Comparison of the effects of lakeshore development on fish communities in Douglas and Burt Lakes, Cheboygan, MI

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Abstract

Coastal development can negatively affect fish communities, nutrient levels, and habitat complexity of inland lakes. We studied the effect of human development on fish communities in two Northern Michigan lakes, one developed (Burt Lake) and one relatively undeveloped (Douglas Lake). Two sites were chosen in each lake to be similar. Fish abundance, diversity, and richness were measured in habitat using minnow traps and seines. Habitat was measured using an adapted form of the Index of Habitat Complexity (IHC) (Hook et al. 2001). Additionally, 14 different water chemistry metrics were measured. Results show statistically significant differences in levels of nitrate, DOC, and Cl^- as well as a significant correlation between IHC and species diversity. These results suggest that habitat complexity more greatly effects fish communities than coastal development alone. (Still working on other discussion points).

Introduction

Freshwater ecosystems face anthropogenic impacts from many sources including global climate change, invasive species, eutrophication, and land-use alteration (Beeton 2002). Of these four impacts, land-use alteration is typically considered a point source impact because of the direct effects of each individual unit of development on its surrounding system. For example, early septic systems associated with lakefront developmentled directly to increased phosphorus levels and eutrophication of many lacustrine systems (Carvalho and Moss 1995, Dodds 2002). Additionally, livestock and lawn fertilizers can increase nutrient input to lake systems leading to algal blooms that can cause taste, odor, and human health problems (Arruda and Fromm 1989, Wnorowski 1992, Jacoby et al. 2000).Some of these effects can be mitigated through preservation of riparian vegetation which can serve as a buffer to these influxes of nutrients and prevent eutrophication.

This vegetation can also provide habitat and refuge for biota in the form of macrophytes and benthic debris.Cover plays a significant role in fish assemblages and evaluating this role can reveal insight into fish community structure (Rodriguez and Lewis 1997). Vegetation is especially important as a means of protection for juvenile species from predatory, deep-water species. (Need to make link from importance of vegetation to destruction of vegetation) As development increases, not only does nutrient flow effect fish communities, but also the affects of destruction of riparian vegetation (Christensen 1996).

Many small inland lakes in Northern Michigan have substantially developed coastlines dominated by homes, marinas, beaches, and businesses, which could have significant impacts on the biota in the lakes they surround. These lakes are economically important as they support vital tourism functions including recreational fishing. Two such lakes are Burt and Douglas lakes in Cheboygan County, Michigan. These lakes both support human activity but do so to varying degrees; Douglas Lake is minimally developed with about 22 residences per mile of coastline and Burt Lake is heavily developed with about 40 residences per mile of coastline (Vande Kopple, personal communication). While Burt Lake has not always been more developed than Douglas (Taylor 1973), the University of Michigan's ownership of the majority of Douglas Lake property has limited development on the lake whereas Burt Lake has had no such barrier to development around its perimeter. Though the lakes differ in size with Douglas Lake at a 13.23

mile perimeter and Burt Lake at a 29.44 mile perimeter, they provide a relevant comparison as they both share climates and underlying geology, and both were glacially formed. Given these factors, it would be expected that fish assemblages would be similar under equal levels of development in similar habitats.

To determine the role of human development in fish community structure, we compared the fish abundance, diversity, and richness across two habitat types between Burt and Douglas Lakes.

Materials and Methods

We studied two sites in Douglas Lake (DL) and two in Burt Lake (BL). We compared two habitats at each lake: one minimally vegetated, sandy beach (DL1, BL1) and one marly, vegetated shoreline (DL2, BL2) (Figure 1). These sites were paired together as equivalent habitat types in each lake. Sites were sampled from July 21-29, 2008.

