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Pond Health: analysis and comparison of population and chemical traits from three ponds in Northfield Minnesota.

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Bio 371

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Abstract

The health of ponds is determined upon both chemical characteristics and invertebrate composition. Labeling the health of the pond through chemical measurements and macroinvertebrate populations can be difficult, but together give a good sense of the current state of the surrounding environment. Analysis and comparisons were conducted to determine the overall health of the two ponds on the south border of the Hauberg Woods, and the James Farm Pond on St. Olaf's campus, all in Northfield, Minnesota. Temperature, pH, conductivity, dissolved oxygen, nitrate and phosphate contents were all measured over a three week period. The chemical measurements were coupled with the collection of aquatic macro-invertebrates and notes of the surrounding landscape. Analysis concluded that the two ponds on the south of the Hauberg woods were in fair condition but have cause for concern due to low dissolved oxygen levels, an acidic-neutral pH, and invertebrate populations dominated mostly by a few species which are resistant to pollutants. The James Farm pond had many species that were more evenly distributed with normal oxygen levels, and more neutral pH. Comparisons concluded that the James Farm Pond conductivity and oxygen levels were much different from the Hauberg ponds. In order to discern the factors that cause these differences further study is needed. Further exploration should look at the soil surrounding the ponds in order to determine any chemicals that may be flowing into each location from run-off. The study should also be conducted over a longer period of time and look at trends or changes in the chemical factors, as well as changes in physical conditions like lawn mowing and larger weather events.

Introduction:

Freshwater bodies like streams lakes and ponds serve as both habitats for life at all stages, and as an indicator of their surrounding environments (). They provide habitats for animals like turtles and fish as well as macroinvertebrates. There are certain conditions that are needed for certain forms of sustained life while other forms are more tolerable (Myslinski, Ginsburg, 1977). These conditions are safe ranges of chemical characteristics such as temperature, pH, conductivity, oxygen, nitrate and phosphate contents.

The concentrations of chemicals that are present in a water source like a pond have the ability to shape the condition of the pond. Some chemicals ranges facilitate life, and some are harmful. The most important chemical levels for life in a freshwater source like a pond are pH and dissolved oxygen (). pH measures the acidity in the water and can greatly affect the ability for life, and specifically fish. The best pH level for any water source is the neutral level of 7 (CEES). However, the range of tolerance for fish is 6.5-8.5 and is also considered the optimal range for streams and groundwater (CEES). As water becomes more basic or acidic the conditions become too hostile for life to exist. Dissolved oxygen is how a lot of life in ponds, again like fish, breathe under water. If there is not enough oxygen in the water then any potential life that breathes under water may not survive. The minimum amount of oxygen in water that will sustain life that needs it is 5 (mg/L)(CEES). The concentrations that are preferred for nitrate and phosphate are very low, as some exists naturally, but not too much. A study of woodland ponds in northern Minnesota found values of pH at 6.50, conductivity from 24-390 (micro-S/cm), nitrogen contents of 0.45 to 3.44 (mg/L) and phosphate contents from 0.08 to 2.22 (mg/L)(Batzer, Palik, Buech, 2004). So there is variability in a few of the values, but most remain in those safe ranges.

These ranges are indicators of possible life for animals like fish. However, there is smaller life such as macroinvertebrates that can tolerate the extreme ends of chemical characteristics and polluted waters that won't necessarily show up in the normal chemical tests (pH, conductivity, nitrates, phosphates)(Myslinski, Ginsburg, 1977)(U.W., 2001)(Chadde). The species make up is a good signal of the water conditions. Furthermore, evenness is as important because it can affect how the richness is viewed. The Shannon and Simpson diversity indices are good measures for how many species occupy the ecosystem, and how abundant each species is (Brower, Zar, vonEnde, 1998). Once the counts of species have been analyzed and compared to their tolerance levels, it can signal the condition of the water not measured directly. If certain high-tolerant species dominate the pond, outside factors may be influencing it's quality like run-off of fertilizers and pesticides (Cope, 1966).

