Human Development Effects on Fish Communities in two in Northern Michigan

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Abstract

Studies have shown that human development has negative effects on lake nutrients and habitats, so we hypothesized that development would also have negative effects on fish diversity, species richness and abundance. We compared two lakes in Northern Michigan, Burt and Douglas Lake, to examine how human development had affected fish assemblages. We collected fish from two sites in developed Burt Lake, and two sites in undeveloped Douglas Lake. We left minnow traps out for one to two days, and seined twice at each site. We also compared nutrient and water chemistry data between the two lakes. We found significant differences in species diversity between the two lakes, as well as between two of the paired sites. We also, found that *Perca flavescens* of presumably the same age were larger at Douglas Lake than Burt Lake. Habitat complexity was compared between the two lakes, and was found to be related to increases in diversity, richness and abundance. We found that habitat complexity had a greater effect on fish community than level of development.

Introduction

Since freshwater lakes are home to 68% of the earth's surface liquid fresh water, it is no surprise that humans depend on them for fishing, maintaining economies and recreation (Beeton 2002). At the same time, the diverse and complicated freshwater ecosystems within the lakes also depend on the same space for habitats and food. Such competition for space between humans and wildlife occurs all over the earth, and the effects of human interaction with the environment have been carefully studied in many different habitats. In aquatic systems, the effects of human development on streams have been given much scientific attention, but much less attention has been given to lakes (Jennings et al. 1999).

The few studies that have been conducted indicate that there are some negative effects on lake ecosystems resulting from human development. Beeton (2002) described "environmental forcing factors", as factors that impact the health of a lake. A few of the most influential environmental forcing factors according to the study are eutrophication, introduction of invasive species and pollution. Such factors change the physical habitat of the lake and affect nutrient cycles. Specifically, increased levels of human development on a lake results in fewer habitats and resources for fishes (Scheurell and Schindler 2002). Habitat changes can have lasting effects on fish populations, since habitat features can strongly affect fish assemblages (Hook et al. 2001). A correlation between fish species richness and abundance and development was found in coastal wetlands in Green Bay, Lake Michigan where richness and abundance were highest in undeveloped habitats (Brazner 1997).

Instead of wetlands, we examined two lakes in northern Michigan in close proximity to each other: Burt Lake and Douglas Lake. The two lakes are close in their geographic location (both are in Cheboygan County, Michigan) so they experience similar climactic changes throughout the year. They are both kettle lakes formed by melting ice blocks during the Laurentian glaciations. Both are considered eutrophic lakes as well.

The greatest difference between the two, besides the fact that Burt Lake has 33.34 miles of shoreline and Douglas has only13.23 miles of shoreline, is that Burt Lake has a higher level of human development that Douglas Lake (Tip of the Mitt 2005). Since human development has been shown to have a negative impact on the general health of lakes and development has been shown to decrease available habitat for fish, we expected to find that fish abundance and diversity would be lower in the more developed Burt Lake.

Materials and Methods

Sites

We chose two sites in each lake, and each was chosen to be similar in habitat to a site in the other lake (See Maps 1-2). The first site we chose in Burt Lake was Maple Bay (BMB), which is a sandy site, covered with *Schoenoplectus*. In Douglas Lake, we chose Hook Point (DHP) to be similar to BMB. DHP also has a sandy substrate and many *Schoenoplectus*. The other site in Burt Lake was Kings Point (BKP), which is a sandy, cobbley site with woody debris. In Douglas Lake, we chose Grapevine Point (DGP) to compare to BKP. Grapevine Point has similar woody debris and sandy, cobbley substrate. We compared the sites using Wentworth Classification Scheme and by calculating IHC (see *Habitat analysis* below). All sites that we chose were along the shoreline. To get an idea of amount of development we compared number of residences per kilometer of shoreline.

Water chemistry

We measured dissolved oxygen (DO), pH and conductivity twice at each lake with a Hach HQ 30d DO meter, Fisher scientific pH meter and a YSL 30 conductivity meter respectively. We also took air and water temperatures each time we went out into the field, which took place six times over 7/21/08-7/29/08.

Nutrients

To compare the nutrients present in both Burt and Douglas lakes, we took nutrient samples four times at each lake. We used acid washed, nalgene bottles to collect water samples, which were stored in a cooler with ice or in a dark place until they could be transferred to a refrigerator before analysis. The water was measured in the UMBS chemistry lab for amounts of total nitrogen, NO_3, NH_4, total phosphorous and PO_4. Another bottle from each lake was measured twice for dissolved organic carbon and chloride. To test for chlorophyll-a, samples were taken from two sources at each lake two times. We collected rocks at each site two times, stored them Ziploc bags with some lake water in a cooler until analysis. Chlorophyll-a samples were also taken from the water column using a syringe and filter papers. The amount of water required to fill the filter paper with chlorophyll-a was recorded, and the filter paper was stored in a cooler until analysis.

