Relationship Between Prey Body Depth, Northern Pike Gape Size and Pike Habitat Utilization in Brown Lake

BIOS 35502: Practicum in Field Biology

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Abstract:

As a top predator which exhibits significant effects on prey fish populations, northern pike, (*Esox lucius)*, are important ecologically and economically. This study aimed to examine the relationship between the size of prey fish and the localization of northern pike of varying gape sizes. The specific hypothesis which was tested is the existence of a positive relationship between prey body depths, prey species, northern pike gape size and northern pike localization. Sampling was conducted at four unique locations over two separate weeks. Sampling locations were found to differ in prey abundances across weeks and overall prey body depth decreased from the first to second week. Neither northern pike abundance nor gape size was found to vary with site or week, suggesting that pike in Brown Lake may follow an ideal free population distrbution.

Introduction:

The northern pike, (*Esox lucius)* holds an important place as a top predator in lake and river ecosystems. In addition to its ecological importance, the northern pike has an economic importance as a hard-fighting sportfish. Pike feeding habits have been shown to affect the numbers and structures of its prey species populations (Frost 1954). Due to its piscivorous nature, the northern pike can also have economic impacts through its consumption of other sportfish. Understanding the distribution of pike within lake ecosystems could have important implications for fisheries management strategies.

Pike have been shown to preferentially select habitat areas which contain high diversity and biomass of prey species (Chapman and Mackay 1984). Pike feeding habits are also influenced partly by morphological constraints (Hart and Hamrin 1988). The size of the pike's mouth is a factor in determining what prey a pike can consume. Prey body morphology is also a factor in pike foraging (Nursal 1973). Pike have been shown to prefer shallow-bodied prey over deep-bodied prey (Nillsson, 1999), and soft-rayed fish over spiny-rayed fish (Eklöv and Hamrin 1989).

Pike also appear to exhibit selectivity in prey species, as shallow-bodied perch are known to constitute a predominant proportion of pike diets (Frost 1954). Pike have also been found to forage on bluegill, and minnows (Savino and Stein 1989). Golden shiner, *Notemigonus crysoleucas*, is included in this study as a consumable prey species due to its shallow body depth and soft-rayed fins (Einfalt and Wahl 1997). Pumpkinseeds are included as a member of the *Lepomis* genus, and their subsequent close relation to bluegill. Based on the stated previous research, this study defines consumable prey fish as yellow perch (*Perca fluviatilis),* golden shiner (*Notemigonus crysoleucas*), bluegill (*Lepomis macrochirus),* pumpkinseed (*Lepomis gibbosus*) having body depths within the consumable limits of pike as measured by gape size.

Optimal foraging theory predicts that pike will feed on prey which gives them the most gain and least cost per foraging event. Pike are known to feed on prey which is of a size class that maximizes energy gain while minimizing handling time. This is a strategy to minimize exposure to conspecifics who may cannibalize or kleptoparasitize the foraging pike (Nilsson and Brönmark 1999).

As a consequence of increased gape size, larger pike are morphologically able to consume larger prey. According to optimal foraging theory, this relationship should translate to larger pike preferentially consuming larger prey. An extension of this dynamic is the habitat localization of pike. If larger pike preferentially consume larger prey, it should be advantageous for these pike to localize to areas which contain high densities of large prey (Eklöv 1997). As the top predator in lake ecosystems, pike above 250mm do not typically have aquatic predators and should not select habitats based on aquatic predation avoidance (Chapman and Mackay 1984). Pike have been shown to engage in both cannabilism and kleptoparasitism which influences the habitat selection of small pike (Nilsson and Brönmark 1999). Additionally, since small pike are morphologically excluded from foraging on larger prey, these pike should localize to areas which contain high densities of small prey in order to maximize foraging gains. Based on these relationships, I hypothesize that northern pike gape size will vary with prey body depth, and prey species across sites. This relationship will be examined by sampling the fish communities at unique sites and comparing the body depth and abundance of prey species with the gape size and numbers of northern pike present.

Methods:

This study was conducted in Brown Lake, located in Gogebic County, MI. This eutrophic lake has a surface area of approximately 63 acres, a maximum depth of approximately 4.5m, an outlet draining into Brown Creek and very turbid water (Secchi Depth 0.7m). Brown Lake contains populations of muskellunge (*Esox masquinongy)*, northern pike (*Esox lucius)*, walleye (*Sander vitreus vitreus)*, black crappie (*Promoxis nigro-maculatus)*, yellow perch (*Perca fluviatilis)*, golden shiner (*Notemigonus crysoleucas*), bluegill (*Lepomis macrochirus)*, pumpkinseed (*Lepomis gibbosus*), and white sucker (*Catastamus cammersanii)* (UNDERC, unpublished).

