TECHNICAL REPORT

DIETS AND PREY PREFERENCE OF NORTHERN SNAKEHEAD

by

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Introduction

Invasive aquatic species can cause ecological harm to biodiversity and economic hardships (Pimentel et al. 2005). Northern snakehead *Channa argus* is an invasive, primarily fish-eating species that is native to Asia. It was introduced to temperate areas of North America in the early 2000s and has been considered a nuisance or invasive largely because of its life history traits (Courtenay and Williams 2004; ANSTF 2014). The species has increased in relative abundance by 10- to 100-fold since introduction in streams tributary to Potomac River, the second largest river of the Chesapeake Bay watershed, and has either maintained or slightly decreased in relative abundance in those streams (Odenkirk and Isel 2016). It has spread rapidly throughout the Chesapeake Bay watershed (Odenkirk and Owens 2005; Love and Newhard 2018) and in newly colonized areas, has gained abundance despite numerous initiatives to encourage lowering population sizes via harvest (Love and Genovese 2019). Negative consequences of this expansion include possible disease transmission (Iwanowicz et al. 2013), possible but minimal effects on population growth of largemouth bass *Micropterus salmoides* (Love and Newhard 2012; Love et al. 2015), and competition with other piscivores if resources become limiting (Saylor et al. 2012).

The ecological disturbance that northern snakehead has caused North American ecosystems has not been widely studied across its introduced range, leaving unresolved whether there are deleterious effects owed to introduction (Orth 2019). There is evidence that the species is a top predator that forages on a wide range of fishes (Saylor et al. 2012) and crayfish and amphibians (pers. obs., JWL; Isel and Odenkirk 2019). In some cases, exotic aquatic predators have elicited strong declines in abundance and changes in aquatic community structure (Pycha and King 1975; Awiti 2011; Gallardo et al. 2016). Introductions of a species can therefore constitute a major

disturbance to an ecosystem. The reason we conducted this work was to assess some aspects of disturbance owed to introduction of northern snakehead. We examined whether northern snakehead showed innate preference for a prey type, which lends insight into whether there is a threat to the persistence of particular prey fishes. Isel and Odenkirk (2019) indicated little prey preference based on diet habits and field surveys. We furthered their research by using outdoor pond experiments with a known fish community to test for prey electivity. The objective of this study was to explore prey preferences for northern snakehead by using outdoor pond experiments.

Methods

We used ten experiments in a pond to examine prey preferences for Northern Snakehead. The pond was a lined, 0.10 hectares outdoor pond filled with water from a reservoir. The pond was covered with a 50 millimeter mesh net to prevent bird or reptiles from entry. Habitat features were added to the pond, including buoys, floats, a 2 meter x 3 meter plastic structure, two nest boxes made of wood (1 meter x 1 meter) and two cinder blocks. Neither type nor number of structural elements changed throughout the experiments. The pond was aerated to provide dissolved oxygen during the experiment. Water temperature in the pond ranged between 20.6 degrees Celisus **–** 29.7 degrees Celisus, with conductivity that ranged 224 microSiemens **–** 290 microSiemens, and dissolved oxygen levels that ranged between 3.0 milligram per liter **–** 11.5 milligram per liter.

We completed the ten pond experiments between May and September (2014 – 2018) that included nine experiments with a single Northern Snakehead (or density = 10 fish per hectare) as the predator (570 millimeters – 715 millimeters) and a control experiment without a predator (see *Supplemental Material*, Data S1). To ensure that we used a density consistent with field

observations, we used a density of snakeheads in the experiment that ranged between 3 fish per hectare **–** 22 fish per hectare, which was the observed range from Potomac River (Love et al. 2015; Odenkirk and Isel 2016). Each experiment lasted 14 days – 24 days, with four experiments being conducted in 2014, three experiments conducted in 2015, one experiment conducted in 2017 and one experiment conducted in 2018 (Table 1). The prey fish community differed slightly for each experiment (see *Supplemental Material*, Data S2), but reflected diet data reported for 57 Northern Snakehead adults that we examined from the Potomac River (see *Supplemental Material*, Data S3) and from Saylor et al. (2012). Prey included: sunfishes *Lepomis* spp. and largemouth bass (Centrarchidae), white perch *Morone americana* (Moronidae), yellow perch *Perca flavescens* (Percidae), minnows (Cyprinidae), and topminnows *Fundulus* spp. (Fundulidae). Prey fishes differed among pond experiments because the numbers and types of collected prey species had differed among electrofishing stream surveys that were conducted for pond experiments.

Prior to introduction to the pond, the total length (millimeters) and weight (grams) of all prey fish were measured (see *Supplemental Material*, Data S2). We aggregated prey fish species into four major groups based on morphology for analysis. Aggregation was necessary because some prey fish species were either occasionally not collected or collected from field sites in very low numbers. These prey fish groups were: 1) broad bodied, spiny-rayed fishes (BSp; black crappie *Pomoxis nigricans* (110 millimeters); bluegill *Lepomis macrochirus* (56 millimeters – 125 millimeters); bluespotted sunfish *Enneacanthus gloriosus* (55 millimeters – 61 millimeters); green sunfish *L. cyanellus* (90 millimeters – 111 millimeters); pumpkinseed *L. gibbosus* (65 millimeters – 130 millimeters)); 2) fusiform, spiny-rayed fishes (FSp; largemouth bass (80 millimeters – 125 millimeters); White Perch (45 millimeters – 120 millimeters); yellow perch

(50 millimeters – 145 millimeters)); 3) golden soft-rayed fishes (GSo; goldfish *Crassius auratus* (50 millimeters – 113 millimeters); golden shiner *Notemigonus chrysoleucas* (45 millimeters – 140 millimeters)); and 4) other soft-rayed minnows or killifishes (OSo; banded killifish *Fundulus diaphanus* (32 millimeters – 110 millimeters); creek chubsucker *Erimyzon oblongus* (90 millimeters – 110 millimeters)*;* mummichog *F. heteroclitus* (40 millimeters – 75 millimeters); spottail shiner *Notropis hudsonius* (95 millimeters – 100 millimeters)). Northern snakehead consumes many types of prey (Courtenay and Williams 2004; Saylor et al. 2012), but longer handling times for BSp or FSp fishes may result in prey species with soft rays to be consumed more frequently, despite their availability. Likewise, GSo may be more conspicuous and also be more often consumed. Aggregation based on morphology and color was necessary because the same types of prey fishes were not collected during field surveys prior to pond experiments. Also, we wanted to broadly generalize prey preference results to other aquatic ecosystems where species may differ. Amphibians (e.g., *Bufo americanus*), which are also potential prey items, could neither be enumerated nor prevented from entering the pond.