The species distribution of macroinvertebrates is a nice compliment to the analysis of the water's chemistry. That is why in a study of three ponds in Northfield Minnesota both macro invertebrate composition and water chemistry were analyzed to determine pond health. Two ponds on the south border of the Hauberg Woods and one on St. Olaf's college campus were subject to data analysis for temperature, pH, conductivity, nitrate and phosphate contents as well as macro invertebrate populations.

The two ponds near the Hauberg Woods have vastly different surroundings than the James Farm pond on St. Olaf's campus. One Hauberg pond is bordered by houses, across from the woods, and bordered by farmland on a third side with grass and a walking path on the fourth (Pond 1) (Figure. 1). The second Hauberg pond is slightly west, on the other side of the walking path, and has train tracks on the far west side, with the Hauberg woods to the north (Pond 2)(Figure. 1). In contrast, the James Farm Pond is surrounded by cattails, woods, and restored prairies (Figure. 2).

One objective of this study was to determine what the overall health status of each pond was (good, moderate, poor). The other objective of this study was to compare the ponds to one another and determine any significant differences ($P<0.05$). Analysis of collected data and comparison with literature will serve as the determination form labeling the health status of the ponds. The analysis of the results of this study should allow for suggestions for further study and allow for speculation of what might potentially be causing any differences.

Methods:

The methods I used to collect the data for this study were selected because it could standardize the way data were collected. These methods were consistent for each of the four visits to the ponds. The four visits to each pond took place between October 20th and November 10th, 2014 (3 weeks).

I collected data on chemical factors using digital instruments in the field. I measured temperature, pH, conductivity, and dissolved oxygen. I submerged the sensors of the digital meters 4 inches below the surface to get consistent readings. To collect data on phosphate and nitrogen content, samples were collected from each visit using acid-washed containers. The samples were then frozen, and tested in the lab using SmartChem. Each measurement was taken once for each visit, totaling 4 samples for each chemical factor over the entire study.

There were a few steps to collecting and identifying invertebrates from each pond. First, after I mildly disturbed the ground, I made three swipes with a dip net submerged 13 inches from the surface to catch any invertebrates. This was done at three different spots around the pond for each visit, and specifically areas that had different surroundings. This meant a total of 36 swipes from each pond over the complete study. I conducted three swipes in three different areas of each pond, on each visit.

Data Analyses:

Three types of data analyses were conducted. The first analysis I conducted was one-way analysis of variance test. The analysis of variance tests compared the mean values of the chemical factor of interest from all three ponds to one another. The factors tested were temperature, pH, conductivity, oxygen, nitrate and phosphate contents (Brower, Zar, vonEnde, 1998) (Table 2).

The second and third analyses conducted were for macroinvertebrate populations. One was the Simpson index of diversity which gave me a numerical representation of probability of selecting two individuals of the same species (Brower, Zar, vonEnde, 1998)(Table 2).The third analysis was the Shannon diversity index which gave the numerical representation of the species richness and evenness (Brower, Zar, vonEnde, 1998) (Table 2).

The last analysis conducted was a t-test to determine if the Simpson indices of each pond were significantly different from eachother. This was signaled from a t-value different from the expected value (Brower, Zar, vonEnde, 1998)(Table 3).

Results:

The three ponds looked at had results that varied, but only slightly and trends can be seen from the raw data (Table 1). It is easy to see that the temperatures trended downward and got smaller in each visit. There wasn't a visible trend in pH values and each measurement was within 0.3 of 7 (Table 1). In contrast, the conductivity values of Hauberg ponds 1 and 2 were almost half of that of the James Farm pond (Table 1). There was variability in the oxygen levels between and within ponds, but with no value above 8.1(mg/L) (Table 1). Similarly there was a lot of variability between and in each pond's nitrate content with no pond reading anything larger than 0.5 (mg/L)(Table 1). However, the phosphate contents did not have as much variability with the James Farm pond having very closely grouped readings at or below 0.05(mg/L) while Hauberg ponds 1 and 2 have values closer to 0.1 and 0.2 (mg/L) respectively (Table 1).