Fish Communities and Habitat

Five minnow traps were set perpendicular to shore at each site along 20 m lines at intervals of 5 m. Traps were set for 24-48 hours and fish were collected three times. Each trap was baited with 6 to 8 nuggetsof dry dog food. We also ran a 5 m seine at each site two times: one trip yielding 6 hauls and one trip yielding 3 hauls. Fishes collected by both methods were identified to species and released. When identification was uncertain, fish were taken back to the lab for confirmation. A haphazard sample of fishes was measured for standard length and released.

We measured substrate by a series of 3, 1 m^2 quadrats set at 10m intervals along each 20 m transect. We evaluated percent benthos coverage, macrophyte species, and grain size using the Modified Wentworth Classification scheme (Wentworth 1922).

We compared habitat features among all sites using an adapted version of the index of habitat complexity (IHC) (Hook et al 2001). In our metric we considered woody debris to be a submergent or emergent macrophyte in that it serves the same role in terms of habitat complexity. IHC was calculated using the formula:

$IHC = [(A_{sub}/3)x(F_{sub}/3)+(A_{emg}/3)x(F_{emg}/2)]/2.$

A values were calculated as an ordinal number related to percent coverage (0=open water, 1=0-33%, 2=34-66%, 3=67-100%). F_{emg} was evaluated from 0-2 based on presence (1) or absence (0) of emergent and floating plants. F_{sub} was similarly evaluated from 0-3 based on three growth forms (rosette, flexous, woody debris). At each quadrat, we calculated the IHC measurement and averaged the three to get an indication of the complexity of the site as a whole.

Water Chemistry

We measured air and water temperature at each site at each visit using a thermometer. We measured dissolved oxygen once per lake using the Hach HQ30d meter, conductivity readings two to three times per lake using the YSI 30 meter, and pH two times per lake using the Fisher Scientific accumet portable laboratory AP61 pH meter, all at near surface depths. We sampled DOC, Cl^-, NO^3, NH^4, total N, PO^4, total P, and alkalinity by collecting samples twice at each site using acid-washed Nalgene bottles. We sampled planktonic chlorophyll-a using Millipore filters and a 60 mL syringe. We sampled benthic chlorophyll-a by collecting rocks and analyzing chlorophyll-a per unit area of rock. Both chlorophyll-aand water chemistry samples were stored in a cooler to regulate temperature and reduce exposure to light before analysis. The University of Michigan Biological Station chemistry lab analyzed water samples.

Statistical Analysis

We compared catch per unit effort (CPUE)and species richness. For CPUE, each day of seining was considered one effort, and each 24 hour day of 5 minnow traps was considered on effort. We used a two sample t-test assuming unequal varianceto establish whether the data are statistically significant ($p < 0.05$) between the two sets of paired sites. We used the Shannon index of diversity to compare fish diversity across sites (Shannon 1948). We used a two sample t-test assuming unequal variance to establish whether the data are statistically significant ($p < 0.05$) between the two sets of paired sites. We also usedtwo sample t-tests assuming unequal variance to establish whether the nutrient data was statistically significant ($p < 0.05$) between lakes. All calculations were made using Microsoft Excel.

Results

Fish Communities and Habitat

Abundance as measured as CPUE varied across sites, though numbers were closer when grouped by lake (Figure 2). There was no significant difference in fish abundance betweenBL1 and DL1 ($t = -0.97$, $n = 5$, $p = 0.39$). There was also no significant difference in fish abundance between BL2 and DL2 ($t= 0.90$,$n= 5$,$p= 0.42$). When both sites are pooled between lakes, there is still no significant difference ($t = -0.79$, $n = 10$, $p = 0.45$) in fish abundance.Shannon index of diversity numbers differed across sites though values were higher at Burt Lake than at Douglas Lake (Figure 3).Species present of fish also differed between sites (Figure 4, 5).Species richness was greater in both Burt Lake sites than in the Douglas Lake sites (Figure 6). IHC values were calculated using terrestrial detritus data and aquatic plant data (Table 1).

Qualitative measurements of length give insight into age structure of*P.flavescens* in both lakes. In Douglas Lake, there is not only a larger *P. flavescens* community, but it is also older than that of Burt Lake (Figure 7).

