Northern Snakeheads in New York City

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Abstract - A population of *Channa argus* (Northern Snakehead) was discovered in the Meadow/Willow lakes system in Queens, NY, in 2005 and monitored annually by electrofishing through 2013. Despite apparently suitable habitat, a variety of forage fish species, and rapid early growth by Snakeheads, the Meadow/Willow Snakehead population has not rapidly increased, as seen in many other areas, nor is there any evidence of negative impact on local species. Catch-per-unit-effort (CPUE) of Snakeheads remained relatively constant during the study period, as did CPUE for most other fish species observed, and Snakehead length–weight relationship was nearly identical to that previously reported from the Potomac Basin Northern Snakehead population. Potential causal factors in this lack of (or delay in) population increase include water quality, the presence of other fish species, and angling pressure, although the exact reasons for slow population growth are unknown.

Introduction

Channa argus Cantor (Northern Snakehead), native to eastern Asia, has been introduced to areas outside its native range, including the United States. This piscivorous, top-level predator is an obligate air breather able to survive temperatures as low as 0 °C, becomes reproductively mature at 2 to 3 years of age, and is capable of spawning multiple times a year (Courtenay and Williams 2004). Given their potential to disrupt aquatic ecosystems, Northern Snakeheads and other members of the genera *Channa* and *Parachanna* have been labeled as injurious wildlife by the US Fish and Wildlife Service. Importation, transportation, or acquisition of live fish or viable eggs of the 2 genera are prohibited through the federal Lacey Act (18 USC 42), and at least 36 states, including New York, prohibit or otherwise regulate 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, MD (Courtenay and Williams 2004); the Potomac River System (Odenkirk and Owens 2005, 2007); the Piney Creek watershed in Arkansas (Fuller et al. 2015); Orange County, NY (M. Flaherty, New York State Department of Environmental Conservation [DEC] Bureau of Fisheries, New Paltz, NY, pers. comm.); and portions of the Delaware River in Pennsylvania and New Jersey (Fuller et al. 2015). In June 2004, New York State enacted emergency regulations to ban live possession of all species of *Channa* and *Parachanna*.

In June 2005, three Northern Snakeheads were retrieved from a fyke net set overnight in Meadow Lake, 1 of 2 connected lakes within Flushing Meadows Corona Park, Queens County, NY. In response to this discovery, both Meadow Lake

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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 the Harlem Meer, another isolated New York City waterbody, the angling ban was rescinded with the provision that anglers report all Snakehead catches.

During the summer of 2011, a new population of Northern Snakeheads was reported and confirmed in a wetland area in College Point, Queens, 4 km north of MWL, at an abandoned airfield known as the Flushing Airport. An additional Snakehead captured by an angler in the Harlem Meer in Manhattan in 2012 indicated the full extent of the Snakehead population in the New York City area remains undetermined at this time. In October 2012, New York State sportfishing regulations were changed to require euthanasia and the reporting of any Snakeheads caught by anglers.

Despite multiple introductions and extensive media attention, information on Northern Snakehead populations in North America outside of the Potomac basin is limited. As such, it is important to gather and report information on effects of such introductions under various environmental circumstances to help inform natural-resource management decisions. In some cases, this kind of information may be used to predict outcomes of invasions or produce models used to evaluate invasive-species management options (Jiao et al. 2009). This paper presents data collected on fish species abundance and catch-per-unit-effort (CPUE) for resident fish species, as well as size and age distribution of captured individuals, between June 2005 and October 2013. We conducted MWL fishery surveys on the Northern Snakehead population, as well as on other fish populations of this lake system. We harvested additional individuals from the Flushing Airport system for age and growth metrics, but attempted no comprehensive population monitoring outside of MWL.

Field-site Description

We performed surveys in MWL (Fig. 1A), connected water bodies located wholly within Flushing Meadows Corona Park, Queens, NY. Meadow Lake is the larger (38.4 ha) and northernmost of the 2 lakes and is connected to the brackish Flushing Bay through a partially constricted outlet in the lake's northeastern corner. Willow Lake (18.2 ha) joins Meadow Lake through a *Phragmites australis* Cav (Common Reed)-constricted canal. Both lakes were a former marsh transformed to a landfill for Brooklyn coal ash prior to the 1964–1965 World Fair (Caro 1974). Located within a city park, both lakes receive direct run-off from surrounding highways and parkland. The system connects directly only to saline waters of Flushing Bay, which allowed for the study of Northern Snakeheads without concern that the population will naturally expand to contiguous freshwater bodies or be naturally supplemented from elsewhere.