Four unique habitat locations were chosen for sampling. Samples were taken from the mouth of the outlet into Brown Creek. This “outlet” habitat area contained both submergent and floating vegetation over a mud substrate. A “beach” habitat area with submergent, emergent, and floating vegetation over a sand substrate was sampled. Additionally, samples were taken from a “wood” habitat containing submergent vegetation over a mud substrate. A “rock” habitat consisting of submergent vegetation over a cobble substrate was also sampled.

Prey fish were sampled by fyke net sets. Fyke nets were set for 24 hours and the contents collected after this period. The length, body depth, and sampling location of the specimens were recorded and the fish immediately released. Specimens were also identified to species. Northern pike were collected utilizing the same netting procedure. The gape size of trapped pike was measured and compared to the body depth of the prey species present at each site. This procedure was repeated during two weeks, the first week of June and the second week of July 2008.

Experimental data were analyzed using SYSTAT 12. The body depth of prey species and gape size of northern pike were analyzed by Analysis of Variance (ANOVA) comparisons of these characteristics across sites. Consumable prey were determined to be yellow perch (*Perca fluviatilis)*, golden shiner (*Notemigonus crysoleucas*), bluegill (*Lepomis macrochirus)*, pumpkinseed (*Lepomis gibbosus*), which had body depths below the largest northern pike’s gape size. These prey were separated by size classes, small yellow perch (length<130mm), medium perch (length<200mm), small bluegill (length<110mm), and small pumpkinseed (length<110mm). The abundance of consumable prey fish was standardized by net sets for each site. The abundances of consumable prey were also compared by one-way Chi-squared analyses across sites. Chi-squared analysis was used to compare the abundance of pike across sites. The abundances of prey fish were compared by Chi-squared analyses across sampling weeks. Analysis Of Variance (ANOVA) testing was used to examine variation in body depth between sampling weeks and sampling sites.

Results:

Chi-squared testing of the total abundance of prey fish between sampling weeks showed no significant difference in the total abundance of prey fish between the two weeks (P=0.746) Variation in prey abundance at two sampling sites was significant between weeks. Chi-squared testing shows a statistically significant increase in prey abundance for the second week at the beach site (P=0.032). Prey abundance at the rock site decreased significantly by the second week as shown by Chi-squared analysis (P<0.0001).

Chi-squared analysis of all possible prey fish (small perch, medium perch, golden shiner, small bluegill, and small pumpkinseed) abundance across sites shows significant variation in prey species abundance across the three sites (rock, beach, and wood) where all species were found (df=8, P=0.000029). These results are illustrated in Table 1. Chi-squared analysis of prey fish present at all sites (medium perch, small bluegill, and small pumpkinseed) also shows that there are significant differences in prey abundance across the four unique sampling sites (df=6, P=0.000984). These site differences are shown in Table 2. Sites were subsequently ranked for pike preference by individual species abundances. Table 3 shows these rankings.

ANOVA testing of prey body depth shows an overall decrease in prey body depth between weeks (df=6, P<0.0001). This trend is illustrated in Figure 1. Although body depth decreased overall, there were no significant differences in prey size between sites. Therefore, prey abundance is used to predict pike localization instead of prey body depth.

ANOVA analysis indicates that northern pike gape size did not vary significantly across sites (P=0.648). Chi-squared analysis indicates that the relative abundance of northern pike did not vary by site or week (P=0.989, P=0.92). Chi-squared analysis also shows that northern pike abundance did not vary by site between weeks (P=0.78).

Discussion:

The results of this study reject the tested hypothesis that northern pike gape size and abundance will vary across unique habitats in a positive relationship with prey fish body depth. Pike abundances also failed to change across a temporal span in response to changes in prey fish species abundances. This unexpected finding is interesting because northern pike showed no apparent preference for a sample site by either numbers caught or the gape size and relative size of the fish caught. The sample sites, however, did vary significantly in their prey species composition across spatial and temporal scales.

The three sample sites which contained all species of prey fish varied significantly in the abundance of prey fish which were found at the sites. The beach site contained the highest abundance of small pumpkinseed, bluegill and golden shiners, and the second-highest abundance of small perch, but had the least medium-sized perch. The rock site had the second-highest relative abundances of all prey species except small perch, which were in the highest abundance at this site. The wood site contained the least-highest relative abundance of all species except medium perch, which were in the highest abundance at this site.

When all sites are compared, the outlet contains the lowest abundances of small pumpkinseed and small bluegill, but has a greater abundance of medium perch than the beach site. The beach site still contains the least medium perch when compared to all sites. All other abundances are the same for the remaining sites when compared to all the sites. This suggests that the outlet site has the lowest potential prey for northern pike as it ranks last in all species except medium perch, where it has the second-lowest abundance. The relative abundances of consumable prey fish are shown in Table 3. Golden shiner and small perch are completely absent from the outlet site. According to this prey composition data in respect of the original hypothesis, the outlet site should have had the lowest number of pike captures, while the rock or beach sites should have had the greatest number of pike catches.

