecosystem.

In this project, I examined the diet of Blue Catfish in Lake Oconee, Georgia. This information will be used to: 1) document the seasonal diets of introduced Blue Catfish in Lake Oconee, Georgia, 2) determine if the introduced Blue Catfish may affect native species, and 3) aid in establishing possible management plans to mitigate any potential negative effects in the Lake Oconee system.

The information presented in this thesis is divided into three chapters. The first chapter encompasses the basic background information of Blue Catfish and justification for the project. The second chapter is a “stand alone” manuscript that describes the project, its methods, results, and discussion. The last chapter discusses the management implications, future Blue Catfish research directions, and other factors that may negatively influence Lake Oconee’s ecosystem.

## LIFE HISTORY OF BLUE CATFISH

### *Taxonomy and Systematics*

Taxonomically, Blue Catfish belong to the Division Teleostei, Subdivision Ostarioclupeomorpha, Superorder Ostariophysi, Order Siluriformes and the family Ictaluridae (Helfman et al. 1997). Blue Catfish belong to the genus *Ictalurus* and the specific epithet is *furcatus* (Graham 1999). Blue Catfish are theorized to have originated in present-day Texas during the Pliocene epoch (Gayet and Meunier 2003).

### *Distribution*

The distribution of Blue Catfish is vast and ranges from the Northeastern United States to Belize in Central America (Graham 1999). Their native range has been restricted by habitat alteration (Graham 1999), but their naturalized range has expanded because of major introductions. This large distribution can be attributed to Blue Catfish being widely introduced to freshwater systems because of this species size, which makes it valuable for recreational, commercial, and for the purpose of controlling other ecologically-damaging predators (Graham 1999; Goeckler 2003). In Georgia, Blue Catfish are native to the Coosa River drainage system, but have been introduced to the Chattahoochee, Oconee and Altamaha rivers (Homer and Jennings 2011). There are large populations of introduced Blue Catfish in Lake Oconee and Lake Sinclair, Georgia (Homer and Jennings 2011).

*Morphology*

Blue Catfish have a similar morphology to other species of the family Ictaluridae, but have several defining morphological traits that distinguish it from other catfishes. Blue Catfish is one of the largest North American freshwater fish species (Graham 1999); the largest individuals can reach 68 kilograms in weight and 165 cm in length (Page and Burr 1991). Blue Catfish have a fusiform and elongated body (Ross 2001) with a rounded head (Hubbs et al. 1991). The mouth is subterminaly positioned (Goldstien and Simon 1999), and the lower jaw does not protract pass the upper jaw (Graham 1999). The upper jaw encases a premaxillary band of teeth (Hubbs et al. 1991). Blue Catfish have a deeply forked caudal fin, a deep anal fin, and a disconnected adipose fin (Hubbs et al. 1991). This species has 30-36 anal rays (Hubbs et al. 1991), six dorsal rays, 8-10 pectoral rays, and eight pelvic rays (Ross 2001). Blue Catfish have four pairs of barbels: one pair of chin barbels, two pairs of maxillary barbels, and one pair of nostril barbels (Page and Burr 1991). Blue Catfish have an olfactory and gustatory system that enables them to detect low concentrations of certain compounds in its environment. Blue Catfish swim bladder is restricted and forms two similarly sized chambers (Ross 2001). This species coloration ranges from black to blue, with silvery-colored sides and a grayish-white coloration on the bottom (Sublette et al. 1990).

Male and female Blue Catfish can be distinguished by external features; specifically, the genital opening is different between the sexes. The papilla of males is pronounced, with a circular-shaped opening, while the female's papilla is less pronounced and the opening is a slit (Moyle 1976). Males are dark blue during mating season (Moyle 1976) and typically grow faster than females (Holley 2006).

*Reproduction*

There are few published studies about the reproductive behavior of Blue Catfish, so little is known about this aspect of the species' life history. The available information suggests that male Blue Catfish mature at age four (length of ~490 mm; TL), and female Blue Catfish mature at age five (length ~590 mm; Perry and Carver 1973). When temperatures reach 21-24 °C during the months of April and May, this species migrates upstream (Pflieger 1997; Graham 1999). Once Blue Catfish arrive upstream, they congregate in large schools and engage in spawning activity. Dams hinder the migration of Blue Catfish to natural spawning grounds, which has resulted in Blue Catfish aggregating below dams to spawn. Blue Catfish males are nest builders and guarders. After spawning, they travel down river.

*Habitat*

Few studies describe the general habitat that Blue Catfish occupy. This species prefers large rivers and streams (Hubbs et al. 1991) with silt-free pools (Pflieger 1975; Glodek 1980; Pflieger 1997). Blue Catfish also inhabit turbid backwaters, main channels of strong-flowing rivers (Burr and Warren 1986), pelagic zones of lakes and reservoirs. This species can tolerate salinities ranging from 3.7 ppt (Perry 1968) to 15 ppt (Waller 1973).

*Behavior*

Blue Catfish exhibit similar behaviors as other species in the Ictaluridae family; however, they do exhibit some key differences. This species is less benthic than other species of Ictaluridae; they mainly occupy the water column where they forage for food. Blue Catfish are omnivorous, opportunistic, and are voracious predators. Blue Catfish forage mostly at night (Davis 1979) and may seasonally migrate in a response to changes in water temperature and to search for other sources of food. In the lower Mississippi River, this species migrates down river for warm water in the winter; other Ictalurids do not display this behavior (Jordan and Everman 1916; Pflieger 1975).

## METHODS OF DIET STUDIES

*Field Work*

Hoop nets and gill nets have also been used in combination with electrofishing to sample Blue Catfish, but this sampling combination creates problems with catch rates and biases. Hoop nets (Nelson 1985) and gill nets (Buckmierer 2007; Evans et al. 2011) can be useful, but yield less captured catfish per hour of effort compared to electrofishing (Nelson 1987). Hoop nets and gill nets can also be size selective and will result in an incomplete sample of the available size classes in the population (Hameley 1975; Yeh 1977; Larrman and Rickman 1982; Nelson 1987; Holland and Peters 1992).

*Laboratory Work (Diet Evaluation)*

To properly determine the diet of a fish species, a specific set of food habit analysis methodology must be applied. The stomachs are categorized by the season of capture to assess any diet shifts seasonally (Manooch 1973). A count is made of the stomachs that are empty and those with contents in them (Jearld 1971). Microscopes are used to identify the contents to the lowest taxon (Manooch 1973; Jolley 2003). Fish species found in the stomach are measured by standard length. If the body of the ingested fish is not digested to the point of being unidentifiable, then they are identified by key characteristics (Manooch 1973). If a prey item cannot be identified because of digestion, it is placed in a category called "unidentified" for data purposes (Jolley 2003). The contents of the stomachs are quantified by prey occurrence, prey frequency, proportion of diet and mass (wet weight; g) for each group (Manooch 1973; Cannamela et al. 1978; Phillips et al. 1996; Jolley 2003; Baumann and Kwak 2011; Bonvechio et al. 2011). After the contents are identified and quantified, the contents and stomach tissue are placed in a serial numbered plastic bag (Baumann and Kwak 2011). Lastly, the data recorded from the stomach contents can be analyzed by different mathematical methods depending on the research question.

## ANALYTICAL METHODS

### *Index of Relative Importance*

The Index of Relative Importance (IRI) is one of the most commonly used methods to assess the diets of animals (Pinkas et al. 1971; Talent 1976). This method allows the researcher to create a scale of level of importance of food items found in a subject's stomach. The values range from 0 to 20,000, with higher values representing the food items that are the greatest importance to the species. It is designed to reduce bias that is created when a single measure of diet is used in the analysis of diet data (Chipps and Garvey 2007). For example, based on IRI score analysis, researchers determined that populations of Blue Catfish in the lower Mississippi River (Eggleton and Schramm 2004) and on Lake Texoma in Oklahoma (Graham 1999; Jackson 1999) fed mainly of Zebra Mussels. Other researchers calculated IRI scores and determined that Asian Clams were the primary food item for Blue Catfish in the Altamaha River, Georgia

(Bonvechio et al. 2011) and California reservoirs (Richardson et al. 1970; Dill and Cordone 1997; Fuller et al. 1999). Lastly, Blue Catfish in an Alabama reservoir rely on mollusks as their primary resource of food (Jolley 2003).

Even though the IRI is one of the most commonly used methods of analyzing diets, it does have two major problems. Firstly, the IRI generates a value based on the abundance, volume, and frequency of occurrence of a food item in a stomach. This is problematic because there may be a large abundance of small organisms that overshadow potentially important larger food items, which could be less abundant at the time. Therefore, the IRI would calculate the smaller organisms to be the most important because of their abundance and rate of occurrence in the stomach. Additionally, even though the volume is incorporated into the IRI score, the volume can also be misleading. Some organisms may be heavier and even if those items are in small abundance these heavier prey items can outweigh smaller and more numerous prey items. Secondly, the IRI does not take into account which food item is more nutritionally beneficial.