Salinity varied with fresh and saltwater inputs, and ranged from 0.4 to 2.4 ppt in Willow Lake and 1.1 to 7.2 ppt in Meadow Lake during the course of this study. Conductivity ranged 742–3560 $\mu S/cm^3$ in Willow Lake and 2015–9300 $\mu S/cm^3$ in Meadow Lake. Average dissolved oxygen (DO) was 9.3 mg/l and 9.4 mg/l in Willow an Meadow lakes, respectively. Meadow lake pH was mostly consistently measured at 9.0, but had one reading as low as 7.0; pH in Willow Lake ranged between 7.0 and 8.1.

Water depth of both lakes was relatively shallow and uniform and was not observed to exceed 1.2 m (4.0 ft) at any time during the study. Bottom substrate was largely mud and muck with infrequent patches of sand and woody debris, and submerged structure consisting of discarded urban debris was common. *Potamogeton* sp. (pondweed) existed in patches around the perimeter of Meadow Lake. Common Reed lined much of the shoreline of MWL, with maintained lawns and playing

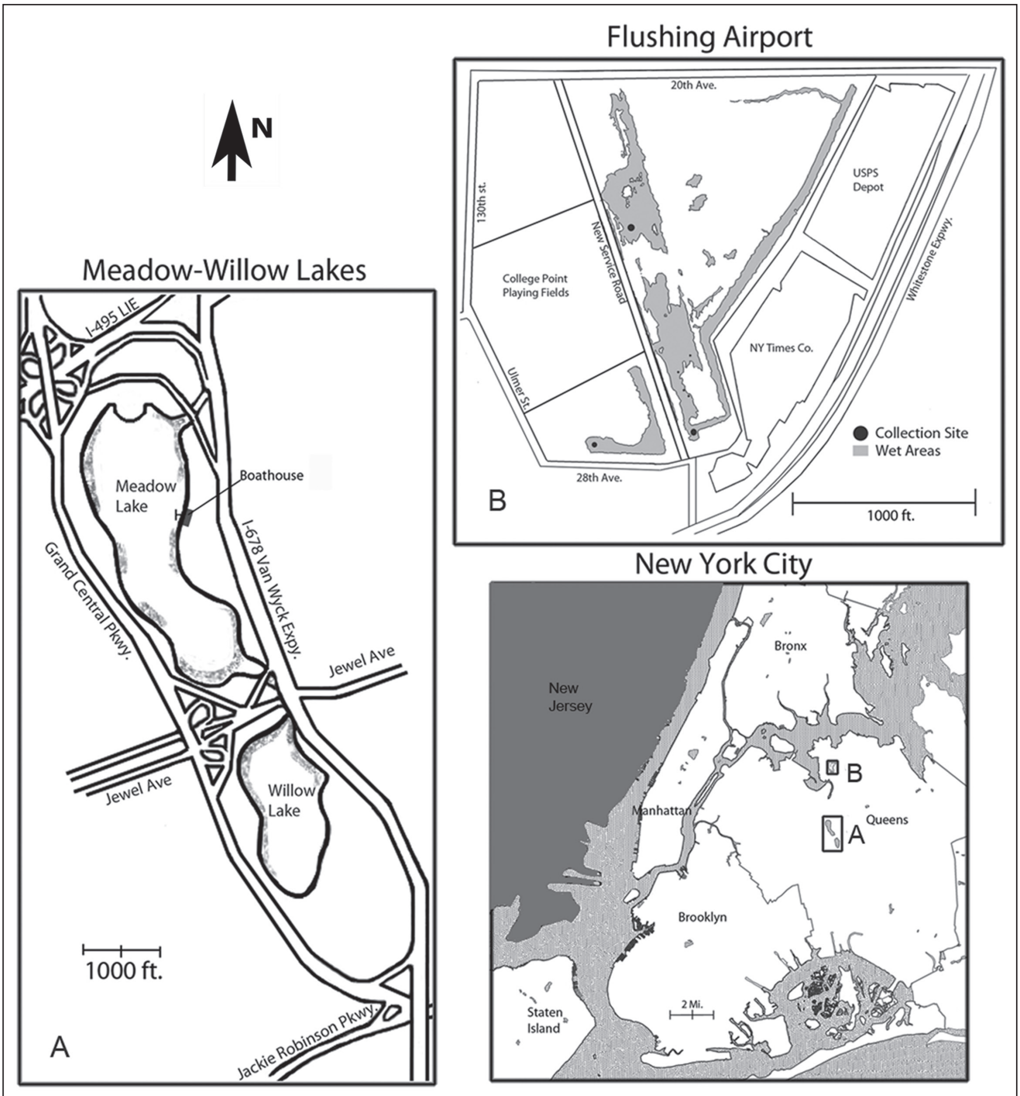

Figure 1. Maps of areas with confirmed snakehead populations in New York City. In Meadow and Willow lakes (A), shaded areas indicate locations of sampling sites. In the Flushing Airport area (B), dots representing sampling sites are scaled according to the number of fish collected.

