Northern Snakeheads in Two New York City Lakes over Four Years

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Abstract

A population of northern snakeheads *Channa argus* was discovered in two connected lakes in Queens, New York in 2005 and monitored by electrofishing over several years. During this time, catch per unit effort of snakeheads has remained relatively constant and that of most other fish species has remained the same or increased. The length-weight relationship is identical to that reported from the Potomac Basin northern snakehead population. Compared with the Potomac Basin, Queens fish are longer per age class as determined from fish scales. Despite being in suitable habitat, the Queens northern snakehead population has not increased as has been observed in other cases. Potential causal factors in this lack of or delay in population increase include water quality and presence of other fish species, although the exact reasons for slow population growth are unknown.

Introduction

The northern snakehead *Channa argus*, native to eastern Asia, has been introduced to areas outside its native range including the United States. This piscivorous top predator is an obligate air breather able to survive temperatures as low as $0^{o}C$ (Courtenay and Williams 2004). Northern snakeheads become reproductively mature at two-three years of age and are capable of spawning multiple times a year (Courtenay and Williams 2004). Northern snakeheads and other members of the genera *Channa* and *Parachanna* have been labeled injurious wildlife by the U.S. Fish and Wildlife Service due to their potential to disrupt aquatic ecosystems (Courtenay and Williams 2004). Importation, transportation or acquisition of live fish or viable eggs of the two genera is prohibited through the Federal Lacey Act (18 U.S.C. 42), and at least 36 states, including New York, prohibit or otherwise regulate the possession of live northern snakeheads or viable eggs.

Several established populations of northern snakeheads have been documented within North America from geographically diverse locations such as Crofton, Maryland (Courtenay and Williams 2004), the Potomac River System (Odenkirk and Owens 2005, 2007), the Piney Creek watershed in Arkansas (Wagner 2009) and Orange County, New York (M. Flaherty, New York State Department of Environmental Conservation [DEC] Bureau of Fisheries, personal communication). In June 2004, New York State enacted emergency regulations to ban live possession of all species of *Channa* and *Parachanna.*

Despite multiple introductions and extensive media attention, there remains limited published information on northern snakehead populations in North America outside of the Potomac basin. It is important to gather and report information on the effects of such introductions to help inform natural resource management decisions in the face of non-indigenous species introductions. In some cases this kind of information may be used to predict outcomes of such invasions or produce models used to evaluate invasive species management options (Jiao et al. 2009).

In June 2005, three northern snakeheads were retrieved from a fyke net set overnight in Meadow Lake, the larger of two connected lakes within Flushing Meadows Corona Park, Queens County, New York. In response to this discovery, both Meadow Lake and linked Willow Lake (collectively, MWL) were closed to fishing to prevent human transport of the invasive fish to other lakes and ponds. After the discovery of a single northern snakehead in another isolated New York City water body, the angling ban was rescinded with the provision that anglers report all snakehead catches. In addition, signs were posted by the New York City Department of Parks and Recreation warning about the potential ecological dangers of releasing snakeheads and providing instructions should one be caught by an angler. As of January 2011, no additional northern snakeheads have been confirmed outside of MWL in New York City.

The MWL system has only one outlet, which leads directly to the saline waters of Flushing Bay. This setting allows for the study of northern snakeheads without the concern that the population will naturally expand to contiguous freshwater bodies. Between June 2005 and October 2010, fishery surveys of MWL were performed through electrofishing, beach seining and trap netting to obtain data on the northern snakehead population as well as on other fish populations of this lake system. This paper describes data collected during this period on fish species abundance, catch-per-unit-effort (CPUE) for all resident fish species, as well as size and age distribution of captured individuals.

Study Site

Surveys were performed in Meadow and Willow Lakes (Figure 1), connected water bodies located wholly within Flushing Meadows Corona Park, Queens. Meadow is the larger (38.4 ha) and northern of the two lakes and is connected to the brackish Flushing Bay through a partially-constricted outlet in the lake's northeastern corner. The smaller Willow Lake (18.2 ha) joins Meadow through a *Phragmites sp.*-constricted canal. Both lakes were a former marsh transformed to a landfill for Brooklyn coal ash prior to the 1964-65 World's Fair (Caro 1974). Located within a city park, the lakes receive direct run-off from surrounding highways and parkland. Salinity varies with fresh and saltwater inputs and ranged from 0.4 to 3.8 ppt during the course of this study. Conductivity ranged from 742 to 6,900 µS/cm. Average dissolved oxygen concentration measured during surveys was 10.35 mg/L and ranged from 6.5 – 13.2 mg/L. Meadow lake pH was consistently measured at 9; pH data from Willow Lake is not available.