Habitat analysis

We categorized the substrate using the Wentworth Classification Scheme (Wentworth 1922) along the transects of the minnow traps (see *Fish collection*) to compare similar habitat types across Burt and Douglas lakes. Quadrat measurements of one square meter were taken at the beginning, middle and end of each line. We placed the quadrat on the bottom of the lake, surrounding the minnow trap. After the substrate had settled, we recorded percent coverage of rock, macrophytes, woody debris and any algae, and sometimes we wore snorkeling masks to be able to more easily examine the lake floor. We identified the plants to species. We also used the data about percent coverage macrophytes and woody debris to calculate the index of habitat complexity for each site, the equation for which is IHC= $(((A_{sub}/3)x(F_{sub}/3))+((A_{em}g/3)x(F_{emg}/2)))/2$ (Hook et al. 2001). (See Fig. 1)

Fish collection

We collected fishes at each of the four sites using two different methods. We seined two to times at each site. Specifically, on 7/21 we seined six times at BMB and six times at BKP, on 7/27 we seined three times each of BMB, BKP, DHP and DGP. On 7/29 we seined six times at DHP and six times at DGP. Fishes caught in the seine were counted, measured haphazardly and either identified at the site and released, or taken back to the lab for identification and preserved. We also used minnow traps to collect fishes. We deployed five wire mesh traps along a line, four meters apart at each site. The traps were set up on 7/21 in Burt Lake, and on 7/24 in Douglas Lake. We checked the traps on 7/23, 7/25, and 7/27 at both sites in Burt Lake, and on 7/26, 7/27, 7/29 at DHP, and on 7/25, 7/27, and 7/29 at DGP. When we initially set the traps, and each time we emptied the traps we baited each one with six pieces of dog food. Fishes caught in minnow traps were counted, and identified at the site or back at the lab.

Statistical analysis

We determined diversity using the Shannon Diversity Index for each site and across lakes (Shannon 1948). T-tests with two samples assuming unequal variances were used to determine if there were statistically significant differences in diversity, abundance and nutrients between the lakes. When we compared data between the two sites, we sometimes compared across site (BMB to DHP, and BKP to DGP), and sometimes across the entire lakes (Burt to Douglas). We calculated averages for diversity, richness and abundance by finding the averages site, per day and then averaging those averages to find a total average. To interpret the fish length data we collected, we made length frequency histograms, just for the *Perca flavescens* found in each lake.

Results

Sites

After calculating IHC for each site, we found differences between the sites (Fig.2). We found differences in the average amount of development (just homes) per kilometer; where there are 22 residences per km on Burt Lake and 12 residences per km on Douglas Lake (Van Dekommpe personal communication).

Water Chemistry

Douglas Lake had more DOC than Burt Lake, 8.96 mg/L compared to 4.14 mg/L. Average conductivity was higher at Burt Lake, 322.3, compared to Douglas Lake, 237.0. Burt Lake also had higher alkalinity levels, 252.8 compared to 182.5. Average pH was similar across the two lakes where Burt Lake has an average pH of 8.3 and Douglas Lake has an average pH of 8.6. (See Fig.2 for more chemistry data).

Nutrients

Comparison of nutrient levels between sites and lakes revealed some major differences between the lakes, although some nutrients were found in similar quantities. T-tests revealed significant differences in CL^- and DOC. Douglas Lake had significantly more DOC than Burt Lake (t=-20.8830, n=4, p=4.66E-06). Burt Lake had significantly more CL^- ($t=14.6952$, $n=4$, $p=0.0007$). Burt Lake had a higher average of NO_3 than Douglas Lake, 32.18 Ng/L compared to 2.13 Ng/L. Also, BKP had higher NO_3 levels than BMB, 10.25 Ng/L compared to 54.10 Ng/L. (See Fig.2 for more nutrient data).

Habitat

IHC varied across the sites. BMB had an IHC score of 0.56, and DHP had a score of 0.09. BKP has a score of 0.14 and DGP had a score of 0.05 (see Fig. 3). A comparison of these values to diversity, richness and abundance can be seen in Figs 4-9.