fields situated beyond the Common Reed in Meadow Lake, and less-manicured vegetated areas located beyond the Common Reed surrounding Willow Lake. The ultimate boundaries in both areas were roadways or highways.

Flushing Airport (Fig. 1B) consisted of mostly freshwater wetland, isolated ponds, canals, and upland second-growth forest on the site of the formerly active airport, with some of the wetlands covering former runways. A shallow L-shaped retention pond was connected to the rest of the wetland system through a double culvert, which in turn was connected through another culvert to a small tributary of Flushing Creek. A pinched-off pipe cut the tributary off from the Flushing Airport System west of the Airport. The size and water level varied throughout the year depending on rainfall, season, and the actions of a construction crew installing a road through the property. Depth ranged from ~10.2 cm (4.0 in) plus an additional 30.5 cm (12 in) of silt to ~45.7 cm (18 in) deep. The area of the entire site including upland areas was 45 ha. DO, salinity, and conductivity in 2014 averaged 10.23 mg/l, 1.25 ppt, and 2433 $\mu S/cm^3$, respectively.

Methods

All fish used in CPUE calculations were caught through boat electrofishing surveys between July 2006 and October 2013. We initially conducted surveys between March and early November; however, since 2010, we conducted all surveys during October and November.

During the study period, we surveyed Meadow Lake 10 times and Willow Lake 8 times. We used a 2.5-cm-mesh fyke net with seven 0.91-m diameter hoops, a 15.24-m leader, and two 7.62-m wings set in 0.00–1.22 m of water in the northeast corner of Meadow Lake. We collected additional Northern Snakehead specimens from throughout the Flushing Airport area through angling and hand-netting between July 2011 and November 2014 and processed those specimens for length, weight, and stomach contents only. Northern Snakeheads used for length–weight and length–age calculations included 16 additional specimens captured in electrofishing and trap-net surveys in 2005, and 1 brought to the DEC offices by a local angler. We did not include in age or weight analysis 7 specimens that had accurate lengths recorded but were missing weight or age measurements.

Electrofishing surveys used for CPUE analysis were executed at night with a 5-m Smith-Root 16H electrofishing boat with 2 umbrella arrays, each with 6 stainless steel dropper cables. Power was supplied by a Kohler 7500-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 variable conductivities of Meadow and Willow lake waters, output varied between 11 and 40 amps of direct current (DC). Crews consisted of 1 driver and 2 dippers equipped with 0.635-mm (¼-in) mesh nets. Dippers attempted to collect all fish species except *Cyprinus carpio* L. (Common Carp) and *Anguilla rostrata* Lesueur (American Eel), which were not netted for logistical reasons, yet all observed individuals were recorded. All netted fish were transferred to live wells for transport to shore for data collection.

We selected shore sites used for data work-up based on boat accessibility. The water level in the system varies from year to year, and every effort was made to repeat sites from previous years, as access and conditions allowed. Additionally, we kept the distance between sampling sites as great as possible during each survey to minimize double-counting individual fish.

We standardized CPUE as the number of fish caught per hour and analyzed trends in CPUE over time for each species using linear regression. We did not include *Dorosoma cepedianum* Lesueur (Gizzard Shad) and *Menidia beryllina* (Cope) (Inland Silverside) in CPUE calculations, as large schools of these fishes were commonly, but sporadically encountered, which would provide misleading estimates of catch rate. We measured the length (mm) and weight (g) of all fish collected through electrofishing, removed scales for age analysis later, and returned all fish except Northern Snakeheads back into the waters from which they were caught. We determined the weight–length relationship for each Northern Snakehead population by linear regression of log-transformed length and weight measurements.

We obtained weights of smaller individuals using an Ohaus CS-5000 digital compact scale and weighed larger individuals using a Rapala 8-kg digital fish scale. We determined ages from fish scales, which we 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 2 independent readers, but in the rare case of a disagreement, a third viewer examined the scale. We measured temperature, dissolved oxygen, salinity, and conductivity with a YSI Model 85 hand-held meter calibrated to ambient temperatures, and pH both with pH paper strips and with a Hannah Instruments HI 991001 meter. We examined stomach contents under a dissecting microscope from either fresh specimens or ones that had been quickly frozen.