The prey fish community was exposed to one adult northern snakehead (570 millimeters – 715 millimeters) for approximately 14 days. During each two-week experiment period, the pond was routinely examined for serpents caught in netting, dead fish floating at the surface, and dissolved oxygen. Across all experiments, a sum of 25 dead prey fishes had been removed from the pond. These individuals, identified by species and length, were excluded from data analysis. After the experiment, the pond was drained and remaining prey fishes were evacuated to a catch box. These survivors were tallied and length was measured. The pond was flushed with water twice following each pond drain to ensure that all fishes were flushed out. Within a year, prey fish may have been used for consecutive experiments following at least a two-week recovery

time in indoor tanks; new prey and predators were obtained for each of the four years of experiments.

Prey preference from the pond experiments was determined using a modified Ivlev's electivity index (Ivlev 1961), which is the relative abundance of an eaten prey species compared to the relative availability of the prey species in the environment. This index has been criticized for its sampling bias because of problems with unknown prey availability and problems with identifying important prey in the gut because of differences in prey digestion (Straus 1979). These biases were reduced by controlling prey availability using outdoor pond experiments with a known community of prey fishes. Unaccounted prey items in the pond at the end of the experiment were assumed to have been eaten. To help meet that assumption, we flushed ponds twice and tried to prevent predation by terrestrial predators by using wildlife netting to cover the ponds. Additionally, we conducted a control experiment without a predator to determine the level of mortality (Table 1). We recovered 96 percent of the fish from the control experiment and did not adjust prey numbers for the experiment.

Ivlev's electivity index *E* was calculated as:

$$E = {}^{r_i - p_i}/_{r_i + p_i}$$

where r_i is percent composition eaten for prey *i* and p_i is percent composition available for prey *i*.

The *E* was calculated for each of the nine pond experiments (see *Supplemental Material*, Data S1). The value r_i was determined by dividing the number of prey consumed within each of the four prey fish groups by the total number of prey consumed among groups. The value p_i was determined by dividing the total number of prey available within each of the four prey fish groups by the total number of prey available. The *E* for each pond experiment was the

preference of a prey fish group by Northern Snakehead relative to the prey fish groups' availability in the prey fish community. The *E* was plotted for each group and each pond experiment. Strong electivity was indicated by values close to 1.0 (strong preference) or -1.0 (strong avoidance). Weak electivity was indicated by values close to 0.0. For the purpose of this study, we noted moderate to strong prey preferences for a group when values ranged between 0.5 **–** 1.0. Box plots of *E* for each prey group were also generated with quartiles to determine whether median values ranged between 0.5 **–** 1.0. To test whether *E* differed from zero for each prey group, we determined the 95% upper confidence limit (UCL) and 95% lower confidence limit (LCL) of *E* for each prey fish group. When zero was included in the interval between limits, we concluded that mean *E* did not differ from zero.

Results

There was no evidence of strong prey preferences for Northern Snakehead when using data from outdoor pond experiments (Figure 1). Conspicuous gold colored, soft rayed minnows were moderately preferred in one ($E = 0.56$) of nine experiments. There was also moderate preference for fusiform, spiny rayed fish ($E = 0.56$) in only one of the experiments. No experiments had moderate to high *E* values for broad bodied spiny-rayed fishes and for other soft-rayed minnows or topminnows. For most prey groups, the median of *E* was near zero or slightly less than zero (Figure 1). On average, *E* did not differ from zero for any prey fish group (mean, 95% LCL & 95% UCL; BSp: -0.15, -0.53 & 0.22; GSo: 0.08, -0.29 & 0.46; FSp: -0.23, -0.71 & 0.25; OSo: -0.21, -0.60 & 0.18), suggesting low prey preference for any prey group used here.

Conclusions

As suggested from observations of snakeheads from field studies (Isel and Odenkirk 2019), we found no evidence of prey preferences for northern snakehead using a known community of

aquatic organisms. Snakeheads generally ate the most common aquatic prey, making multiple species potential targets. Snakeheads may also prefer to eat the most easily captured prey, but this hypothesis requires additional study.

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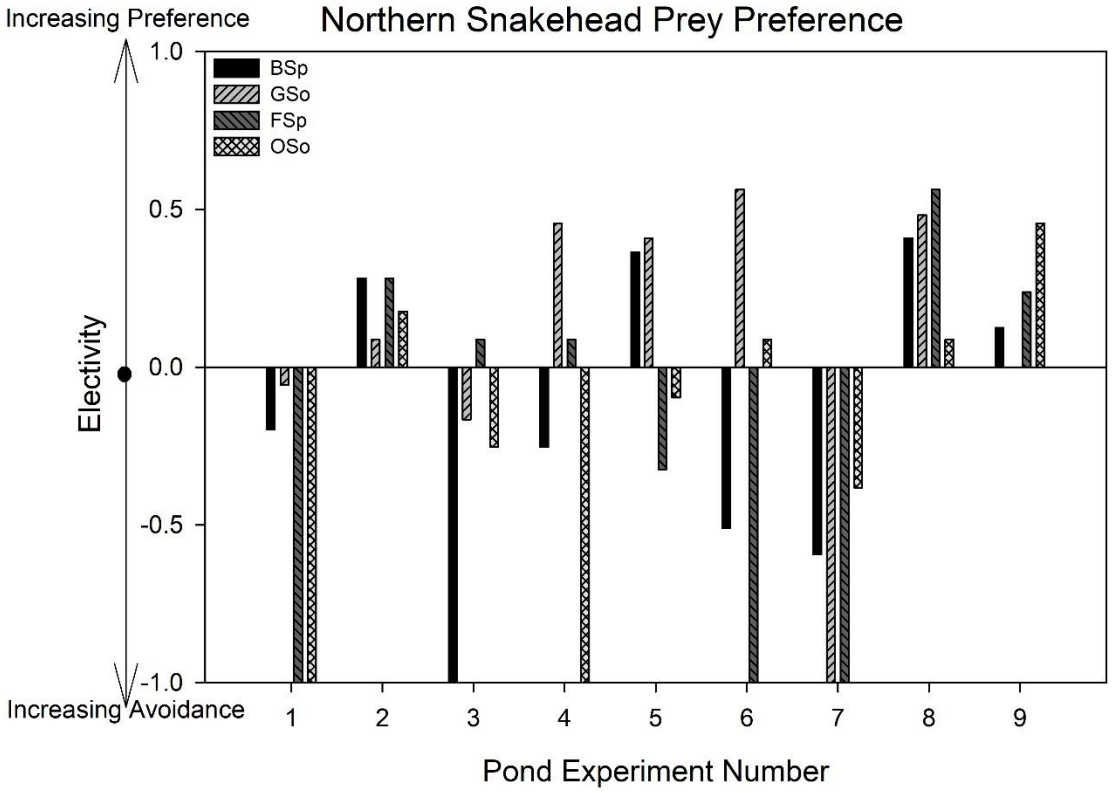
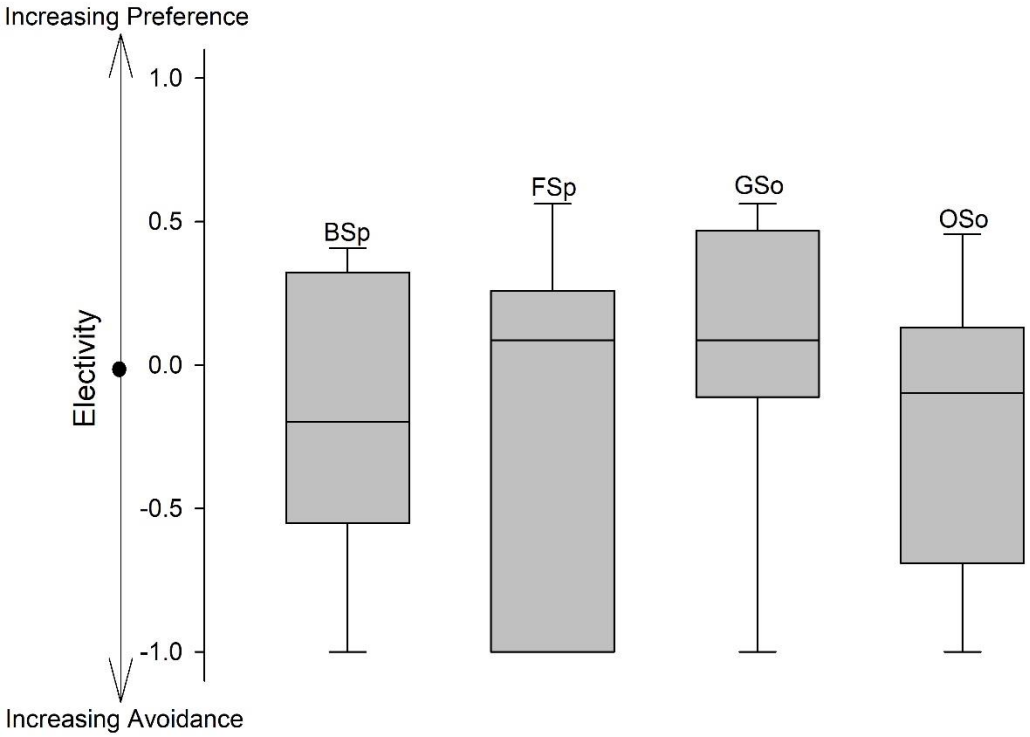
Table 1. For dated pond experiments (2014 – 2018), northern snakehead *Channa argus* of various total lengths (mm) were added to ponds with a certain number of available prey (# Prey Avail.) for a certain number of days (Days) and remaining prey (# Prey Remain) were counted at the end of the experiment. Outdoor pond experiments were conducted in Brandywine (Maryland) at a regional field station operated by Maryland Department of Natural Resources. A control experiment was conducted in July 2014 to compute the difference in number of prey fish when a northern snakehead was not added to pond.