Water Chemistry

Average pH was lower in Burt at 8.28 than in Douglas at 8.64. Additionally, conductivity was higher in Burt at 322 µS/cm than in Douglas at 237µS/cm. Dissolved oxygen differed slightly between the lakes at 9.77 mg/L in Douglas and 8.84 in Burt mg/L. Average planktonic and benthic chlorophyll-a were both higher in Burt than in Douglas at 2.74 to 0.73 and 4.97 to 4.30, respectively. Nitrate was significantly higher in Burt than in Douglas ($t = 2.33$, $n = 4$, $p = 0.05$) though total N was almost similar (Table 2). Additionally, DOC ($t = -20.88$, $n = 4$, $p = 2.33\text{x}10^{-6}$) was significantly higher in Douglas Lake, while Cl^- was significantly higher in Burt Lake ($t = 14.70$, $n = 4$, $p = 3.42\text{x}10^{-4}$).

Discussion

Fish Communities and Habitat

Abundance data was not significant leading to the adoption of the null hypothesis that there is no statistical difference in abundance of fish communities in Burt and Douglas Lakes. One possible explanation for these data is that the sites chosen in Burt Lake, while comparable to those in Douglas, were not in themselves developed enough to warrant the classification. IHC and abundance values do not clearly reflect any differences between the two sites though it would be expected that development would alter these numbers based on previous research

(Bryan and Scarnecchia 1992, Brazner1997, Jennings et al. 1999). These studies however look more specifically at pristine sites as opposed to developed sites like dikes, riprap or landfills, in spite of diverse habitat structure. One implication of our study could be that fish assemblages in similar habitats do not differ despite development. This is not to say that development has no effect, but it could be that communities are affected in multiple ways that complicate the model further.

IHC was used in this study as opposed to an index of structural complexity because of relative homogeneity between comparable sites in terms ofrugosity. Rugosity is used in some complexity indices under the assumption that greater benthic surface area provides more space for biotic colonization and additional areas of protection for mobile organisms (Stevenson and Bain 1999).This is an important factor in measuring development because coastal refuge provides cover for juvenile fish species, regardless of its origin. Jennings et al. (1999) suggest that even though riprap is introduced by humans, species richness was greatest in these areas because of habitat complexity strengthening the notion that it is complexity and not necessarily development that drives fish communities. Scheuerell and Schindler (2004) agreed, citing that lakeshore development removes two important habitat features, namelycoarse woody debris and aquatic vegetation, which decreases spatial aggregations of fish.

Sites in this study were chosen based on similar habitat types, and in turn similar levels of protection for juvenile fishes, so while Burt Lake as a whole is more developed than Douglas Lake, it could be that the sampling sites represent nursery grounds for the whole of the lake. If that is the case, Figures 3 would represent juvenile assemblages of predominant planktivorousfish species in each lake. The data do suggest that juvenile yellow perch populations in Burt Lake are more heavily predated than those in Douglas Lake.Hanchin et al. (2005) sampled Burt Lake and found that mean yellow perch length was 8.9 cm. Additionally they found that 26 percent of the total community consisted of piscivorous fish. Food web interactions would suggest that Burt Lake perch must not only outcompete other juvenile species, they must also grow at a faster rate prior to reproduction to reduce the chance of predation (Dodds 2002).

(Need to find more data on Douglas Lake)

Water Chemistry

Initial interpretation of the data would suggest differences in pH and conductivity to be anthropogenic, but Schultz (1985) suggests that these differences can be accounted for by underlying geology between Burt and Douglas Lakes. As Carp Creek travels underground to connect the two lakes, it interacts with soluble limestone which would cause increased dissolved particles while still buffering against acidic pH caused by available H^+ ions available underground. This is important to note because it demonstrates that, though these lakes are similar, they are not completely interchangeable due to other biogeochemical processes that cause variations between the systems.

(More coming soon…including suggestions for future research and conclusions)

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