Fish

T-tests revealed significant differences in diversity. At BMB average diversity was 0.66 on the Shannon Diversity Index, and at DHP average diversity was 0.85. T-tests on these results showed a significant difference ($t=5.0264$, $n=5$, $p=0.0024$). There were no significant differences in diversity between BKP and DGP ($t=2.1636$, $n=5$, $p=0.0737$). T-test did, however, find significant differences between diversity between the two lakes ($t=3.976$, $n=10$, $p=0.0009$). (See Figures 4-5)

Richness tended to be higher at Burt Lake (Figures 5-6). BMB had a richness of 7 and DHP had a richness of 3. BKP had a richness of 9 while DGP had a richness of 5. Burt Lake also had a higher richness than Douglas Lake, 11 compared to 6. The distribution of the different species found can be seen in Diagrams 1-3. (See Figures 6-7)

Catch-per-unit-effort (CPUE) varied across the two lakes and four sites. Average CPUE was highest at DGP where it was 12.83, but average CPUE was lowest at DHP where it was 0.61. CPUE at BKP was 3.53, and 2.08 at BMB. Total average CPUE was different between the two lakes, where it was 2.81 at Burt Lake and 6.27 at Douglas Lake. T-tests revealed no significant differences in either site for abundance. Between BMB and DHP t-tests results were ($t=0.9123$, $n=5$, $p=0.4035$), and between BKP and DGP results were ($t=-0.9709$, $n=5$, $p=0.3866$). Between Douglas Lake and Burt Lake, t-tests also revealed no significant difference in abundance ($t=-0.7790$, $n=10$, $p=0.4530$). (See Figures 8-9)

The average length distribution of the fishes collected differed between the two lakes. In general, the fishes assumed to be the same age in Douglas Lake were larger than the fishes in Burt Lake. The greatest difference was found between the *Perca flavescens* found in the two lakes. (See Figures 10-11)

Discussion

We did not support our hypothesis that Burt Lake would have lower abundance and diversity of fishes compared to Douglas Lake. T-tests did not indicate any statistically significant differences between abundance, but there was a significant difference in diversity between Burt and Douglas Lakes, and between BMB and DHP. Although both lakes seem to be similar in abundance of fish, our data suggest that Burt Lake has a more diverse fish community. This suggests that habitat has a greater effect on fish communities in Burt Lake than development does, which is similar to the findings in Hook et al. 2001.

The *Perca flavescens* differed in length distribution, which is a result we did not expect. According to the standard length of the fish we caught in seines, the *Perca flavescens* tended to be bigger in Douglas Lake. This is not a result that is discussed in other studies done on human development effects on lakes. Perhaps there are smaller fish in these shoreline habitats in Burt Lake, because the lake has more game fish, like walleye, who normally prey on the smaller juvenile fish, thereby reducing the number of fish that grow to be larger (Hanchin et al. 2005). Burt Lake has had a history of stocking game fish, sine the lake is a popular spot for fishing in Northern Michigan (Tip of the Mitt 2005).

Unlike the fish length data, there are data from other studies regarding human development effects on fish populations in lakes. Research conducted on changes in distribution of fishes along a development gradient found that human development does cause changes in fish community composition (Scheurell and Schindler 2004). The article attributes the changes in fish assemblages to substrate changes, prevention of terrestrial input, removal of habitat such as woody debris and changes in nutrient levels due to development. When we compared the IHC of our specific sites, we found that abundance, diversity and richness all increased with increasing habitat complexity (see Figures 12-14). This could be due to the fact that more complex habitats had more macrophytes, and these are places where we would expect to find high fish abundance (Bryan and Scarnecchia 1992). Higher fish abundance in areas with abundant macrophytes can be attributed to the fact that fish use vegetation for feeding, hiding and spawning (Bryan and Scarnecchia 1992).

The lack of any significant abundance difference between Burt and Douglas could be attributed to certain qualities of Burt Lake, which may have been absent in the Scheurell (2004) study. We sampled a site that had woody debris, BKP. Even if there has been a decline in woody debris in Burt Lake in general, we could still expect to find regular fish populations in the sites that still contain woody debris. Also, the fact that the water in Burt Lake still seems to be able to support fish communities despite shoreline development could be attributed to the lake's large size. Burt Lake has a good carrying capacity (ability to absorb human impacts and still maintain good water quality) due to its large volume (623,173,568 m^3) and rapid flushing rate (Tip of the Mitt 2005). Additionally, most of the Burt Lake's watershed is undeveloped, so the water flowing in is of good quality, and could influence Burt Lake's water quality (Tip of the Mitt 2005).

