Lake and Bog Fish Survey and Water Chemistry Comparison to 1985 Records at UNDERC

BIOS 569: Practicum in Field Biology

Ardis Copenhaver
Advisors: Dr. Todd Crowl and Dr. Karen Francl

2005

Abstract

The relationship between water chemistry and species composition was examined by conducting a fish survey of eight lakes and four bogs and gathering water chemistry data. The relationship between water chemistry over a 20-year period and its effects on the species composition was determined with no significant change in water clarity and conductive; however, a significant change of pH was detected. The changes in water chemistry were found to have no distinct effect upon species richness. A principal components analysis revealed trends in species composition across sites; however the correlations did not present any strong relationship between the first three components and water chemistry. However, a minor trend was present between component II and conductivity. These results maybe due to the limited number of sites selected and the limited number of specimens collected. In comparison to the 1985 species lists some past recorded species were not found. This may have been due to the limited collection time and techniques that were available. However, the survey extensively updated the species list from the previous records.

Introduction

The University of Notre Dame Environmental Research Center (UNDERC)'s property contains approximately 35 lakes and bogs. In 1985, 24 of 35 lakes and bogs of UNDERC were surveyed and data was collected creating a student's guide of the present species and water chemistry (Table 3, 4; St. Amand 1985). The chemical data has been gathered since 1975 and summarized according to *The Student's Guide to UNDERC* (Table 3.). The chemical tests of the past records were conducted using the Hach water chemistry kits (St. Amand 985). However, only a limited number of lakes and bogs were surveyed and tested, which limits the ability to compare past and future data. In addition, some large lakes such as Tenderfoot Lake (ca.182 ha) would be difficult to conduct an accurate survey of the entire species pool. However, smaller bodies of water

<6ha (e.g., Hummingbird and Morris) would allow for a more accurate survey (Table 5; St. Amand 1985).

The goal is to create a complete species list of selective lakes and bogs on the property, in which multiple surveying techniques will be implemented. I recognize that each sampling method contains biases. For example, minnow traps would be used no more than 5 meters from land or 5m deep depending on the environment. This would limit the amount and diversity of species collected to small, shallow-inhabiting fish and juvenile piscivorous fish (Hansen 2004). Seine netting collects samples within a limited area depending on the size of the net (Francl-pers. comm.). Gill netting samples are also restricted by the net and opening size, collecting only fish large enough to be captured in the net (Francl-pers. comm.). The technique using rod and reel with artificial bait is biased towards piscivores. In addition, artificial baits have varying results due to size, color and motion of the bait. The effectiveness of this technique also varies on the species of piscivores present and their environments (Francl-pers. comm.).

Many factors contribute to changes in lake and bog fish composition, such as predation, both aquatic and terrestrial. Predators affect the food web contributing to the absence of certain fish in an area's lakes or bogs. In accordance with the trophic cascade theory, lakes and bogs dominated by piscivores will have fewer planktivores, while those areas dominated by planktivores will have few to no piscivores. For example, if piscivores are removed from an ecosystem the various planktivores will dominate the area (Carpenter 1997). Another factor that affects fish composition is the habitat's water chemistry. If physical conditions change within an aquatic environment, populations may not adapt and species composition may shift resulting in a decrease of species richness. Öhman (2004) considers acidity of aquatic environments to be a major factor affecting species diversity. Degerman and Lingdell (1993) found that acidity affects gill morphology in addition to inactivating an important hatching enzyme for eggs. In addition, the degree of change from the previous conditions affects species' adaptation rate to their environments (Öhman 2004).

Its is possible that the water chemistry of UNDERC's lakes and bogs may have been altered within the past 20 years due to anthropogenic influences (e.g. species introductions), minor climatic changes (changes in temperature or yearly rainfall), or the acidification of environments due to acid rain. From this assumption, we hypothesized that fish species distribution and diversity may have been altered, as well. Thus, a fish survey of eight lakes and four bogs at UNDERC was conducted, in addition to determining water chemistry measurements for a comparison study to 1985 records. We hypothesized that changes in water chemistry, if detected would result in a significant change in species composition.