The shallow water depth of both lakes is relatively uniform and was not observed to exceed four feet at any time during the study. Bottom substrate is largely mud and muck with areas of sand and woody debris. Common reed *Phragmites australis* lines much of the shoreline of MWL with maintained lawns and playing fields beyond the *Phragmites* in Meadow Lake and less manicured vegetated areas beyond the *Phragmites* surrounding Willow Lake. The ultimate boundaries in both areas are roadways or highways. Pondweed *Potamogeton sp.* exists in patches around the perimeter of Meadow Lake. Submerged structure consisting of discarded urban debris is common.

Methods

All fish used in catch-per-unit-effort (CPUE) calculations were caught through boat electrofishing surveys between July 2006 and October 2010. Approximately 50% of the electrofishing surveys were executed in the summer, the remainder occurred in spring and fall. During the study period a total of six surveys were conducted in Meadow Lake and five in Willow. Additional northern snakehead fish used for length-weight and length-age calculations included twelve captured in two electrofishing surveys in 2005 using Smith-Root boats similar to the one described below, four fish captured by trap net in the summer of 2005 and one brought to the DEC offices by a local angler. Trapped fish were caught with a 2.54 cm mesh fyke net with seven 0.91 m-diameter hoops, a 15.24 m leader, and two 7.62 m wings set in zero to 1.21 m of water in the northeast corner of Meadow Lake.

Electrofishing surveys used for CPUE analysis were executed at night with a five meter Smith-Root 16H electrofishing boat with two umbrella arrays, each with six stainless steel dropper cables. Power was supplied by a Kohler 7,500 Watt generator set to 170 Volts. Frequency varied between 50 and 120 pulses per second and was adjusted during surveys for maximum effectiveness. Due to the variable conductivities of Meadow and Willow Lakes, output varied between 11 and 40 Amps of Direct Current (DC). Crews consisted of one driver and two dippers equipped with 0.635 cm mesh nets. Dippers attempted to collect all fish species except common carp *Cyprinus carpio* and American eels *Anguilla rostrata*, which were not netted for logistical reasons but all observed individuals were recorded. All netted fish were transferred to live wells for transport to shore where data collection was conducted. Average generator "on-time" was 61.5 minutes and ranged between 30 – 87 minutes throughout the reported surveys. Average number of fish collection sites was 3.5 and ranged between 2 and 6. Electrofishing sites were selected arbitrarily and the distance between sampling sites was kept as great as possible to minimize the potential to catch or observe snakeheads observed but not netted at earlier sites. Snakeheads were collected or observed only near the shoreline (Figure 1).

Catch per unit effort was standardized as the number of fish caught per hour. Surveys were conducted annually and semi-annually during the study period as scheduling allowed. Gizzard shad *Dorosoma cepedianum* and silversides *Menidia sp.* were not included in CPUE as large schools of these fishes were commonly but sporadically encountered, which would provide misleading estimates of catch rate. Length (mm) and weight (g) measurements were taken for all fish collected through electrofishing; scales were also removed for later age analysis. All fish except northern snakeheads were returned to the water. The weight-length relationship for the northern snakeheads was determined by linear regression of log transformed length and weight measurements.

Weights of smaller individuals were obtained using an Ohaus CS-5000 digital compact scale; larger individuals were weighed using a Rapala 8 kg digital fish scale. Ages were determined from fish scales mounted on 0.03 mm clear AA acetate with a rolling press and read on a Micron 375 microfiche reader. Every scale was viewed by at least three independent readers. Temperature, dissolved oxygen, salinity and conductivity were measured with a YSI Model 85. pH was measured with an Oakton waterproof pHTestr.

