# Upland land-use and the effects on upper trophic level dynamics and structure

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## ABSTRACT

Land-use change can have a profound effect on trophic structure and dynamics. Fish and macroinvertebrate samples were collected in forested rivers, restored cranberry bogs, active cranberry bogs and abandoned bogs. There was a change in dominant fish species with brook trout in forested, fantail darter in the restored bogs, and Fourspine sticklebacks in the active as well as the abandoned bog. Macroinvertebrate samples showed higher biodiversity in the forested river as hypothesized. The lowest was seen in the abandoned bogs. These results provide important information for conservation and restoration of cranberry bogs. The best way to re-establish the biodiversity and composition of fish and macroinvertebrate families is to actively restore the area.

## INTRODUCTION

Tropic interactions take place between all organisms within an ecosystem. Determining the fate of energy and nutrients within an ecosystem is key to understanding the effects of how an alteration will affect the system. For example, when a change in the physical features of the riparian zone takes place, it will impact the trophic relationships by altering the flow of nutrients and energy. One of the most significant impacts may be the alteration in the base of the food chain. Modifications of the land use in riparian zones will change the abundance and composition of primary producers. This modification will be displayed in the upper levels of the food web, allowing for some species to survive and some to fail to complete successfully for resources and die out completely. One mechanism, which leads to changes in species composition, is whether the grazing or detrital pathway is dominant. Therefore, a change such as watershed land use has the ability to alter trophic dynamics and structure, by having a significant impact on the base of the food web and species composition and abundance of species in the ecosystem.

It has been well documented that past land use on a riparian zone has a significant long-term impact on species diversity in the ecosystem, even if efforts at restoration have been made (Harding et al, 1998). This negative affect of anthropogenic influence is most clearly seen on agriculture lands. The reconditioning of the land so that it closely resembles its original state may not be great enough to promote the natural biodiversity that existed in the water body before the watershed alteration took place. Impacts that negatively influence biodiversity have a detrimental impact on the stability of an ecosystem as a whole (Lehman and Talman, 2000). Impacts on the riparian zone of a water body can have a significant influence on the physical factors that determine species composition (Pusey, 2003). Soil and nutrient inputs, chemical inputs, thermal radiation, terrestrial vegetation inputs and UV light will affect the biodiversity that is exhibited in a system and the level of each factor can vary widely when there is a land-use change in the riparian zone. Therefore, the changes in land use are important in determining the health of the aquatic ecosystem.

## METHODS

To compare the effects of riparian land-use use on upper trophic level dynamics and structure, three different freshwater rivers were selected, the Coonamessett, Quashnet and Mashpee rivers (figure 1). Each river has different aspects with their riparian land-use histories. Two of these rivers, the Coonamessett and Quashnet, have had the immediate riparian zone significantly altered by previous and current land use. Parts of the Coonamessett are currently being used as an active cranberry bog and have applications of fertilizers and pesticides. There is no terrestrial vegetation over the water body, which would potentially increase photosynthesis of the phytoplankton present in the system. In the middle of the Coonamessett, Coonamessett site B, there is a section of the river that was at one time a bog, but was abandoned and succession resulted. The Quashnet was a cranberry bog until 1954 when Hurricane Carol resulted in salt-water invasion of the bogs. The bogs in some areas were then abandoned, Quashnet site C, and have also allowed for succession to take place, and other parts, Quashnet site B, were actively restored to allow for trout spawning. Part of the restoration effort included in-water growth removal, to create banks, undercutted was preformed, baffles were added and riparian vegetation was planted. In the restored part of the river, there is vegetation directly over the water source, while the abandoned parts also have overhead vegetation as well. The upper part of the Quashnet is an inactive cranberry bog, but is still being actively maintained, although, there is no pesticide and fertilizer application as found in the active Coonamessett bogs. Contamination of Diethyl Bromide, a jet fuel additive from a nearby air base, prevents the cranberries from being consumed by humans, but the owner is still actively maintaining the area. In this study, we are still considering it an active cranberry bog. The Mashpee is the most natural of the three river systems, and has had no current or previous riparian land-use alterations immediately adjacent to the river. However, it has its own nutrient inputs from the housing developments that are present in the watershed. The Mashpee, like the restored section of the Quashnet, has vegetation directly over the river. In these three rivers, most of the water is supplied by groundwater seeps along the length of the river.