Methods

Species Survey

Eight lakes and four bogs of UNDERC were surveyed using seine netting, gill netting, minnow traps, and rod and reel with artificial baits (Appendix 3). However, few bogs (Tender, Ed's, Bolger, and Beaver) were considered too dangerous to carry out all methods due to substrate consistency and vegetation construction affecting water access. In addition, few sites were not surveyed with a few techniques due to the assumptions of certain species would not be present in certain harsh environments to save time and effort. The seine nets used were ca.1.2 m wide x 5m and 25 m long. Two gill net types were used (15m x 3" (ca. 5 cm) squares and a 28m experimental gill net with five different mesh sizes) with one net being set at random and checked after 4 hours at each site. Another method includes setting 10 minnow traps (Gee's Minnow Traps) at each site for smaller species and checking the traps after a period of 24 hours upon being set (Soranno 1990). In addition, a rod and reel with artificial bait was used to collect and examine larger piscivorous species approximately for 2 hours. However, a time limit was set if nothing was caught within 30 minutes upon the first cast. To minimize temporal biases, the survey attempted to maintain a constant time of day in which samples were collected and identified using each method. With each survey technique, the species, weight and/or length of each specimen captured was determined. In addition, voucher specimens were also collected to ensure accurate identification and to contribute to the research facilities' teaching collection. The species collected and identified were compared to the past records of species that were present in the particular chosen lakes and bogs.

Water Chemistry Tests

The water chemistry measures consisted of measuring color (apparent and true), specific conductance, pH, clarity (secchi depth), temperature to be compared to 1985 data. The 1985 data was measured using the Hach water chemistry kits, but in this survey several instruments were used to determine these variables. The water chemistry data was collected using secchi disk, pH meter, and a Hanna Instrument conductivity meter. The water samples collected were tested for true and apparent color with a spectrophotometer. In addition, the water chemistry data for all sites was collected within a 24-hour period in order to minimize bias from ambient temperature and precipitation.

Statistical Analysis

Principle components analysis using NTSYS-pc 2.02 (Applied Biostatistics, Inc., 1998) was performed to set up a fish distribution between the sites. The first three principle components having the greatest variance were used to set up a scatter plot of the species distribution. The diagram was made to show the components with the greatest variance exhibiting the species distribution between the sites. In addition, the plot showed the extreme high loading species. The three calculated components were each correlated with three water chemistry variable (pH, clarity, and conductivity) using SYSTAT 11 (Systat software, Inc. 2004.) to determine if a significant relationship exists. The three water chemistry variables of 1985 and 2005 were also compared using paired t-tests to determine if a significant change of water chemistry had occurred in the past 20 years.

Results

The survey collected several species not originally recorded in the 1985 species list (Table 4). In addition, a few species were not collected at certain sites that the past records established were present. *Umbra limi* were not collected from Tuesday and Morris contrary to the 1985 records. In Kickapoo, *Esox masquinongy* and *Promoxis nigramaculatus* or *annularis* were not collected as well. *Micropterus dolomieui* was not collected from Raspberry and *Pimephales notatus* was not found in Morris. In addition, numbers of species were not found in Bolger Bog compared to the 1985 survey.

In the principle components analysis expected variation of component I and II was approximately 39% with an actual variation of approximately 56%. The first component gave ~31% variance distinctly separating out Tuesday and Morris from the other surveyed sites (Figure 1). In addition, component I separated high loading species found within the separated sites. The only high loading species on the positive axis found in the other 10 sites was *Umbra limi* (0.4328). Meanwhile, a number of high loading species on the negative axis were found in Tuesday and Morris consisting of *Esox lucieus* (-0.4855), *Lepomis* *gibbosus* (-0.5460), *Pimephales notatus* (-0.7416), *Pimephaes promelas* (-0.7524), *Cyprinella caerula* (-0.8478), *Notropis photogenis* (-0.8733), and *Notemigonus crysoleucas* (-0.9651).