*PSIRI (Prey Specific Index of Relative Importance)*

Although the IRI index has proven useful in describing the food habits of animals, scientists are now suggesting a new improved index, the Prey Specific Index of Relative Importance (Brown et al. 2011). The PSIRI is derived from the original formula, but has differences in the methods to calculate the IRI % score.

$$\text{IRI \%} = \%FO \times (\%N + \%W)$$

$$\text{PSIRI \%} = \%FO \times [(\%PN \times \%FO) + (\%PW \times \%FO)]$$

$$= \%FO^2 \times (\%PN + \%PW)$$

Where,

%F0= % of stomachs containing each prey item

%N & %PN= % of each prey item

%W & %PW = % weight of each prey item

Scientists suggest that PSIRI should replace the IRI because the PSIRI exhibits a more balanced treatment of the prey quantity; secondly, the PSIRI eliminates the fluctuating behavior of the product across taxonomic levels of prey (Brown et al. 2011). The new index fixes this problem because the new equation eliminates the dependence that %N and %W have on the %FO, by mathematically separating the first two variables from the %FO. This results in the following equation.

$$\%PSIRI = \frac{\%FO \times (\%PN + \%PW)}{2}$$

Where %FO is the frequency of occurrence of a food item, %PN is the numerical amount of each prey item, and %PW is the weight of each prey item. All of these variables can be used to calculate the PSIRI%. The PSIRI is relatively new and has only been used in a few studies. The index was used to describe the diet of Banded Guitar Fish in Costa Rica (Espinoza 2013) and the Smoothhound Shark in Latin America (Moreno-Sanchez et al. 2013)

*Prey Accumulation Curves*

Prey accumulation curves are a graphical tool used to determine if a sample size of stomachs is adequate to base a conclusion about the diet of a specific species (Cook et al. 2010). This graph is composed of two variables, comparing the number of prey items, against the number of stomachs sampled. The rate at which new prey items are identified decreases as more stomachs are examined. At a certain point on the graph, the identification of new items will cease and the graph will reach an asymptote. This asymptote indicates that the sample size is adequate and a conclusion on the diet of a species can be drawn. Additionally, the samples in each prey accumulation curve will be placed in a random order, 10 times and analyzed again to eliminate bias. This process further confirms the strength of the sample size and the validity of the diet conclusion. Lake Oconee Blue Catfish diet data were subjected to the prey accumulation analysis for each region/season combination.

## FEEDING ECOLOGY

There are few published studies focusing on the feeding ecology of Blue Catfish, but this species' differences in diet are related to size class and location of the population (Etnier & Starnes 1993; Graham 1999). Blue Catfish generally are omnivorous, but exhibit three general feeding stages throughout their ontogeny. Individuals ≤100 mm TL typically feed on zooplankton, those 100-240 mm TL feed on benthic invertebrates, and those ≥ 240 mm TL are typically piscivores (Darnell 1958; Minckley 1962; Perry 1969; Davis 1979). Blue Catfish diet can also differ depending on location. For example, Blue Catfish inhabiting coastal brackish waters feed mostly on crab, bay anchovies, and small minnows (Brown et al. 1961). In addition, Blue Catfish in rivers feed on crayfishes, larval dragonflies, and various other insect larvae (Brown and Dendy 1961; Darnell 1961; Lambou 1961; Eggleton and Schramm 2004; Bonvechio et al. 2011). Blue Catfish in reservoirs mainly feed on introduced bi-valves (Richardson et al. 1970; Dill and Cordone 1997; Fuller et al. 1999; Graham 1999; Jackson 1999). Seasonality can also influence feeding behavior within a location because different prey items may be more readily available or more abundant during different seasons (Dendy 1946; Bailey and Harrison 1948; Lambou 1961; Singer 1973; Oue 1975; Cannamela et al. 1978).

There have been few studies that have examined seasonality in Blue Catfish diet; however, some feeding shifts related with season have been observed. Specifically, Blue Catfish prey on mollusks in the summer, mollusks and fish in the fall, fish in the winter, and aquatic insects in the spring (McMahon 1983; Stoeckel et al. 1997; Moser et al. 1999; Grist 2002; Magoulick 2002; Eggelton et al. 2004; Jolley and Irwin 2003; Bonvechio 2011).

Generally, Blue Catfish feed exclusively on Asian Clams (*Corbicula fuminea)* or other bivalve species during the summer and the early fall seasons (Britton et al. 1979; McMahon 1983; Stoeckel et al. 1997; Moser et al. 1999; Grist 2002; Magoulick 2002; Eggelton et al. 2003; Bonvechio 2011). The ability for Blue Catfish to exploit abundant and widely distributed Asian Clams as a resource has aided in the rapid dispersal of Blue Catfish (Evans et al. 1979; Orth et al. 2013). Lastly, during winter months, Blue Catfish are almost completely picivorous, most often feeding on shad (*Dorsoma spp.*; Edds et al. 2002; Magoulick 2002; Orth et al. 2013).

# CHAPTER TWO

# FOOD HABITS OF BLUE CATFISH (ICTALURUS FURCATUS) INTRODUCED INTO LAKE OCONEE, GEORGIA[1]

[1] G. E. Mitchell and C.A. Jennings. To be submitted to the *Southeastern Naturalist*

**ABSTRACT**

Blue Catfish are native to the Coosa river drainage in northwest Georgia, but recently (1997) have been discovered outside of this range, in Lake Oconee. In Lake Oconee, their abundance and growth rates have increased dramatically, but their food habits are unknown. Therefore, food habits of Blue Catfish were determined by examining the stomachs of 808 specimens from Lake Oconee's upper and lower regions during all seasons from summer 2012 to summer 2013. Stomach contents were analyzed using the Index of Relative Importance. The dominant prey items during the summer season in the upper region were Asian Clams (*Corbicula fluminea;* 98%), Asian Clams (67%) in the fall, Mayflies *(Ephemeroptera*; 64%) in the winter, and Mayflies (84%) dominated the spring prey diet. The dominant prey items during the fall season in the lower region were Asian Clams (*Corbicula fluminea;* 41%), Threadfin Shad (*Dorsoma petenense*; 49%) in the winter and Mayflies (79%) dominated the spring prey diet. The results show that the diet of introduced Blue Catfish in Lake Oconee, Georgia, is omnivorous and is based on whatever is most abundant at the time. More importantly, the results also show that they are not preying intensely on native bi-valves and fish species. The sheer amount of Asian Clams that Blue Catfish consumed can possibly be a form of control on the invasive species in this lake.

INDEX WORDS: Diet, index of relative importance, Lake Oconee

## INTRODUCTION AND LITERATURE REVIEW

The Blue Catfish (*Ictalurus furcatus*), a member of the Ictaluridae family, is one of the largest freshwater fishes in North America (Graham 1999). The Blue Catfish's native range historically has spanned from the Ohio River drainage into Belize (Graham 1999). Because of this species large size, it represents an important species for commercial, recreational, and predator-control purposes such as controlling invasive snails (Ledford et al. 2006) within the United States (Graham 1999; Michalet and Dillard 1999; USDI and USDC 2001); as a result, it has experienced wide-spread introduction nationally (Graham 1999; Higgins 2006). Blue Catfish are native to the Coosa river drainage in northwest Georgia (Glodeck 1979), but recently have been discovered outside of this range (Homer and Jennings 2011). Blue Catfish were first discovered in the Oconee River system about 18 years ago; they were documented in Lake Sinclair in 1996 and Lake Oconee in 1997 (Homer and Jennings 2011; Fig 1). In Lake Oconee, their abundance and growth rate have increased dramatically (Homer and Jennings 2011; Fig 2).

Because of its introduction into many water bodies, this species can have negative effects on native aquatic communities (Wilcove et al. 1998; Lodge et al. 2000; Jelks et al. 2008). For example, increases in Blue Catfish population sizes have been correlated with declines of native White Catfish (*Ictalurus catus*) via predation in the Chesapeake Bay watershed (Schloesser et al. 2010) and in Lake Oconee, a large reservoir in central Georgia (Homer and Jennings 2011; Fig. 2). Literature pertaining to the feeding ecology of either native or introduced Blue Catfish populations is minimal, and research examining the dynamics between introduced Blue Catfish populations and their native prey species is needed to determine introduced Blue Catfish trophic role in the ecosystem.

In this project, I examined the diet of Blue Catfish in Lake Oconee, Georgia. This information will be used to: 1) document the seasonal diets of introduced Blue Catfish in Lake Oconee, Georgia, 2) determine if the introduced Blue Catfish may affect native species, and 3) aid in establishing possible management plans to mitigate any potential negative effects in the Lake Oconee system.

## MATERIAL AND METHODS

*Study Area*

The study was conducted on Lake Oconee, which is located in central Georgia on the Oconee River (Fig. 1). Lake Oconee was formed in 1979 when Wallace dam was constructed on the Oconee River for the purposes of hydro-electric power and recreational activities (Michalet and Dillard 1999; USDI and USDC 2001). Lake Oconee is the second largest lake in the state and spans through three counties of Georgia. It covers 77,094 hectares of surface area and has 374 miles of shoreline. The lakes deepest depth is 95 feet and has an average depth of 21 feet.

*Field Sampling*

Fish and water quality sampling occurred at 12 Georgia Department of Natural Resources (GADNR) standardized sampling stations (Fig. 3) that vary in habitat type. The lake was stratified into an upper and lower region to account for habitat variation. The upper region is shallower h and possesses more riverine habitat types than the lower region; whereas, the lower region is much deeper and possesses more lacustrine habitat types than the upper region. There were seven GADNR sampling stations (4, 5, 6, 7, I-20, Billboard, Tressel) in the upper region of Lake Oconee and five sampling stations (1, 2, 8, 9, and 12) in the lower region of Lake Oconee

(Fig. 3). Both regions were sampled separately, throughout each season to account for seasonal variability. Seasonal periods were determined using temperature and water stratification characteristics. Each gill net mesh-size (2-inch, 3-inch, and 4-inch) was randomized with a random number chart, and then one net was set at each station. Once captured, each fish was placed in a 1:1 ice to water slurry to be euthanized (Blessing 2010). When euthanization was complete, the specimens were transported to a laboratory at the University of Georgia, Warnell School of Forestry and Natural Resources for storage and processing. In the lab, the fish were weighed to the nearest kg, measured to the nearest mm (Total length; Manooch 1973) and their stomachs were excised. Length-Weight frequency graphs were created from the length and weight measurements (Appendix). The stomachs were then placed in labeled jars with 10% formalin for three days before being stored in ethanol. Each jar was labeled with a serial number, date, location, and time of stomach removal.

*Laboratory Procedures*

Standard diet assessment procedures were used to process the fish stomachs. The stomachs remained in the 10% formalin solution for three days to allow the tissue to fix and effectively stop digestion. After this period, the stomachs were stored in 70% ethanol solution (Jolley 2003; Roberts et al. 2006). Stomachs were surgically opened and stomach contents were removed. Empty stomachs and full stomachs were counted and listed separately (Jearld 1971). Contents of the non-empty stomachs were identified to the lowest taxon possible (Manooch 1973; Jolley 2003). The contents of the stomachs were quantified by enumerating the frequency of occurrence of each prey item, proportion of each food item, and the wet mass weight (g) of each group of species (Jearld 1971; Manooch 1973; Jolley 2003).

