How does proximity to human development affect water quality characteristics in streams?

NRCA Student: Jennifer Lee[1]

Community Partner: Meghan Lally[2]

[1]Manchester High School, [2]Department of Energy and Environmental Protection

ABSTRACT

Human development can impact freshwater ecosystems in a number of ways. This investigation sought to evaluate these impacts through a macroinvertebrate-based analysis of various points in a local stream. Specifically, I evaluated whether there was a discernible difference between certain macroinvertebrate-based water quality metrics at points with different proximities to human development to draw conclusions about the overall health of the stream. To do so, samples of macroinvertebrates were collected from four riffle sites in the stream and analyzed to the family level. In addition, pH, phosphorous, and dissolved oxygen levels were measured at each site. Examination of macroinvertebrate results showed that while the stream was overall healthy, there were some interesting disparities between sites. Sites further away from human development and more upstream demonstrated more diversity, a greater presence of pollution-indicator orders, and fewer indicators of organic pollution. These results imply that there may be an inverse relationship between stream ecosystem quality and proximity to human development, an implication that is particularly relevant as suburban developments continue to expand and impact ecosystems like that of this stream.

INTRODUCTION

Between 1985 and 2010, Connecticut gained an astounding 149 million square acres of developed land—land that is characterized by the presence of roads, rooftops, and parking lots. About 19% of Connecticut is now developed land.[1] Such a dramatic increase can translate to significant impacts on surrounding freshwater ecosystems, such as loading sediments, storm runoff, fertilizers, and other chemicals into roadside streams, substances that damage the health of freshwater ecosystems in the surrounding watershed.

This investigation focused on Birch Mountain Brook, a stream that runs through Manchester, Connecticut. The area, in recent decades, has been the site of extensive suburban development, with new houses continuing to be built. Accordingly, I evaluated the impacts of these developments on water quality indicators, such as water chemistry and macroinvertebrate (see Fig. 6 for examples) analyses. Such analysis can provide valuable information about the health of a stream, as many families can be used to indicate the presence or absence of pollution. By comparing sites that were less proximate to human development and more upstream to those that were directly downstream of human developments like roads and bridges, water chemistry and macroinvertebrate analyses could show whether human development actually had an effect on the stream's health.

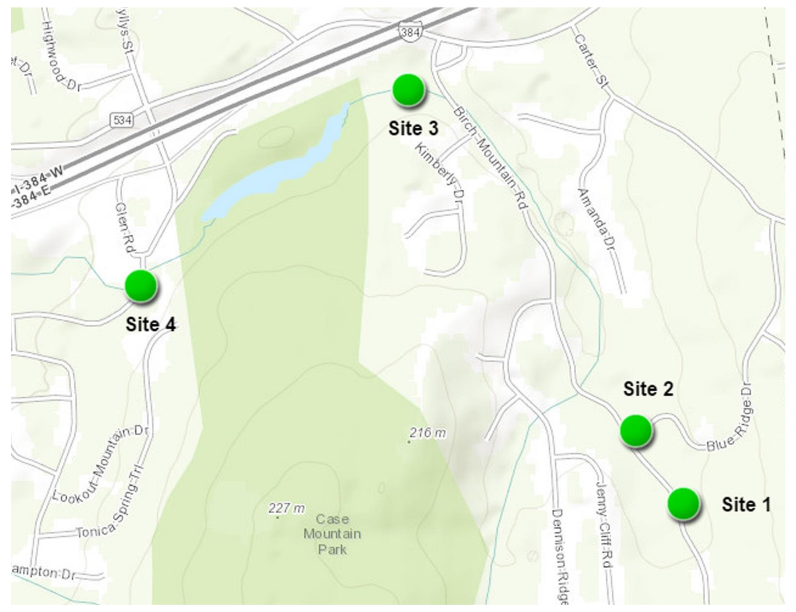

Fig. 1. Map of the sites along Birch Mountain Brook where macroinvertebrates were collected. Site 1 is the most upstream, and site 4 is the most downstream. Site 4 is the only site downstream of Case Pond.