The second component gave ~56% variance distinctly separating out Tuesday and Morris as well. Component II separated the positive high loading species of *Esox lucieus* (0.6806), *Lepomis macrochirus (0.7216)* and *Lepomis gibbosus* (0.7283) being found at Morris. Meanwhile the negative high loading species were found at Tuesday consisting of *Notropis photogenis* (-0.4722), *Culaea icanstans* (-0.4880), *Pimephaes promelas* (-0.6185), and *Pimephales notatus* (-0.6291).

The water chemistry results did show changes since 1985 (Table 3). The pH of each site had increased, however Hummingbird was the only site to result in a minor decrease of 0.5. Half of the sites resulted in a decrease in specific conductance since 1985. The water clarity was compared with 4 out of 12 sites resulting in an increase secchi depth. The 1985 and 2005 data was compared using paired t-tests. Both water clarity (0.5321) and conductivity (0.5798) resulted in insignificant p-values; however, the change in pH was significant (0.0004896). Each component of the principle components analysis was statistically tested using a correlation between pH, water clarity and specific conductance. Components I, II and III when correlated with pH and water clarity were determined to be insignificant (Table 2). The correlation between the components and conductivity were all insignificant; however there was a minor trend between component II and conductivity.

Discussion

The survey and statistical analyses failed to support the original hypotheses. After 20 years, the water chemistry did not change sufficiently to have a significant affect upon species composition. All correlations were found to be insignificant for each comparison between each component and each variable. Several reasons may explain the insignificant results. First, the number of sites and the amount of fish collected may not have been sufficient to show any significant correlation. The amount of fish collected was limited by the number of times each method was used due to time, equipment and assistance available. Another aspect that may have affected the results was the amount of time that was allotted between 1985 and 2005. There may not have been sufficient time and outer effects upon UNDERC's property to show a great change in water chemistry and species richness. This indicated that UNDERC's aquatic environments have been fairly chemically stable since 1985 with little disruption of the physical aquatic conditions and species composition. In addition, the number of techniques was limited due to costs and the possible hazardous affects the methods may have on the environment and the species populations.

The comparison of pH measurements of 1985 and 2005 showed that the all sites had an increase in pH, except for Hummingbird indicating that a majority of sites are becoming more basic than acidic. The pair t-test resulted that a significant change in pH levels had occurred. However, the explanation for the increase was not determined. The significant difference maybe due to human and instrumental error of the past, because instruments were not as advanced as today. Half of the sites resulted in an increase in specific conductance. However, the change in conductance was insignificant. The reason for this maybe due to human/instrumental error or no significant change had occurred in the past 20 years. In addition, only four out of twelve sites resulted in a decrease in water clarity with the p-value indicating that no significant change occurred. This indicated that the aquatic environments are changing, but not significantly over time. Nonetheless, component I, II, and III when correlated with three water chemistry variables were insignificant, except for a minor trend between component II and conductivity. This indicated that water chemistry had no significant relationship with species composition. Thus, these significant and insignificant chemical changes had no affect upon species richness.

The principle component analyses showed that certain species tend to exist in certain environments with other species. However, the explanation for these specific composition trends was not determined. Certain common ideas that may affect these compositions are the presence or absence of predation in which if a larger number of pisicivores are present than fewer planktivorious species would be present (Carpenter 1997). In addition, some species compositions were more common throughout the 12 sites compared to other species. Both components I and II, separated Morris and Tuesday indicating that these sites had unique species distribution compared to the other site having similar species compositions.

The survey found species that were not originally listed in the 1985 records, which maybe due to anthropogenic introduction or may have not been collected in the past. However, there were species not collected during the survey, which maybe due to the techniques not being efficiently carried out. Of the three possibilities, changes in water chemistry probably did not have a great effect on those species, because we found that our data did not correlate with species richness. However, the other two explanations maybe considered because the survey was limited.