Results

We collected 62 Northern Snakeheads from MWL during the entire study period, the majority by electrofishing (the additional specimen donated by a local angler was used only for deriving length, weight, and age data). We collected 37 specimens from Flushing Airport. During electrofishing surveys, snakeheads exhibited a very strong leaping escape response compared to other species, similar to behavior noted in previous reports (Odenkirk and Owens 2005), resulting in fish observed but not netted. Snakeheads were collected or observed only near shoreline (Fig. 1). We had heard anecdotal reports of snakeheads in canals feeding into the northeast corner of Meadow Lake and linking the 2 lakes, but site characteristics precluded effective sampling of these areas. The majority of specimens collected or observed were adults, including 2 gravid females.

Catch per unit effort

American Eel, Common Carp, *Morone Americana* Gmelin (White Perch), *Lepomis* spp. (sunfish), and Gizzard Shad were the most commonly collected or observed species during electrofishing surveys, with Northern Snakehead the sixth

Table 1. Average percentages of fish species of Willow and Meadow lakes, Queens, NY, collected during electrofishing surveys between 2006 and 2013. Common Carp and American Eels were observed, but not captured, and are not included in the table.

Willow Lake	7/19/2006	11/2/2006	7/15/2008	3/25/2009	10/13/2010	10/18/2011	10/16/2012	10/29/2013
Inland Silverside	33.55	0.00	9.28	0.00	12.00	13.74	4.34	4.37
Gizzard Shad	24.34	58.91	66.17	3.70	26.61	6.59	5.43	7.92
White Perch	5.92	15.55	11.98	7.41	27.30	28.02	60.79	41.80
Lepomis gibbosus (L.) (Pumpkinseed)	35.31	23.48	8.38	48.15	22.78	48.72	24.29	38.80
Northern Snakehead	0.22	1.13	0.60	14.81	0.70	0.18	1.09	1.64
Carassius auratus (L.) (Goldfish)	0.22	0.21	0.60	7.41	0.00	0.00	0.00	0.27
Lepomis macrochirus Rafinesque (Bluegill)	0.00	0.21	2.40	7.41	5.91	0.92	0.95	0.27
Largemouth Bass	0.00	0.00	0.00	0.00	3.48	1.10	2.71	4.92
Ameiurus nebulosus Lesueur (Brown Bullhead)	0.00	0.31	0.30	11.11	0.87	0.55	0.41	0.00
Other	0.44	0.20	0.30	0.00	0.35	0.18	0.00	0.19

Meadow Lake	4/7/2008	7/8/2008	3/24/2009	7/6/2009	4/7/2010	4/8/2010	10/14/2010	11/3/2011	9/19/2012	10/28/2013
Inland Silverside	0	2.38	9.09	0.00	0	4.23	44.69	9.36	51.82	6.67
Gizzard Shad	1	0.00	0.00	0.00	0	2.82	7.08	3.37	1.52	5.83
White Perch	88	45.24	54.54	53.85	76	67.61	34.96	68.16	39.52	62.50
Pumpkinseed	2	16.67	18.18	15.38	4	0.00	11.5	16.48	6.48	17.50
Northern Snakehead	5	11.9	13.64	2.56	0	0.00	0.88	2.25	0.00	4.17
Goldfish	4	21.43	4.55	25.64	0	0.00	0.00	0.00	0.00	0.00
Bluegill	0	0.00	0.00	0.00	16	22.54	0.44	0.00	0.06	0.00
Largemouth Bass	0	0.00	0.00	0.00	0	0.00	0.44	0.37	0.00	0.00
Brown Bullhead	0	2.38	0.00	0.00	0	2.82	0.00	0.00	0.06	0.00
Other	0	0.00	0.00	2.56	0	0.00	0.00	0.00	0.55	3.33

most common species collected (Table 1). Since their discovery, the electrofishing CPUE of Northern Snakeheads fluctuated, but did not show a consistent trend, either decreasing or increasing, in either lake (Fig. 2). While the Northern Snakehead CPUE slightly increased during the past 2 electrofishing surveys (5.5 in 2013 and 5.9 in 2012), CPUE of most other species in MWL was similarly variable

