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A Review of Aquatic Insects as Biomonitors of Water Quality

Liz Barr
Dr. Hellenthal

Recent studies have shown that aquatic invertebrates can serve as indicators of water quality. In addition to taking direct samples of the water and testing for various metals, pH, dissolved oxygen, and organic matter, biologists have been able to aide the chemists by using aquatic insects as site monitors of water quality. Aquatic insects are being used to estimate concentrations of trace metals present in the water that are in such low concentrations that they are not detected in water sample analysis. Because each insect has different tolerances to changes in water chemistry such as pH, amount of dissolved oxygen, and amount of heavy metals, the presence and absence of certain species has been associated with good or poor water quality. In order to learn anything from changes in invertebrate populations, studies must be done over a longer period of time to ensure a baseline population for comparison and to ensure that the sample was done thoroughly.

Aquatic insects are capable of concentrating metals in a known proportion to the concentration of the metal present in the water. These concentrations can be determined even after the current has swept away much of the needed water sample to arrive at the same conclusion. In addition, aquatic insects accumulate metals in their bodies in high enough concentrations that are detectable whereas the concentration of these metals in the water is too low to be noticed.

An article written by T.R. Lynch, C.J. Popp and G.Z. Jacobi titled, "Aquatic Insects as Environmental Monitors of Trace Metal Contamination: Red River, New Mexico" in 1988, supports these ideas. They used mayflies (Ephemeroptera, 4 genera), stoneflies (Plecoptera, 6 genera), caddisflies (Trichoptera, 3 genera) and true flies (Diptera, 2 genera) for their study.

The examination of these insects helped detect episodic discharges of trace metals, Mo, Mn and Cu, from the mill to the environment. The data showed that concentrations of Mo, Mn, and occasionally Cu, were greater downstream of the mill than upstream. These metals remained stored in the insects at almost the same concentrations even fifteen months after the last spill when metal concentrations in the water and sediments were declining.

Other aquatic biologists have also done studies using aquatic insects as biomonitors of trace metals. The article, "Aquatic Insects as Biological Monitors of Heavy Metal Pollution," written by Barry Nehring in 1976 studied the usefulness of aquatic insects as indicators of heavy metal pollution. He felt that in order to use aquatic insects as biological monitors they must be able to survive the pollution for further analysis, they must concentrate the toxic metal in relative proportion to the metal content of the water, and the insects should accumulate the metal in a predictable amount over a short duration.

Mayflies and stoneflies were used in his experiments to test Cu, Pb, Ag and Zn concentrations. Comparisons were made between the average exposure levels and the average accumulation levels show that the level of accumulation in the insect was a 100 times greater than the level of exposure. The correlation coefficients that were calculated linking insect accumulation and concentration in the water for each metal show that insects do concentrate metals in relative proportion to the metal concentration in the water. Further statistical analysis of the data led to the "concentration factor" making it possible to estimate the level of exposure by knowing the accumulation. The conclusion of Nehring's study were that aquatic insects do concentrate heavy metals by some predictable factor.

Aquatic insects, under the conditions of that test, appear to be good indicators of heavy metal pollution and useful in determining metal concentrations in the water long after the polluted water has flowed past. A few years later in 1979, Nehring along with Robert Nisson and George Minansian decided to re-test the validity of the concentration factor method. Their findings were written up in an article titled "Reliability of Aquatic Insects Versus Lead Water Samples as Measures of Aquatic Lead Pollution."

These biologists compared the usefulness of the concentration factor to atomic absorption spectrometry and found that while neither was one hundred percent accurate, the results from both methods were comparable. However, there are a number of advantages to using the concentration factor method. First, using the concentration factor method makes for easier detection of trace levels of pollution that are not detectable by direct AAS analysis. Secondly, water samples should be processed immediately whereas dried insect samples do not change with time and do not need immediate analysis, and thirdly, aquatic insects provide a more accurate representation of the amounts of pollution in the stream. AAS analysis only accounts for the pollution in the water column and it overlooks the pollution in the sediments. The study also showed that the concentration factors for each genus of insect produced results that were as reliable as the water samples for up to six months after the initial calculation of the concentration factor. This shows that normal changes in physical and chemical water variables to dot change the usefulness or accuracy of the concentration factor method significantly.

Not only have aquatic insects been used for pollution analysis based upon their abilities to accumulate metals, but the presence and absence of different genera have also been used to indicate water quality. Different genera and species of aquatic insects have different tolerance limits with clean water generally characterized by generalists and poor water quality characterized by specialists that can adapt to the unfavorable conditions. While detection of gross pollution is fairly easy for the biologist because the normal flora and fauna is usually replaced by sewage fungus and Turbificidae, less severe pollution is harder to identify. Long-term studies of the invertebrate communities are needed to be able to detect smaller, less obvious changes.