The survey developed a more detailed species listing than previously available and the water chemistry tests showed minor temporal changes. The hypothesis was rejected on the basis that no significant correlation between species composition and water chemistry variables was found. However, each site established that certain species tend to exist in particular environments together. In addition, pH was the only significant change that occurred, however the change was not sufficient to have a great affect on species composition. Further research could be done to understand these particular communities and how these communities established themselves. In addition, this particular hypothesis could be tested once again, but with a larger number of sites and samples sizes using a greater variety of techniques.

Acknowledgements

I would like to thank my advisor Dr. Todd Crowl for his guidance and field assistance within my particular research. For Dr. Karen Francl, I deeply appreciate your support and advice throughout the planning and summer research as well as securing the needed equipment and the comparison reference that established the basis of my research. I would also like thank Dr. Anne Chouinard for her advice, assistance, and instruction on collection techniques both in and out of the field. I would like to express my gratitude towards The Bernard J. Hank Family Endowment, which supported the course as well as allowing me to take part in this research experience. Last, I want to thank Nancy Chock, Claire Freemen, Greg Peters, Jeffrey Ross, and Michael Tiso for there assistance in the field and as colleagues.

Work Cited

Applied Biostatistics, Inc., 1998. NTSYSpc 2.02i.

Carpenter, S. R., and K. L. Cottingham. 1997. Resilience and restoration of lakes. Conservation Ecology 1:2. URL: http://www.ecologyandsociety.org/vol1/iss1/art2/.

Degerman, E. and P.-E. Lingdell. 1993. pHisces-fisk som indicator på lågt pH. Information från Sötvattenslaboratoriet, Drottningholm 3: 37-54.

Hansen, M. J., P. S., Newman, C. J. Edwards. 2004. A Reexamination of the Relationship between Electrofishing Catch Rate and Age-0 Walleye Density in Northern Wisconsin Lakes. North American Journal of Fisheries Management 24: 429-439.

Öhman, J. 2004. The effects of water chemistry on fish species distribution. Graduate Thesis, Swedish University of Agriculture Sciences. 1-26.

Soranno, P. A. 1990. Methods of the Cascading Trophic Interactions Project. University of Wisconsin: 60-63.

St. Amand, A., S. R. Carpenter, and R. W. Greene. 1985. A Student's Guide to U.N.D.E.R.C. University of Notre Dame: 19-44.

SYSTAT software, Inc. 2004. SYSTAT 11. Point Richmond, CA

Table 1. Surface Area and Categorization of UNDERC Sites

Site	Surface Area (ha)	Bog or Lake
Morris	5.7	Lake
Ward	1.1	Lake
Kickapoo	5.3	Lake
Bog Pot	no specific data	Lake
Raspberry	2.9	Lake
Tuesday	1.2	Lake
Firestone	~3	Lake
Hummingbird	1	Lake
Bolger Bog	no specific data	Bog (seepage lake)
Ed's Bog	no specific data	Bog (seepage lake)
Beaver Bog	no specific data	Bog
Tender Bog	0.96	Bog

Table 2. R and p-Values of the Three Components and Water Chemistry Correlations

	Component I	**Component II**	**Component III**
pH	-0.242 (0.449)	0.211 (0.511)	0.168 (0.602)
Water Clarity	-0.411 (0.184)	0.225 (0.481)	0.219 (0.495)
Conductivity	-0.093 (0.774)	**0.455 (0.137)**	0.443 (0.150)