However, diversity of fish is not always an indication of a healthy lake. We found a large difference in the amount of NO_3 present in Burt Lake compared to Douglas Lake, and this is probably due to nitrate run-off from lawns along the shoreline. The fact that BKP has so much more nitrate than even BMB supports the idea that the increased nitrate comes from lawn fertilizer run-off. The area where we sampled near Kings Point Boat Launch is right next to a community of private homes, whose lawns run very close to the lakeshore. Our sample site at Maple Bay, however, was near a campsite with sand, dirt and some grass, which was probably not fertilized. Such high levels of nutrients like nitrate are often bad for lakes, since they can lead to toxic algal blooms, loss of oxygen (which could be the reason for the lower DO levels at Burt Lake), and fish kills (Carpenter et al. 1998). Chloride, another nutrient found in significantly greater quantities in Burt Lake, can be indicative of other pollutants associated with development and human activity (Tip of the Mitt 2005). It is interesting to note, however, that some studies have not found a correlation between increased development and decreased water quality. Stedman et al. (2006) did not find that more developed lakes were more turbid, had higher levels of chlorophyll or different water color, even if development increased phosphorus and decreased available habitat.

The increased levels of DOC in Douglas Lake as compared to Burt Lake could be explained by higher levels of leaf litter and riparian vegetation. Leaf litter is thought to increase levels of DOC (Uselman et al. 2007), and since Douglas Lake has a less developed shoreline, it could be expected to have higher levels of riparian vegetation and leaf litter than Burt Lake. For fishes, more leaf litter could mean more shredders, which are macroinvertebrates on which fish feed.

The higher diversity levels in Burt Lake could be explained by the fact that Burt Lake is heavily used for fishing. Except for the *Etheostoma nigrum*, all of the species present in Burt Lake but not Douglas Lake are common bait fish in the United States (Scott and Crossman 1973) (see figures 15-17). The fishes found in Douglas but not Burt Lake, *Micropterus dolomieui* and *Lepomis macrochirus*, are not bait fish, but game fish (Scott and Crossman 1973). It is possible that the fishes we found in Burt Lake and not in Douglas Lake are simply present because anglers have used them for fishing, and dumped their leftover bait into the water.

It should be noted that some of our Douglas Lake fish data could be skewed based on a seine conducted on 7/29 at Grapevine Point. In one seine we found a school of about 300 *Notropis hudsonius*. This number does not reflect the number of fish we normally caught at DGP, or at any of our sites. The large number certainly influenced CPUE data, by increasing our average CPUE for DGP and Douglas Lake. However, we decided to include it in our data anyway, since it is interesting to note that such large schools of *Notropis hudsonius* can be found at DGP.

Although we found that diversity was greater at Burt Lake than Douglas Lake, our nutrient data suggest Burt Lake may not necessarily be healthier than Douglas. Further studies are suggested in order to demonstrate to the residents along Burt Lake, and those who use the lake for fishing and boating, that care needs to be taken with their lake in the future. More increases in nutrient input to the lake could lead the eutrophication, which could ultimately spoil the relatively healthy fish population Burt Lake has today.

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Tables and Graphs

Site	IHC Value	Substrate	Vegetation	Depth Range of Minnow Traps	Onshore Vegetation
BMB	0.139	Medium sand, marl, and clay	*Chara spp., Schoenoplectus spp.,* and some type of mossy algae	46 cm to 142 cm	Deciduous trees beginning at least a meter from shoreline
DHP	0.056	Medium sand, marl	*Schoenoplectus spp.,* some type of mossy algae, *Najas flexilis*	64 cm to 79 cm	Deciduous trees beginning at least a meter from shoreline
BKP	0.167	Medium sand, coarse sand, pebbles	*Chara spp.*, some type of mossy algae, lots of woody debris	46 cm to 85 cm	Deciduous and coniferous trees growing along shore, overhanging
DGP	0.278	Medium sand, marl, pebbles	*Chara spp., Potemogeton spp., Najas flexilis*, lots of woody debris and leaf litter	27 cm to 100 cm	Deciduous and coniferous trees growing along shore, overhanging

Figure 1 shows the IHC value, substrate type based on the Wentworth Classification Scheme, vegetation, depth range of minnow traps and the type of onshore vegetation at each site.