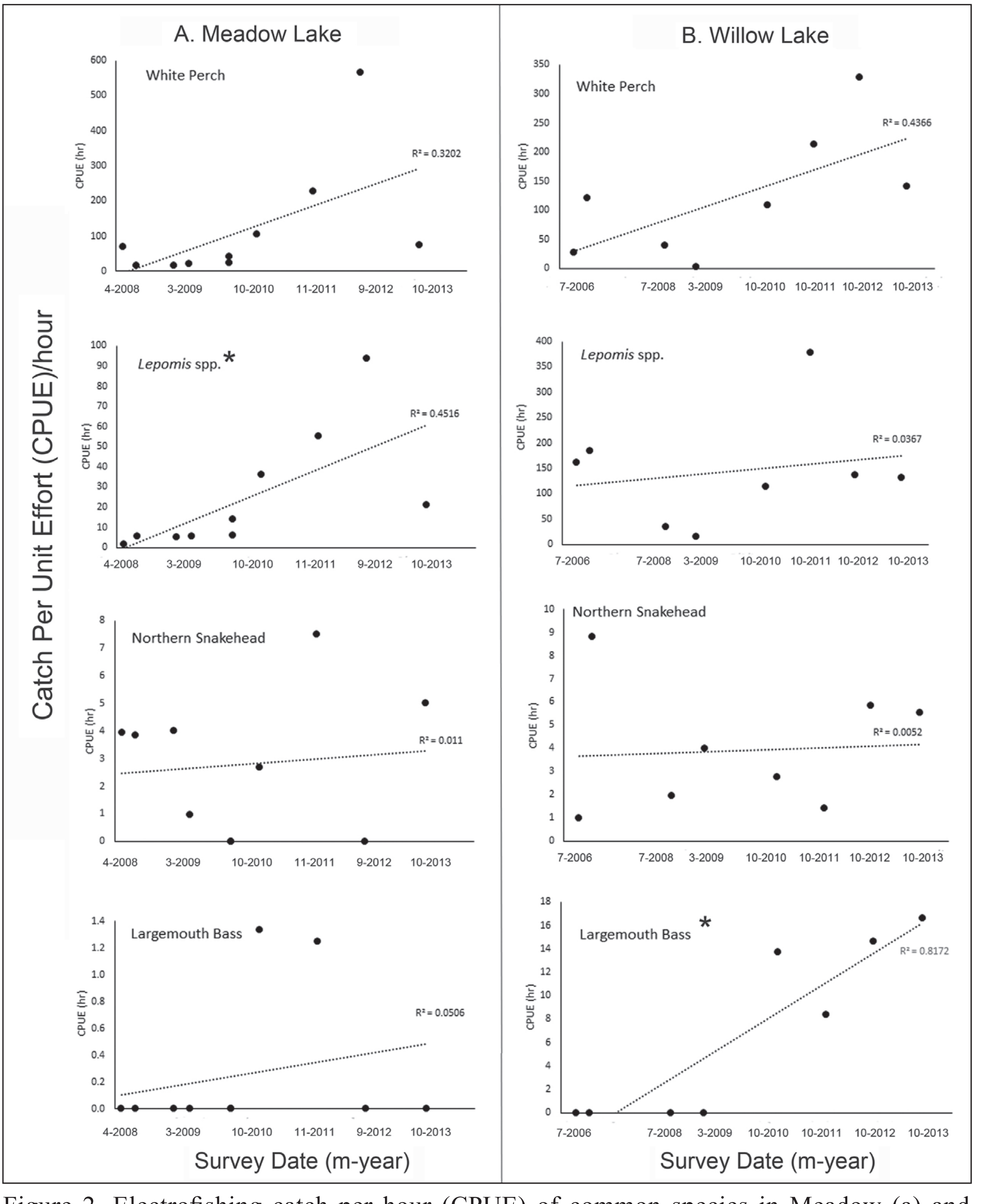

Figure 2. Electrofishing catch per hour (CPUE) of common species in Meadow (a) and Willow (b) lakes, NY, 2006–2013. Trend lines represent linear regression of CPUE by the number of days between surveys. Asterisks to the right of the species name indicate that the regression is significant at $P < 0.05$.

(Fig. 2). Species richness remained stable or increased, rising from 6 species per survey in Meadow Lake in 2008 to 12 species in 2010 and 9 in 2013. Similarly, diversity in Willow Lake increased from 7 species in 2008 to 11 species from 2011–2013. Shannon-Weiner diversity index values (H′), standardized to sampling effort, fluctuated but was relatively stable in Meadow Lake, rising to a high of 1.32 in autumn 2010, but dropping to a low of 1.00 in autumn 2013. In Willow Lake, H′ dropped to a low of 0.33 in July 2008, but rose to a high of 1.70 in autumn 2013.