Table 3. Comparison of 1985 and 2005 Water Chemistry Data

Sites	1985 pH	2005 pH	1985 Secchi Depth (m)	2005 Secchi Depth (m)	1985 Color (True)	2005 Color (True) (A)	1985 Specific Conductance (uMho/cm)	2005 Specific Conductance (uMho/cm) (µS)
Morris	5.8	7.2	1.3	2.09	80	1.296	95	117
Ward	6.7	8.2	no data	2.25	40	1.762	157.5	189.7
Kickapoo	6.7	7.8	1.75	2.35	35	0.915	75	90.5
Bog Pot	5.2	6.2	1.25	1.5	130	1.907	22.3	12.7
Raspberry	6.4	6.7	1.7	3.7	30	1.365	20	12
Tuesday	5.3	6.7	1.63	2.6	70	0.969	18.5	13
Firestone	5.95	6	no data	0.88 (max depth)	no data	0.789	12	13
Hummingbird	5.6	5.1	2.5	0.81	90	1.51	28	22.7
Bolger Bog	5.4	6.7	0.75	1.73	323	1.177	44	30.2
Ed's Bog	4.2	5.9	1.13	1.03	175	0.98	18.5	27.3
Beaver Bog	3.6	4.7	2.125	0.76	125	1.215	27.3	18.8
Tender Bog	3.5	4.3	1.25	0.86	71.3	1.543	30.3	33.4

Table 4. Comparison of 1985 and 2005 Species List

Sites	1985 Species List	2005 Species List
Morris	*Esox lucieus* (Northern Pike) *Perca flavescens* (Yellow Perch) *Pimephales notatus* (Bluntnose Minnow) *Umbra limi* (Central Mudminnow)	*Esox lucieus* *Perca flavescens* *Notemigonus crysoleucas* (Golden Shiner) *Lepomis gibbosus* (Pumpkinseed) *Cyprinella caerula* (Blue Shiner) *Phoxinus esos* (Northern Red-bellied Dace) *Notropis photogenis* (Silver Shiner) *Lepomis macrochirus* (Blue Gill)
Ward	<u>none</u> <u>listed</u>	*Pimephales notatus* *Culaea icanstans* *Umbra limi* *Etheostoma exile* (Iowan Darter)
Kickapoo	*Esox masquinongy* (Muskellunge) *Perca flavescens* *Promoxis nigramaculatus* or *annularis* (Crappie) *Esox lucieus*	*Umbra limi* *Esox Lucieus* *Perca flavescens* *Lepomis macrochirus*
Bog Pot	<u>*none*</u> <u>*listed*</u>	*Umbra limi* *Culaea incanstans* *Phoxinus esos*
Raspberry	*Micropterus salmoides* (Largemouth Bass) *Micropterus dolomieui* (Smallmouth Bass)	*Lepomis macrochirus* *Micropterus salmoides* *Lepomis gibbosus*
Tuesday	*Pimephales notatus* *Umbra limi*	*Culaea icanstans* *Notropis photogenis* (Silver Shiner) *Notemigonus crysoleucas* *Pimephales notatus* *Phoxinus esos* *Pimephaes promelas* (Fathead Minnow) *Cyprinella caerula*
Firestone	<u>*none*</u> <u>*listed*</u>	*Umbra limi* *Culaea incanstans* *Notemigonus crysoleucas* *Phoxinus esos*

Hummingbird	*Perca flavescens*	*Umbra limi* *Lepomis macrochirus* *Lepomis gibbosus* *Perca flavescens* *Notemigonus crysoleucas* *Phoxinus esos*
Bolger Bog	*Pimephales notatus* *Umbra limi* *Culaea icanstans* (Brook Stickleback) *Perca flavescens* *Phoxinus esos* (Northern Red-bellied Dace) *Esox lucieus* *Lepomis macrochirus* (Blue Gill) Cyprinidae (shiners) Catostomidae (suckers)	*Culaea incanstans* *Phoxinus esos* *Umbra limi*
Ed's Bog	*None listed*	*None listed*
Beaver Bog	*None listed*	*Umbra limi*
Tender Bog	*None listed*	*None listed*