	Site					
	BL1	**DL1 - Hook**	**BL2**	**DL2 - Grapevine**	**BL Avg**	**DL Avg**
DOC (mg C/L)	4.29	8.92	3.99	8.99	4.14	8.96
Cl^- (mg Cl^-/L)	9.48	6.06	9.57	6.14	9.52	6.1
NO^3 (Ng N/L)	10.25	1.75	54.1	2.5	32.17	2.12
NH^4 (Ng N/L)	14.35	3.35	13.25	17.7	13.8	10.53
Total N (mg N/L)	0.59	0.43	0.51	0.68	0.55	0.55
PO^4 (Ng P/L)	1.55	0.5	1.7	2.25	1.62	1.38
Total P (Ng P/)	9.18	10.38	6.53	11.79	7.85	11.08
Alkalinity	248.6	-	256.9	182.5	252.75	182.5
Planktonic Chlorophyll (Ng/L)	[redacted]				2.74	0.73
Benthic Chlorophyll (Ng/cm^2)					4.97	4.3
Conductivity					322.3	237
pH					8.28	8.64
DOC (mg/L)					8.84	9.77

Figure 2 Shows average nutrient and water chemistry measurements for each site and lake.

	Quadrat	Asub	Fsub	Aemg	Femg	IHC	Average IHC
BL1	1	1	1	0	0	0.083333	
	2	2	2	0	0	0.333333	
	3	0	0	0	0	0	0.138888889
DL1	1	2	2	0	0	0.333333	
	2	2	2	0	0	0.333333	
	3	1	2	0	0	0.166667	0.277777778
BL2	1	1	1	2	1	0.25	
	2	1	1	1	1	0.166667	
	3	1	1	0	0	0.083333	0.166666667
DL2 hook	1	0	0	0	0	0	
	2	0	0	0	0	0	
	3	1	1	1	1	0.166667	0.055555556

Figure 3 Shows the index of habitat complexity for each site. A_{sub} refers to the average ordinal ranking of nine subsamples of substrate area covered by submergent macrophytes. F_{sub} refers to the average number of submergent growth forms detected. A_{emg} is the ordinal ranking of the nine subsamples of water surface area covered by emergent macrophytes. F_{emg} is the average number of emergent growth forms detected.

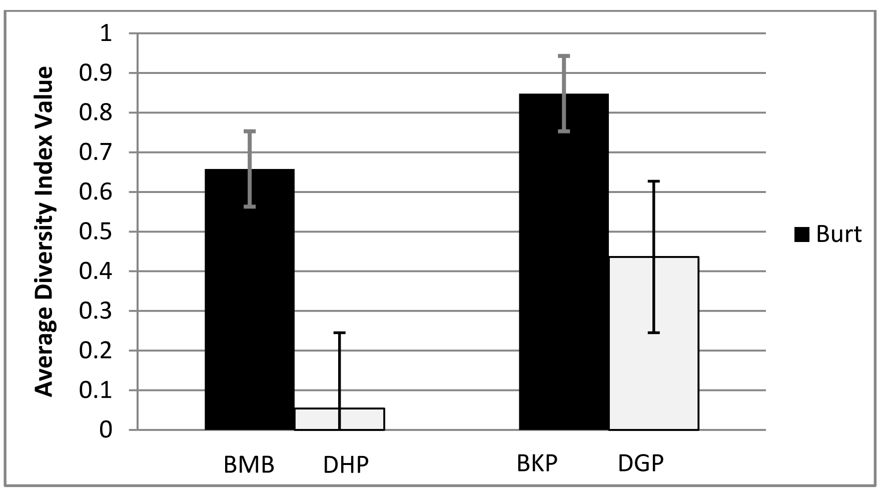

Figure 4 shows average diversity value for each site, based on the Shannon Diversity Index. These indices indicate how diverse each site was, while taking into account evenness of species distribution. Paired sites are shown next to each other.

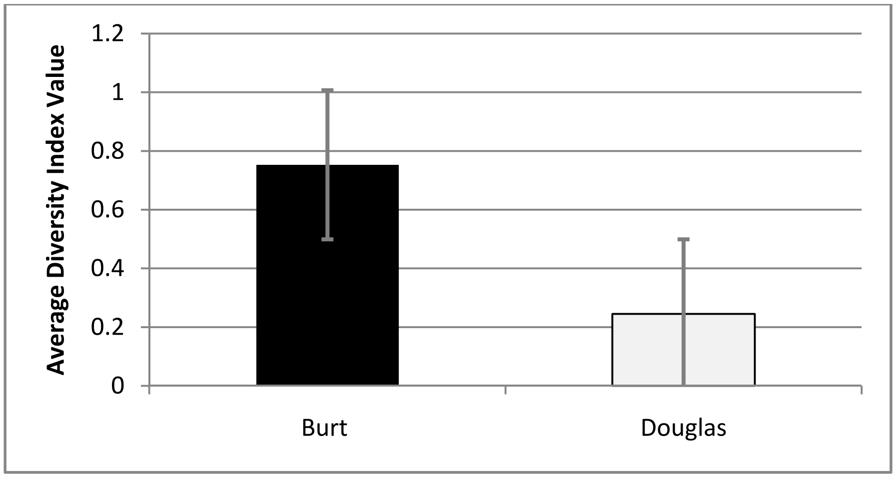

Figure 5 shows average diversity index values for both lakes based on the Shannon Diversity Index. These indicate how diverse each lake is, taking into account the evenness of species distribution.