Experiment	Start Date	# Prey Avail.	# Prey Remain	Days	Total Length (mm)
1	6/2/2014	28	24	14	660
2	7/2/2014	28	15	14	N/A[1]
3	7/23/2014	30	27	14	625
4	8/28/2014	25	18	18	620
5	6/4/2015	33	21	14	600
6	6/22/2015	25	20	14	570
7	7/13/2015	37	34	14	600
8	8/13/2017	20	06	17	570
9	5/5/2018	48	25	24	715
Control	7/31/2014	29	28	15	none

[1]Snakehead measurement not available.

Figure 1. Upper Panel: Electivity indices (i.e., preference) for northern snakehead *Channa argus* for prey fishes grouped into: BSp - broad bodied, spiny-rayed fishes (Black Crappie *Pomoxis nigricans*; bluegill *Lepomis macrochirus*; bluespotted sunfish *Enneacanthus gloriosus*; Green Sunfish *L. cyanellus*; Pumpkinseed *L. gibbosus*); FSp - fusiform, spiny-rayed fishes (Largemouth Bass; white perch *Morone americana*; yellow perch *Perca flavescensi*); GSo - golden soft-rayed fishes (Goldfish *Crassius auratus*; Golden Shiner *Notemigonus chrysoleucas*); and OSo - other soft-rayed minnows or topminnows (Banded Killifish *Fundulus diaphanus*; Creek Chubsucker *Erimyzon oblongus*); Mummichog *F. heteroclitus*; Spottail Shiner *Notropis hudsonius*). Lower Panel: Box plot of electivity of prey fish groups. Horizontal lines in boxes represent medians of electivity bounded by a lower 25^{th} and an upper 75^{th} percentiles for outdoor pond experiments conducted at a regional field station for Maryland Department of Natural Resources in Brandywine (Maryland) in 2014 - 2018.


Increasing Preference
Northern Snakehead Prey Preference
1.0
0.5
0.0
-0.5
-1.0
Electivity
BSp
GSo
FSp
OSo
Increasing Avoidance
1
2
3
4
5
6
7
8
9
Pond Experiment Number


Increasing Preference
1.0
0.5
0.0
-0.5
-1.0
Electivity
BSp
FSp
GSo
OSo
Increasing Avoidance

Supplemental Material S1. Summarized data on the number (Nu.) of prey per species that were available and presumably consumed from ten pond experiments with start and end dates between May and September (2014 – 2018) at a Maryland Department of Natural Resources' field research station in Brandywine (Maryland). Each pond experiment included a single Northern Snakehead (density = 10 fish per hectare) as the predator (570 millimeters – 715 millimeters), or no snakehead as a control. Tallied prey fishes were morphologically grouped for analysis as: 1) broad bodied, spiny-rayed fishes (BSp; black crappie *Pomoxis nigricans*; bluegill *Lepomis macrochirus*; bluespotted sunfish *Enneacanthus gloriosus*; green sunfish *L. cyanellus*; pumpkinseed *L. gibbosus*; 2) fusiform, spiny-rayed fishes (FSp; largemouth bass; white perch *Morone americana*; yellow perch *Perca flavescens*; 3) golden soft-rayed fishes (GSo; goldfish *Crassius auratus*; golden shiner *Notemigonus chrysoleucas*); and 4) other soft-rayed minnows or killifishes (OSo; banded killifish *Fundulus diaphanus*; creek chubsucker *Erimyzon oblongus*); mummichog *F. heteroclitus*; spottail shiner *Notropis hudsonius*). Aggregation was necessary because some prey fish species were either occasionally not collected or collected from field sites in very low numbers,