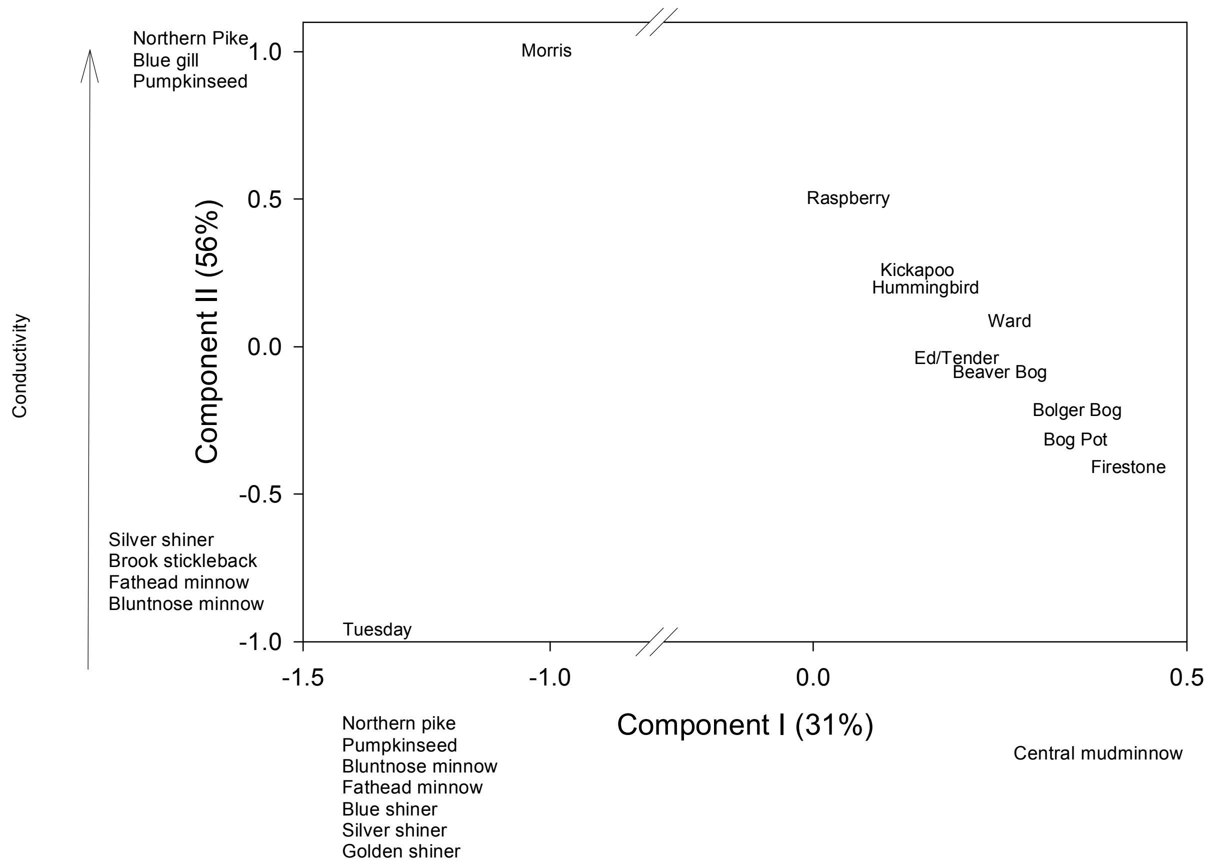

Figure 1. Principle component analysis showed the species distribution of the surveyed sites. Component I had an actual variance of 31% and component II had a variance of 56%. Morris and Tuesday were separated from the other sites by both components. In addition, the figure shows the positive and negative high loadings of each component.

Appendix 1. The Number of Each Species Collected at Each Site.