Results

A total of 52 northern snakeheads were collected from MWL during the study period, the majority by electrofishing (Table 1). (The additional specimen donated by a local angler was used only for deriving length, weight and age data). During electrofishing surveys, snakeheads exhibited a very strong leaping escape response compared to other species, similar to previous reports (Odenkirk and Owens 2005), resulting in additional fish that were observed but not netted (Table 1). There are also anecdotal reports of snakeheads in the canals feeding into the northeast corner of Meadow Lake and linking the two lakes, but physical characteristics precluded effective sampling of these areas. The majority of specimens collected or observed were full grown adults, including two gravid females. Most of the stomachs examined were empty, but a few contained identifiable food items consisting of parts of a grass shrimp *Palaemonetes pugio*, mummichogs *Fundulus heteroclitus*, and a backbone consistent with a silverside.

Catch Per Unit Effort

American eels, common carp, white perch *Morone americana* and sunfish *Lepomis spp.* were by far the species most commonly collected or observed (excluding *D. cepedianum* and *Menidia spp.*) during electrofishing surveys (Table 2). Northern snakehead was the sixth most common species collected. Since their discovery, electrofishing CPUE of northern snakeheads has fluctuated, but has not shown a consistent trend towards either decrease or increase in either lake. Northern snakehead CPUE in Willow Lake was highest in 2006 (Figure 2), hitting lows in 2008 in Willow and in 2009 in Meadow, while increasing again slightly in 2010 (Figure 2). During this same period, CPUE of most other species in Willow Lake was variable with no consistent positive or negative trend. In Meadow Lake, CPUE for most species remained stable or increased (Figure 2). Species richness and Shannon-Weiner Diversity Index values (H’), standardized to sampling effort, have likewise remained stable or increased, rising from six species per survey in Meadow Lake in 2008 to thirteen species in 2010 and fluctuating between seven and ten species in Willow. H’ has fluctuated between a low of 1.03 in March 2009 to a high of 1.32 in fall 2010 in Meadow Lake. H’ has been more volatile in Willow, which while in most years varies between 1.2 and 1.4, dropped to a low of 0.33 in July 2008 before increasing in subsequent years.

Age and Length

Not every captured individual was aged or weighed successfully; in the early part of the study many individuals were too large for the available scale and scales were not collected from every fish. The northern snakeheads for which ages were determined from scales ranged from 0-5 yrs, with age 2 being the most abundant age class (n=38, Figure 3). Total length (TL) of all fish (n=53) ranged from 96-790 mm but the total sample consisted mostly of larger, adult individuals (mean = 564 mm TL, SD = 175mm; Figure 3). A comparison of age and weight suggests that most growth occurs in years 0-3, with individuals in young age classes frequently achieving sizes above 550 mm TL (Figure 3). Total weight (n= 29) ranged from 9 – 5,035g (mean= 2,231.6g, SD =1,442.7g). The length- weight relationship was as follows:

$\log_{10}W = -5.17 + 3.06\log_{10}TL$ (n=29, R^2=.996)

Discussion

Conditions in MWL should be well suited for the northern snakehead population to expand based on known habitat requirements (Courtenay and Williams 2004). The lakes are shallow with submerged aquatic vegetation, an ample food source consisting of crustaceans and small fish, and a temperature range suitable for northern snakeheads (Herborg et al. 2007; Lapointe et al. 2010). Northern snakeheads, as evidenced through capture of young-of-the-year fish and multiple age classes, have an established breeding population in these lakes, but after four years of data collection, there is no evidence of the magnitude of population growth observed in the Potomac Basin (Odenkirk and Owens 2007).

It is unclear why the northern snakehead population has been slow to expand in MWL. One possible factor could be the resident fish species such as common carp. The CPUE of carp in MWL is greater than twice that of the next highest carp CPUE found through other DEC electrofishing surveys in New York City lakes and ponds. The unusually high numbers of carp could be affecting snakehead population growth by increasing lake turbidity to the point that eggs or fry may be impacted (Auld and Schubel 1978). However, northern snakehead habitat often includes turbid water (Courtenay and Williams 2004). Other coexisting fish species potentially impacting this northern snakehead population are the plentiful white perch, an abundant population of American eels, or recently observed largemouth bass (*Micropterus salmoides*). Any of these species have the potential to interfere with recruitment of juvenile northern snakeheads through predation or some other means. Additionally, *Lepomis* spp., also present in MWL, are potential egg predators, however northern snakeheads are known to aggressively defend their nests (Courtenay and Williams 2004).