*Stomach Content Analysis*

Each Blue Catfish stomach was placed into a specific group based on season, region, station, and date to properly analyze the stomach contents. First, the stomachs were separated by upper and lower regional stations and among seasons. After all food items had been processed for each region and among seasons, the IRI% and PSIRI% scores were calculated (Brown et. al. 2011). Additionally, the IRI% and PSIRI% were compared solely on a relative basis to determine if the two indices produced different rankings for the dominant prey items for each region, and among seasons. Lake Oconee Blue Catfish diets were used to construct prey accumulation curves to determine if the sample sizes for each region/season combination was sufficiently large to conduct the diet analysis.

## RESULTS

*Diet Data Summary*

A total of 808 Blue Catfish were caught and stomachs were analyzed for diet content from Lake Oconee Georgia from June 2012-June 2013. An average of 14 Blue Catfish were captured for each sampling trip with 87% of the catch being attributed to 2-inch mesh-size gill-nets. A total of 303 (57% full) Blue Catfish stomachs were collected from the lower region and 504 (55% full) stomachs were collected from the upper region. A total of 453 (57%) stomachs contained prey items, and the stomach fullness percentage varied from a high of 71% to a low of 51% by season. Prey accumulation curves determined that sample sizes were sufficiently large to draw diet content conclusions for all seasons and regions for Blue Catfish in Lake Oconee (Figures 8, 9, 10, 11, 12).

## DIET ANALYSIS 1 (IRI)

*Lower Region Seasonal Diet (IRI)*

Diet of Blue Catfish varied seasonally in the lower region of the lake. The dominant prey items (IRI %) identified for the fall sampling season were Asian Clams (41%), flies (*Diptera*; 27%), mayflies (*Ephemeroptera*; 25%), and Threadfin Shad (*Dorsoma petenense*; 8%; Table 1). The dominant prey items for the winter sampling season were Threadfin Shad (49%), Asian Clams (32%), mayflies (16%), and flies (1%; Table 1). For the winter season, Blue Catfish diet shifted from predominantly Asian Clams in the fall to mainly a piscivorous diet in the winter. Blue Catfish diet shifted from a piscivorous diet in the winter, to a largely aquatic insect diet in the spring. Dominant prey items for the spring season were mayflies (79%), Asian Clams (14%), crappie (*Pomoxis spp*.; 3%), Threadfin Shad (2%), and flies (2%; Table 1).

*Upper Region Seasonal Diet*

Diet of Blue Catfish also varied seasonally in the upper region of the lake. The dominant prey items (IRI %) identified for the summer sampling season were Asian Clams (98%) and flies (2%; Table 1). The dominant prey items for the fall sampling season were Asian Clams (67%), Threadfin Shad (25%), mayflies (6%), and flies (3%; Table 1). Dominant prey items for the winter season were mayflies (64%), Threadfin Shad (26%), Asian Clams (9%), and flies (1%; Table 1). The diet shift in the winter to aquatic insects continued into the spring season. Dominant prey items for the spring season were mayflies (84%), crappie (9%), Asian Clams (7%), flies (2%), and Threadfin Shad (0.22%: Table 1).

## DIET ANALYSIS 2 (PSIRI)

*Lower Region Seasonal Diet*

Based on the Prey Specific Index of Relative Importance (PSIRI%), the dominant prey items for the fall season were Asian Clams (44%), flies ( 24%), mayflies (22%), and Threadfin Shad (6%; Table 2). Winter season Blue Catfish diet shifted from predominantly Asian Clams in the fall season to mainly a piscivorous diet in the winter season (Table 2). Winter season's dominant prey items were Asian Clams (41%), Threadfin Shad (21%), mayflies (10%), and flies (6%; Table 2). Dominant prey items for the spring season were mayflies (42%), Asian Clams (25%), Threadfin Shad (5%), flies (3%) and crappie (0.5%; Table 2).

*Upper Region Seasonal Diet*

The upper region PSIRI % scores varied among seasons. Summer Blue Catfish prey items consisted of Asian Clams (76%) and flies (1%). Blue Catfish continued to feed on Asian Clams as their main diet source during the fall.  Dominant prey items for fall were Asian Clams (67%), Threadfin Shad (16%), mayflies (5%), and flies (3%). Dominant prey items for the winter season were mayflies (64%), Asian Clams (28%), Threadfin Shad (19%), and flies (2%). Blue Catfish preyed primarily on mayflies (62%), Asian Clams (12%), Threadfin Shad (1%), crappie (0.4%), and flies (0.04%: Table 2) during the spring.

## DIFFERENCES BETWEEN IRI% AND PSIRI%

*Lower Region*

Percentages for IRI and PSIRI were sometimes similar and sometimes different, but in general, variability relied heavily on season and location. The IRI% dominant prey items identified for fall were Asian Clams (41%), flies (27%), mayflies (25%), and Threadfin Shad (8%; Table 1). Although, PSIRI% percentages were different for the fall season, PSIRI%

dominant prey item rankings were the same as IRI% dominant prey item rankings for the fall season, with PSIRI% ranking Asian Clams (44%) first, followed by, flies ( 24%), mayflies (22%), and Threadfin Shad (6%; Table 2). The IRI% dominant prey items for winter were Threadfin Shad (49%), Asian Clams (32%), mayflies (16%), and flies (1%; Table 1). Winter PSIRI% dominant prey item ranking were different from IRI% dominant prey items. Winter PSIRI% ranking consisted of Asian Clams (41%), Threadfin Shad (21%), mayflies (10%), and flies (6%; Table 2). The IRI% dominant prey items for the spring season were mayflies (42%), Asian Clams (25%), Threadfin Shad (5%), flies (3%) and crappie (0.5%; Table 2). During the spring season, both percentages and rankings were different for PSIRI% when compared to IRI% rankings. Spring PSIRI% ranked mayflies (79%) as the dominant item, followed by Asian Clams (14%), crappie (*Pomoxis* spp.; 3%), Threadfin Shad (2%), and flies (2%; Table 1).

*Upper Region*

Percentages for upper region IRI and PSIRI scores were sometimes similar and sometimes different, but generally, variability relied heavily on season and location. The IRI% dominant prey items for the summer were Asian Clams (98%) and flies (2%; Table 1). Summer PSIRI% dominant prey item rankings were the same as the summer IRI% rankings, but they differed in percentages. Summer PSIRI% prey items consisted of Asian Clams (76%) and flies (1%). The IRI% dominant prey items for fall were Asian Clams (67%), Threadfin Shad (25%), mayflies (6%), and flies (3%; Table 1). Fall PSIRI% rankings remained the same as the fall season IRI%, but PSIRI% percentages were different. Fall PSIRI% dominant prey items were Asian Clams (67%), Threadfin Shad (16%), mayflies (5%), and flies (3%). Winter IRI% ranking consisted of mayflies (64%), Threadfin Shad (26%), Asian Clams (9%), and flies (1%; Table 1). Winter PSIRI% percentages and rankings differed from the winter IRI%. Winter PSIRI%

dominant prey items were mayflies (64%), Asian Clams (28%), Threadfin Shad (19%), and flies (2%). Spring dominant IRI% prey items were mayflies (84%), crappie (9%), Asian Clams (7%), flies (2%), and Threadfin Shad (0.22%: Table 1). Rankings and percentages of the spring PSIRI% analysis were different from the IRI% analysis, resulting in PSIRI% spring ranking to be mainly composed of mayflies (62%), followed by Asian Clams (12%), Threadfin Shad (1%), crappie (0.4%), and flies (0.04%: Table 2).

## DISCUSSION

*Lower Region Seasonal Diet*

Introduced Blue Catfish in Lake Oconee, as in other studies (Darnell 1958; Minckley 1962; Perry 1969; Davis 1979), could best be characterized as an omnivorous, opportunistic predator. This opportunistic feeding behavior explains why Blue Catfish in Lake Oconee exhibited uniform diet shifts as the season's progressed (Britton et al. 1979; Mchmahon 1982; Stoeckel et al. 1997; Moser et al. 1999; Grist 2002; Magoulick 2002; Eggelton et al. 2003; Jolley and Irwin 2003; Bonvechio 2010). Lower region Blue Catfish diet shifted from bivalves in the summer, fish in the fall, continuing to feed on fish in the winter, and shifted to aquatic insects in the spring. These shifts were likely a product of the opportunistic behavior of the Blue Catfish interacting with the availability of prey items, particularly when those prey items were highly abundant. Therefore, the seasonal abundance of the various prey items has shaped the diet of Blue Catfish in Lake Oconee, Georgia.

## LOWER REGION DOMINANT PREY ITEMS

*Asian Clams*

In Lake Oconee, Asian Clams were a major resource for Blue Catfish throughout the fall (41%; Table 1) season. This consumption pattern can be explained by the Asian Clams life history, in which it spawns twice annually (Summer/Fall). This spawning pattern enables this species to reach their highest abundances during the summer and early fall seasons (Higuti et al. 2007). Additionally, Asian Clam's spawning behavior also makes them more vulnerable to predation because they spawn in open, shallow-water habitat. Additionally, each Asian Clam spawning event is followed by a period of major die-offs (Higuti et al. 2007). Consequently, there is a notable decline in the Asian Clam consumption (14%; Table) during the winter season, because Asian Clams are not able to survive the extreme cold temperatures **(**Mattice et al. 1976; Lucy et al. 2012).

The topology of Lake Oconee may explain the difference in consumption rates of Asian Clams between the upper (67%) and lower (41%; Table 1) regions of the lake. The upper region is shallower and more riverine than the lower region, which is a more lacustrine-like habitat. Asian Clams require shallow habitat, so their phytoplankton food source can photosynthesize (Gardner et al. 1976; McMahon 1983). Therefore, the upper reaches of the lake may have higher abundances of Asian Clam, which is expressed in the high abundance of the clams in the diet of the Blue Catfish in the upper region of the lake.