Sites	*Perca flavescens*	*Lepomis gibbosus*	*Lepomis macrochirus*
	Yellow Perch	Pumpkinseed (sunfish)	Blue Gill
Morris	2	6	5
Ward	0	0	0
Kickapoo	2	0	1
Bog Pot	0	0	0
Raspberry	0	1	7
Tuesday	0	0	0
Firestone	0	0	0
Hummingbird	2	1	1
Bolger Bog	0	0	0
Ed's Bog	0	0	0
Beaver Bog	0	0	0
Tender Bog	0	0	0
Sites	*Esox lucieus*	*Cyprinella caerula*	*Notropis photogenis*
	Northern Pike	Blue Shiner	Silver Shiner
Morris	20	9	6
Ward	0	*0*	0
Kickapoo	10	0	0
Bog Pot	0	0	0
Raspberry	0	0	0
Tuesday	0	4	27
Firestone	0	0	0
Hummingbird	0	0	0
Bolger Bog	0	0	0
Ed's Bog	0	0	0
Beaver Bog	0	0	0
Tender Bog	0	0	0
Sites	*Pimephales notatus*	*Umbra limi*	*Phoxinus esos*
	Bluntnose Minnow	Central Mudminnow	Northern Red-bellied Dace
Morris	0	0	9
Ward	0	1	0
Kickapoo	0	11	0
Bog Pot	1	5	138
Raspberry	0	0	0
Tuesday	22	0	1
Firestone	0	31	4
Hummingbird	0	2	0

Bolger Bog	0	23	15
Ed's Bog	0	0	0
Beaver Bog	0	11	0
Tender Bog	0	0	0

Sites	*Pimephaes promelas* Fathead Minnow	*Culaea icanstans* Brook Stickleback	*Micropterus salmoides* Largemouth Bass
Morris	0	0	0
Ward	0	3	0
Kickapoo	0	0	0
Bog Pot	0	17	0
Raspberry	0	0	2
Tuesday	2	5	0
Firestone	0	27	0
Hummingbird	0	0	0
Bolger Bog	0	8	0
Ed's Bog	0	0	0
Beaver Bog	0	0	0
Tender Bog	0	0	0

Sites	*Etheostoma exile* Iowan Darter	*Notemigonus crysoleucas* Golden Shiner
Morris	0	36
Ward	1	0
Kickapoo	0	0
Bog Pot	0	0
Raspberry	0	0
Tuesday	0	53
Firestone	0	6
Hummingbird	0	0
Bolger Bog	0	0
Ed's Bog	0	0
Beaver Bog	0	0
Tender Bog	0	0

Appendix 2. The Number of Species Collected Using Each Technique.

			Collecting	Technique	
Scientific Name	**Common Name**	**Minnow Traps**	**Seine Netting**	**Gill Netting**	**Rod and Reel**
Perca flavescens	Yellow Perch	2	1	1	2
Lepomis gibbosus	Pumpkinseed (sunfish)	0	1	5	2
Lepomis macrochirus	Blue Gill	2	5	0	6
Micropterus salmoides	Largemouth Bass	0	0	0	2
Esox lucieus	Northern Pike	0	0	7	23
Cyprinella caerula	Blue Shiner	0	13	0	0
Notropis photogenis	Silver Shiner	20	13	0	0
Notemigonus crysoleucas	Golden Shiner	34	62	0	0
Pimephales notatus	Bluntnose Minnow	22	1	0	0
Umbra limi	Central Mudminnow	79	22	0	0
Phoxinus esos	Northern Red-bellied Dace	16	151	0	0
Etheostoma exile	Iowan Darter	1	0	0	0
Pimephaes promelas	Fathead Minnow	1	1	0	0
Culaea icanstans	Brook Stickleback	18	38	0	0

Appendix 3. Survey Techniques Used at Each Site.

Site	Minnow Traps	Seine Netting	Gill Netting	Rod and Reel
Morris	X	X	X	X
Ward	X		X	X
Kickapoo	X	X	X	X
Bog Pot	X	X	X	X
Raspberry	X	X	X	X
Tuesday	X	X	X	X
Firestone	X	X	X	X
Hummingbird	X		X	X
Bolger Bog	X		X	X
Ed's Bog	X			X
Beaver Bog	X			X
Tender Bog	X			X