An article written by F.T.K. Pentelow, "Sewage Effluents and Fish," points out some of the tolerance ranges for different orders of insects. For example, stoneflies were found to be intolerant of organic pollution but indifferent to rising zinc levels whereas the oligochaetes had opposite responses. Stoneflies are also known to be more sensitive to low oxygen levels than mayflies which is apparent by their distribution, thus their distribution is confined to rivers and more turbulent water than the mayflies. The article also noted that net-spinning caddisfly abundance generally increases slightly with an increase in sewage pollution, probably because an increase in sewage pollution corresponds to an increase in food supply. Aquatic insects have a variety of different responses to changes in water quality. To understand these responses the morphological characteristics, the food requirements and the metabolic needs of the insect should be understood.

Just as these responses are unique to each genus, they are also unique to the specific habitat. Quite natural fauna changes along the continuum of a river, not necessarily because of pollution but because of varying types of substratum, differences in water flow and changes in carbon sources. For this absence/presence method to be useful, studies must be done prior to the damage caused by pollution. Not only do studies have to be long-term to note the change, but they need to be done effectively. The lifecycles of the invertebrates should be known. If a certain insect is absent it could be because it is in the larval stage and difficult to find.

There are basically two types of sampling; the relative and the absolute. Relative sampling samples adults only and while it is fast and inexpensive the results can be biased. Sampling is done somewhat randomly and time spent in certain areas might be greater than time spent elsewhere. The efficiency with which each species is sampled might not be equal. However, on the whole this method does allow larger samples to be taken that promotes the reliability of the population estimates. In contrast, the absolute method produces standardized results, but the area sampled is much smaller. While this method does sample both larvae and adults, it does take more time. This is a quantitative study whereas the relative method is more qualitative. Generally both types of sampling on done on an area to decrease error. It is important to think about what kind of sampling, repetition, and the time of year samples are taken. With thorough sampling, useful data can be obtained that can be helpful in assessing water quality.

A field study done on the River Kshipra in India by S.A. Vattakeril and A.P. Diwan, showed an inverse correlation between biological oxygen demand and chemical oxygen demand, and species diversity index values. BOD and COD values were as high as 320 mg/l and 482 mg/l respectively which corresponded to a species diversity index value of zero. Species diversity numbers, using the Shanon Weaver index, were assigned to each station. Normal values range from 0.0 to 4.0 with less than 1 indicating poor water quality, 1-3 moderate and values greater than 3 reflecting good water quality.

There were six field stations where invertebrates were collected and water chemistry measurements taken. The site that was the furthest up stream had a Shanon Weaver index of zero. This station had the highest pH, the highest amount of total dissolved and suspended solids, the lowest amount of dissolved oxygen, but the highest demand for oxygen, and a secchi disc transparency of zero. Nothing was found there except for 108 *Eristalis sp.* This species of diptera, which was absent from all other stations, signifies poor water quality.

The study also showed that the Diptera genus *Chironomous tentans* is an indicator of species diversity. This species was not present at station one either, but it was present at the other five stations. Analysis of the community structure revealed that when the abundance of this species was high, species diversity was low. For example, station three had 1321 *C. tentans* but the species diversity equaled three, and when the number of *C. tentans* was 18, the species diversity was equal to 15. Thus, the researchers concluded that the abundance of *C. tentans* is inversely directed to species diversity. However, a decrease in *C. tentans* must be associated with an improvement in water quality, not a decrease in water quality as was evident in station one.

The increase in species diversity can be due to the less stressed conditions met at each of the stations. The farther down stream, the lower the TDS and TSS, and the higher the DO and lower nitrate and phosphate concentrations. Farther away from the head of the river, the cleaner the river and the greater the species diversity. The toxins were adsorbed to the sediments upstream or diluted by the time they reached the other stations and their effects were less damaging.

Eyre and Foster in 1989 researched and wrote, "A Comparison between aquatic Heteroptera and Coleoptera communities as a basis for environmental and conservation assessments in static water sites". Unfortunately, their results were inconclusive however they feel that beetles could be a good indicator of acidification. More research should be done in that area. They also felt that because of the lack of rarity indices based on the distribution of aquatic Heteroptera in comparison to aquatic Coleoptera using Heteroptera might only have limited application. They felt beetles might be more useful in providing a way of rapidly and accurately assessing a site.