Water quality of MWL could be a factor in curtailing a northern snakehead population increase. These lakes regularly receive salt water from Flushing Bay, although observed salinity was still relatively low, ranging from 0.4 to 4.0 parts per thousand. There is little published information on the exact water quality tolerances of this species. In the Potomac population, tracked individuals were observed primarily in considerably lower salinities of 0.1- 0.2 ppt (Lapointe 2010). Also of note is the relatively high pH of Meadow Lake. Although data is not available, pH is assumed to be high in Willow as well, given the history of the area as a coal ash dump. These pH levels are higher than those reported in other areas where northern snakeheads have proliferated, e.g. Crofton Pond, MD (Lazur and Jacobs 2002). While snakeheads can tolerate a wide range of environmental conditions (Courtenay and Williams 2004), it is possible that together these factors may be having an impact on recruitment.

Northern snakeheads are top predators, and non-native predator introductions have often led to negative ecological outcomes in aquatic systems (Cox and Lima 2006). However, during this period, CPUE of fish species other than snakeheads, including prey, have fluctuated from survey to survey but have shown no evidence of population decline. In the Potomac, despite an increase in northern snakehead numbers, populations of other species, as in this study, have not been affected either (Jiao et al. 2009). Surveys of Meadow Lake since 2006 have shown an increase in total fish CPUE and those of Willow Lake have shown little change. Other indicators of community health, species richness and H', have likewise fluctuated but not decreased overall since northern snakeheads were first reported.

While population growth rates differ, the physical characteristics of the northern snakeheads in MWL are similar to those published for the Potomac Basin population. The length-weight relationship is identical (to two decimal points) to that calculated for the Potomac population and the age distribution tends towards younger fish, although the average age is considerably lower than that for the Potomac fish (Odenkirk and Owens 2005, 2007). One consideration, however, is different age determination methods. In the Potomac Basin, otoliths were used to determine age, whereas scales were used in MWL, making the data less comparable. In MWL, we found northern snakehead scale annuli to be clearly defined, making scales a viable option for determining ages. Although scales are frequently used for age determination in many fish species, little documentation is available for their use in aging northern snakeheads. Additional data on the accuracy of ages obtained from northern snakehead scales would be highly desirable.

One notable feature of the MWL northern snakehead population is the large average size of individuals. Within each age class, MWL snakeheads were larger in average total length than those from the Potomac Basin (Odenkirk and Owens 2005, 2007) suggesting that snakehead growth rate in MWL is relatively fast. Based on comparisons of age and size, these large sizes are attained within the first few years, with slower growth in subsequent years.

Small sized individuals seem to be rare in MWL since only two northern snakeheads smaller than 100 mm have been obtained to date. The population skews toward larger individuals in general- the majority have been large adults, suggesting that recruitment or reproduction is hindered, but once recruited, individuals can thrive. As they grow, northern snakeheads become less vulnerable to the other predators in the lake, e.g. white perch, although predation by conspecifics is feasible.

The low capture rate of MWL juvenile northern snakeheads suggests that either reproduction of these fish is somehow limited or they are breeding in areas of MWL that are difficult to sample effectively. A rapid growth rate might also explain the low CPUE of small size classes, as it would present a limited window for their capture. Sampling effort is limited to a few trips a year, further reducing the probability of sampling during the fry or juvenile stages. Once recruited, however, growth rate into adulthood is high, but sources of adult mortality exist in MWL.

Anecdotal reports suggest anglers are removing adult snakeheads. This activity, in conjunction with the adults removed during each electrofishing survey, may be limiting reproduction and/or recruitment. Perhaps low reproduction/recruitment is due to a combination of adult removal and water quality which does not favor snakehead reproduction and/or recruitment, but the reason for low juvenile abundance is not known at this time.

Thus far, northern snakeheads seem to have integrated themselves into the fish assemblage of MWL. While there is not yet any observed adverse effect of northern snakeheads in MWL, models predict that these fish will have a negative ecological impact on fish in North America (Jiao et al. 2009). It is too early to predict that northern snakeheads will never expand or have an ecological impact in MWL, as the complete impact of a non-native species may take decades to manifest (Essl et al. 2010). Continued careful monitoring will be necessary to track the growth and impact of northern snakeheads in Meadow and Willow Lakes.