Start Date	End Date	Experiment	Eaten BSp	GSo
8/28/2014	9/15/2014	NSH1	2	3
7/23/2014	8/6/2014	NSH2	0	1
7/2/2014	7/16/2014	NSH3	8	1
6/2/2014	6/16/2014	NSH4	3	1
6/22/2015	6/26/2015	NSH5	1	1
6/4/2015	6/18/2015	NSH6	6	2
7/13/2015	7/27/2015	NSH7	1	0
8/13/2017	8/30/2017	NSH8	6	4
5/5/2018	6/8/2018	NSH9	9	0
7/31/2014	8/15/2014	Control	0	0
Start Date	**End Date**	**Experiment**	**Eaten FSp**	**Eaten OSo**
8/28/2014	9/15/2014	NSH1	2	0
7/23/2014	8/6/2014	NSH2	1	1
7/2/2014	7/16/2014	NSH3	2	2
6/2/2014	6/16/2014	NSH4	0	0
6/22/2015	6/26/2015	NSH5	0	3

6/4/2015	6/18/2015	NSH6	1	3
7/13/2015	7/27/2015	NSH7	0	2
8/13/2017	8/30/2017	NSH8	3	1
5/5/2018	6/8/2018	NSH9	5	9
7/31/2014	8/15/2014	Control	0	0
Start Date	**End Date**	**Experiment**	**Eaten Total**	**Available BSp**
8/28/2014	9/15/2014	NSH1	7	12
7/23/2014	8/6/2014	NSH2	3	16
7/2/2014	7/16/2014	NSH3	13	16
6/2/2014	6/16/2014	NSH4	4	16
6/22/2015	6/26/2015	NSH5	5	11
6/4/2015	6/18/2015	NSH6	12	10
7/13/2015	7/27/2015	NSH7	3	14
8/13/2017	8/30/2017	NSH8	14	9
5/5/2018	6/8/2018	NSH9	23	25
7/31/2014	8/15/2014	Control	0	14
Start Date	**End Date**	**Experiment**	**Available GSo**	**Available FSp**
8/28/2014	9/15/2014	NSH1	4	6
7/23/2014	8/6/2014	NSH2	5	3
7/2/2014	7/16/2014	NSH3	3	4
6/2/2014	6/16/2014	NSH4	4	4
6/22/2015	6/26/2015	NSH5	1	4
6/4/2015	6/18/2015	NSH6	3	7
7/13/2015	7/27/2015	NSH7	1	6
8/13/2017	8/30/2017	NSH8	5	3
5/5/2018	6/8/2018	NSH9	0	11
7/31/2014	8/15/2014	Control	1	4
Start Date	**End Date**	**Experiment**	**Available OSo**	**Available Total**
8/28/2014	9/15/2014	NSH1	3	25
7/23/2014	8/6/2014	NSH2	6	30
7/2/2014	7/16/2014	NSH3	5	28
6/2/2014	6/16/2014	NSH4	4	28
6/22/2015	6/26/2015	NSH5	9	25
6/4/2015	6/18/2015	NSH6	13	33
7/13/2015	7/27/2015	NSH7	16	37
8/13/2017	8/30/2017	NSH8	3	20
5/5/2018	6/8/2018	NSH9	12	48
7/31/2014	8/15/2014	Control	10	29

Supplemental Material S2. Prey species used during outdoor pond experiments (by date) with total length (millimeter) and weight (in grams), when available (NA = not available). Where noted, some fish were excluded for analysis because they were retrieved floating at surface or in netting, presumably dying for reasons other than consumption by northern snakehead *Channa argus*.

Date	Species	Scientific Name	TL (mm)	Weight (g)	Excluded?
6/2/2014	Banded Killifish	*Fundulus diaphanus*	90	NA	no
6/2/2014	Banded Killifish	*Fundulus diaphanus*	83	NA	no
6/2/2014	Banded Killifish	*Fundulus diaphanus*	68	NA	no
6/2/2014	Banded Killifish	*Fundulus diaphanus*	76	NA	no
6/2/2014	Bluegill	*Lepomis macrochirus*	80	NA	no
6/2/2014	Bluegill	*Lepomis macrochirus*	82	NA	no
6/2/2014	Bluegill	*Lepomis macrochirus*	88	NA	no
6/2/2014	Bluegill	*Lepomis macrochirus*	86	NA	no
6/2/2014	Bluegill	*Lepomis macrochirus*	90	NA	no
6/2/2014	Bluegill	*Lepomis macrochirus*	125	NA	no
6/2/2014	Bluespotted Sunfish	*Enneacanthus gloriosus*	61	NA	no
6/2/2014	Golden Shiner	*Notemigonus chrysoleucas*	111	NA	no
6/2/2014	Golden Shiner	*Notemigonus chrysoleucas*	126	NA	no
6/2/2014	Golden Shiner	*Notemigonus chrysoleucas*	122	NA	no
6/2/2014	Pumpkinseed	*Lepomis gibbosus*	88	NA	no
6/2/2014	Pumpkinseed	*Lepomis gibbosus*	105	NA	no
6/2/2014	Pumpkinseed	*Lepomis gibbosus*	99	NA	no
6/2/2014	Pumpkinseed	*Lepomis gibbosus*	73	NA	no
6/2/2014	Pumpkinseed	*Lepomis gibbosus*	102	NA	no
6/2/2014	Pumpkinseed	*Lepomis gibbosus*	70	NA	no
6/2/2014	Pumpkinseed	*Lepomis gibbosus*	97	NA	no
6/2/2014	Pumpkinseed	*Lepomis gibbosus*	97	NA	no
6/2/2014	Pumpkinseed	*Lepomis gibbosus*	90	NA	no
6/2/2014	White Perch	*Morone americana*	97	NA	no
6/2/2014	White Perch	*Morone americana*	118	NA	no
6/2/2014	White Perch	*Morone americana*	93	NA	no
6/2/2014	White Perch	*Morone americana*	92	NA	no
6/2/2014	White Perch	*Morone americana*	91	NA	yes
6/2/2014	White Perch	*Morone americana*	97	NA	yes
6/2/2014	White Perch	*Morone americana*	76	NA	no
6/2/2014	White Perch	*Morone americana*	86	NA	no
6/2/2014	Yellow Perch	*Perca flavescens*	93	NA	no
6/2/2014	Yellow Perch	*Perca flavescens*	136	NA	no
7/2/2014	Banded Killifish	*Fundulus diaphanus*	105	NA	no
7/2/2014	Banded Killifish	*Fundulus diaphanus*	78	NA	no

