TIDAL COMMUNITY EXCHANGE BETWEEN THE HUDSON RIVER AND A TRIBUTARY

A Final Report of the Tibor T. Polgar Fellowship Program

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ABSTRACT

Over the course of the summer of 2014, a fyke net was used to sample the fish fauna of the Indian Kill in Staatsburg, New York, during ebb and flood tides. This provided insight into which species were entering and leaving, and when, over the summer in an attempt to characterize their usage of the tributary. A total of 309 individuals representing 17 species were caught. While species richness did not change with tide phase or day/night cycles, a lower Shannon-Weaver diversity index and a less even distribution among the species moving at night suggest that immigrating and emigrating species have a preference for nocturnal movements. More fish left the stream during ebb tide than entered during flood tide, representative of large numbers of a relative few species migrating out of the tributary. Some species previously described as exhibiting potamodromous behaviors, such as the white perch (*Morone americana*) and white sucker (*Catostomus commersonii*) showed similar behaviors in the Indian Kill but require further study to confirm reproduction. In the case of the American eel (*Anguilla rostrata*), movements clustered close to the new moon.

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INTRODUCTION

The health of the environment is dependent on the health of its subsystems. Though health is a difficult term to define when it comes to a river system, the health of the Hudson River watershed is of utmost importance to the people and animals that live in and around it. There is a popular theory among freshwater ecologists that the health of the system can be determined by the diversity and status of fish fauna (Karr 1981 in North America; Harris and Silveira 2001 in Australia; Pont et. al. 2007 for Europe). For this to be a useful assumption, though, it must first be understood how fish interact with and use the habitats provided by the estuary and its tributaries.

Some species are considered residents in particular habitats, spending significant portions of their adult lives year-round using the resources of a particular area. Other species move daily from habitat to habitat, foraging in one and taking shelter in another (Wooden 1999). Many species only use a given habitat during specific parts of the year: spring spawning runs, for example. Tributaries in particular play a vital role in the life cycle of many fish in the Hudson River. Some anadromous fish, such as alewife, spend a significant portion of their upriver time in tributaries, while the river's only catadromous fish, the American eel, often spends years maturing in the tributaries (Schmidt and Lake 2006). There are many indicators that eels are important players in the ecosystems of the Hudson River. Where they are present, they are often present in high densities, and their tendency towards opportunistic feeding may make them a good candidate for invasive species control (Mount et al. 2011). Unfortunately, though there are areas where their numbers are strong, numbers have decreased substantially along the east coast of North America over the last decades (Velez-Espino and Koops 2010).

The seasonal use of tributaries by fish considered residents in the main river, or potamodromy, is less well understood. While there are two definite examples of species that absolutely rely on seasonal access to tributaries (white suckers and smallmouth bass), there are many species whose presence in tributaries is cyclical but without clear indicators of their use or how critical their time in the tributaries is to their life cycle (Schmidt and Lake 2006).

This study is an attempt at describing general movements of fish into and out of the Indian Kill, a small tributary of the Hudson River, during the summer. The tributary activity of a number of species is well known during the spring, but the post-spawning activity during the summer is less well understood. It is hoped that by observing the summer fish biota further understanding of biota-habitat interactions can be obtained, especially with suspected potamodromous species.

METHODS

The focus of this study was the Indian Kill in Staatsburg, NY, a small stream with sections of rock and mud bottom. The sample site was located at its tidal mouth immediately downstream from the bridge on Thompson Lane in the Mills Norrie State Park, roughly 600 meters upstream from the Hudson River. Samples were taken between June 11th and August 15th, 2014.

The stream was sampled for fish with a fyke net, roughly 12 ft by 12 ft with two trailing zipper bags and a mesh of 0.5 cm, for four-hour intervals between high and low tides, with a temporal buffer of approximately an hour on either side of the tidal extremes. The fyke was anchored with rebar poles pounded into the stream bed, and the

wings of the fyke extended across the entire stream and were anchored on the bottom with rocks. The mouth was open towards the flow of the tides, facing upstream for ebb tide and downstream for flood tide. A durable plastic boat float was placed in the second bag of the net to provide an air pocket to avoid drowning any turtles who wandered into the net.

Over the course of the study period, 32 samples totaling 128 sample hours were carried out. These were evenly distributed between four distinct sample types, 8 samples or 32 hours each of: daytime flood tides, daytime ebb tides, nighttime flood tides, and nighttime ebb tides (See Appendix 1 for a list of sample dates). Sampling was postponed during heavy rain events due to the threat of flooding.