*Threadfin Shad*

Differences in consumption rates of Threadfin Shad were observed between the upper and lower lake regions. Lower region Blue Catfish preyed upon Threadfin Shad heavily during the winter season (48%; Table 1). In comparison, the upper region winter diet consisted of only 26% Threadfin Shad. The large representation of Threadfin Shad in lower region Blue Catfish diet can be explained by the seasonal movement patterns of Threadfin Shad and Blue Catfish. Threadfin Shad are intolerant of rapid changes in temperature (Jester et al. 1972), which causes them to overwinter in the deepest regions of the lake where temperatures are low, but the temperature remains constant throughout the winter (Schael et al. 1995). Coincidently, Blue Catfish overwinter and restrict their movement to the deepest parts of reservoirs or lakes as well (Jordan and Everman 1916; Pflieger 1975). Therefore, both Threadfin Shad and Blue Catfish overwintering patterns overlap in space and time. This overlap is the reason why Threadfin Shad occur in the diet of lower region Blue Catfish during the winter.

*Mayflies*

Blue Catfish preyed upon mayflies most during the spring (79%; Table 1) season. The life history of mayflies offers an explanation to why this order of insect was so prevalent in the spring diet of Blue Catfish. First, this species is a burrowing species that sheds its exoskeleton on the surface of the water during the spring emergence period (Elliott 1972; Brattian 1981, 1982; Sivaramakrishnan, 2000). Secondly, almost all of the mayflies found in Blue Catfish stomachs were in their nymph stage or sub-imago stage ($1^{st}$ adult stage; Elliott 1972; Brattian 1981, 1982; Sivaramakrishnan 2000). This finding suggests that Blue Catfish preyed upon mayflies when dissolved oxygen on the bottom of the lake was low, which cues mayflies to emerge from their burrows at the bottom of the lake during the spring and travel to the surface to metamorphose into adults (Nagell 1977; Hocutt et al. 1982; Crowder et al. 1982; Brinkhurst 1984; Magnuson et al. 1985).

## UPPER REGIONAL DOMINANT PREY ITEMS

*Asian Clam*

Asian Calms were the main staple in the diet of upper region Blue Catfish during the summer season (98%; Table 1). Most importantly, Asian Clams occurred at a higher rate in Blue Catfish diet in the upper region than in the lower region of Lake Oconee. This phenomenon can be explained by two essential factors. First, the upper region meets the photic-zone habitat requirement of Asian Clams, which enable them to feed on phytoplankton (Gardner et al. 1976; McMahon 1983). Secondly, there is a large amount of nutrient loading from cattle, chicken, and agricultural operations in the upper region of Lake Oconee (Bachoon et al. 2009). High nutrient loading has led to an unusual high rate of algal production in the upper lake region (Bachoon et al. 2009). Consequently, the high abundance of algae may contribute to the large abundance of Asian Clams in the upper region (GADNR 1995; Hubbard et al. 2004; Monahan et al. 2008; Bachoon et al. 2009; Fraser et al. 2009).

Even though Asian Clams can survive the digestive system of Blue Catfish at a rate of 72% when temperatures are below 21.1 ºC (Gatlain et al. 2012), they also exhibit a 0 % survival rate when Blue Catfish water temperatures exceed 21.1 ºC (Gatlain et al. 2012). Therefore, Asian Clams wouldn't survive gut passage during the summer or fall months when they are most abundant (Brown 2007; Kappes et al. 2011; Gatlin et al. 2013) and have the greatest potential for dispersal (Parmalee 1965; Carlton 1993; Voelz et al. 1998; Domaneschi et al. 2002; Brown 2007; Kappes et al. 2011; Gatlain et al. 2012).

Lastly and most importantly, native bivalves occurred at a low rate (n=4) throughout all seasons. This low rate of predation is a positive result, but also may be indicative of the state of the native bivalve population. Specifically, Blue Catfish may not be feeding on native bivalves because these populations are quite low, and hence Blue Catfish only feed on the most abundant prey items for each season.

*Threadfin Shad*

Threadfin Shad were most dominant in diet of upper region Blue Catfish during the fall (25%) and winter (26%). However, Threadfin Shad never ranked as the primary prey item in upper region Blue Catfish diet as it did in the lower region. Threadfin Shad may have been absent from the summer diet because this species migrates upstream into the tributaries to spawn in shallow areas during the summer (Jester et al. 1972; Pierce 1977). Furthermore, Threadfin Shad were absent in the upper region during the winter season because they overwinter in the lower region of the lake where temperature is less variable (Minckley 1963).

*Mayflies*

Mayflies were most dominant in the diet of upper region Blue Catfish at the end of winter (64%) and for the duration of the spring season (84%). Mayflies represented in the diet at the end of winter may be the transitional period between the winter diet of fish and the mayfly diet of spring.

## DIET ANALYSIS 2 (PSIRI%)

*Lower Region Differences Between IRI% and PSIRI%*

PSIRI% analysis produced some changes in ranking of dominant prey items among lower region diet data. The winter season analysis produced a change in ranking, where the primary prey item of Threadfin Shad dropped in ranking and Asian Clams became primary. This transposition in ranking contradicts earlier mentioned reasoning for Asian Clams being fairly absent from Blue Catfish diet during the winter, because Asian Clams cannot tolerate low temperatures **(**Mattice et al. 1976; Lucy et al. 2012). Furthermore, this result does not agree with Blue Catfish diet shifting trends that predict the diet of the summer and early fall to be mainly composed of bivalves (Britton et al. 1979; Mchmahon 1982; Stoeckel et al. 1997; Moser et al. 1999; Grist 2002; Magoulick 2002; Jolley and Irwin 2003; Eggelton et al. 2003; Bonvechio 2011). This finding suggests that the PSIRI% ranking system does not make biological sense for the subject being studied. Unfortunately, there aren't any other studies that document this trend and more studies would need to be implemented to examine this issue.

*Upper Region Differences Between IRI% and PSIRI%*

The rankings for the winter season diet changed when the data was subjected to PSIRI% analysis. Mayflies remained the primary prey item, but Asian Clams ranking shifted to the second most common prey item. As in the lower region, this change in ranking does not agree with published accounts of Asian Clam life-history, because they are intolerable of low temperatures. However, this change in ranking can be explained by the manner in which the PSIRI% index is calculated. When PSIRI% is calculated, the formula seeks to isolate each of the variables (%FO, %PW and %PN). Therefore, Asian Clams may rank as the primary prey item in particular seasons, which doesn't agree with their life history, because of their sheer weight. If the weight is truly the source of the problem in the analysis, then the PSIRI% may have created a weight problem while trying to address other issues.

# CHAPTER THREE

# MANAGEMENT IMPLICATIONS AND FUTURE RESEARCH

## ROLE OF BLUE CATFISH IN LAKE OCONEE

Blue Catfish are apex predators in Lake Oconee for two reasons. First, introduced Blue Catfish are believed to alter communities of ictalurid species (Brown et al. 1961; Minckley 1962; Perry 1969; Fabrizio et al. 2010, 2012; Schlosesser et al. 2011; Groves et al. 2012; Garman et al. 2012). By-catch data from Homer and Jennings (2011) and more recently, from the present diet study, suggest that Blue Catfish may have altered the native ictalurid community by interfering with the habitat use of Channel Catfish in Lake Oconee. Channel Catfish were captured in shallow sampling sites, and Blue Catfish were captured in deep sampling sites of Lake Oconee. Although Channel Catfish habitat occupancy was not a main objective of this study and the sampling size was not sufficient to make a solid conclusion about true habitat partitioning, this finding may suggest that habitat segregation between the two species is occurring and is an effort by Channel Catfish to avoid predation or competition for resources with Blue Catfish. One may argue that Blue Catfish are not an apex predator in reference to the minimal occurrences of both Channel and White Catfish in Blue Catfish stomachs. However, even though Channel Catfish were not found in Blue Catfish stomachs at high rates (N=4), the fact that Channel Catfish occurred in Blue Catfish stomachs at all shows the predatory potential that Blue Catfish can exert on Channel Catfish. The absence of Channel and White Catfish occurrences in the diet compared to other prey items can possibly be attributed to the possible habitat segregation mentioned earlier, which means that those species are not available in the habitat that Blue Catfish are inhabiting  or that White Catfish may have very low abundances in the lake (e.g., Homer and Jennings 2011).  The low-abundance hypothesis is supported with data collected in the present study, as only one White Catfish in Lake Oconee during my sampling. Lastly, apex predators focus their consumptive pressure on the most abundant prey items during each season (Minckley and Deacon 1959; Swingle 1967; Turner and Summerfelt 1971). This phenomenon was observed in Lake Oconee, as the primary items in the diets of Blue Catfish during each season were always the most abundant prey items in the lake for that period of time.

Researchers theorized that Blue Catfish gut tracts can aid in the dispersal of Asian Clams throughout non-native ecosystems; however, when considering various characteristics of Asian Clam life history, Blue Catfish may play a larger role in the control of Asian Clams than in their dispersal. First, Asian Clams survived Blue Catfish gut tracts at a survival rate of 72% when water temperatures were below 21.1 ºC (Gatlain et al. 2012). Consequently, this high survival rate has led researchers to believe there may be a potential for Blue Catfish to aid in the dispersal of Asian Clams. Secondly, even though Asian Clams can survive temperatures below 21.1 ºC (Gatlain et al. 2012), they still experience massive die-offs from extremely low fall and winter temperatures and high summer temperature (0% survival rate, Gatlain et al. 2012), above 21.1 C (Higuti et al. 2007). Thirdly, Asian Clams experience peak populations during the summer and low populations during the fall and winter. Additionally, Blue Catfish feed (IRI%= 98%) on Asian Clams during periods of high Asian Clam abundance, highest potential for dispersal, and massive die-offs during the summer. Blue Catfish also feed heavily on Asian clams during fall and winter seasons when Asian Clam populations are low. Therefore, because Blue Catfish feeding habits align with the peaks, lows and highest dispersal potential of Asian Clam life history, Blue Catfish may act as some form of control on Asian Clams in Lake Oconee, rather than a dispersal mechanism as is theorized previously by some authors (Gatlain et al. 2012). Evidence supporting this theory is that Asian Clams cannot survive the high temperatures in Blue Catfish gut tracts during the summer, when they have the highest potential for dispersal. More studies would need to be conducted to investigate the level of control Blue Catfish can have on Asian Clam populations in Lake Oconee.