7/2/2014	Banded Killifish	*Fundulus diaphanus*	85	NA	no
7/2/2014	Bluegill	*Lepomis macrochirus*	110	NA	no
7/2/2014	Bluegill	*Lepomis macrochirus*	110	NA	no
7/2/2014	Bluegill	*Lepomis macrochirus*	100	NA	no
7/2/2014	Bluegill	*Lepomis macrochirus*	70	NA	no
7/2/2014	Golden Shiner	*Notemigonus chrysoleucas*	140	NA	no
7/2/2014	Goldfish	*Crassius auratus*	105	NA	no
7/2/2014	Goldfish	*Crassius auratus*	105	NA	no
7/2/2014	Goldfish	*Crassius auratus*	50	NA	no
7/2/2014	Pumpkinseed	*Lepomis gibbosus*	80	NA	no
7/2/2014	Pumpkinseed	*Lepomis gibbosus*	90	NA	no
7/2/2014	Pumpkinseed	*Lepomis gibbosus*	100	NA	no
7/2/2014	Pumpkinseed	*Lepomis gibbosus*	85	NA	no
7/2/2014	Pumpkinseed	*Lepomis gibbosus*	80	NA	no
7/2/2014	Pumpkinseed	*Lepomis gibbosus*	90	NA	no
7/2/2014	Pumpkinseed	*Lepomis gibbosus*	90	NA	no
7/2/2014	Pumpkinseed	*Lepomis gibbosus*	90	NA	no
7/2/2014	Pumpkinseed	*Lepomis gibbosus*	100	NA	no
7/2/2014	Pumpkinseed	*Lepomis gibbosus*	80	NA	no
7/2/2014	Pumpkinseed	*Lepomis gibbosus*	90	NA	no
7/2/2014	Pumpkinseed	*Lepomis gibbosus*	110	NA	no
7/2/2014	Spottail Shiner	*Notropis hudsonius*	100	NA	yes
7/2/2014	Spottail Shiner	*Notropis hudsonius*	95	NA	no
7/2/2014	Yellow Perch	*Perca flavescens*	125	NA	no
7/2/2014	Yellow Perch	*Perca flavescens*	140	NA	no
7/2/2014	Yellow Perch	*Perca flavescens*	145	NA	no
7/2/2014	Yellow Perch	*Perca flavescens*	145	NA	no
7/2/2014	Yellow Perch	*Perca flavescens*	90	NA	no
7/23/2014	Banded Killifish	*Fundulus diaphanus*	108	NA	no
7/23/2014	Banded Killifish	*Fundulus diaphanus*	107	NA	no
7/23/2014	Banded Killifish	*Fundulus diaphanus*	108	NA	no
7/23/2014	Banded Killifish	*Fundulus diaphanus*	107	NA	no
7/23/2014	Banded Killifish	*Fundulus diaphanus*	106	NA	no
7/23/2014	Banded Killifish	*Fundulus diaphanus*	108	NA	no
7/23/2014	Bluegill	*Lepomis macrochirus*	109	NA	yes
7/23/2014	Bluegill	*Lepomis macrochirus*	108	NA	no
7/23/2014	Bluegill	*Lepomis macrochirus*	112	NA	no
7/23/2014	Goldfish	*Crassius auratus*	108	NA	no
7/23/2014	Goldfish	*Crassius auratus*	113	NA	no
7/23/2014	Goldfish	*Crassius auratus*	110	NA	no
7/23/2014	Goldfish	*Crassius auratus*	110	NA	no
7/23/2014	Goldfish	*Crassius auratus*	108	NA	no
7/23/2014	Green Sunfish	*Lepomis cyanellus*	111	NA	yes
7/23/2014	Pumpkinseed	*Lepomis gibbosus*	111	NA	no
7/23/2014	Pumpkinseed	*Lepomis gibbosus*	110	NA	no
7/23/2014	Pumpkinseed	*Lepomis gibbosus*	109	NA	no
7/23/2014	Pumpkinseed	*Lepomis gibbosus*	112	NA	no

7/23/2014	Pumpkinseed	*Lepomis gibbosus*	110	NA	no
7/23/2014	Pumpkinseed	*Lepomis gibbosus*	110	NA	no
7/23/2014	Pumpkinseed	*Lepomis gibbosus*	110	NA	no
7/23/2014	Pumpkinseed	*Lepomis gibbosus*	107	NA	no
7/23/2014	Pumpkinseed	*Lepomis gibbosus*	107	NA	no
7/23/2014	Pumpkinseed	*Lepomis gibbosus*	111	NA	no
7/23/2014	Pumpkinseed	*Lepomis gibbosus*	110	NA	no
7/23/2014	Pumpkinseed	*Lepomis gibbosus*	111	NA	no
7/23/2014	Yellow Perch	*Perca flavescens*	114	NA	no
7/23/2014	Yellow Perch	*Perca flavescens*	113	NA	no
7/23/2014	Yellow Perch	*Perca flavescens*	107	NA	no
7/31/2014	Banded Killifish	*Fundulus diaphanus*	85	5	no
7/31/2014	Banded Killifish	*Fundulus diaphanus*	90	6	no
7/31/2014	Banded Killifish	*Fundulus diaphanus*	86	NA	no
7/31/2014	Banded Killifish	*Fundulus diaphanus*	85	5	no
7/31/2014	Banded Killifish	*Fundulus diaphanus*	75	NA	no
7/31/2014	Banded Killifish	*Fundulus diaphanus*	85	7	no
7/31/2014	Banded Killifish	*Fundulus diaphanus*	75	NA	no
7/31/2014	Banded Killifish	*Fundulus diaphanus*	80	6	no
7/31/2014	Banded Killifish	*Fundulus diaphanus*	75	NA	no
7/31/2014	Banded Killifish	*Fundulus diaphanus*	80	5	no
7/31/2014	Bluegill	*Lepomis macrochirus*	81	9	no
7/31/2014	Bluegill	*Lepomis macrochirus*	72	6	no
7/31/2014	Bluegill	*Lepomis macrochirus*	76	8	no
7/31/2014	Golden Shiner	*Notemigonus chrysoleucas*	125	22	no
7/31/2014	Pumpkinseed	*Lepomis gibbosus*	105	27	no
7/31/2014	Pumpkinseed	*Lepomis gibbosus*	97	20	no
7/31/2014	Pumpkinseed	*Lepomis gibbosus*	109	30	no
7/31/2014	Pumpkinseed	*Lepomis gibbosus*	96	23	no
7/31/2014	Pumpkinseed	*Lepomis gibbosus*	95	17	no
7/31/2014	Pumpkinseed	*Lepomis gibbosus*	100	22	no
7/31/2014	Pumpkinseed	*Lepomis gibbosus*	100	23	no
7/31/2014	Pumpkinseed	*Lepomis gibbosus*	90	14	no
7/31/2014	Pumpkinseed	*Lepomis gibbosus*	85	10	no
7/31/2014	Pumpkinseed	*Lepomis gibbosus*	78	8	no
7/31/2014	Pumpkinseed	*Lepomis gibbosus*	85	11	no
7/31/2014	Yellow Perch	*Perca flavescens*	68	NA	no
7/31/2014	Yellow Perch	*Perca flavescens*	130	27	no
7/31/2014	Yellow Perch	*Perca flavescens*	145	33	no
7/31/2014	Yellow Perch	*Perca flavescens*	120	17	no
8/28/2014	Black Crappie	*Pomoxis nigromaculatus*	110	NA	no
8/28/2014	Bluegill	*Lepomis macrochirus*	60	NA	no
8/28/2014	Creek Chubsucker	*Erimyzon oblongus*	110	NA	no
8/28/2014	Creek Chubsucker	*Erimyzon oblongus*	90	NA	no
8/28/2014	Golden Shiner	*Notemigonus chrysoleucas*	110	NA	no
8/28/2014	Goldfish	*Crassius auratus*	70	NA	no
8/28/2014	Goldfish	*Crassius auratus*	100	NA	no