At the end of any particular sample, the bags of the fyke would be accessed through zippers sewn in the top and animals extracted through use of a dip net. If the tide was too high or visibility very poor, the net was removed from its supports and brought on land and the fish would be extracted from there, though this less-preferred method was only rarely used. Fish were placed in a bucket and processed from there. Identification was mainly done on site, though if identity confirmation was needed a picture was taken and provided to a consultant (R.E. Schmidt, pers. comm.). Total length was measured and fish were released afterwards. American eels were anesthetized with clove oil before measurement.

RESULTS

Over the course of two months of sampling, 309 individual fish were caught in the Indian Kill, representing 17 distinct species. Table 1 shows the number caught of each

species and their mean lengths. After the sample periods, it was discovered that there is a private pond upstream from the sample site that may be manually drained periodically into the Indian Kill (R.E. Schmidt pers. comm.). It is unclear how this affected the catch and would be worth further investigation.

It should be noted that the numbers on Table 1 represent fish that were likely moving either upstream or downstream and do not necessarily represent the population that dwell in the Indian Kill. Yellow bullheads were present in the greatest numbers, but were caught as schooling young-of-the-year (YOY) and were largely captured towards the end of the sampling period. Bluegills were present in almost every sample and are therefore ubiquitous.

YOY bluegill, largemouth bass, white sucker, and brown and yellow bullhead were all traveling concurrently with adults during the summer in the Indian Kill. This is reflected in the

Table 1: Total Catch. % Ebb represents the portion of that species caught during an ebb tide.

Common Name (*Genus species*)	**Number**	**Mean Length/SD (cm)**	**% Ebb**
American Eel (*Anguilla rostrata*)	21	36.8/17.6	71%
Bluegill (*Lepomis macrochirus*)	57	11.3/5.2	54%
Brown Bullhead (*Ameiurus nebulosus*)	17	9.5/5.9	88%
Carp (*Cyprinus carpio*)	2	71.8/1.1	100%
Fallfish (*Semotilus corporalis*)	5	20.9/5.2	0%
Golden Shiner (*Notemigonus crysoleucas*)	6	12.5/6.5	33%
Green Sunfish (*Lepomis cyanellus*)	10	11.0/1.8	70%
Largemouth Bass (*Micropterus salmoides*)	9	8.4/12.1	56%
Mummichog (*Fundulus heteroclitus*)	2	6.7/1.6	50%

Common Name (*Genus species*)	Number	Mean Length/SD (cm)	% Ebb
Pumpkinseed (*Lepomis gibbosus*)	11	10.7/2.6	45%
Redbreast Sunfish (*Lepomis auritus*)	8	16.0/2.5	50%
Smallmouth Bass (*Micropterus dolomieu*)	1	21.4/NA	0%
Striped Bass (*Morone saxatilis*)	4	6.6/0.8	75%
Tessellated Darter (*Etheostoma olmstedi*)	9	6.1/1.0	33%
White Perch (*Morone americana*)	40	17.5/2.6	37%
White Sucker (*Catostomus commersonii*)	25	13.5/11.7	88%
Yellow Bullhead (*Ameiurus natalis*)	82	5.9/5.7	70%

large standard deviations relative to average length present for these species. Striped bass are an anadromous species that typically spawn further downriver in the main body of the Hudson in May and June (Fay et al. 1983), the majority happening between kilometer 54 and 98 (close to Newburgh), though there is evidence of spawning up to Albany (Waldman 2006). They were present in small numbers and exclusively YOY, likely representing dispersal of the new young.

The Shannon-Weaver diversity index was used to compare the diversity of the fish moving through the Indian Kill during different periods because it takes both richness and equitability into account (Peet 1974). The equation for the Shannon-Weaver diversity index is as follows:

$$H' = -\sum_{i=1}^{s} (p_i Lnp_i)$$

Evenness measures how evenly distributed individuals are throughout the species present. It is calculated by comparing a diversity measurement to a maximum theoretical value. Outputs range from 0 to 1, where 1 is complete evenness and 0 means the population is skewed towards one species. *H'* and evenness, E_H, were calculated over the entire

summer, and for the total day yield, night yield, ebb tide yield, and flood tide yield independently. These results are shown in Table 2. Evenness is computed as follows:

$$E = \frac{H'}{H'_{\max}}$$

H'_{total} gives an upper limit for the diversity index of any given proportion but gives no information in and of itself – it was used here merely as a way to compare the different subsets. On the whole, the Indian Kill's diversity is distributed relatively evenly (E_H = 0.88). Substantially more (171%) individual fish moved at night than during the day. While species richness is comparable between the two, the difference in diversity

Table 2: The Proportion, Richness, Diversity, and Evenness of different sample periods. It should be noted that E_H scales logarithmically, so 0.9 is further from 1.0 than 0.8 from 0.9.