The raw data was able to be plugged directly into R Commander (R Studio), which converted them into means to analyze variance between the ponds (Table 1). The analyses of variance for the means between the James Farm and both Hauberg ponds had results that were not necessarily surprising. The tests resulted in significance in temperature, pH, nitrate and phosphate contents ($P>0.05$)(Table 2). These are in contrast to the results for conductivity and dissolved oxygen between the three ponds which were not significant ($P<0.05$)(Table 2) and that the means were substantially different.

The calculation of the Shannon indices resulted in the James Farm pond having a larger index values than both Hauberg pond 1 and 2 (Table. 2). Likewise, the James Farm pond had the largest Simpson index of the three ponds looked at (Table. 2). One visible trend of the index values is that the Hauberg ponds 1 and 2 did not differ by much with both being just below 0.7 (Table. 2).

One test to determine if the index values are significantly different is by conducting a t-test. A t-test comparing the Simpson index values to each other resulted in the James Farm pond being significantly different from the both Hauberg ponds 1 and 2 (Table. 3). Meanwhile, the results showed that Hauberg pond 1 and Hauberg pond 2 were not different from one another (Table. 3).

Discussion:

Chemical significance:

The chemistry of a freshwater source is the basis for determining it's health. Temperatures vary with air temperature and climate, something that cannot be controlled. However, some chemical characteristics can be kept from varying outside of its natural range.

For instance, the two Hauberg ponds had significantly different conductivity levels ($P<0.05$)(Table. 1) than the James Farm. Northfield Minnesota tends to have water gaining quite a bit of magnesium and iron. Meaning that there could be something tying up the dissolved ions like pollution or pesticides (Cope, 1966). Similarly was the case with dissolved oxygen, with there being significantly less dissolved oxygen (mg/L) in the two Hauberg Ponds (Tabel. 1). This could be an effect of some outside factor could be affecting the levels of oxygen. The remainder of the chemical factors were deemed to not be different (pH, nitrate, phosphate)($P>0.05$)(Table. 1). Although there were differences from the Hauberg ponds to the James Farm pond, the levels still fell within to safe ranges (Wilhm, Dorris, 1968)(CEES).

Invertebrate significance:

It is clear that the James Farm pond has a better composition of invertebrates than the two Hauberg Ponds. This conclusion comes from the James Farm pond's higher Shannon index of diversity which depicts how many species there (Table. 2). Likewise, it has a higher Simpson index which measures how evenly distributed or represented each species is in the population (Table. 2)(Brower, Zar, vonEnde, 1998). Furthermore, the Simpson indices of the two Hauberg ponds were found to be significantly different from the James Farm when the t-test was conducted (Table. 3)(Brower, Zar, vonEnde, 1998).

This is further evident when looking at the raw counts and actual species present in the two Hauberg ponds (Table. 2) and comparing them to their tolerability (Figure. 1) (U.W., 2001). The two Hauberg ponds have a large representation of Amphipods (scuds) and O. Diptera (Chironomidae)(non-red midges)(Table. 2) These species are 'semi-tolerant' to pollutants, while they both also have small representations of leeches which are tolerant to pollutants (Figure. 1) U.W., 2001).

This is in contrast to the James Farm pond which has a wider range of species, that are evenly distributed (Table. 2). The species that compose the population there are Odonata (anisoptera) and (zygoptera) (Dragon and Caddisflies) which are 'semi-sensitive' to pollutants (Figure. 1) (U.W., 2001). Furthermore there is a representation of O. Plecoptera (stonefly nymphs) that are 'sensitive' to pollutants (Figure. 1) (U.W., 2001). The differences in species diversity and evenness, coupled with the tolerance of the species determined the James Farm pond to have a better composition of macro invertebrates.