8/28/2014	Goldfish	*Crassius auratus*	80	NA	no
8/28/2014	Goldfish	*Crassius auratus*	100	NA	no
8/28/2014	Green Sunfish	*Lepomis cyanellus*	90	NA	no
8/28/2014	Largemouth Bass	*Micropterus salmoides*	80	NA	no
8/28/2014	Largemouth Bass	*Micropterus salmoides*	90	NA	no
8/28/2014	Largemouth Bass	*Micropterus salmoides*	110	NA	no
8/28/2014	Largemouth Bass	*Micropterus salmoides*	90	NA	no
8/28/2014	Largemouth Bass	*Micropterus salmoides*	100	NA	no
8/28/2014	Pumpkinseed	*Lepomis gibbosus*	90	NA	no
8/28/2014	Pumpkinseed	*Lepomis gibbosus*	80	NA	no
8/28/2014	Pumpkinseed	*Lepomis gibbosus*	120	NA	no
8/28/2014	Pumpkinseed	*Lepomis gibbosus*	120	NA	yes
8/28/2014	Pumpkinseed	*Lepomis gibbosus*	130	NA	no
8/28/2014	Pumpkinseed	*Lepomis gibbosus*	100	NA	no
8/28/2014	Pumpkinseed	*Lepomis gibbosus*	110	NA	no
8/28/2014	Pumpkinseed	*Lepomis gibbosus*	110	NA	no
8/28/2014	Pumpkinseed	*Lepomis gibbosus*	120	NA	no
8/28/2014	Pumpkinseed	*Lepomis gibbosus*	110	NA	no
8/28/2014	Pumpkinseed	*Lepomis gibbosus*	110	NA	no
8/28/2014	Yellow Perch	*Perca flavescens*	100	NA	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	50	NA	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	60	3	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	78	3.6	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	80	3.8	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	78	4	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	75	3.6	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	72	3.8	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	76	4	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	75	3.9	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	75	4.2	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	72	3.3	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	50	1.7	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	70	3	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	75	4.5	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	75	3	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	65	3	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	65	2	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	60	3	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	82	6	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	90	8	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	110	16	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	80	7	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	68	2	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	90	7	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	80	6	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	78	4	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	85	4	no

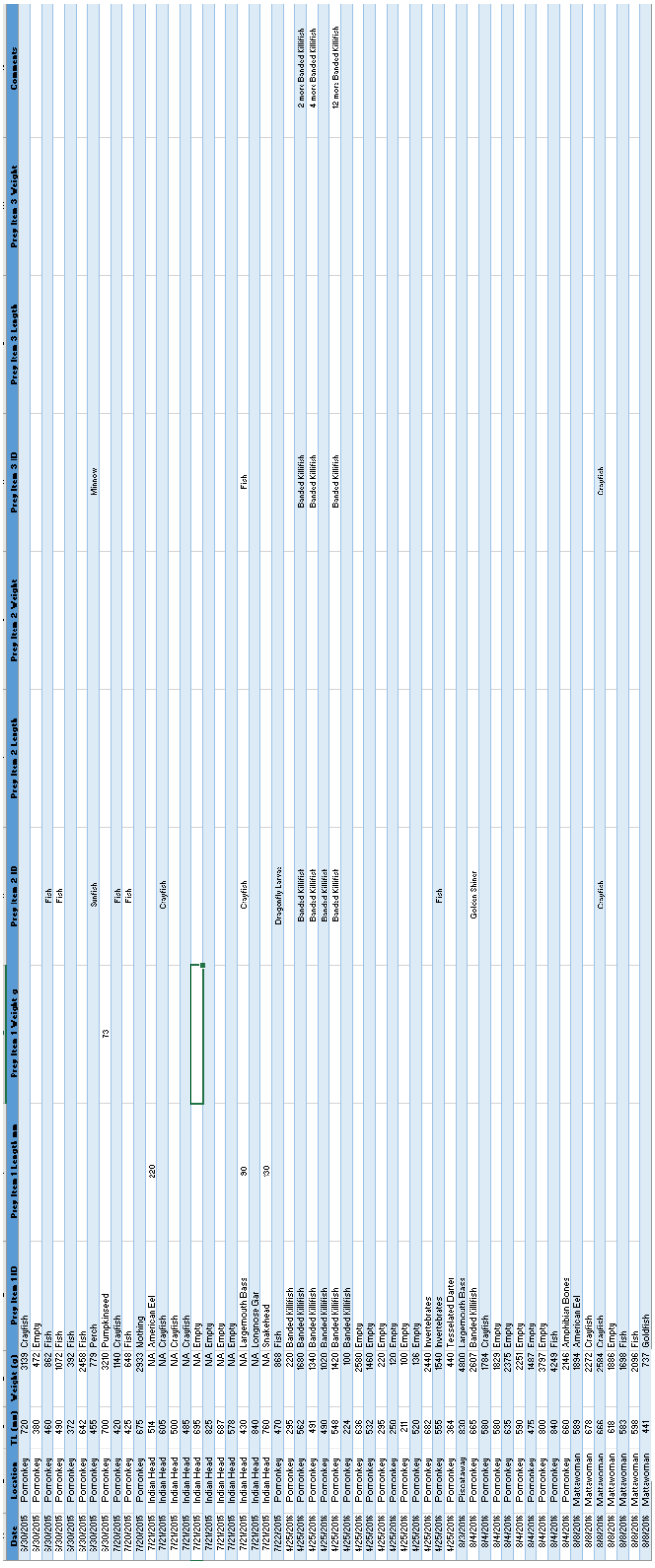
6/4/2015	Banded Killifish	*Fundulus diaphanus*	82	4	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	70	3	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	82	4	no
6/4/2015	Banded Killifish	*Fundulus diaphanus*	80	4	no
6/4/2015	Bluegill	*Lepomis macrochirus*	95	17	no
6/4/2015	Bluegill	*Lepomis macrochirus*	100	18	no
6/4/2015	Bluegill	*Lepomis macrochirus*	70	6	no
6/4/2015	Bluegill	*Lepomis macrochirus*	75	9	no
6/4/2015	Bluegill	*Lepomis macrochirus*	75	8	no
6/4/2015	Bluegill	*Lepomis macrochirus*	118	38	no
6/4/2015	Golden Shiner	*Notemigonus chrysoleucas*	131	25	no
6/4/2015	Golden Shiner	*Notemigonus chrysoleucas*	100	10	no
6/4/2015	Golden Shiner	*Notemigonus chrysoleucas*	92	8	yes
6/4/2015	Golden Shiner	*Notemigonus chrysoleucas*	120	17	no
6/4/2015	Golden Shiner	*Notemigonus chrysoleucas*	120	21	no
6/4/2015	Largemouth Bass	*Micropterus salmoides*	125	24	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	75	9	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	90	14	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	70	6	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	75	10	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	95	19	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	70	7	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	110	21	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	105	28	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	82	12	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	82	12	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	100	23	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	100	25	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	80	9	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	108	31	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	95	16	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	90	15	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	80	10	no
6/4/2015	Pumpkinseed	*Lepomis gibbosus*	98	24	no
6/4/2015	White Perch	*Morone americana*	110	17	no
6/4/2015	White Perch	*Morone americana*	110	19	no
6/4/2015	White Perch	*Morone americana*	120	24	no
6/4/2015	Yellow Perch	*Perca flavescens*	140	28	no
6/4/2015	Yellow Perch	*Perca flavescens*	126	22	no
6/4/2015	Yellow Perch	*Perca flavescens*	122	20	no
6/4/2015	Yellow Perch	*Perca flavescens*	124	23	no
6/4/2015	Yellow Perch	*Perca flavescens*	132	26	no
6/4/2015	Yellow Perch	*Perca flavescens*	133	24	no
6/4/2015	Yellow Perch	*Perca flavescens*	140	34	no
6/4/2015	Yellow Perch	*Perca flavescens*	122	19	no
6/4/2015	Yellow Perch	*Perca flavescens*	130	28	no
6/22/2015	Banded Killifish	*Fundulus diaphanus*	85	7	no