## FUTURE RESEARCH /MANAGEMENT IMPLICATIONS

Although the diet of Blue Catfish in Lake Oconee during the 2012-2013 has been determined, there are still other functions to their ecological and trophic role that need to be investigated further. Blue Catfish fed heavily on Asian Clams during the clam's spawning periods. The rate at which the clams are being consumed may have some degree of control over the clam's population; however, this rate is probably insufficient to eradicate the clams from Lake Oconee. Therefore, further research is necessary to determine what consumption rate would be necessary to suppress Asian Clam populations.

Blue Catfish and Channel Catfish may be partitioning the habitat in Lake Oconee so as to avoid direct competition between each other.  This hypothesis could be evaluated formally and yield information about the possible occurrence of habitat segregation between Blue Catfish and Channel Catfish as has been suggested in other studies (Gasaway 1970; Klaassen et al. 1971; Walburg 1976; Cannemela et al. 1978; Hubert et al. 1992; Graham 1999; Hubert 1999; Edds et al. 2002). Therefore, Blue Catfish may be suppressing the diet diversity of Channel Catfish because of habitat segregation in Lake Oconee. Furthermore, the mechanism for excluding Channel Catfish from habitat needs to be investigated to determine if direct predation or competition for food resources drives the behavior.

Blue Catfish are not the only species that may have altered ictalurid populations in Lake Oconee. Some scientists have implicated Flathead Catfish (*Pylodictis olivaris*) as another apex predator that may have an even greater effect on White Catfish and Channel Catfish populations than Blue Catfish (Thomas 1995; Bonvechio 2011; Scolesser et al. 2011; Orth et al. 2013). When Flathead Catfish are introduced into an aquatic system, they quickly decimate native ictalurid populations. Therefore, in the investigation of catfish declines, Flathead Catfish could be considered as a contributing culprit to the declines (Thomas 1995; Bonvechio 2011; Scolesser et al. 2011; Orth et al. 2013), even though Blue Catfish are considered to be the primary culprit. Additionally, a stable isotope analysis could be conducted to determine whether Blue Catfish or Flathead Catfish are higher in the trophic web. Furthermore, the food habits and movements of Flathead Catfish in Lake Oconee could be assessed because Flathead Catfish were only captured in areas where Channel Catfish were not present. This spatial segregation between the species may suggest that Flathead Catfish also play a role in excluding Channel Catfish to marginal shallow habitat in Lake Oconee. Therefore, future studies could evaluate not only Blue Catfish habitat use, but also the habitat use of Flathead Catfish in comparison to that of Channel Catfish.

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## FIGURES AND TABLES

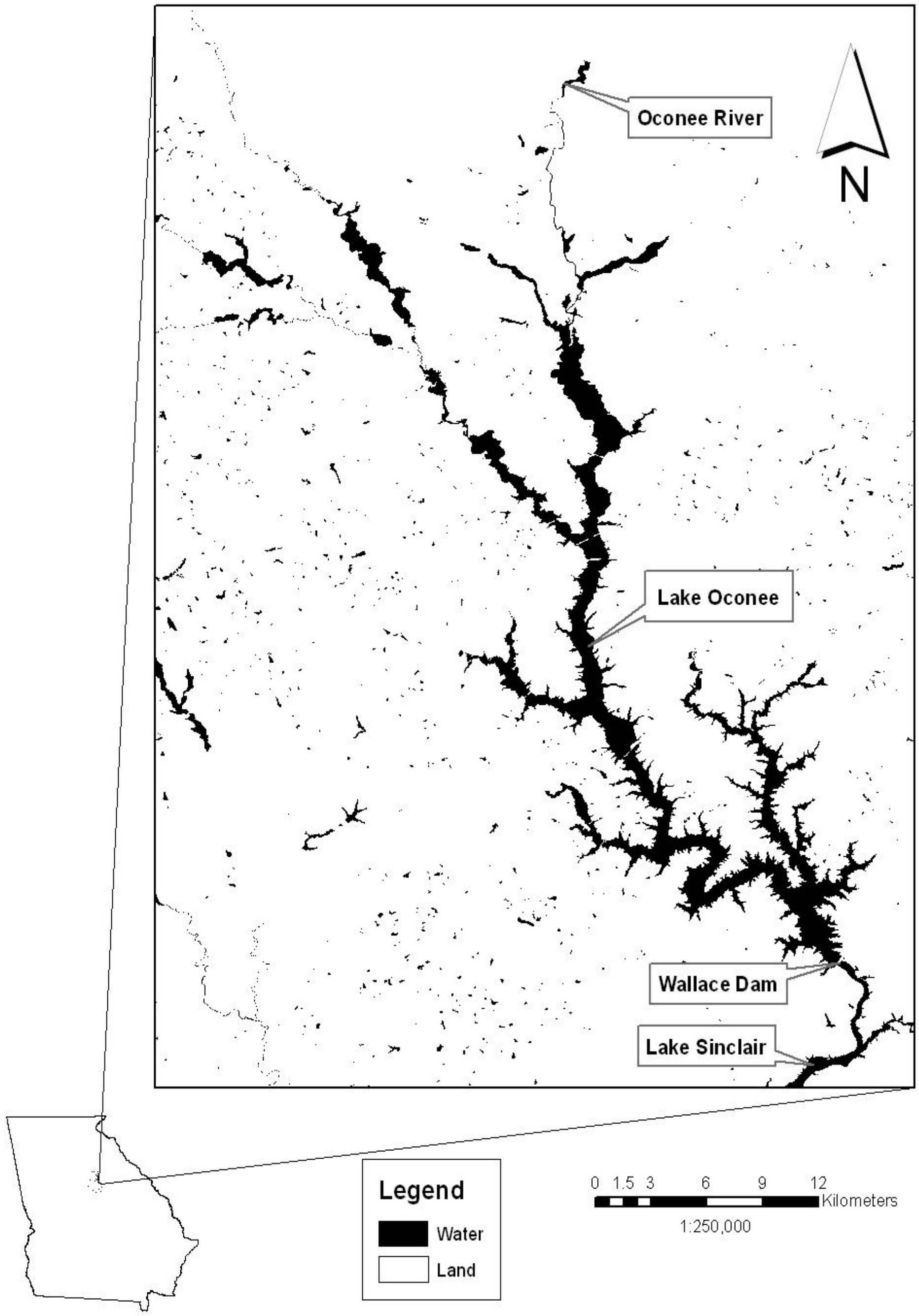


Figure 1. Map showing the location of Lake Sinclair, Wallace Dam, and Lake Oconee in middle GA.

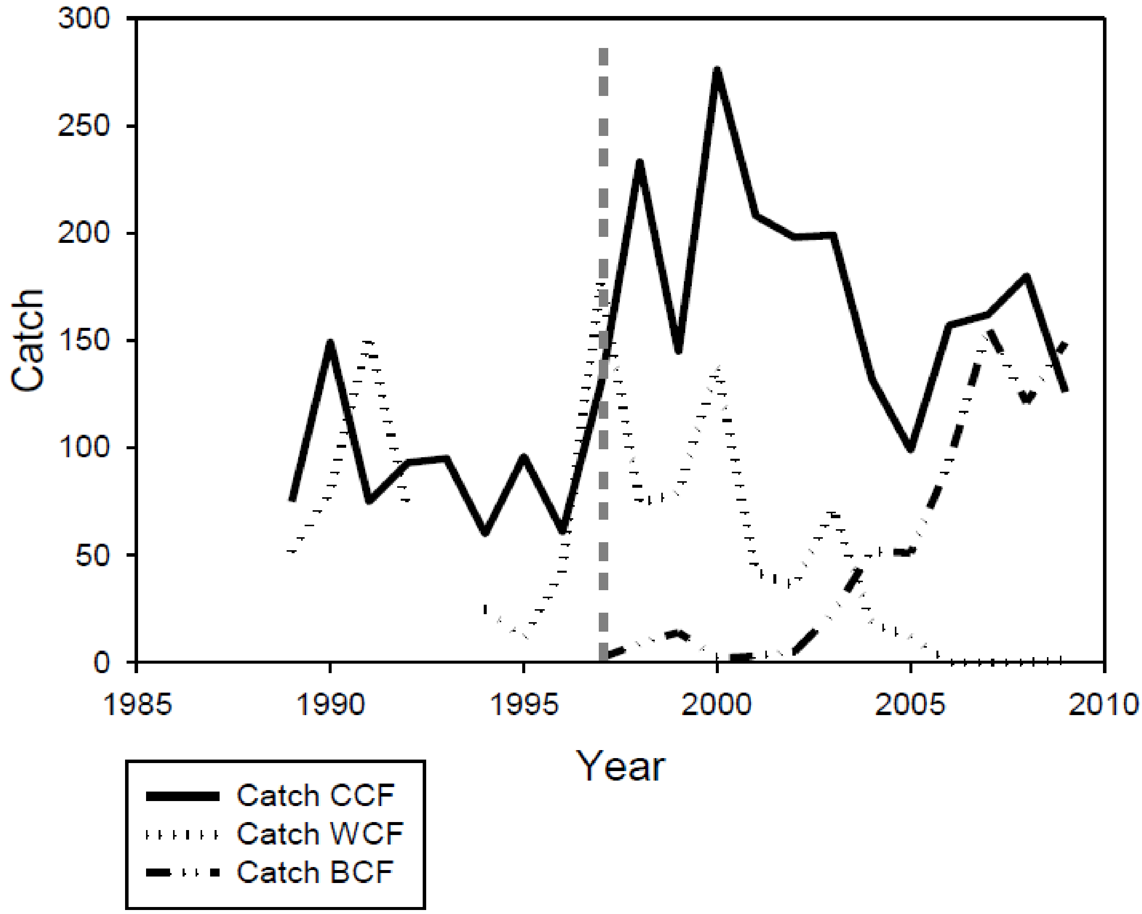


Figure 2. Gillnet catch of White catfish, Blue Catfish and Channel Catfish in Lake Oconee, GA during the period 1985-2010 (used with permission from Homer and Jennings 2011).