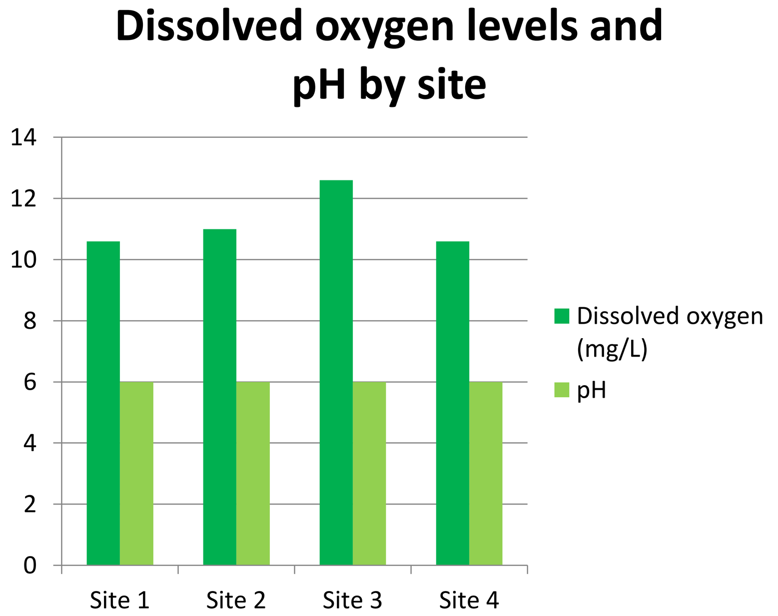

Fig. 2. Dissolved oxygen and pH levels were very stable throughout all four sites. Dissolved oxygen levels in the stream are relatively high, thanks in part to the water's cold temperature and the generally good quality of the stream.

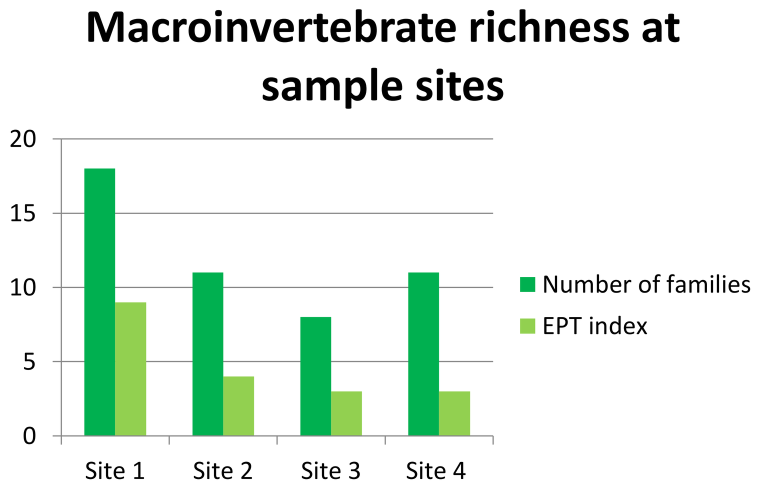

Fig. 3. The total number of families found at each site as well as the number of families belonging to the three most pollution-sensitive orders (EPT). Because these orders are so sensitive to pollution, they are often not found in polluted waters, making their presence a good indicator of high water quality.

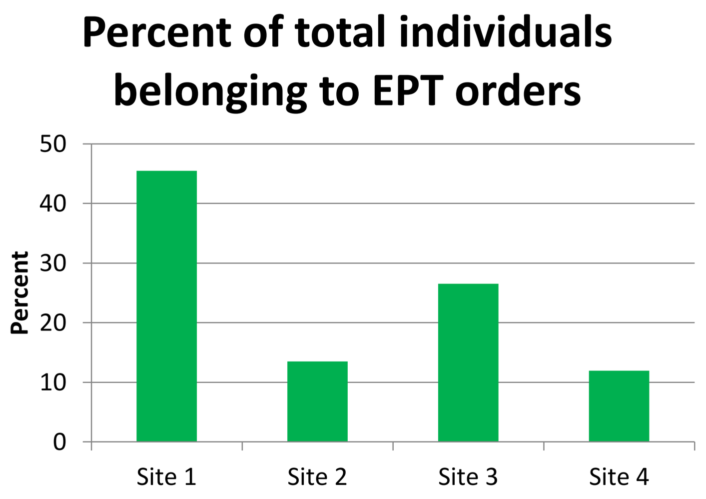

Fig 4. Another take on the EPT index, which uses the percent of all the macroinvertebrates in a given sample belonging to these pollution-sensitive orders.