Although prey abundance did not change across all sites by sampling week, it did change at two sites. Prey abundance at the beach site increased by the second sampling. Conversely, prey abundance at the rock site decreased by the second sampling. A multitude of factors could have driven these changes. The hatching and growth of prey fish to catchable size could explain the increase in prey abundance at the beach site. Additionally, increased seasonal vegetative cover at the beach site may have resulted in a more diverse habitat which could harbor greater numbers of prey fish by the second sampling week. The decrease in prey abundance at the rock site is an interesting finding. This may have been caused emigration due to an increase in available vegetated habitat in other areas in the lake. Alternatively, the initially high numbers of prey fish may have been due to fish localizing to the area in response to its rocky, graveled bottom as a spawning site (Robillard and Marsden, 2001., Danylchuk and Fox, 1996). These fish may have vacated the site after spawning and returned the site to naturally low numbers of prey fish. In spite of these temporal differences, pike capture rates fail to reflect the change in prey fish abundance.

Total prey fish body depth significantly decreased from the first to second sampling week. Increased numbers of catchable smaller fish may be the reason for this decrease in total prey body size. This trend was reflected at the outlet site which also showed a decrease in prey body depth. Pike capture success is greater with smaller fish and the handling time is lower for these fish, which results in less exposure to cannibalism or kleptoparasitism (Nilsson and Brönmark 1999). This relationship would predict that greater numbers of pike would be captured at all sites, particularly the outlet site during the second sampling week. Alternatively, optimal foraging theory emphasizes the role of larger prey fish in pike diets. This strategy predicts pike abundances to be greatest during the first sampling week, when larger prey was present, in particular, at the outlet site. In light of these differences, the lack of a significant difference in pike captures at the outlet site between weeks could be seen as a dynamic equilibrium between large pike optimally foraging and small pike avoiding cannibalism or kleptoparasitism. However, the lack of variation in pike gape size at this site, suggests that different size classes of pike are not using the outlet with different strategies.

The failure of pike to localize to certain sites based on prey abundance, composition, or size, may be due to the pike's behavioral characteristics. As sit-and-wait predators, pike have a relatively immobile nature (Savino and Stein 1989, Eklöv, 1992). Pike have also been shown to exhibit strong homing behavior and some have been found to stay in the same zone of a lake between years (Eklöv 1997). This suggests that pike will not select better habitats because they will not encounter them due to their tendency to stay in a home range area.

The lack of significant differences between pike capture sites is also supported by the theory of ideal free distribution. This theory has been shown to hold true for pike which choose habitats based on intrinsic fitness gradients and this results in a population distribution which equalizes fitness across habitats (Haugen et al. 2006).

The failure of pike captures to exhibit trends towards a certain habitat is an interesting finding which could be influenced by a multitude of factors. This study was limited in its scope by monetary and temporal resources. More data may have been obtained if all the sample sites in Brown Lake had been accessible to seining. Additionally, the netting of the fyke nets may have failed to capture the smallest prey fish available at each site. The smallest fish caught had a body depth of 11mm, and more small fish may have been caught had the netting been finer. Two sizes of nets were used in order to control for this, but some fish may have avoided capture due to body size or ability to see and avoid the netting. Furthermore, the woody site had to be abandoned during the first week and this potential set of data was excluded from the study. Northern pike's foraging strategy as a sit-and-wait predator may also have contributed to the relatively low capture rate of pike in fyke nets.

Further studies should examine alternative sampling strategies in order to maximize the sampling across all species and sizes of fish. Future work should also focus on in-depth study of specific pike in order to examine their foraging strategies within lake ecosystems. Further study should also focus on manipulating habitat ecosystems in the lab in order to clearly determine the role of prey fish in pike localization choices. This work could also focus on giving up densities for different habitat types or different prey types.

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Tables and Figures:

Table 1: All Consumable Prey Fish Abundance by Site.

	All Consumable Prey Fish Abundance				
Site	Golden cpns	small perch cpns	med perch cpns	small ps cpns	small bluegill cpns
rock	7.75	18.34	16.45	6.75	6.75
beach	13.50	11.27	2.76	9.25	13.88
wood	0.33	3.04	16.70	5.00	5.00

This table illustrates differences in the abundance of all consumable prey fish across the three sites where all prey fish were found. Chi-squared analysis indicates significant differences in abundance of consumable prey fish across sites (df=8, P=0.000029). Data are standardized by catch per net set (cpns). Golden shiner are abbreviated "golden" and pumpkinseed are represented by "ps".

Table 2: Consumable Prey Fish Abundance Across All Sites.