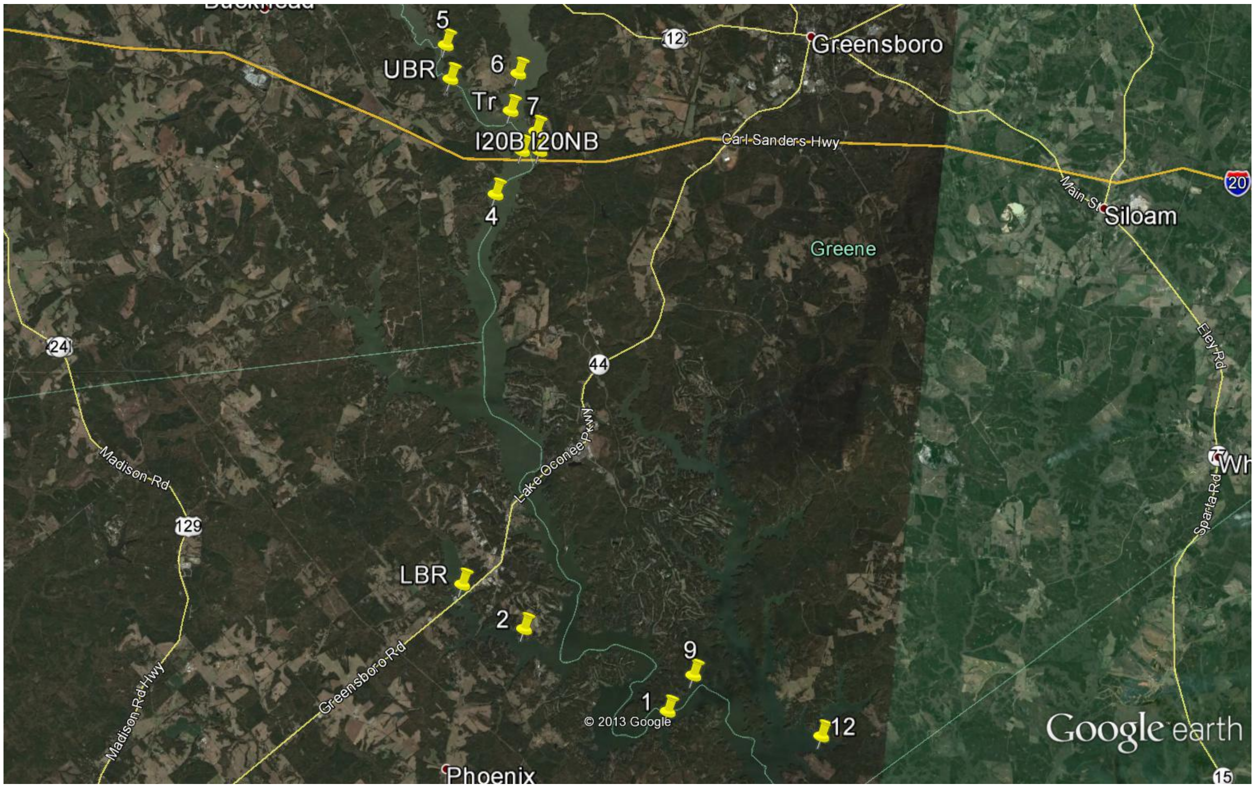


Figure 3. Illustration of 12 Georgia Department of Natural Resources standardized sampling in Lake Oconee, GA.

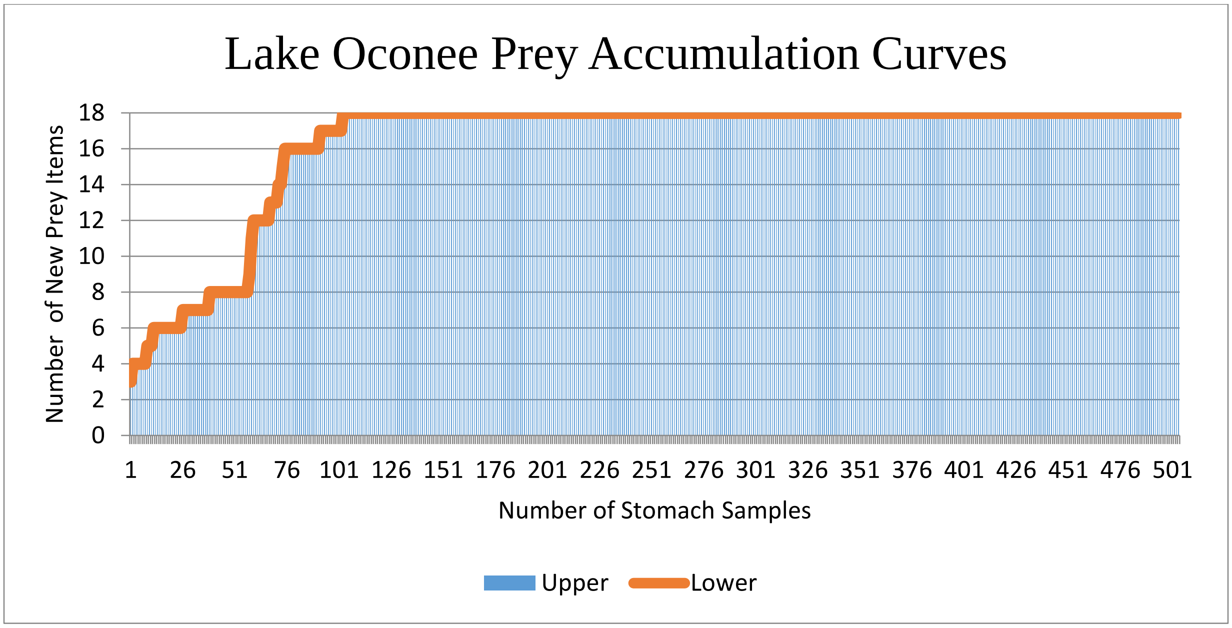


Figure 4. Blue Catfish prey accumulation curves for the upper and lower regions of Lake Oconee, GA (2012-2013).

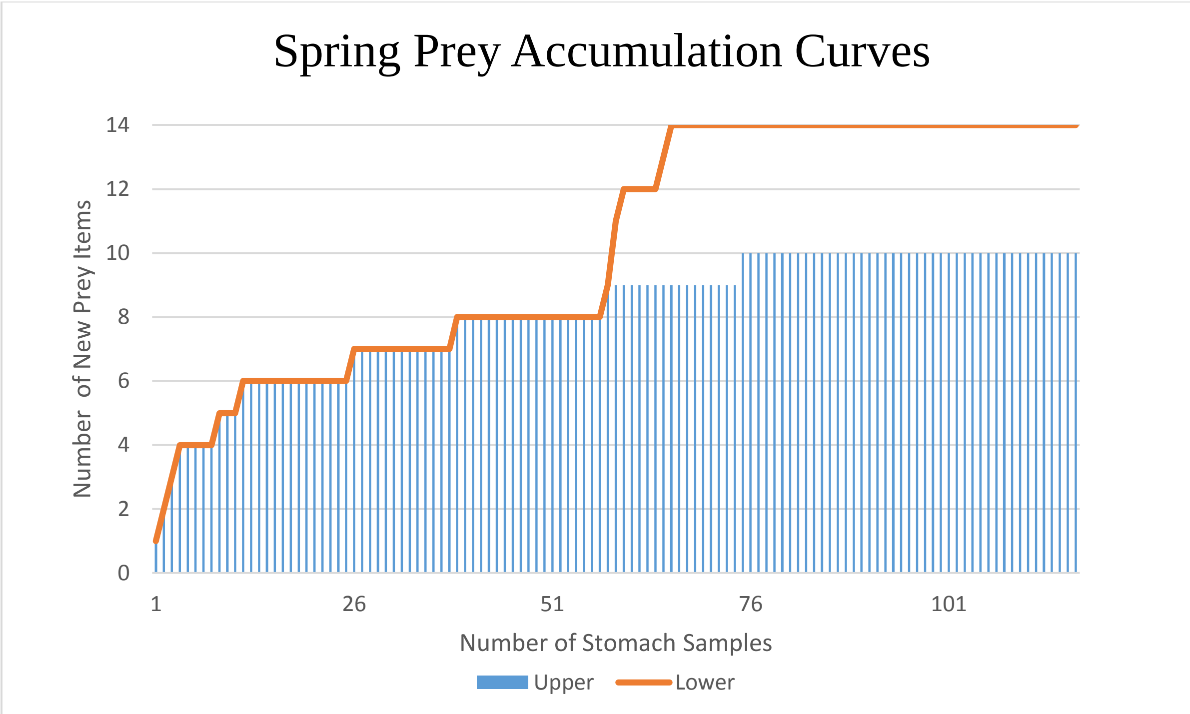


Figure 5. Spring Blue Catfish prey accumulation curves for the upper and lower regions of Lake Oconee, GA (2012-2013).