Period	**Proportion**	**Richness**	**Diversity**	**Evenness**
Total	1	17	H'_{total} = 2.48	E_H = 0.88
Day	0.269	15	H'_{day} = 2.21	E_H = 0.82
Night	0.731	15	H'_{night} = 2.09	E_H = 0.77
Ebb	0.605	15	H'_{ebb} = 2.17	E_H = 0.80
Flood	0.395	16	H'_{flood} = 2.26	E_H = 0.82

and evenness mean that a small number of species represent a larger proportion of the night sample. This suggests that transient species are preferentially immigrating and emigrating at night.

Fifty-three percent more fish moved downstream with the ebb tide than moved upstream with the flood tide. This means more individuals were leaving than entering. The lower diversity index and richness of fish in ebb tide samples shows that fewer species were leaving than entering, but at significantly higher numbers; specifically

American eel, brown bullhead, white sucker, and yellow bullhead. This also suggests that transient species were leaving as the summer progressed.

An analysis of weekly catch was done for each species. Since the sampling effort for each week was not consistent (4 hours for one particularly stormy week, up to 20 hours maximum), numbers were normalized by sampling effort (catch per hour of sample time) instead of the raw catch numbers for every week. When analyzed individually bluegill, redbreast, pumpkinseed, and tessellated darter, all of which were named tributary residents by Schmidt and Lake (2006), were consistently caught and should be considered residents of the Indian Kill. Green sunfish fall within this category too, although they were not mentioned in the 2006 paper. Figure 1 shows a comparison of the six non-resident species that demonstrated some periodicity (American eel, largemouth bass, striped bass, white perch, white suckers, and yellow bullheads) with the

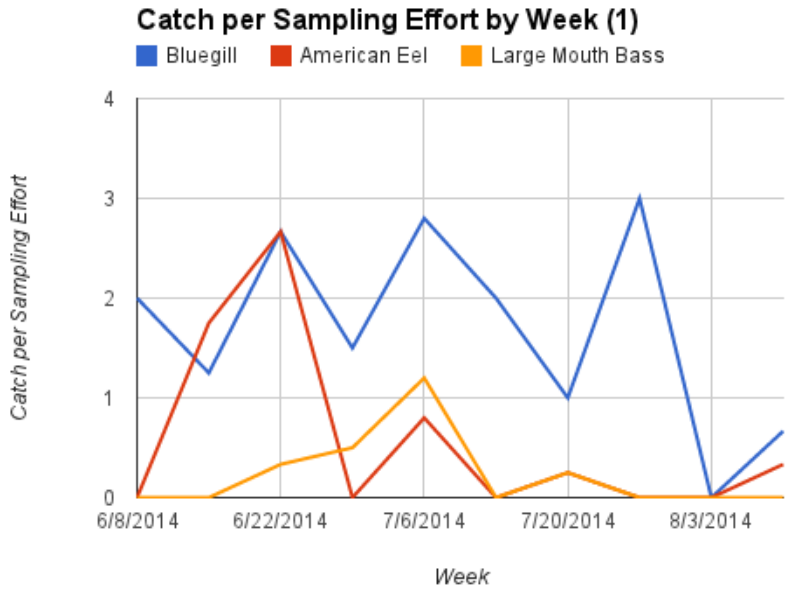

Figure 1A: Catch per Sampling Effort by Week for American Eel and Largemouth Bass. Catch per sampling effort is normalized catch for each four hour sample time per week.