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Tables

Lake	Capture Method			
	Electrofishing Captured	Electrofishing Escaped (Observed)	Fyke Net	Seine Net
Meadow	34	21	4	1*
Willow	17	8	0	0

Table 1: Location and method of capture for all *C. argus* individuals collected or observed Between July 2005 and October 2010. * Refers to a single individual from Meadow Lake which independently leaped into a boat.

Species Common	Species Latin	Frequency (%)	
		Willow Lake	Meadow Lake
American Eel	*Anguilla rostrata*	18.8	52.8
White Perch	*Morone americana*	25.3	15
Common Carp/ Goldfish	*Cyprinus carpio/ Carassius auratus*	10.7	26.5
Pumpkinseed	*Lepomis gibbosus*	37.9	2.4
Bluegill	*Lepomis macrochirus*	3.2	1.1
Northern Snakehead	***Channa argus***	**1.7**	**1.8**
Largemouth Bass	*Micropterus salmoides*	1.3	0.1
Brown Bullhead	*Ameiurus nebulosus*	0.9	0.2
Gizzard Shad	*Dorosoma cepedianum*	Abundant*	0.01
Silversides	*Menidia* spp.	Abundant*	Abundant*
Other		0.3	0.2

Table 2: Species assemblage of Meadow/Willow Lakes, based on percentage occurrence from all surveys.
*Present in large but intermittently occurring schools.