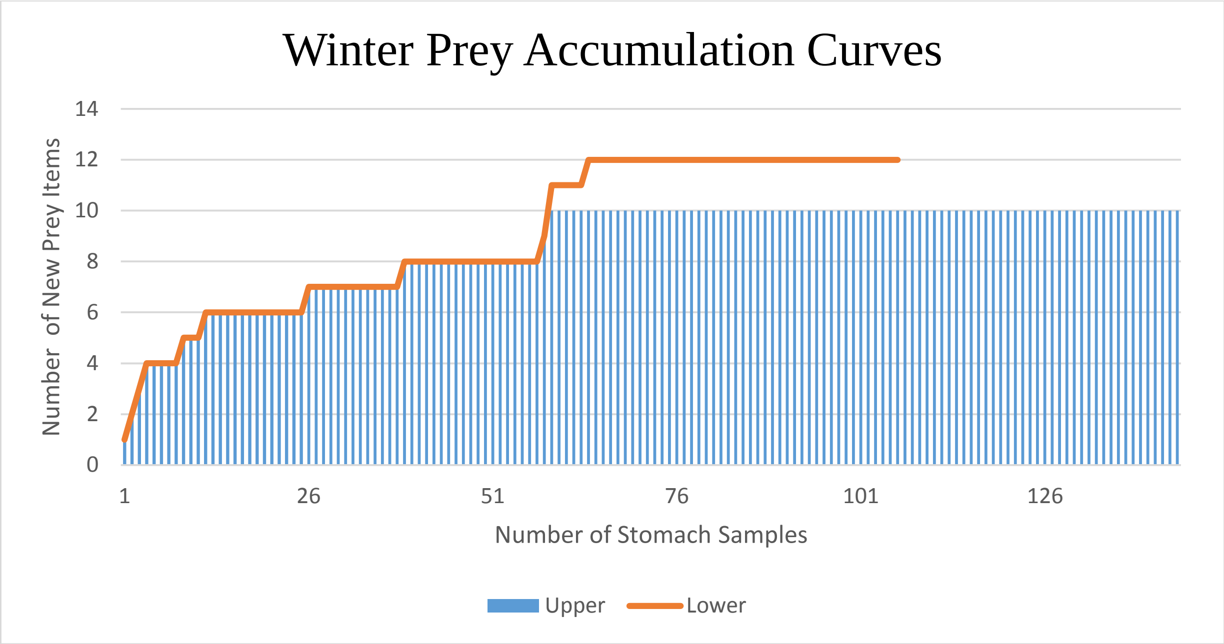


Figure 6. Winter Blue Catfish prey accumulation curves for the upper and lower regions of Lake Oconee, GA (2012-2013).

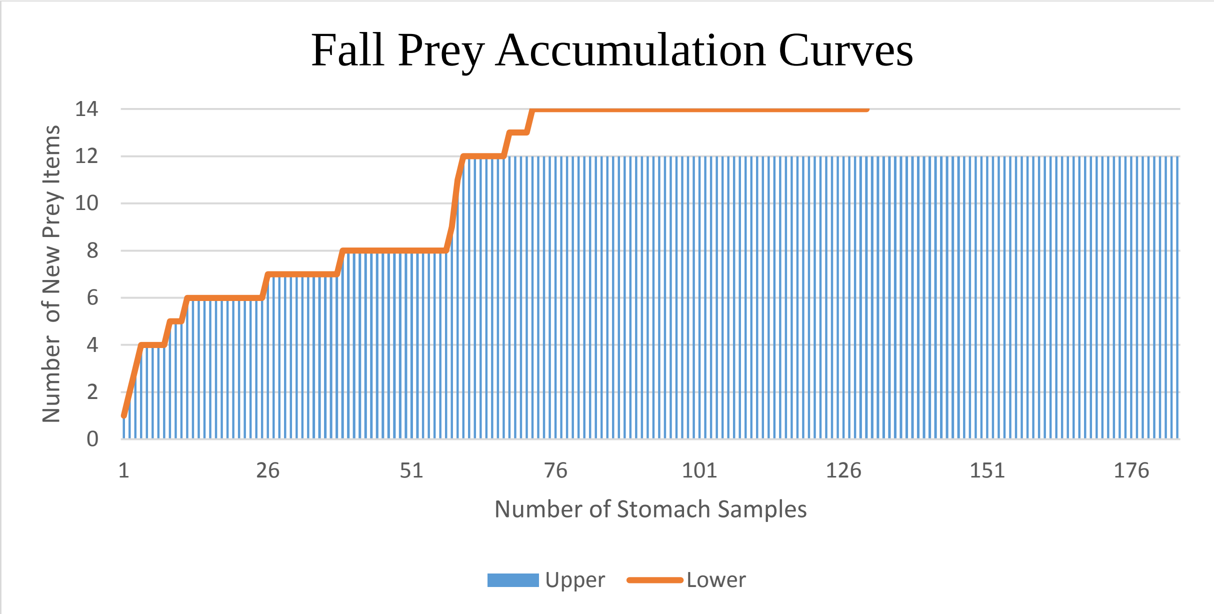


Figure 7. Fall Blue Catfish prey accumulation curves for the upper and lower regions of Lake Oconee, GA (2012-2013).

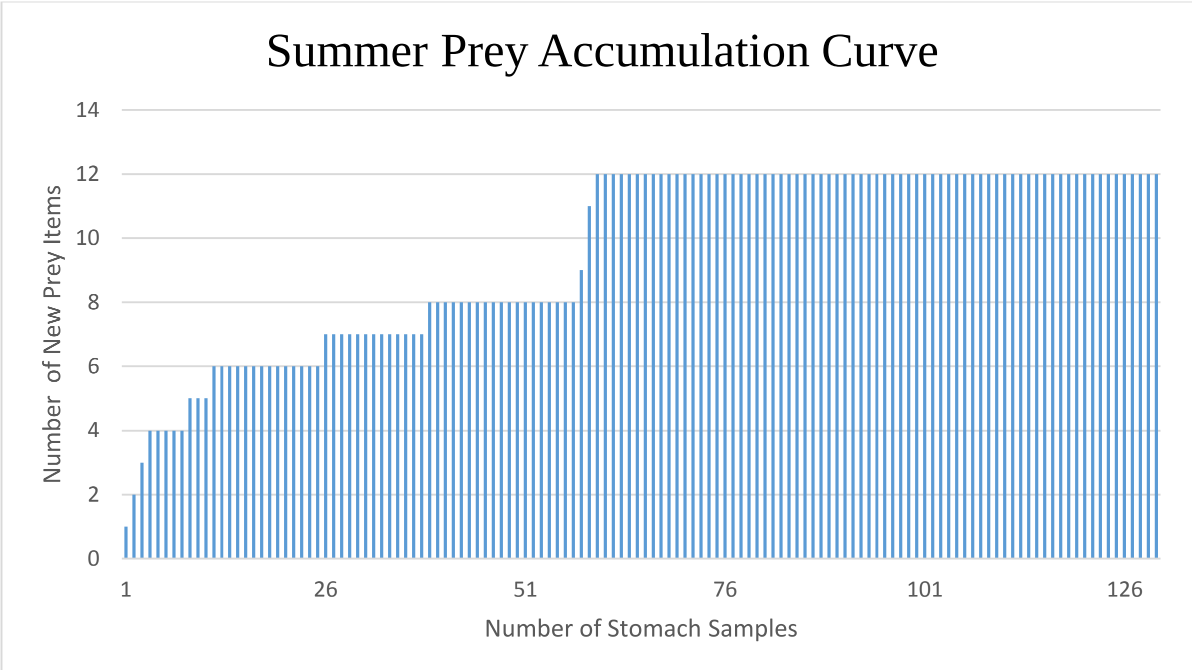


Figure 8. Summer Blue Catfish prey accumulation curves for the upper and lower regions of Lake Oconee, GA (2012-2013).

Table 1. Food item in stomachs of Blue Catfish (N=453) and Index of Relative Importance Percentage by region from Lake Oconee, GA, 2012-2013. SU=Summer, F=Fall, W=Winter, SP=Spring, Up=Upper Region, Low=Lower Region.

| **Prey Items** | **SU** | | **F** | | **W** | | **SP** | |
|---|---|---|---|---|---|---|---|---|
| | **Up** | **Low** | **Up** | **Low** | **Up** | **Low** | **Up** | **Low** |
| **Insects** | | | | | | | | |
| Diptera | 0.48 | N/A | 2.61 | 26.8 | 0.85 | 1.29 | 0.00 | 1.91 |
| Ephemeroptera | 0.07 | N/A | 5.80 | 24.5 | 64.2 | 16.2 | 83.3 | 78.7 |
| **Fish** | | | | | | | | |
| Dorsoma spp. | 0.79 | N/A | 24.6 | 7.83 | 25.7 | 49.0 | 0.22 | 1.98 |
| I. punctatus | 0.00 | N/A | 0.07 | 0.02 | 0.00 | 0.24 | 0.00 | 0.39 |
| I. furcatus | 0.00 | N/A | 0.03 | 0.00 | 0.30 | 0.58 | 0.12 | 0.32 |
| Pomoxis spp. | 0.29 | N/A | 0.00 | 0.00 | 0.38 | 0.41 | 8.79 | 2.70 |
| M. saxatilis | 0.00 | N/A | 0.16 | 0.00 | 0.00 | 0.29 | 0.18 | 0.09 |
| C. carpio | 0.00 | N/A | 0.00 | 0.00 | 0.00 | 0.04 | 0.00 | 0.13 |
| **Crustaceans** | | | | | | | | |
| C. fluminea | 97.6 | N/A | 66.4 | 40.6 | 8.59 | 31.8 | 7.40 | 13.5 |
| Unionidae | 0.00 | N/A | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 |
| Daphina spp. | 0.31 | N/A | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Amphipoda | 0.00 | N/A | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 |
| Decapoda spp. | 0.20 | N/A | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 |

Table 2. Food item in stomachs of Blue Catfish (N=453) and Specific Prey Index of Relative Importance Percentage by region from Lake Oconee Georgia, 2012-2013. SU=Summer, F=Fall, W=Winter, SP=Spring, Up=Upper Region, Low=Lower Region.