6/22/2015	Banded Killifish	*Fundulus diaphanus*	81	6	no
6/22/2015	Banded Killifish	*Fundulus diaphanus*	80	5	no
6/22/2015	Banded Killifish	*Fundulus diaphanus*	80	5	no
6/22/2015	Banded Killifish	*Fundulus diaphanus*	80	8	no
6/22/2015	Banded Killifish	*Fundulus diaphanus*	56	NA	no
6/22/2015	Banded Killifish	*Fundulus diaphanus*	84	5	no
6/22/2015	Banded Killifish	*Fundulus diaphanus*	72	NA	no
6/22/2015	Banded Killifish	*Fundulus diaphanus*	75	NA	no
6/22/2015	Bluegill	*Lepomis macrochirus*	60	NA	no
6/22/2015	Bluegill	*Lepomis macrochirus*	60	NA	no
6/22/2015	Bluegill	*Lepomis macrochirus*	105	26	no
6/22/2015	Bluegill	*Lepomis macrochirus*	68	5	no
6/22/2015	Bluegill	*Lepomis macrochirus*	65	NA	no
6/22/2015	Bluespotted Sunfish	*Enneacanthus gloriosus*	55	NA	no
6/22/2015	Golden Shiner	*Notemigonus chrysoleucas*	135	26	no
6/22/2015	Pumpkinseed	*Lepomis gibbosus*	98	25	no
6/22/2015	Pumpkinseed	*Lepomis gibbosus*	86	15	no
6/22/2015	Pumpkinseed	*Lepomis gibbosus*	85	14	no
6/22/2015	Pumpkinseed	*Lepomis gibbosus*	80	13	no
6/22/2015	Pumpkinseed	*Lepomis gibbosus*	88	15	no
6/22/2015	White Perch	*Morone americana*	110	18	no
6/22/2015	Yellow Perch	*Perca flavescens*	130	NA	yes
6/22/2015	Yellow Perch	*Perca flavescens*	123	22	no
6/22/2015	Yellow Perch	*Perca flavescens*	132	22	no
6/22/2015	Yellow Perch	*Perca flavescens*	135	24	no
6/22/2015	Yellow Perch	*Perca flavescens*	134	24	no
8/13/2017	Banded Killifish	*Fundulus diaphanus*	55	NA	no
8/13/2017	Banded Killifish	*Fundulus diaphanus*	60	3	no
8/13/2017	Banded Killifish	*Fundulus diaphanus*	50	NA	no
8/13/2017	Banded Killifish	*Fundulus diaphanus*	34	NA	yes
8/13/2017	Banded Killifish	*Fundulus diaphanus*	32	1	no
8/13/2017	Golden Shiner	*Notemigonus chrysoleucas*	50	1	no
8/13/2017	Golden Shiner	*Notemigonus chrysoleucas*	45	1	no
8/13/2017	Golden Shiner	*Notemigonus chrysoleucas*	50	1	no
8/13/2017	Golden Shiner	*Notemigonus chrysoleucas*	55	1	no
8/13/2017	Goldfish	*Crassius auratus*	80	7	no
8/13/2017	Mummichog	*Fundulus heteroclitus*	50	NA	no
8/13/2017	Pumpkinseed	*Lepomis gibbosus*	105	23	no
8/13/2017	Pumpkinseed	*Lepomis gibbosus*	95	22	no
8/13/2017	Pumpkinseed	*Lepomis gibbosus*	105	23	no
8/13/2017	Pumpkinseed	*Lepomis gibbosus*	105	20	no
8/13/2017	Pumpkinseed	*Lepomis gibbosus*	110	35	no
8/13/2017	Pumpkinseed	*Lepomis gibbosus*	90	15	no
8/13/2017	Pumpkinseed	*Lepomis gibbosus*	105	21	no
8/13/2017	Pumpkinseed	*Lepomis gibbosus*	105	22	no
8/13/2017	Pumpkinseed	*Lepomis gibbosus*	110	26	no
8/13/2017	Pumpkinseed	*Lepomis gibbosus*	120	36	no