Last summer I studied aquatic beetle distribution and water chemistry. There were not many direct connections between the two; however I did find that the pH ranges for the beetles found were narrower than the other parameters tested. The conductivity, alkalinity, and color tolerance ranges for the beetles were generally larger than the pH ranges.

Like Eyre and Foster, I feel that a lot of the data from my work is not that conclusive, however I can see how beetle distribution could be linked to acidification.

In conclusion, I feel that aquatic insects are very useful in assessing heavy metal pollution. Heavy metals are very toxic even at low concentrations that being able to detect them at trace levels is very important. It is also important in terms of the environmental movement to be able to show how long metals actually stay in the water. I think that using insects based on their presence or absence in an area as an indicator of water quality needs more work to be used as a tool without relying on other methods. There are a lot of abiotic and biotic interactions that we might not know about that could be responsible in determining community structures. Right now the studies have been on polluted rivers and generalizations of the population dynamics have been made. There is not much of a comparison as to what the water was like beforehand. I do not think that we are at the point to say that because this one species is present the stream is polluted, without knowing that the dissolved oxygen is low, the secchi depth is low, and the TDS and TSS are high. That is not to say that in conjunction with other methods, this way does not have its strengths.

Works Cited

Arden, R, Gaufin, Ph. D., and Calrence M. Tarzell, Ph.D. 1952. "Aquatic Invertebrates as Indicators of Stream Pollution". Public Health Report. Vol. 67. pp. 57-64. Attempts to relate the results of the qualitative and quantitative compositions of aquatic populations to environmental conditions.

Brusen, MA. 1970. "Drift Periodicity of Some Riffle Beetles (Coleoptera: Elmidae)." Journal of Kansas Entomological Society. 43(4):364. Conditions and frequency Elmid beetles change habitats.

Davis, JB, and George, JJ. 1986. "Benthic Invertebrates as Indicators of Urban and Motorway Discharges". pp. 291-302. In: Hamilton, RS and Hamilton RM (eds.). Special issue: Highway Pollution. Proc. of the Second International Symposium, London, UK, 7-11 July 1986. Article was very specific about a few invertebrates and all the chemicals associated with urban and motorway discharge.

Eyre, MD, Foster, GN. 1989. "A Comparison of Aquatic Heteroptera and Coleoptera Communities as a Basis for Environmental and Conservation Assessments in Static Water Sites." Journal of Applied Entomology. 108: 355-362. Conclusions are not that significant, but they feel that beetles could be used to test for acidification. Less hopeful about the uses of Heteroptera.

Landin, Jan. 1976. "Methods of Sampling Aquatic Beetles in the Transitional Habitats at Water Margins". Freshwater Biology. 6: 81-87. Compares the relative and the absolute sampling methods.

Landin, Jan. 1976. "Seasonal Patterns in Abundance of Water-Beetles Belonging to the Hydrophiloidea (Coleoptera)". Freshwater Biology. 6: 89-107. Life cycle and abundance of the Hydrophiloidea beetle throughout the year.

Lynch, TR, Popp, CJ and Jacobi, EZ. 1988. "Aquatic Insects as Environmental Monitors of Trace Metal Contamination: Red River, NM". Water, Air and Soil Pollution. 42: 19-31. Insects can be used to measure trace metals that would otherwise be undetected in water samples.

McShaffrey, D and McCafferty, WP. 1987. "The Behavior and Form of Psephenus Herricki DeKay (Coleoptera: Psephenidae) in Relation to Water Flow." Freshwater Biology. 18(2): 319-324. Morphological adaptations of the Penny Beetle and how it compensates for different flow rates. A physicists perspective.

Nehring, RB. 1976. "Aquatic Insects as Biological Monitors of Heavy Metal Pollution. Bulletin of Environmental Contamination and Toxicology." 15(2) 147-154. Shows that insects concentrate metals in a proportion relative to the concentration of the metal in the water and the insects concentrate metals by a predictable factor.

Nehring, RB, Nisson, R and Minasian, G. 1979. "Reliability of Aquatic Insects vs. Water Samples as Measures of Aquatic Lead Pollution." Bulletin of Environmental Contamination and Toxicology. 22(2): 103-108. Study comparing the concentration factor method and AAS.

Vattakeril, SA and Divan, AP. 1991. "Community Structures of Benthic Macroinvertebrates and their Utility as Indicators of Pollution in River Kshipra, India." Environmental Publications. 10:1-11. Shows how communities change from polluted area to less polluted area. Abundance of each different insects and the corresponding water chemistry at each site.