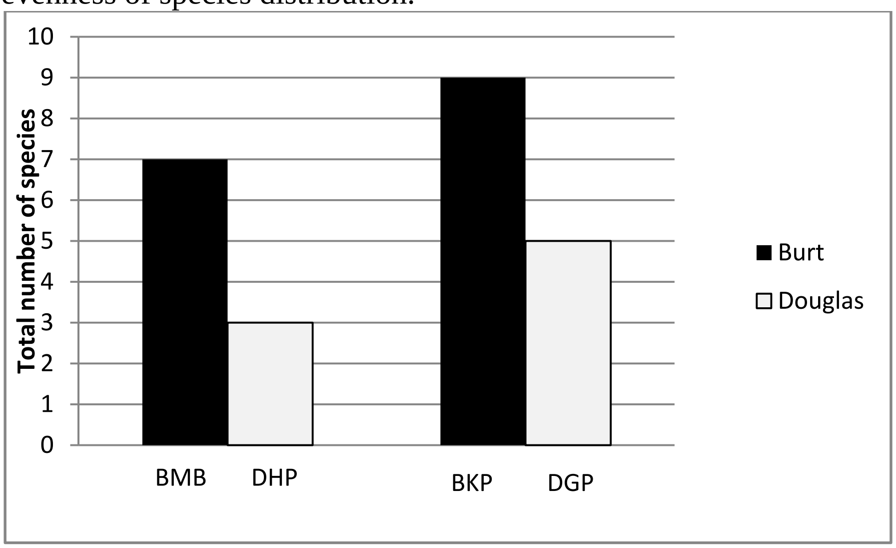

Figure 6 shows the richness at each site, and indicates the total number of species without taking into account evenness.

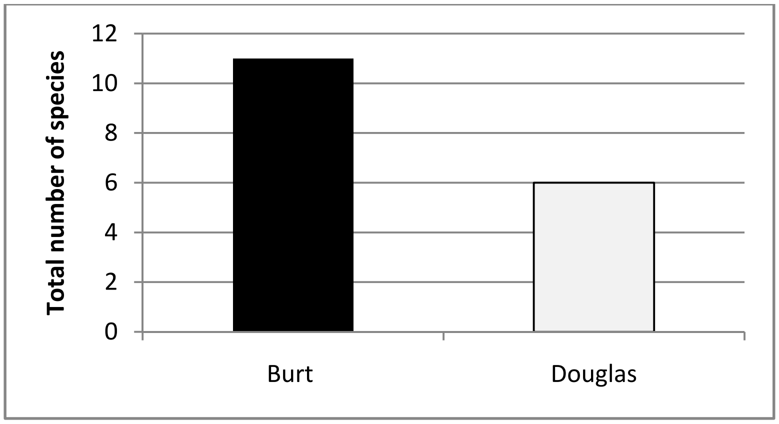

Figure 7 shows richness at each lake without taking into account evenness.

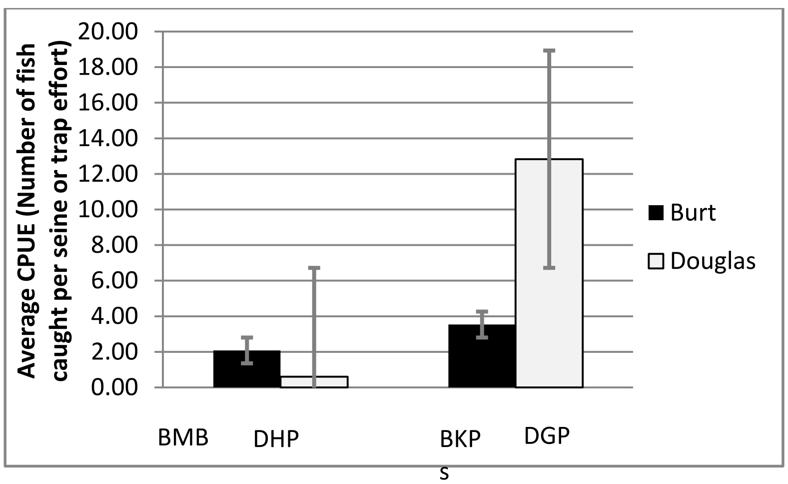

Figure 8 shows average CPUE for each site, indicating abundance. Paired sites are shown next to each other.

