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The Effect of Man-Made and Beaver Dams on Benthic Invertebrate Populations

Abstract

Dams have the ability to alter many aspects of natural hydrology, particularly benthic invertebrate communities. Man-made dams can cause many problems in lotic ecosystems via habitat fragmentation, substrate sifting, and chemical alteration. The effects of a beaver dam and a man-made dam on the Maple River were compared to determine which dam had a greater impact on the surrounding environment. After statistically analyzing dissolved oxygen levels, nitrate levels, and EPT taxa richness, it was determined that the man-made dam caused a significant change in the downstream EPT taxa richness of the stream, whereas the beaver dam had no significant effect. The cause of the increase in the EPT population downstream of the man-made dam appeared to be less related to a change in water quality than it was to a dramatic change in substrate quality. It is concluded that EPT Taxa richness alone cannot adequately assess water quality in lotic systems obstructed by dams.

Introduction

Man-made dams and beaver dams disrupt their surrounding environment, and have the potential to change many properties of the water bodies they impede. Dams reduce water velocity and cause retention of sediments, organic matter, and water (Allan and Cushing 2001). Because terrestrial vegetation near the banks may die due to flooding in proximity to the dam, oxygen levels in that particular area may decrease, while nutrient levels, such as nitrate, may increase (Giller and Malmqvist 1998). These properties of dams alter the population structure of the benthic invertebrate communities.

The most important factors regulating the population of benthic invertebrates are temperature, water velocity, vegetation, dissolved substances, and substrate composition (Hynes 1970). The relative abundance of invertebrate species is also altered by the presence of dams (Allan 1995). There is a reduction in benthic invertebrate species richness immediately below dams, but an increased total abundance of species, because a reduction in habitat heterogeneity favors certain species over others (Allan 1995). This phenomenon can be partially explained by the fact that dams enlarge the area of water both in the impoundment before the dam and the plunge pool immediately downstream of the dam, allowing for a greater gross amount of organisms, yet being suitable for only certain species (Hynes 1970).

The total number of individuals of the invertebrate orders *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies) found in a given location is a generally accepted indicator of water quality (Lenat 1988). This is known as the EPT Taxa index. These invertebrates are chosen indicators because of their low tolerance for poor water quality (Allan and Cushing 2001). The higher number of EPT individuals in a given area is a quantitative way to determine water quality (Lenat 1988).

The EPT taxa index is a fairly reliable indicator of water quality (Lenat 1988). However, when dams are placed in hydrologic systems, the substrate quality is changed by filtration of sediment or retention of organic matter. There is a threshold level of fine sediment accumulation in the substrate where benthic invertebrate abundance and diversity is greatly reduced (Kaller and Hartman 2003). The degree of filtration of sediment by dams varies, depending on whether it is a man-made dam or a beaver dam. Beaver dams separate large rocks and cobbles from smaller particles that can pass through the wood debris. Man-made dams are much less permeable and may filter the substrate to an even smaller particle size. Thus, the substrate below the dam is often much finer than that above the dam. In this case, there would be few benthic invertebrates, regardless of water quality (Quinn and Hickey 1990). This is because of the apparent intolerance the three taxa have for fine sediment (Kaller and Hartman 2003). Changes in the water velocity of the river due to the insertion of a dam may also affect the population of EPT taxa (Hynes 1970).

The goal of this experiment was to determine the magnitude of impact that man-made dams and beaver dams have on rivers and streams, and, if possible, for which the effect is greater, using the benthic invertebrate population as an indicator of water quality. Because of the more irreversible attributes of a man-made dam, including deep penetration of the substrata and use of cement or other foreign material, we hypothesized that there would be a greater negative impact on both the benthic invertebrate community and water quality near a man-made dam versus a beaver dam. Beaver dams have even been found to improve the downstream water quality of rivers (Schulte and Rosell 2004). Therefore we expected to find an increase in EPT below the beaver dam, and a decrease in EPT below the man-made dam. The primary objective of this paper is to determine the effect of both a beaver dam and a man-made dam on water quality by sampling the upstream and downstream benthic invertebrate populations.