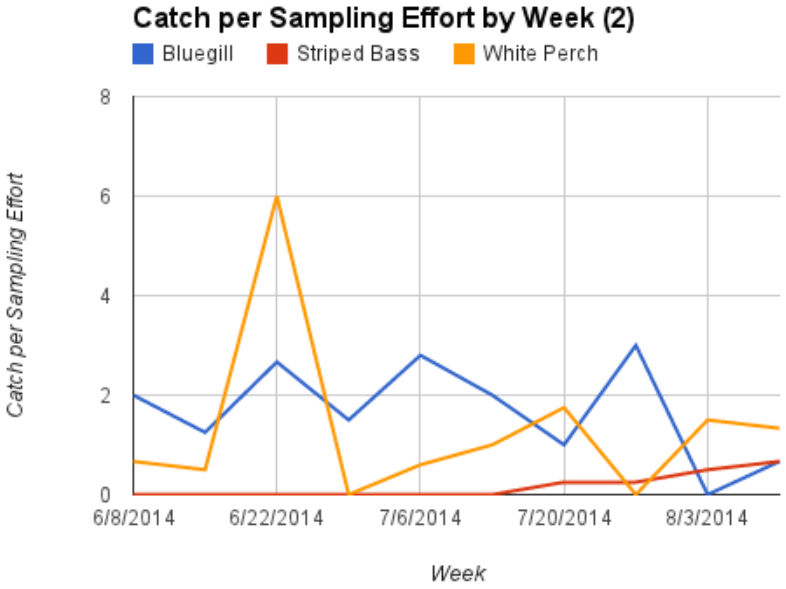

Figure 1B: Catch per Sampling Effort by Week for Striped Bass and White Perch. Catch per sampling effort is normalized catch for each four hour sample time per week.

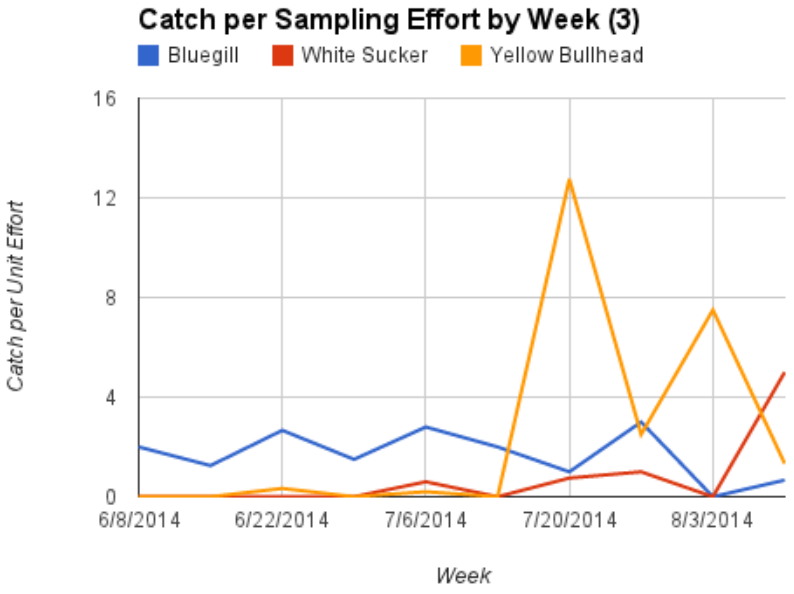

Figure 1C: Catch per Sampling Effort by Week for White Sucker and Yellow Bullhead. Catch per sampling effort is normalized catch for each four hour sample time per week.

bluegill, which was chosen to be the representative resident species because of a high population. The remaining species did not have enough data to draw conclusions from.

Largemouth bass were not caught in large numbers, but catches were clustered around the end of June through July (Figure 1A). One adult was caught and the remainder were obvious YOY. Largemouth bass are clearly reproducing in the Indian Kill but likely not in large numbers. Striped bass, as noted earlier, were only caught as YOY near the end of the summer, likely around the time they were moving north from spawning sites. Yellow bullheads were mostly caught in July and August after a probable spawning period, as most were YOY that were caught as schools, as displayed by the large peaks in Figure 1C.

Schmidt and Lake (2006) outlined species confirmed and suspected of potamodromous behavior. White sucker are listed as completely potamodromous, relying exclusively on tributaries for breeding. Figure 1C shows a dramatic increase in white sucker movement towards the end of the summer in the Indian Kill. The week of August 3rd represents a series of young white suckers leaving the stream, whereas the consistently low numbers caught beforehand were exclusively adults. White perch are listed as partially potamodromous, with the possibility that tributaries provide a significant portion of their breeding habitat. Breeding season is typically in the early spring, though not all tributaries where adults have been present have had observable spawning events (Schmidt and Lake 2006). Figure 1B shows that more white perch were caught towards the beginning of the summer than towards the end, consistent with fish of breeding age leaving after the spring runs. No juveniles were caught, and the methods employed would not collect eggs or larvae, so it is unclear whether the Indian Kill is

providing spawning habitat for white perch. Employing plankton nets for the collection of larvae and eggs could represent further research effort.

All American eels captured were sexually immature adult yellow eels that should be considered residents of the Indian Kill (Schmidt and Lake 2006). However, Figure 1A shows a substantial periodicity in their movements inconsistent with their residential nature. There is some correlation between moon phase and eel movements, with eels preferentially moving longer distances on darker nights close to the new moon (Schmidt et al. 2009). Figure 2 shows the catch per sample effort for bluegill (as a control) and American eel related to moon phase over the summer. There is a clear increase in capture of eels per sample effort as the moon phase moves towards the new moon, reinforcing this claim.