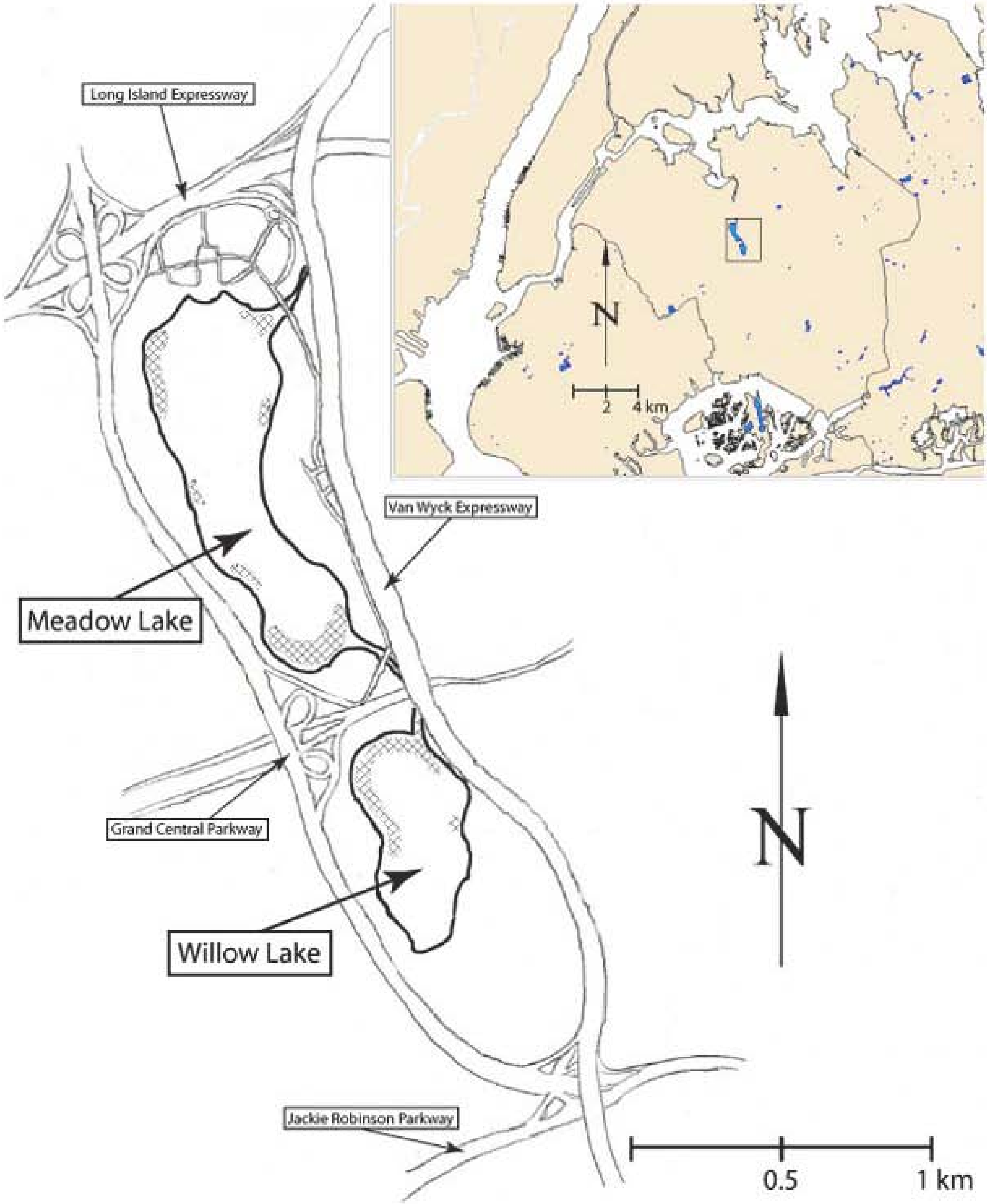

Figure 1: Meadow and Willow Lakes in Flushing, NY. Hatched sections indicate areas of each lake where northern snakeheads were observed or captured.