	Consumable Prey Fish Abundance		
All Sites	medium perch cpns	small bluegill cpns	pumpkinseed cpns
outlet	5.77	0.33	0.28
rock	16.45	6.75	6.75
beach	2.76	13.88	9.25
wood	16.70	5.00	5.00

This table illustrates the differences in consumable prey fish across all sites. Golden shiner and small perch were not found at the outlet site and are omitted from this table. Chi-squared analysis indicates significant differences in consumable prey fish abundance across the sites (df=6, P=0.000984). Data are standardized by catch per net set (cpns).

Table 3: Prey Fish Ranking By Site.

	Prey Fish Ranking (Higher Numbers=Higher Abundance)					
Site	Golden shiner	small perch	medium perch	small ps	small bluegill	Total Rank
outlet	0	0	2	1	1	4
rock	3	4	3	3	3	16
beach	4	3	1	4	4	16
wood	2	2	4	2	2	12

This table illustrates the sites as ranked by prey fish abundance. Each fish class is ranked with 4 signifying highest abundance among the 4 sites. Zeros indicate no fish were found at that site. The rock and beach sites have the greatest amount of consumable prey fish. The outlet site contains the least amount of consumable prey fish. Pumpkinseed are represented by "ps".

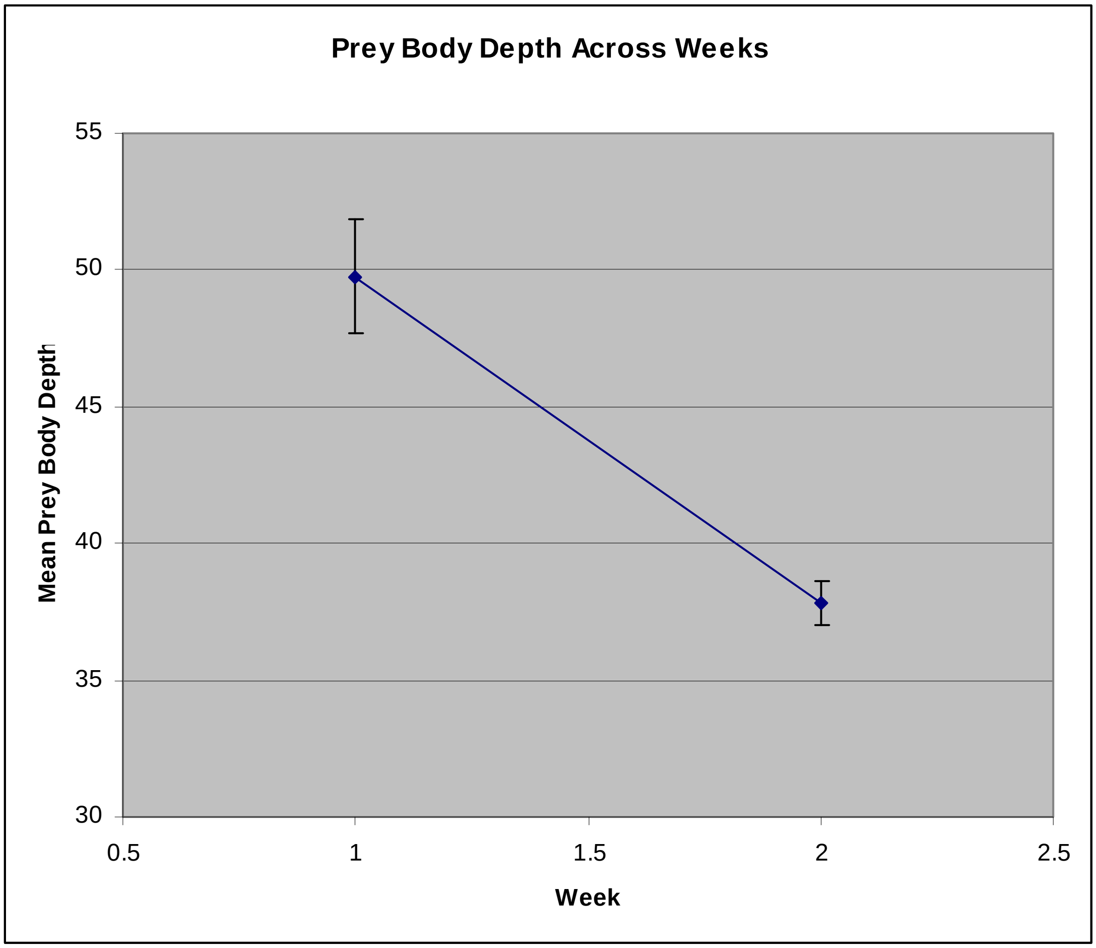

Figure 1: Prey Body Depth Across Weeks. This figure shows the decrease in prey body depth from the first to second week. ANOVA testing found this decrease to be statistically significant (P<0.0001). Increases in juvenile fish catches the second week likely drove this trend.