Methods

To investigate our hypotheses, four sampling sites were chosen on the east branch of the Maple River in Pellston, Michigan. The sites were chosen based on their relationship to a man-made dam (45° 32’ N, 84° 46’ W) and a beaver dam (45°32’ N, 84°45’ W) that impound the river, approximately one mile apart from one another. The four sites (upstream and downstream of the beaver dam, and upstream and downstream of the man-made dam) were approximately 100 meters from the dam pond or impoundment, varying slightly due to differences in accessibility to the areas. Each of the measurements was taken during the afternoon and within the same two-week period between late May and early June before the emergence of adult insects. At each site, stream width was measured and divided into five equally spaced areas from which to sample. Three samples were taken from the areas closest to the two banks and from the middle of the river (Figure 1). Two more samples were taken five meters upstream of the first three sample areas from between the bank and the middle of the river, on both sides (Figure 1).

Dissolved oxygen (DO) was measured with a dissolved oxygen meter (Yellow Springs Instrument, Model 55/50) by taking the average of five readings from each of the five sampling areas. Temperature at each site was taken with a field thermometer. Water samples were taken at each site in acid-washed bottles to be analyzed for nitrate (NO_3) content (Baird, 1990; Kaller and Hartman, 2004). Water velocity was measured with a flow meter (Marsh McBirny Flo-Mate, Model 2000).

The five equally spaced areas were sampled for benthic invertebrates using approximately 0.25m x 0.25m kick-nets. The substrate in front of the net was sufficiently disturbed by kicking an area approximately one half-meter by one half-meter for twenty seconds. Benthic invertebrates caught in the nets were sorted into separate bottles with forceps and immediately preserved in 70% ethyl alcohol. They were then counted and identified to order. The number of invertebrates and the relative abundance were used to calculate the EPT taxa richness for each of the four sites (Kaller and Hartman 2004).

Using these numbers, any differences in the benthic invertebrate communities and water quality upstream and downstream of the man-made and beaver dams were assessed using Wilcoxon Signed Ranks Tests. Alpha for all tests was set at 0.05. The upstream water velocity was compared to the downstream water velocity for both the man-made and the beaver dam to determine site similarity. Upstream dissolved oxygen levels were compared with downstream dissolved oxygen levels for both dams. Nitrate (NO_3) levels were similarly compared. Finally, EPT taxa richness was calculated at upstream and downstream sites for both dams and compared.

Results

There was no significant difference in water velocity upstream and downstream of either the man-made or the beaver dam (p =0.225, z=-1.214). There was also no significant difference in upstream and downstream dissolved oxygen levels at the beaver dam (p=0.138, z=-1.483). There was, however, a difference in dissolved oxygen levels at the man-made dam (p=0.043, z=-2.023).

For nitrate levels at the beaver dam, one upstream sample contained 6.0 µg/l of nitrate, and one downstream sample contained 7.4 µg/l. For the man-made dam, an average upstream nitrate level (two replicates) of 5.0 µg/l increased dramatically to an average level at the downstream site (three replicates) of 122.27 µg/l. There was no difference in EPT taxa richness at the beaver dam (p=0.144, z=-1.461), yet there was a significant difference in EPT taxa richness upstream and downstream of the man-made dam (p=0.043, z=-2.023) (Table 1).

Discussion

Our results indicated that some change was occurring in the water passing through the man-made dam that was not occurring as it passed through the beaver dam. The velocity of the stream was not altered in any significant way by either the man-made or beaver dam, remaining at an average of 0.3 meters per second. Some studies have found that benthic invertebrate populations are relatively independent of velocity and depth (Stark 1993). In our experiment, this phenomenon appears to apply. Nonetheless, a certain level of control was obtained by dealing with dams that are associated with stretches of water that flow at an approximately equal velocity.

The man-made dam had a greater impact on the hydrology of the river than the beaver dam, causing marked differences in the EPT taxa richness, dissolved oxygen levels, and soluble nitrate levels. Neither EPT taxa richness, dissolved oxygen levels, nor nitrate levels were altered in any significant way at the beaver dam sites.

There is not sufficient evidence to suggest that the beaver dam improved the water quality of the river. In fact, the increase of EPT taxa downstream of the man-made dam (from 1 to 254) suggests that the man-made dam improved the water quality. In free-flowing lotic systems, this large of a difference would indicate an improvement of water quality (Lenat 1988). On EPT taxa indexes, a sample of only one individual would classify the water quality upstream of the man-made dam as "Very Poor," and a sample of 254 individuals would classify the water quality downstream of the man-made dam as "Excellent" (Lenat 1988). It is unreasonable to expect that the water quality transitioned from being "Very Poor" to "Excellent" simply by passing through the man-made dam. The aforementioned EPT taxa indexes apply to free-flowing rivers and streams, and may vary for different geographical zones.