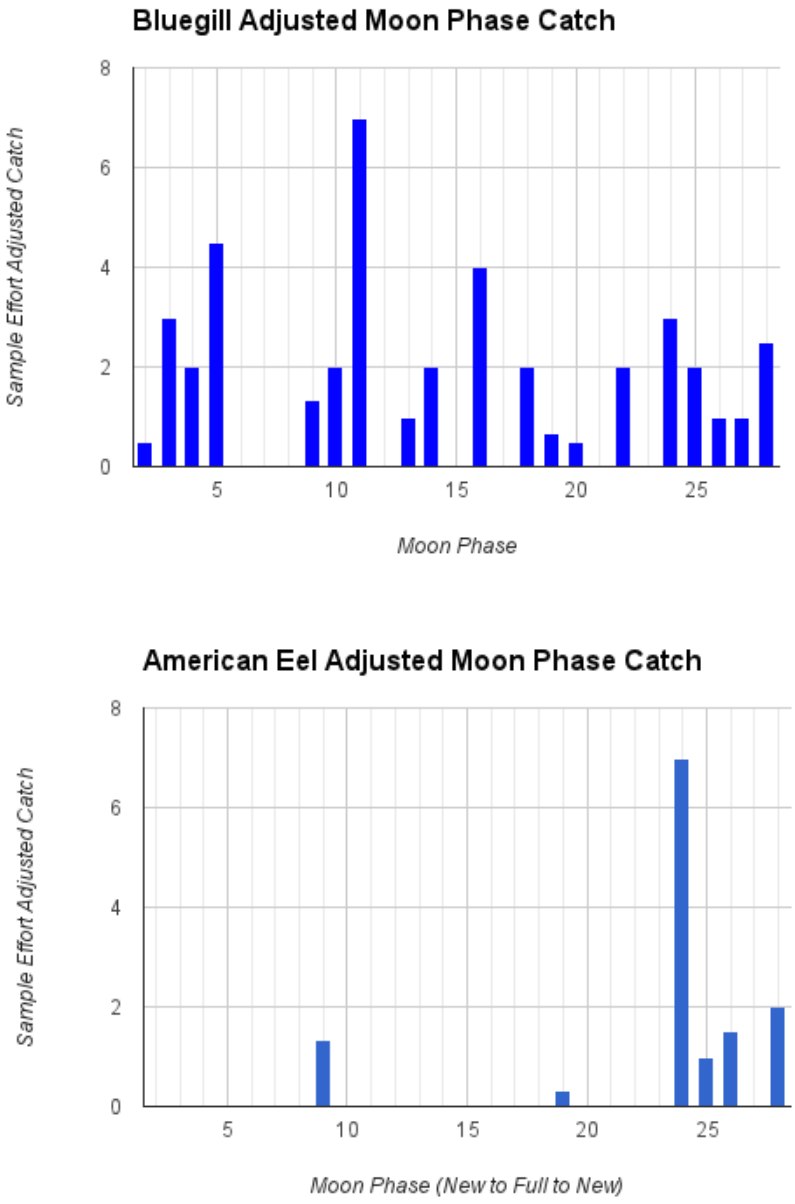

Figure 2: Adjusted Moon Phase Catch for Bluegill and American Eel. Moon phase is considered "new" at 0 and 29 and "full" at 15. Bluegill show no particular proclivity for moon phase, but American eel cluster close to the new moon as the nights get darker.

Yellow bullhead, brown bullhead, white sucker, largemouth bass, and golden shiners all showed discrete divisions in size categories present (Appendix 2). This likely represents a division in usage of the Indian Kill by different age classes of these species. This gives further evidence that these species are using the Indian Kill at least as a refuge for young-of-the-year, if not spawning.

The data displayed here shows that the Indian Kill provides spawning habitat for many species.

Two species of economic and ecological importance are using the Indian Kill as nurseries in which their young can mature safely away from larger predators: American eel likely year-round, and striped bass at least during the summer. Though it's unclear what the true

population of American eel is in the Hudson River, it is clear that their numbers have dropped significantly in the past decades (Velez-Espino and Koops 2010). Knowledge of how they use their habitat before a serious population crash occurs is vital.