Age and length

The MWL Northern Snakeheads for which ages were determined ranged from 0 to 6 years, with age 2 being the most abundant age class (n = 56; Table 2). Total length (TL) of all Snakeheads collected (n = 62) ranged from 97–813 mm, with the total sample consisting mostly of larger, adult individuals (mean = 571.5 mm TL, SD = 161 mm; Fig. 3). Total weight of MWL Snakeheads (n = 55) ranged from 9 to 5330 g (mean = 2231.6 g, SD = 1442.7 g).

Snakeheads taken from the Flushing Airport were smaller than those captured at MWL. With no age-0 fish captured, Airport fish ranged in size from 384 to 605 mm in length and from 680 to 1559 g in weight (Fig. 3). All Airport fish ages were between 1 and 3 years, with age class 2 being dominant in this population as well (n = 33; Table 2). A comparison of age and weight suggested most growth occurred in years 0–3, with individuals in young age classes frequently achieving sizes above 550 mm TL (Fig. 3).

The equation for the length–weight relationship from MWL Snakeheads was:

$$\log_{10}W = -5.20 + 3.07\log_{10}TL \ (n = 51, R^2 = 0.995)$$

The length-weight relationship in the Flushing Airport Snakeheads, based on a smaller sample size and a smaller length range, demonstrated a shallower slope:

$$\log_{10}W = -3.56 + 2.42\log_{10}TL \ (n = 33, R^2 = 0.833)$$

Diet

We dissected the stomachs of 24 Snakeheads from MWL and 21 Snakeheads from the Flushing Airport and analyzed their contents. Of those, 20 MWL fish and

Table 2. Age distribution of captured Northern Snakeheads in Queens, NY, based on scale annuli. Meadow and Willow lakes fish were captured between 2005 and 2013, Flushing Airport fish between 2011 and 2013.

Age	Meadow and Willow lakes	Flushing Airport
0	5	0
1	10	8
2	24	20
3	12	3
4	9	0
5	4	0
6	3	0
Total	67	31

18 Airport fish contained food items. The most common food item in the MWL system was fish; when identifiable, the most common fish prey were *Lepomis* spp. consumed by 4 MWL individuals (Table 3). Airport Snakeheads mostly consumed insects, especially dragonflies and water beetles (Table 3).

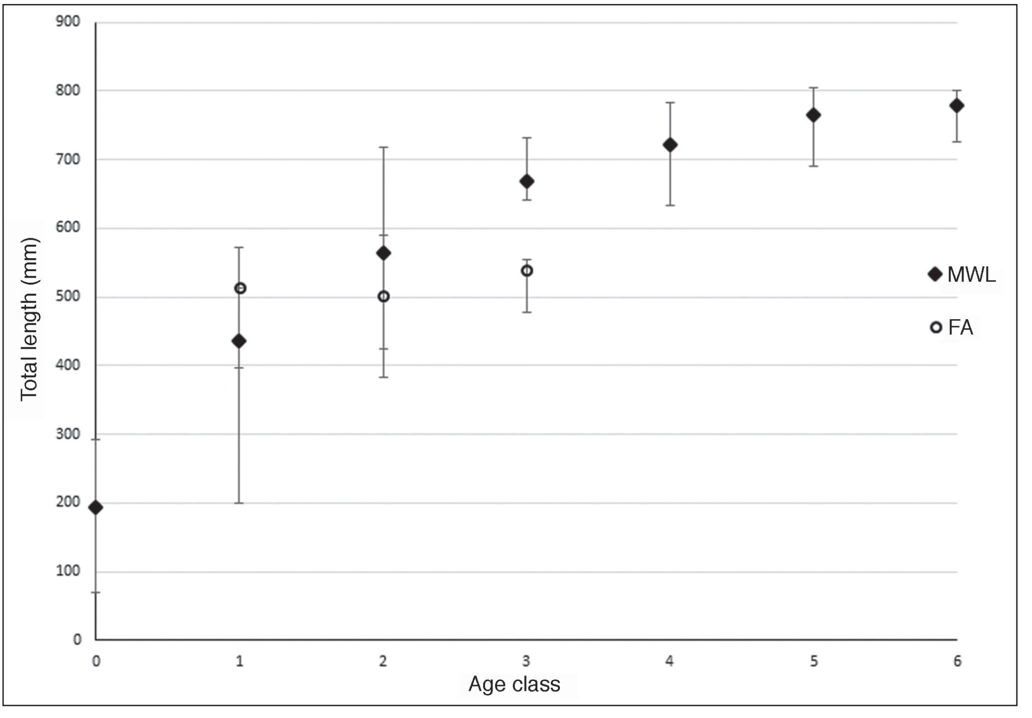

Figure 3. Mean Length at age for Northern Snakehead collected in Meadow and Willow lakes (MWL) and Flushing Airport (FA) sites. Error bars represent the maximum and minimum length for each age class.