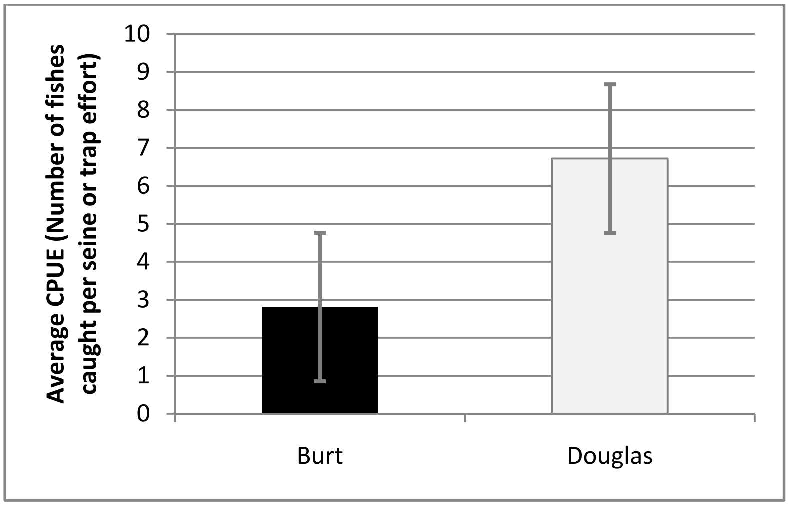

Figure 9 shows average CPUE for each lake, indicating abundance.

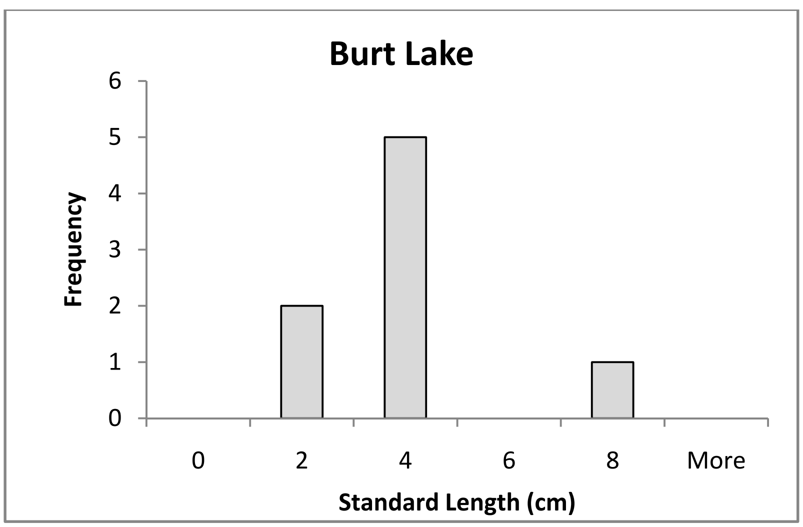

Figure 10 shows the distribution of *Perca flavescens* of similar standard lengths (from the tip of the nose to the base of the tail) found in Burt Lake.

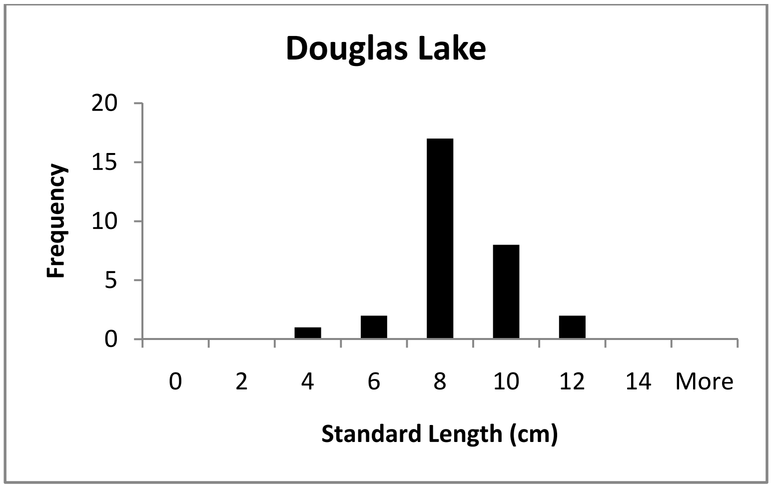

Figure 11 shows the distribution of *Perca flavescens* of similar standard lengths (from the tip of the nose to the base of the tail) found in Douglas Lake.