This study did not seek to compare the Indian Kill and other tributaries of similar size. Further research can use similar methods for diversity assessment to compare other tributaries, though each tributary would need to be sampled in the same year to avoid any year-to-year differences. The diversity index from this year can be compared to other years of the Indian Kill to track how movement changes in future years.

Table 3: Findings by Species

Species	Usage
American eel (*Anguilla rostrata)*	Large, continuous size range and lack of sexually mature silver eels suggests refuge for maturing eels (Appendix 2). Consistent with catadromous designation. Greater numbers left than entered over the summer (Table 1) with a preference for moving at night close to the new moon (Figure 3).
Bluegill (*Lepomis macrochirus*)	Broad size range (Appendix 2) and lack of overall movement (Table 1) suggest bluegill are residents, consistent with current thought.
Brown Bullhead (*Ameiurus nebulosus*)	Age class split between young and adults (Appendix 2) suggest non-residency, consistent with a greater presence during ebb tide samples (Table 1).
Carp (*Cyprinus carpio*)	Numbers were very low and individuals were large and leaving (Table 1). Unclear how tributary was used, consistent with Possible Insignificant potamodromy designation in Schmidt and Lake (2006).
Fallfish (*Semotilus corporalis*)	Low numbers, even size distribution. Only caught in flood tides but numbers too low for significant analysis (Table 1).
Golden Shiner (*Notemigonus crysoleucas*)	Low numbers (Table 1) of unclear activity consistent with observations in Schmidt and Lake (2006). Age classes split between small and large (Appendix 2).

Green Sunfish (*Lepomis cyanellus*)	Less ubiquitous than bluegill (Table 1) with normal size distribution (Appendix 2). Should be counted as resident, though more were caught during ebb tides.
Largemouth Bass (*Micropterus salmoides*)	Almost exclusively YOY but for one adult (Appendix 2). Entered and left with equal frequency (Table 1), primary activity earlier in the summer (Figure 2).
Mummichog (*Fundulus heteroclitus*)	Too few caught to draw conclusions (Table 1). More common in marsh areas than streams.
Pumpkinseed (*Lepomis gibbosus*)	Stable number of a range of sizes (Table 1, Appendix 2). Entered and left with equivalent frequency, resident - consistent with Schmidt and Lake (2006).
Redbreast Sunfish (*Lepomis auritus*)	Stable number of a range of sizes (Table 1). Entered and left with equivalent frequency, resident - consistent with Schmidt and Lake (2006).
Smallmouth Bass (*Micropterus dolomieu*)	One caught, leaving on ebb tide (Table 1). Labelled as fully potamodromous in Schmidt and Lake (2006) though activity cannot be confirmed here.
Striped Bass (*Morone saxatilis*)	Low numbers of YOY caught (Table 1), clustered at end of summer (Figure 2). Possibly seeking refuge.
Tessellated Darter (*Etheostoma olmstedi*)	Few caught, of a consistent size (Table 1). Residents as per Schmidt and Lake (2006). Smaller sizes would not be caught by the mesh size used.
White Perch (*Morone americana*)	Large catch (Table 1) representing one age class (Appendix 2) mostly towards beginning of summer (Figure 2) might represent tail end of breeding run, consistent with partial potamodromous behavior in Schmidt and Lake (2006)
White Sucker (*Catostomus commersonii*)	Three distinct age classes were caught (Appendix 2), mostly on ebb tide (Table 1), majority towards the end of summer (Figure 2). Dependent on tributaries for spawning, would need larval confirmation.
Yellow Bullhead (*Ameiurus natalis*)	Highest number caught (Table 1) though concentrated at the end of the summer (Figure 2). Age class split between YOY and breeding adults (Appendix 2). Schooling behavior often caused large single catch.