Dams alter the substrate quality by diminishing the effects of erosion below the dam pond, and by retaining sediment near the impoundment, as it reduces the water velocity. Such alterations in substrate alone are enough to cause a significant change in the population of benthic invertebrates (Kaller and Hartman 2004). Benthic invertebrates are much more suited to rock and cobble substrates than to fine sediment such as clay or sand (Quinn and Hickey 1990). In this study, fine sediment was the dominant substrate type above the man-made dam and only one invertebrate was found, whereas below the dam, rock, cobble, and fallen logs dominated the substrate and a much greater amount of invertebrates was found. The beaver dam produced no great changes in the river substrate. Both upstream and downstream of the beaver dam, the substrate was fairly mixed, with slightly more sand and clay than rock and cobble. A corresponding low number of EPT taxa was found in both areas.

Although the increase in EPT taxa richness below the man-made dam would seem to point toward an improved water quality, an analysis of nitrate levels would seem to contradict such an observation. The nitrate levels upstream of both dams and downstream of the beaver dam were below 8 μg/l. The average nitrate level found at the sampling site downstream of the man-made dam was 122.27 µg/l, nearly 25 times the upstream level. This increase corresponds with a study by the United States Geological Survey in Alabama that found that 88% of the sampled sites on rivers and streams exceeded the acceptable nitrate levels when associated with anthropogenic manipulations such as dams (McPherson, Gill, and Moreland 2004). In our experiment, it is of particular interest that the greatest number of benthic invertebrates collected at any of the sampling sites occurred at the site with the greatest concentration of nitrate. This is startling, given that *Ephemeropterans*, *Plecopterans*, and *Trichopterans* are generally very sensitive to changes in water quality (Quinn and Hickey 1990). However, since all sample nitrate levels were less than one mg/l, this increase in concentration may be irrelevant to the benthic community. It has also been found that increasing nitrate levels in water may correspond with decreasing ammonia (NH_4) levels, and that this in turn may cause water to be less toxic (Reif 2002). Therefore, our data illustrate the effect of man-made dams on the EPT taxa via substrate transformation rather than alterations to water quality alone.

Conclusion

The man-made dam has had an enormous effect on the benthic invertebrate community and chemical composition of the Maple River, whereas the beaver dam has had little to no effect. The data showed higher levels of benthic inveretebrates in the river following the man-made dam. It was also here that there was a profound difference in nitrate levels. However, we believe that the change in the benthic invertebrate population was due more to the alteration of substrate quality by the man-made dam than to the decrease in downstream water quality. The nitrate levels, although there was a notable increase downstream of the man-made dam, were relatively low, whereas the substrate alterations caused by the man-made dam were quite dramatic. Therefore, this experiment supports our hypothesis that the man-made dam in question has had a profound effect on the EPT levels of the Maple River, yet the cause of the difference in EPT numbers appeared to be due to the change in substrate quality rather than the change in water quality. Thus, because dams dramatically alter the habitat of benthic invertebrates, an accurate analysis of water quality must also involve an evaluation of substrate quality and nutrient concentration. In conclusion, the water quality of lotic systems obstructed by dams cannot be accurately determined using only the EPT taxa richness as an indicator.

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Figures

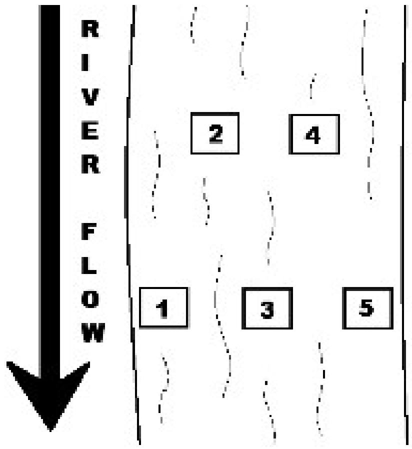

Figure 1: Sampling Site Layout

	Upstream EPT Taxa Richness	Downstream EPT Taxa Richness
Man-Made Dam	1	254
Beaver Dam	12	28

Table 1: Differences in EPT Taxa Upstream and Downstream of Man-Made and Beaver Dam