Conclusions:

The combination of low Shannon and Simpson indices with low oxygen levels keeps the health level of the two Hauberg Woods ponds being labeled moderate. Although the chemical levels fell within safe ranges and aren't too different than the study of northern woods ponds in Minnesota (Batzer et. al. 2004), there is cause for concern, their populations are made up of mainly pollutant resistant invertebrates (Myslinski, Ginsburg, 1977), while the James Farm pond had larger indices showing more species represented equally (Table. 2)(Brower, Zar, vonEnde, 1998). This signals that something, possibly from the nearby surroundings is affecting the water quality that cannot be measured from just the chemical nutrients tested, like pesticides or runoff of fertilizers (Cope, 1966). This may need to be further studied. Given the current chemical and population state of the two Hauberg ponds, I suggest measures be taken to improve their health. First, I recommend any possible contribution from the housing lawns be stopped. Specifically the bagging of grass clippings. Furthermore, that any fertilizers being used on the lawns be stopped. One last suggestion would be that a barrier be put in place that prevents run off from the train tracks and farmland going into the ponds.

Further study may change the conclusions determined by this study. However I would suggest that any further study be conducted over a longer period of time, and include a time of year when anthropogenic effects like farming, lawn mowing and fertilization may be taking place. I also suggest that any continued study collect invertebrates over a larger period of time because of how certain disturbances may affect their populations.

Acknowledgements

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Table. 1: Table of raw measurements and calculated means. This table also show the results to the analysis of variance for each chemical factor shown by the ANOVA P-Value row.

Pond	Temp	pH	Conductivity	Oxygen	Nitrate	Phosphate
Hauberg Pond 1	11.9	6.7	300.6	5.04	0.1262	0.188
	10.1	6.8	332.4	5.7	0.0554	0.118
	9.3	6.9	400.8	5.2	0.0908	0.047
	7.7	7.1	420.2	5.31		0.051
Mean (SD)	**9.750 (1.746)**	**6.875 (0.170)**	**363.500 (56.361)**	**5.312 (0.281)**	**0.0908 (0.0354)**	**0.101 (0.0665)**
Hauberg Pond 2	12.2	7.2	330.1	5.55		0.112
	12	7	360.4	6.01	0.5409	0.451
	10.5	6.8	392.6	7.2	0.1312	0.158
	8	6.9	430.8	8.1	0.1515	0.115
Mean	**10.675 (1.937)**	**6.975 (0.171)**	**378.475 (43.221)**	**6.715 (1.155)**	**0.2745 (0.2309)**	**0.209 (0.1626)**

James Farm Pond	12.1 11.4 9.1 7.8	7.1 7 7 7.2	650 680 701 710	7.71 7.94 8.2 7.87	0.1009 0.2627 0.0503 0.106	0.05 0.035 0.037 0.038
Mean	**10.100 (1.998)**	**7.075 (0.095)**	**685.250 (26.650)**	**7.930 (0.204)**	**0.1299 (0.0919)**	**0.040 (0.0067)**
ANOVA P-Value	**0.79**	**0.224**	**3.53e-06 *** **	**0.00167 ****	**0.289**	**0.111**

Significance Codes *** is <0.0001 ** is <0.01

Table. 2: This table has the raw counts of taxa found in each pond. It contains the number of species (richness) as well as the Shannon and Simpson diversity indices.

Taxon name (o. is order)	Hauberg #1	Hauber g #2	James Farm
O. Isopoda	10	12	0
O. Amphipoda	81	64	29
O. Ephimeroptera	0	0	23
O. Odonata (anisoptera)	5	2	19
O. Odonata (zygoptera)	1	0	21
O. Hemiptera (notonectidae)	25	0	13
O. Trichoptera	0	0	27
O. Diptera (Tipulidae)	0	0	19
O. Diptera (Chironomidae)	43	36	16
Annelidia Hirudinea	5	7	0
O. Plecoptera	0	0	9
Richness	7	5	9
Total Individuals	170	121	176
Shannon (H')	**0.602**	**0.504**	**0.933**

Simpson (Ds)	**0.686**	**0.623**	**0.883**

Table. 3: This table shows the results of the t-test conducted to compare each site's Simpson index to one another.