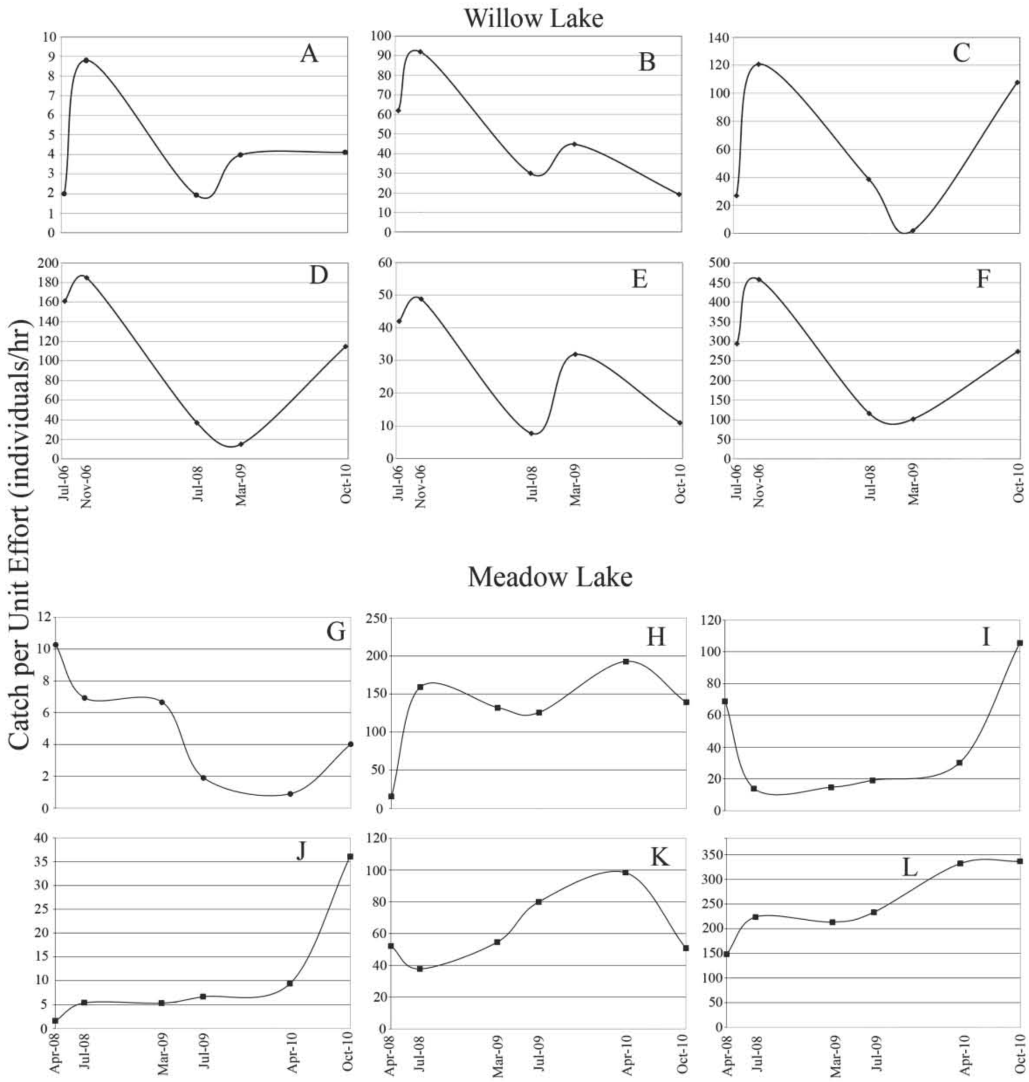

Figure 2: Electrofishing Catch Per Unit Effort (CPUE) of common species in Meadow and Willow Lakes, 2006-2010. 2a-f, Willow Lake. 2g-l, Meadow Lake. 2a, g- northern snakehead; 2b,h- American eel; 2c,i- white perch; 2d,j- bluegill and pumpkinseed; 2e,k- common carp and goldfish; 2f,l- Total CPUE for Willow and Meadow Lakes (excluding silversides and gizzard shad), respectively.

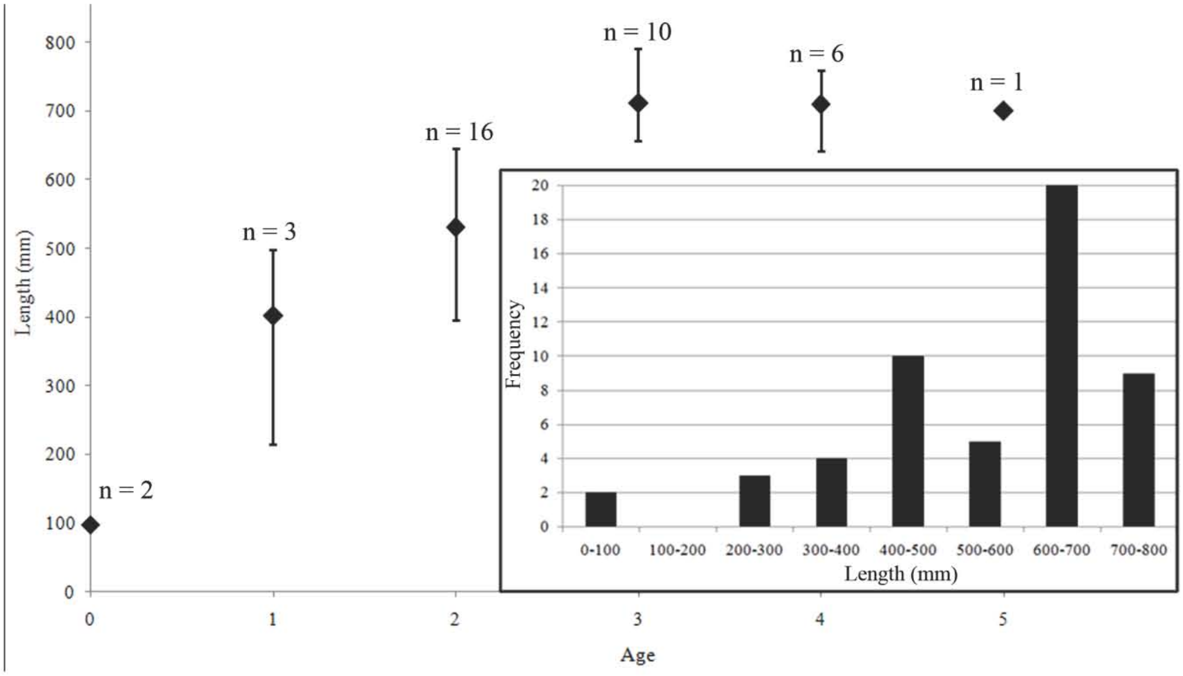

Figure 3: Average length (TL) per age class of captured northern snakeheads from Meadow and Willow Lakes (n-38). Error bars represent minimum and maximum TL for that age class.
Inset: Frequency distribution of all captured northern snakeheads (n=53).