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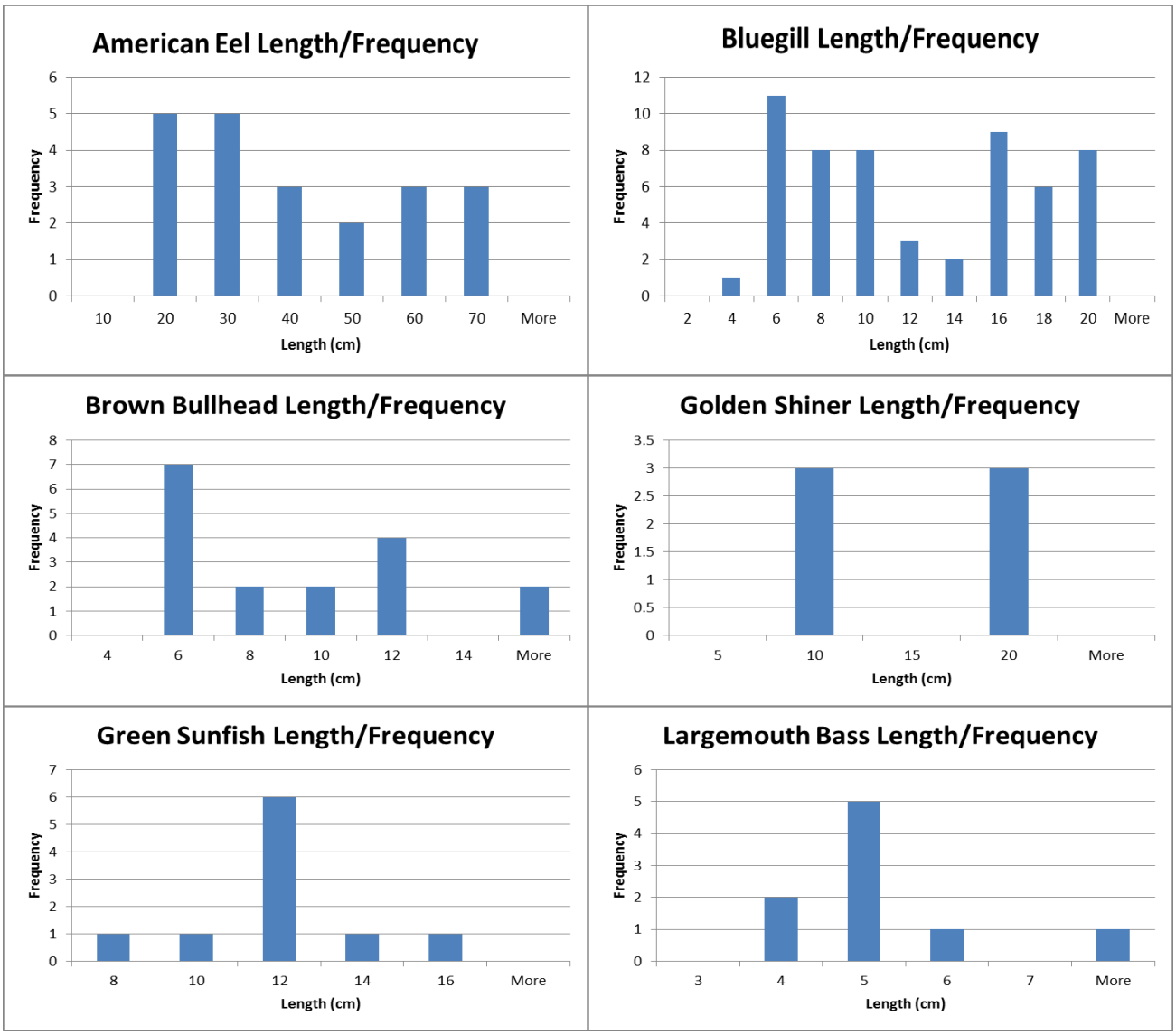
APPENDICES