T-Test	Hauberg #1	Hauberg #2	J. F.
Hauberg #1	NA	NA	NA
Hauberg #2	**1.56**	NA	NA
J.F.	**7.72***	**8.19***	NA

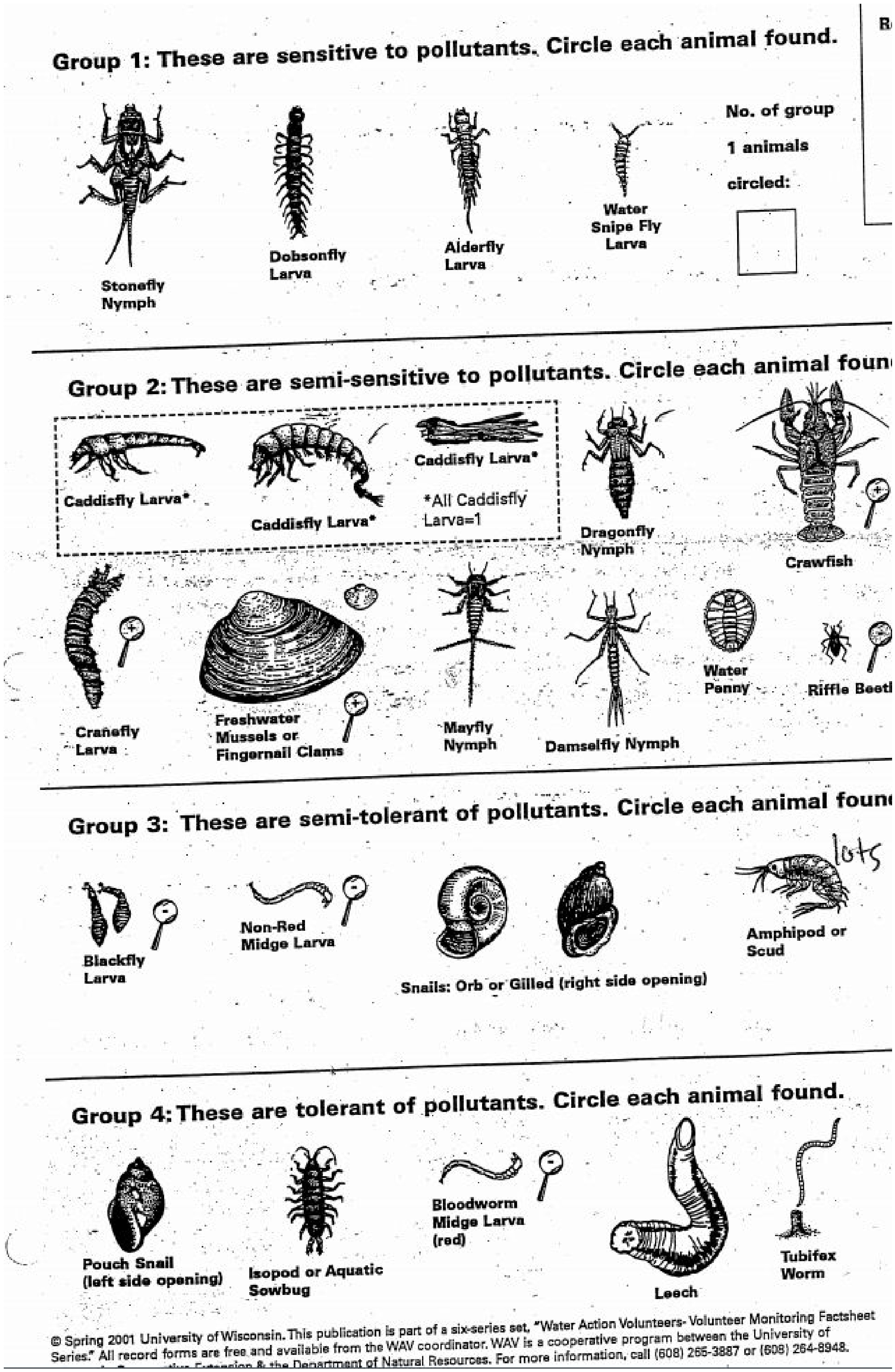

Figure. 1: This figure shows pictures and names of species in the groups of their ability to tolerate pollutants in the water.

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