MATERIALS AND METHODS

Area of Study

- This investigation was conducted in various sections of Birch Mountain Brook, a stream that flows adjacent to Birch Mountain Road, through Case Pond, and under Spring Street in Manchester, CT (see Fig. 1).
- The specific habitats used were riffles, which are fast-moving, somewhat rocky segments where many macroinvertebrates live.
- Four sections of Birch Mountain Brook were studied.

Data Collection

- For each site, dissolved oxygen, phosphate, and pH levels were tested according to the test manufacturers' directions.
- Macroinvertebrate samples were collected during October and November 2015, the standard season for data collection of this type.
- A series of steps were followed to collect each set of sample organisms.
  1. Select a riffle habitat and chose six different stops to collect macroinvertebrates.
  2. Kick and scrape bugs into a net, being sure to turn over rocks and dig through sand. Dump contents of net into a container.
  3. Later, dump the live sample into a tray. Randomly select a subsample of the bugs, rocks, and sand that may be in the tray and add to another tray. "Float" the sample by adding water so most organisms float to the surface. Most organisms will still be alive at this point.
  4. Pick out organisms and place in a vial of alcohol to preserve for identification. Work through the sample until 100 bugs have been found and preserved. This produces one macroinvertebrate sample for one site.

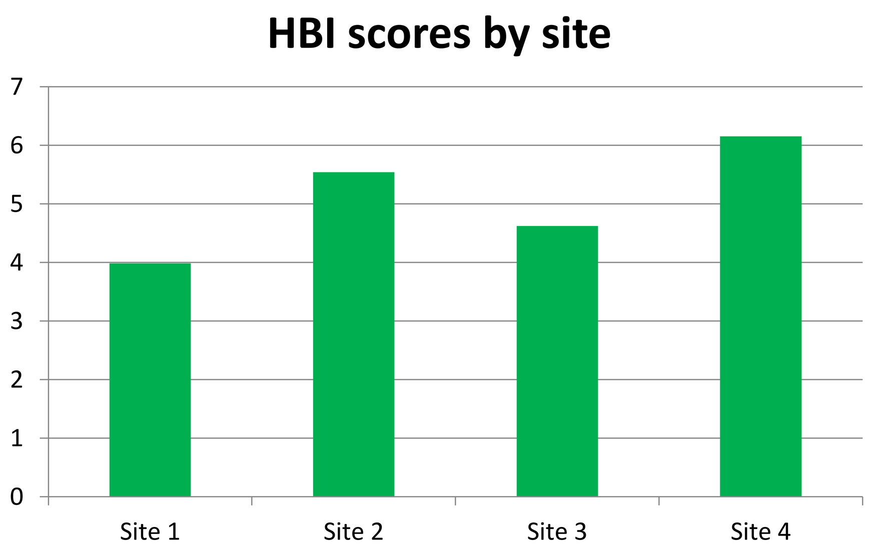

Fig 5. The lower a site's HBI score, the lower its potential for organic pollution, and vice versa. This index is based on macroinvertebrate families' organic pollution tolerance values. Based on this scale, site 1 is "very good, possible slight organic pollution"; site 2 is "fair, fairly substantial pollution probable"; site 3 is "good, some organic pollution probable"; and site 4 is "fairly poor, substantial pollution likely".[1]

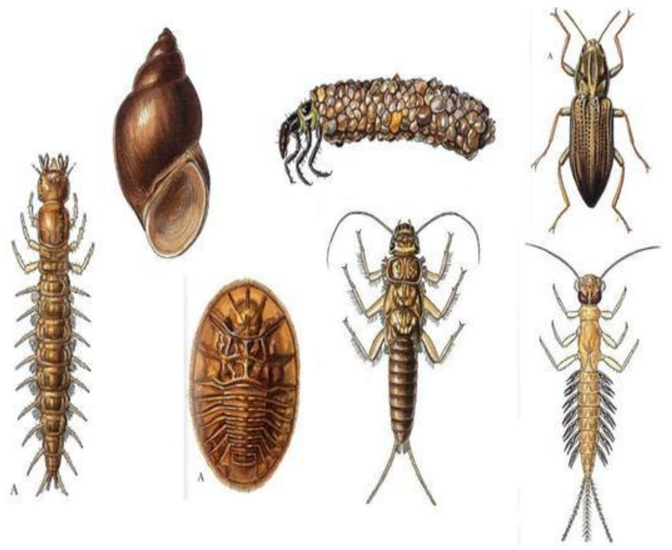

Fig. 6. This diagram[2] shows a few examples of macroinvertebrates found in many streams. The majority of the macroinvertebrates found looked like these examples. Clockwise from the top right hand corner, these are examples of Hemiptera (true bugs), Ephemeroptera (mayflies), Plecoptera (stoneflies), a water penny, Megaloptera (dobsonflies), Gastropoda (snail), and Trichoptera (caddisflies).