Table 3. Food items found in Northern Snakehead stomachs between 2006 and 2013. Counts indicate the number of individuals that had consumed these items. Many stomachs contained more than one of each item. Empty stomachs are not listed.

Food Item	Meadow and Willow lakes (n = 20)	Flushing Airport (n = 18)
Lepomis spp. (sunfish)	4	0
White Perch	3	0
Gizzard Shad	1	0
Inland Silverside	1	2
Fundulus heteroclitus (L.) (Mummichog)	1	1
Grass Shrimp	2	0
Indeterminate fish	1	2
Nepomorpha (waterbugs)	0	7
Gastropoda (snails)	0	2
Odonata: Anisoptera (dragonflies,all stages)	0	8
Plant matter	0	1
Other insect	0	5

Discussion

Northern Snakeheads have an established breeding population in the MWL system, as evidenced through capture of young-of-the-year fish and multiple age classes, yet after 7 years of observation there is no evidence of the type of expansive population growth observed in the Potomac Basin. In that system, Odenkirk and Owens (2007) found that Snakehead CPUE increased by a factor of nearly 31 between 2004 and 2006, and by 2009, Snakeheads had spread widely throughout the entire Potomac system (Jiao et. al. 2009). The only increase we observed was higher Snakehead CPUE in Meadow Lake in 2012 and 2013 compared to 2011; however, Snakeheads as a percentage of total catch did not increase during that period, suggesting that the higher Snakehead CPUE during the final 2 years was a sampling artifact, i.e., more Snakeheads were captured only because more fish overall were captured. The greater number of fish caught in those years might be attributable to environmental conditions, such as increased water clarity and shoreline access, which increased catch efficiency of all fish species during later surveys.

The low Snakehead population growth was unexpected, as conditions in MWL should have been well suited for the population to expand rapidly, based on known habitat requirements (Courtenay and Williams 2004). The lakes are shallow with submerged aquatic vegetation providing an ample food source, consisting of *Palaemonetes* sp. (grass shrimp) and small fish, with a suitable temperature range for snakeheads (Herborg et al. 2007, Lapointe et al. 2010). Nonetheless, while Northern Snakeheads tolerate a wide range of environmental conditions, there is little published information on their water-quality tolerance (Courtenay and Williams 2004).

In MWL, water chemistry could be a factor in curtailing Northern Snakehead population increase. MWL regularly receives salt water from Flushing Bay, although observed salinity is still relatively low, ranging from 0.4 to 7.0 ppt. In the Potomac population, tracked individuals were observed primarily in considerably lower salinities of 0.1–0.2 ppt, although individuals have been routinely captured in salinity as high as 7.6 ppt (Lapointe et al. 2010, Starnes et al. 2011). MWL also has relatively high pH, levels higher than those reported in other areas where Northern Snakeheads have proliferated (e.g., at Crofton Pond, MD; Lazur and Jacobs 2002).

Another possible factor affecting Snakehead population growth could be the influence of resident fish species, such as Common Carp or Gizzard Shad. The observed number of Carp in MWL far exceeds that observed anywhere else in New York City (NYS DEC 2015). The unusually high number 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). High numbers of Gizzard Shad may further increase lake turbidity and exacerbate the impact (Schaus 2007); however, Northern Snakehead habitat often includes turbid water (Courtenay and Williams 2004).

Other coexisting fish species potentially affecting this Northern Snakehead population are White Perch, an abundant population of American Eels, and/or recently observed *Micropterus salmoides* Lacépede (Largemouth Bass). Any of these species have the potential to limit recruitment of juvenile Snakeheads through predation or other means. Additionally, *Lepomis* spp. are known egg predators, though Northern Snakeheads are known to aggressively defend their nests (Courtenay and Williams 2004). Snakehead mortality due to angling may also be having an impact, although this is impossible to measure since the majority of catches are not thought to be reported, despite regulations. A number of factors could be keeping the Snakehead population from increasing, but identifying specific causal factors is not possible at this time.