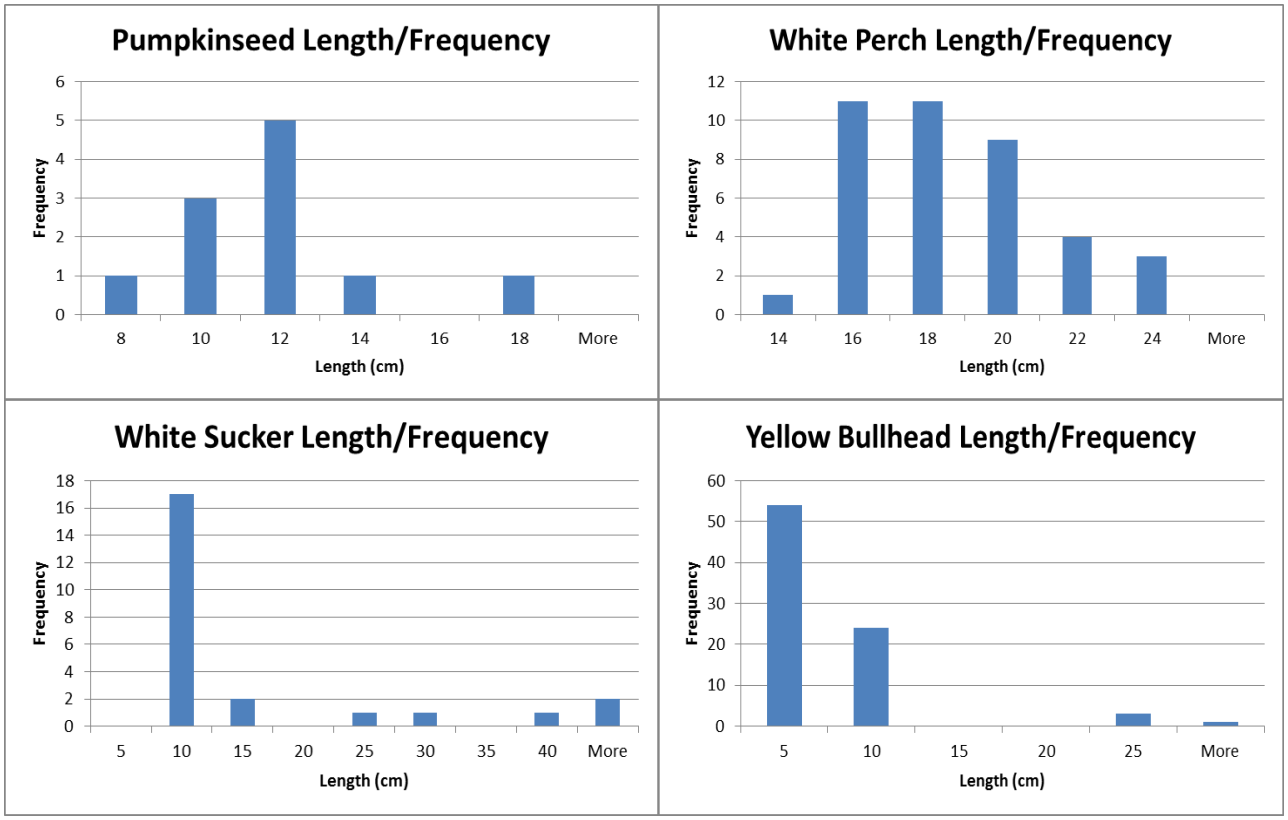
Appendix 1: Sample Dates, Times, and Tidal Stage

Date	Time	Tidal Stage
6/11/14	13:00-17:00	Daytime Ebb
6/12/14	9:00-13:00	Daytime Flood
6/13/14	15:15-19:15	Daytime Ebb
6/17/14	6:15-10:15	Daytime Ebb
6/17/14	12:15-16:15	Daytime Flood
6/19/14	15:00-19:00	Daytime Flood
6/20/14	16:00-20:00	Daytime Flood
6/21/14	22:00-2:00	Nighttime Ebb
6/22/14	18:00-22:00	Nighttime Flood
6/23/14	24:00-4:00	Nighttime Ebb
6/25/14	19:15-23:15	Nighttime Flood
6/29/14	11:15-15:15	Daytime Flood
7/1/14	12:30-16:30	Daytime Flood
7/6/14	21:00-1:00	Nighttime Ebb
7/7/14	17:00-20:45	Daytime Flood
7/8/14	23:00-3:00	Nighttime Ebb
7/9/14	12:00-16:00	Daytime Ebb
7/10/14	19:30-23:00	Nighttime Flood
7/16/14	12:45-16:45	Daytime Flood
7/22/14	18:15-22:15	Nighttime Flood
7/23/14	12:50-16:50	Daytime Ebb
7/23/14	18:50-23:00	Nighttime Flood
7/24/14	20:00-24:00	Nighttime Flood
7/25/14	2:00-6:00	Nighttime Ebb
7/29/14	16:30-20:30	Daytime Ebb
7/30/14	5:00-9:00	Daytime Ebb
8/1/14	13:00-17:00	Daytime Flood
8/1/14	19:00-23:00	Nighttime Ebb
8/5/14	21:00-2:00	Nighttime Ebb

8/5/14	3:30-7:30	Nighttime Flood
8/14/15	19:15-23:15	Nighttime Ebb
8/15/14	0:40-4:40	Nighttime Flood
8/15/14	7:00-11:00	Daytime Ebb

Appendix 2: Length/Frequency Histograms




Pumpkinseed Length/Frequency
Frequency
0
1
2
3
4
5
6
8
10
12
14
16
18
More
Length (cm)
White Perch Length/Frequency
Frequency
0
2
4
6
8
10
12
14
16
18
20
22
24
More
Length (cm)
White Sucker Length/Frequency
Frequency
0
2
4
6
8
10
12
14
16
18
5
10
15
20
25
30
35
40
More
Length (cm)
Yellow Bullhead Length/Frequency
Frequency
0
10
20
30
40
50
60
5
10
15
20
25
More
Length (cm)