| **Prey Items** | **SU** | | **F** | | **W** | | **SP** | |
|---|---|---|---|---|---|---|---|---|
| | **Up** | **Low** | **Up** | **Low** | **Up** | **Low** | **Up** | **Low** |
| **Insects** | | | | | | | | |
| Diptera | 1.59 | N/A | 3.30 | 23.8 | 2.43 | 5.80 | 0.04 | 0.04 |
| Ephemeroptera | 1.24 | N/A | 5.30 | 21.7 | 37.3 | 9.70 | 83.3 | 62.2 |
| **Fish** | | | | | | | | |
| Dorsoma spp. | 1.83 | N/A | 16.17 | 6.18 | 18.8 | 0.79 | 0.22 | 0.79 |
| I. punctatus | 0.00 | N/A | 0.32 | 0.17 | 0.00 | 0.23 | 0.00 | 0.15 |
| I. furcatus | 0.03 | N/A | 0.03 | 0.00 | 0.18 | 0.20 | 0.06 | 0.06 |
| Pomoxis spp. | 0.12 | N/A | 0.16 | 0.00 | 0.27 | 0.25 | 8.79 | 0.44 |
| M. saxitilis | 0.03 | N/A | 0.33 | 0.00 | 0.09 | 0.24 | 0.07 | 0.07 |
| C. carpio | 0.00 | N/A | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 | 0.11 |
| **Crustaceans** | | | | | | | | |
| C. fluminea | 76.4 | N/A | 68.42 | 44.34 | 28.3 | 11.7 | 7.40 | 11.6 |
| Unionidae | 0.00 | N/A | 0.64 | 0.00 | 0.00 | 0.00 | 0.04 | 0.04 |
| Daphina spp. | 8.62 | N/A | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Amphipoda | 0.00 | N/A | 0.00 | 0.00 | 0.00 | 0.00 | 0.04 | 0.04 |
| Decapoda spp. | 0.07 | N/A | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.00 |
| **Other** | | | | | | | | |
| Hirudinea | 0.03 | N/A | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Polychaete | 0.03 | N/A | 0.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**APPENDIX**

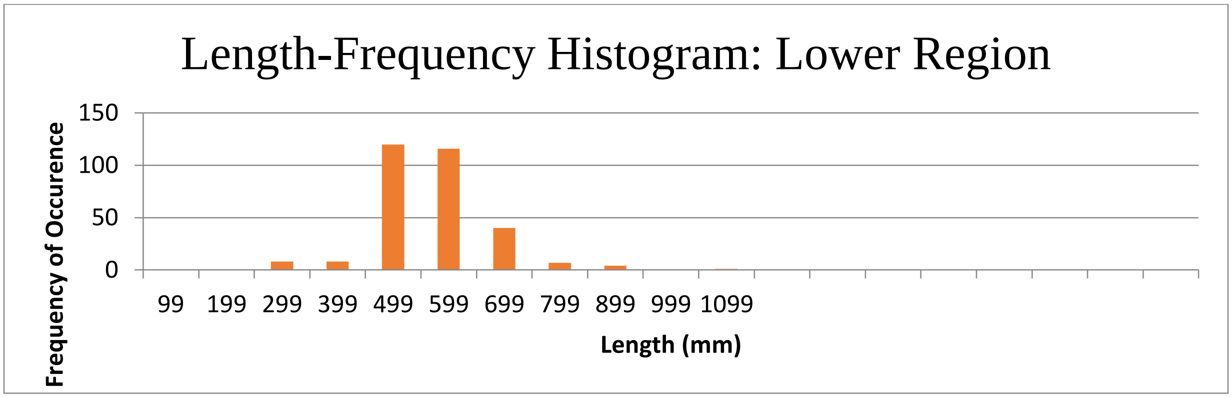


Figure 9. Length-frequency histogram of Blue Catfish in the lower region of Lake Oconee, GA, sampled during (2012-2013).

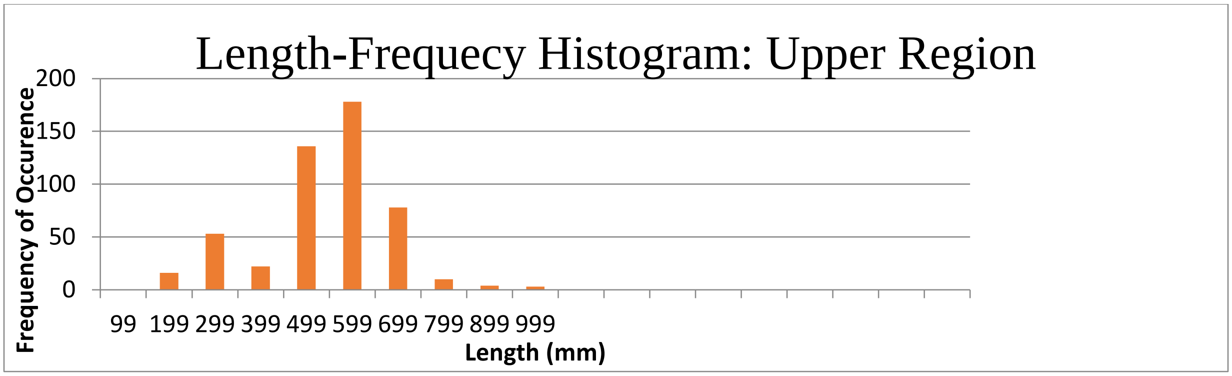


Figure 10. Length-frequency histogram of Blue Catfish in the upper region of Lake Oconee, GA (2012-2013).

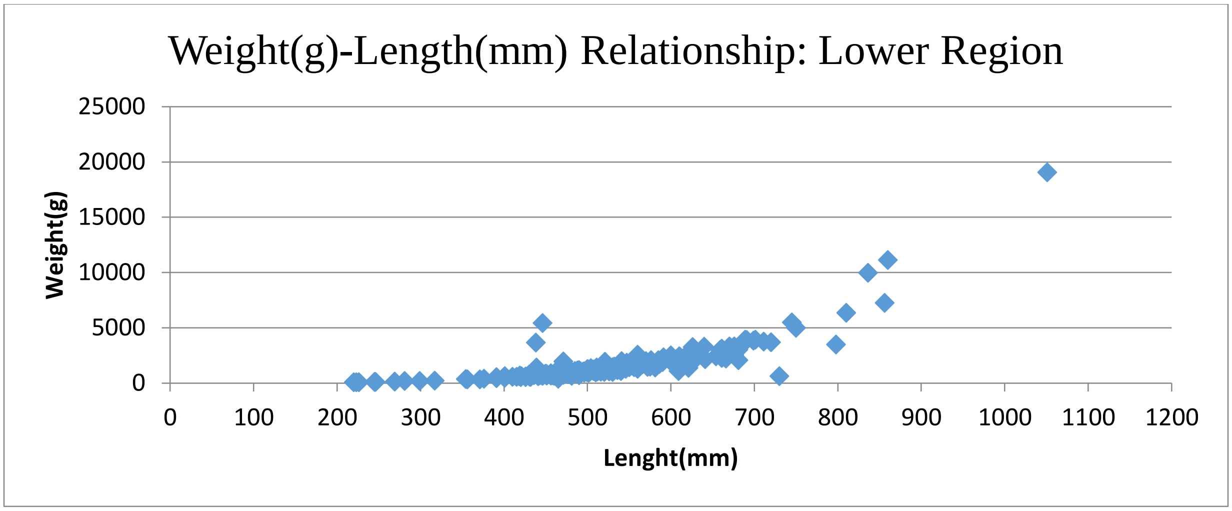


Figure 11. Length-weight frequency of the Blue Catfish from the lower region of Lake Oconee, GA, (2012-2013).

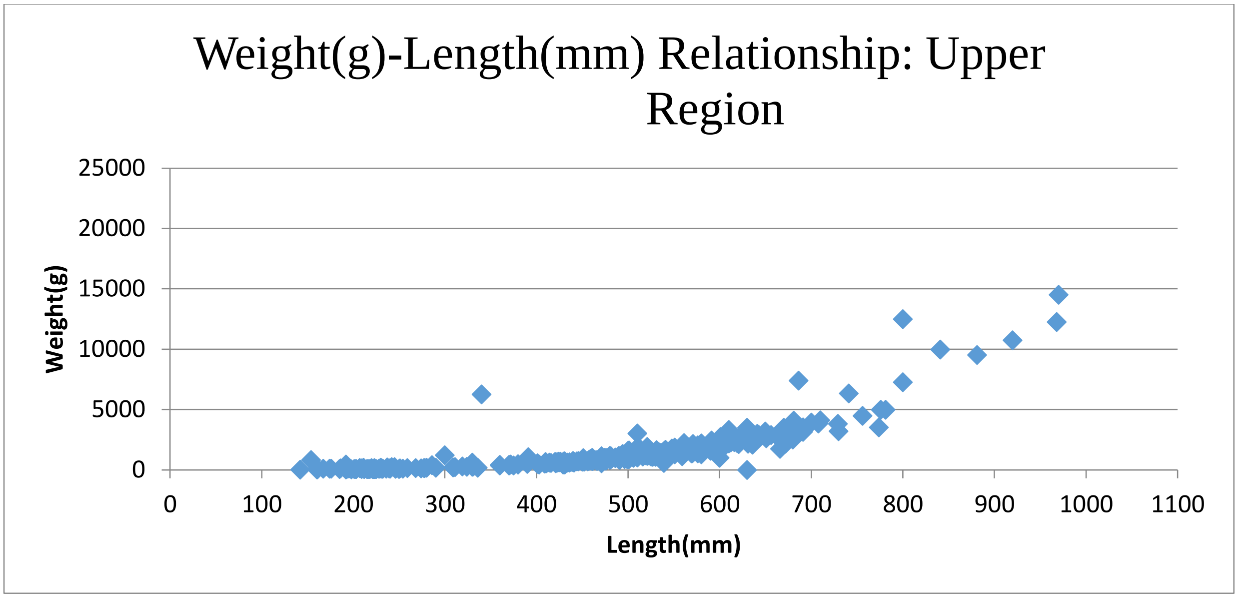


Figure 12. Length-weight frequency of Blue Catfish from the upper region of Lake Oconee, GA (2012-2013).