Northern Snakeheads are apex predators (i.e., existing at the top of a food chain, often affecting prey populations), and non-native predator introductions have often led to negative ecological outcomes in aquatic systems (Cox and Lima 2006); however, there is no evidence that Snakeheads in MWL are reducing populations of other fish species in the lake. During the study period, CPUE of other fish species, including prey, fluctuated from survey to survey, but showed no evidence of population decline. Other indicators of community health (e.g., species richness, H′) have likewise fluctuated in MWL but not decreased overall since Snakeheads were first reported. Similarly, in the Potomac River, populations of other fish species have not yet been affected, despite the increase in and expansion of the Snakehead population (Jiao et al. 2009).

The lack of impact on other fish species in MWL is notable. Diet analysis shows that Snakeheads in MWL directly consume local species, but not yet in sufficient quantities to cause a noticeable population decline. The observed diet of MWL Snakeheads was similar to the diet recorded for the Potomac Snakehead population, where it overlapped with Largemouth Bass diet (Saylor et al. 2012), although Potomac Bass populations were not seriously impacted (Love and Newhard 2012). Forecast models for the Potomac system, however, suggest that Northern Snakeheads may eventually negatively impact Largemouth Bass populations when the 2 species sufficiently overlap geographically (Love and Newhard 2012).

Largemouth Bass were first recorded in MWL during a survey in 2010, after the snakehead introduction, with Bass numbers increasing in Willow Lake since then. Multiple size classes indicated that Bass were successfully reproducing. Given the relatively small size of the system, overlap between the 2 species is anticipated, providing further opportunity to continue monitoring the interaction between an introduced and resident native predator.

Physical characteristics of Northern Snakeheads in MWL were similar to those published for the Potomac Basin population. Length–weight relationship was nearly identical (Odenkirk and Owens 2005, 2007), as was length-at-age (Odenkirk et al. 2013). MWL Snakehead growth was very rapid, with most occurring in the first few years and relatively large sizes attained by age 1. As an aside, our study relied on scales instead of otoliths to determine age, given the majority of the Snakeheads in this study were under 3 years of age. Scales were collected from the base of the pectoral fin, the location identified as providing the most accurate results for younger Snakeheads (Gu et. al. 2013). Considering the close resemblance to the Potomac length–age summary data, these results provide reasonable confidence in the accuracy of the ages in this study, particularly in the younger Flushing Airport fish. As found by Gu et al. (2013), however, scales tend to underestimate age in older individuals, so there may be some uncertainty in the age determination of the older MWL Snakeheads.

While no larger Snakehead specimens had been obtained from the Flushing Airport site, length-at-age data suggested rapid growth occurred during the first year for fish in that population as well. The length and weight of Flushing Airport fish stabilized after age 1, however, and their weights were low compared to MWL fish. Reduced growth was possibly a result of the Flushing Airport fish being food-limited in comparison to those fish at MWL. Stomach contents collected from Flushing airport Snakeheads were poor quality (mostly insects and a few small prey fish) compared to MWL stomach contents (mostly more and larger prey fish). In both MWL and Flushing Airport populations, however, average length-at-age was considerably greater than recorded lengths for Northern Snakeheads in their native range (Gascho Landis et al. 2011).

Small-sized Northern Snakeheads were either rare or difficult to capture in MWL; only 2 individuals smaller than 100 mm were obtained. The known bias of electrofishing—affecting larger individuals more than smaller individuals—was likely a contributing factor in the low capture rate for juvenile snakeheads (Reynolds 1996). Small individuals were also more difficult to spot in the turbid water; however, numerous small individuals of other species were captured throughout the study, so sampling bias was probably not the complete explanation. Rapid first year growth, for example, may have presented only a limited window in which very small snakeheads might have been sampled. It may also be that Northern Snakehead reproduction was limited or occurred in areas of the system that were difficult to sample; yet, the sampled population's larger adults indicated that successful growth was possible beyond juvenile stage. The reason for low juvenile capture rates was probably a combination of sampling bias and other factors, but the complete reason remains unknown 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 Snakeheads in MWL, models predict these fish will have a negative ecological impact on native fishes in North America (Jiao et al. 2009). It is too early to predict that Northern Snakehead will never have an ecological impact in MWL, as the complete impact of a non-native species may take decades to manifest (Essl et al. 2011). Continued careful monitoring of Northern Snakeheads in New York City will provide an opportunity to further understand the impacts of this introduced predatory fish and its interactions with native species in an urban freshwater environment.

Acknowledgments

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