8/13/2017	Pumpkinseed	*Lepomis gibbosus*	90	15	no
8/13/2017	White Perch	*Morone americana*	115	22	no
8/13/2017	White Perch	*Morone americana*	110	17	no
8/13/2017	White Perch	*Morone americana*	115	27	yes
8/13/2017	White Perch	*Morone americana*	110	21	no
5/15/2018	Banded Killifish	*Fundulus diaphanus*	70	3.4	no
5/15/2018	Banded Killifish	*Fundulus diaphanus*	65	3.6	no
5/15/2018	Banded Killifish	*Fundulus diaphanus*	56	2.4	no
5/15/2018	Bluegill	*Lepomis macrochirus*	92	16.4	no
5/15/2018	Bluegill	*Lepomis macrochirus*	72	7.6	no
5/15/2018	Bluegill	*Lepomis macrochirus*	56	3.3	no
5/15/2018	Bluegill	*Lepomis macrochirus*	75	11	no
5/15/2018	Mummichog	*Fundulus heteroclitus*	52	2.3	no
5/15/2018	Mummichog	*Fundulus heteroclitus*	60	4	no
5/15/2018	Mummichog	*Fundulus heteroclitus*	45	17	no
5/15/2018	Mummichog	*Fundulus heteroclitus*	60	3.8	no
5/15/2018	Mummichog	*Fundulus heteroclitus*	52	1.5	no
5/15/2018	Mummichog	*Fundulus heteroclitus*	75	5.9	no
5/15/2018	Mummichog	*Fundulus heteroclitus*	61	3.6	no
5/15/2018	Mummichog	*Fundulus heteroclitus*	40	0.9	no
5/15/2018	Mummichog	*Fundulus heteroclitus*	50	1.5	no
5/15/2018	Mummichog	*Fundulus heteroclitus*	65	3	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	90	14.2	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	72	8	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	87	14.1	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	82	16.6	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	80	13.2	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	80	9.8	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	85	14.1	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	72	6.4	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	75	9.4	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	80	11	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	75	8.3	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	85	11.9	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	80	10.2	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	75	8.6	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	70	6.6	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	100	25.2	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	75	8	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	65	5.7	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	90	14.9	no
5/15/2018	Pumpkinseed	*Lepomis gibbosus*	70	6.6	no
5/15/2018	White Perch	*Morone americana*	80	7.3	yes
5/15/2018	White Perch	*Morone americana*	120	23.4	no
5/15/2018	White Perch	*Morone americana*	76	6.2	no
5/15/2018	White Perch	*Morone americana*	117	21.2	yes
5/15/2018	White Perch	*Morone americana*	112	18.5	yes

5/15/2018	White Perch	*Morone americana*	87	9.5	yes
5/15/2018	White Perch	*Morone americana*	80	7	no
5/15/2018	White Perch	*Morone americana*	85	8.4	no
5/15/2018	White Perch	*Morone americana*	92	11	yes
5/15/2018	White Perch	*Morone americana*	80	6.2	no
5/15/2018	White Perch	*Morone americana*	85	9.3	no
5/15/2018	White Perch	*Morone americana*	90	9.6	yes
5/15/2018	White Perch	*Morone americana*	80	7.2	no
5/15/2018	White Perch	*Morone americana*	45	NA	yes
5/15/2018	White Perch	*Morone americana*	90	10.6	no
5/15/2018	White Perch	*Morone americana*	80	7.7	no
5/15/2018	Yellow Perch	*Perca flavescens*	50	40.2	no
5/15/2018	Yellow Perch	*Perca flavescens*	90	10.1	no
5/15/2018	Yellow Perch	*Perca flavescens*	125	20	yes

Supplemental Material S3. Diets and sizes of fifty-seven northern snakeheads that were examined from three locations within Potomac River (Indian Head or lower Mattawoman Creek, upper Mattawoman Creek, and Pomonkey Creek; Maryland). Prey were identified, measured (in mm) and weighed (in g), when possible.



Date	Location	TL (mm)	Weight (g)	Prey Item 1 ID	Prey Item 1 Length mm	Prey Item 1 Weight g	Prey Item 2 ID	Prey Item 2 Length	Prey Item 2 Weight	Prey Item 3 ID	Prey Item 3 Length	Prey Item 3 Weight	Comments
6/30/2015	Pomonkey	720	3139	Crayfish									
6/30/2015	Pomonkey	380	472	Empty									
6/30/2015	Pomonkey	460	862	Fish			Fish						
6/30/2015	Pomonkey	490	1072	Fish			Fish						
6/30/2015	Pomonkey	370	562	Fish									
6/30/2015	Pomonkey	642	2455	Fish									
6/30/2015	Pomonkey	455	779	Perch			Sunfish			Minnow			
6/30/2015	Pomonkey	700	3210	Pumpkinseed		13							
7/20/2015	Pomonkey	420	1140	Crayfish			Fish						
7/20/2015	Pomonkey	425	648	Fish			Fish						
7/20/2015	Pomonkey	675	2324	Nothing									
7/21/2015	Indian Head	514	1000	American Eel	220								
7/21/2015	Indian Head	605	N/A	Crayfish			Crayfish						
7/21/2015	Indian Head	500	N/A	Crayfish									
7/21/2015	Indian Head	485	N/A	Crayfish									
7/21/2015	Indian Head	695	N/A	Empty		1							
7/21/2015	Indian Head	825	N/A	Empty									
7/21/2015	Indian Head	667	N/A	Empty									
7/21/2015	Indian Head	578	N/A	Empty									
7/21/2015	Indian Head	430	N/A	Largemouth Bass	90		Crayfish			Fish			
7/21/2015	Indian Head	840	N/A	Longnose Gar									
7/21/2015	Indian Head	760	N/A	Snakehead	130								
7/22/2015	Pomonkey	470	888	Fish			Dragonfly Larvae						
4/25/2016	Pomonkey	295	230	Banded Killifish									
4/25/2016	Pomonkey	625	1690	Banded Killifish			Banded Killifish			Banded Killifish			2 more Banded Killifish
4/25/2016	Pomonkey	491	1340	Banded Killifish			Banded Killifish			Banded Killifish			4 more Banded Killifish
4/25/2016	Pomonkey	490	1020	Banded Killifish			Banded Killifish						
4/25/2016	Pomonkey	548	1420	Banded Killifish			Banded Killifish			Banded Killifish			12 more Banded Killifish
4/25/2016	Pomonkey	224	100	Banded Killifish									
4/25/2016	Pomonkey	636	2560	Empty									
4/25/2016	Pomonkey	526	1660	Empty									
4/25/2016	Pomonkey	295	220	Empty									
4/25/2016	Pomonkey	250	120	Empty									
4/25/2016	Pomonkey	211	100	Empty									
4/25/2016	Pomonkey	520	136	Empty									
4/25/2016	Pomonkey	682	2440	Invertebrates			Fish						
4/25/2016	Pomonkey	595	1540	Invertebrates									
4/25/2016	Pomonkey	364	441	Banded Killifish									
8/3/2016	Piscataway	830	4800	Largemouth Bass									
8/4/2016	Pomonkey	665	2807	Banded Killifish			Golden Shiner						
8/4/2016	Pomonkey	580	1784	Crayfish									
8/4/2016	Pomonkey	580	1623	Empty									
8/4/2016	Pomonkey	635	2375	Empty									
8/4/2016	Pomonkey	590	2377	Empty									
8/4/2016	Pomonkey	475	1467	Empty									
8/4/2016	Pomonkey	800	3797	Empty									
8/4/2016	Pomonkey	840	4249	Fish									
8/4/2016	Pomonkey	660	2146	Amphibian Bones									
8/8/2016	Mattawoman	589	1884	American Eel									
8/8/2016	Mattawoman	678	2264	Crayfish			Crayfish			Crayfish			
8/8/2016	Mattawoman	695	2800	Crayfish									
8/8/2016	Mattawoman	618	1898	Empty									
8/8/2016	Mattawoman	583	1638	Fish									
8/8/2016	Mattawoman	538	2096	Fish									
8/8/2016	Mattawoman	441	737	Goldfish									