RESULTS

Water Chemistry

- Most sites showed similar pH and dissolved oxygen levels (see Fig. 2).
- All four sites had below-detection levels of phosphorous.

Macroinvertebrates

- Overall family diversity—Site 1, the furthest upstream site, had by far the greatest number of families (18) compared to the downstream sites (Fig. 3).
- EPT index—This index measures water quality by calculating the number of different families belonging to the three most pollution-sensitive orders of macroinvertebrates—Ephemeroptera, Plecoptera, and Trichoptera (Fig. 6)—in a given sample. The metric does not take into account the number of individuals in these families. Site 1 had the highest EPT index (9), while Site 3 and Site 4 were tied for the lowest EPT index with a score of only 3 (Fig. 3).
- Percent of individuals belonging to EPT orders—Site 1 had the greatest proportion of individuals belonging to the EPT orders (45.5%). Site 2 and Site 4 had the lowest proportions, 13.5% and 12% respectively (Fig. 4) .

RESULTS CONT.

- *Feeding groups*—Each macroinvertebrate family can be grouped into five main feeding groups—collector-gatherers, scrapers, collector filterers, shredders, and predators. Based on the properties of each feeding group, one can draw conclusions about things like the presence of environmental stressors or organic pollution in ecosystems.
  - Site 1 consisted mostly of scrapers (40.26%), with very few collector-filterers. Scrapers generally indicate high water quality and are a good sign for this site. Shredders (23.38%), the next most abundant group, are also sensitive to environmental stressors and toxins, indicating that this site was not polluted by any major toxin.
  - Most organisms in site 2 were collector-gatherers (56.76%). Again, the feeding group with the fewest organisms was collector-filterers (2.70%). Collector-gatherers have various pollution intolerances, depending on the family. The abundance of shredders in this site (21.62%) is also a good sign.
  - Site 3 consisted mainly of shredders (28.57%), indicating a lack of toxins or environmental stressors. However, the next most abundant group is collector-filterers (24.49%), which feed on fine particulate organic matter that can be the result of organic pollution. Oftentimes, an abundance of collector-filterers indicates organic pollution.
  - In site 4, most organisms were collector-gatherers (61.96), like site 2, and very few were scrapers (2.17%). Collector-gatherers have a variety of tolerances depending on the family.
- *Modified Hilsenhoff Biotic Index*—The HBI provides a measure for a potential for organic pollution as the weighted average of the organic pollution tolerances of all individuals in a given sample. The higher the HBI score, the higher the potential for organic enrichment. Site 1 had the lowest HBI score, and Site 4 had the highest (Fig. 5).

Fig. 7 (right). Photo of supplies used to collect macroinvertebrates.

Fig. 8 (left). Testing oxygen levels at Site 3.

CONCLUSIONS

Overall, these results suggest that Birch Mountain Brook is a relatively healthy stream, based on its high oxygen content (Fig. 2) and the presence of indicators like scrapers and shredders, EPT order members (Fig. 4), and other organisms like a young brook trout found in Site 3 (a species that requires high oxygen levels and generally good water quality).

However, there were some marked differences between sites in many of the water quality metrics used. Downstream sites generally showed more indicators of mild pollution and lower water quality according to the water quality metrics used, with a few exceptions in the case of Site 3. While these results do not point directly to human impact, they may suggest that human developments like roads, houses, and tunnels—all of which are found in increasing concentration the further downstream one goes—can have an impact on the stream ecosystem. This point is particularly salient in an era when suburban developments in Manchester and other towns like it are continuing to expand, producing vast quantities of pollutants through sediments, stormwater runoff, fertilizers, and other chemicals that are an inevitable result of modern lifestyles. More investigation would be required to make a more direct link between these lifestyles and pollution in these ecosystems, so as to inform conservation efforts in the future.

ACKNOWLEDGEMENTS

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