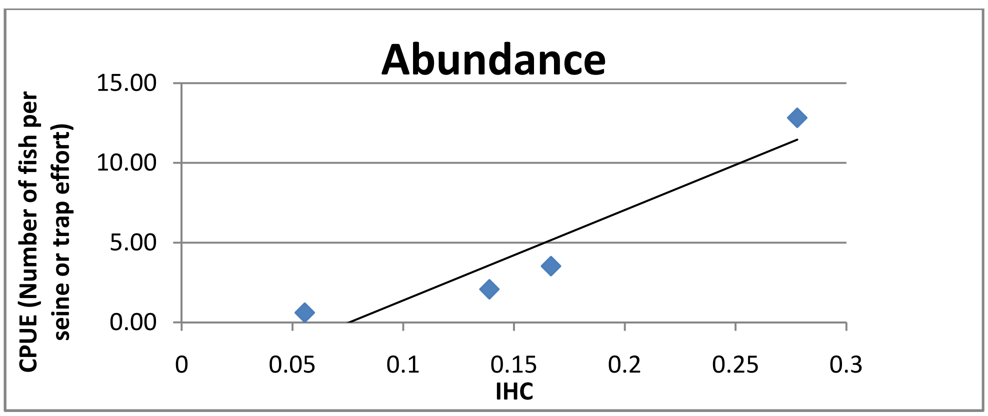

Figure 12 shows the relationship between CPUE (abundance) and IHC (habitat complexity). The trend line shows a general increase in abundance as habitat complexity increases.

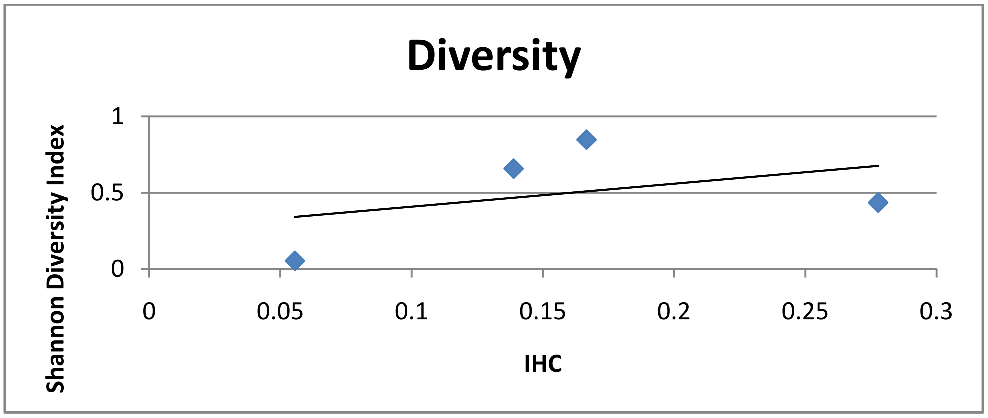

Figure 13 shows the relationship between diversity and IHC. The trend line shows a general increase in diversity as habitat complexity increases.

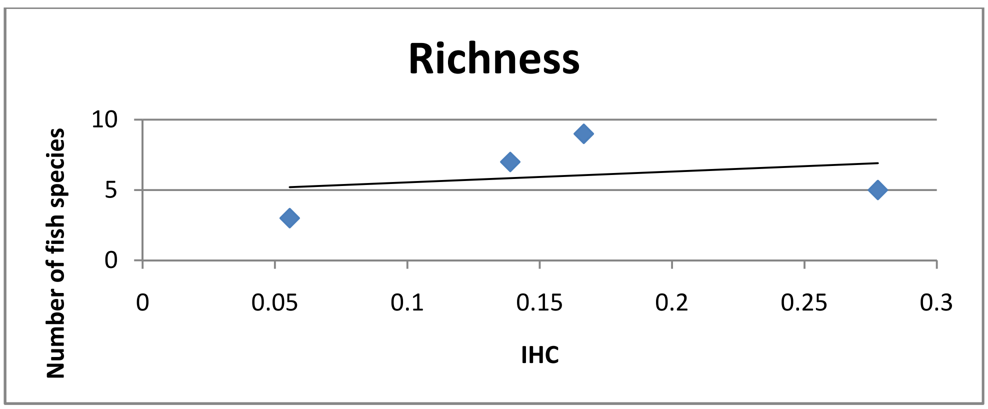

Figure 14 shows the relationship between species richness and IHC. The trend line shows a general increase in species richness as habitat complexity increases.