These different sites allow for comparison between four different land use types, riparian zones that are heavily forested actively restored bogs, active bogs and abandoned bogs. From this data collection, it is possible to determine the success rate of actively restoring the river as an alternative to abandoning the river and allowing natural succession to take place and the differences between pristine sites and active cranberry bogs. Three sites were selected within each river, giving a total of nine sites. Sites designated with the letter A are the most upstream, sites with a B letter are in the middle and sites with the letter C are the furthest downstream. There are three forested sites, Mashpee site A, B and C, one restored cranberry bog site, Quashnet site B, three active cranberry bogs, Coonamessett site A, C and Quashnet site A, and 2 abandoned cranberry bog sites, Coonamessett site B and Quashnet site C.

To characterize these rivers, we collected discharge, water temperature and nutrient inputs. Water samples at four different sites, Coonamessett site B, Coonamessett site C, Quashnet site B, and Mashpee site B, were gathered on November 11$^{th}$, 2003 and November 23$^{rd}$, 2003 to examine ammonium, nitrate and phosphate. Ammonium concentrations were analyzed using a modification of the phenolhypochlorite method

(Solarzano, 1969) using the spectrophotometer at a wavelength of 640 nanometers. Nitrate was analyzed using the Latchet Flow Injection Autoanalyzer. Phosphate samples were analyzed spectrophotometrically using ascorbic acid at 885 nanometers (Murphy and Riley, 1962). Discharge rates were also collected at the same four selected sites on November 11th, 2003 using a mechanical Flowmeter Model 2030. For a single cross section of the each of the selected sites, the depth of the river was calculated every 10 centimeters while the flow of the river was calculated every 20 centimeters at 20%, 40% and 80% of the river depth. Flows and depths were placed into an equation that calculated the discharge rates of the different rivers. River temperature was calculated using a HOBO water temperature loggers that were carefully placed in the stream on November 11th, 2003 to be under the water at all times during sampling. If this were not done in this method, we would find that air temperature was being measured rather than water temperature. These temperature loggers collected data every 30 minutes until December 4th, 2003, when they were removed. Time was also allowed for the temperature loggers to reach equilibrium. Data collected before Noverember 12th, 2003 at 12:01AM was not considered. Data collected after December 4th, 2003 at 12:30 PM was also thrown out, as that was the removal time for the temperature loggers.

To understand the difference in higher trophic levels between the three different river ecosystems, sampling the rivers for fish and insects is necessary. To measure the fish abundance and biodiversity, passive fishing methods were used. Each minnow traps were baited with approximately 17.3 grams of cat food in a plastic lunch baggie with 10 small holes made from a probe. Each of the nine sites in the three different rivers had three minnow traps. Minnow traps were left out with the bait for 48 hours then removed from the water and examined for fish. Traps were then left out of the water for 24 hours to allow for fish to move back to their normal densities and position. After the 24 hours, the traps were rebaited with new cat food. Fish samples were collected five times in all of the Coonamessett River sites, on November 12th, 16th, 19th, 22nd, and 25th, 2003. Fish samples were collected for all of the Quashnet and Mashpee Rivers four times, on November 16th, 19th, 22nd, and 25th, 2003. Fish samples would be later identified down to species, and certain species, Eastern Brook Trout and Fourspine Sticklebacks, would be examined for Fulton's condition factor [$K=(\text{weight}/(\text{length})^3)*100000$], a measure of nutritional state and energy storage by comparing weight for a given length of the fish (Schreck and Moyle, 1990).

Macroinvertebrate samples were taken using a Surber sampler on November 22nd, 2003 in each of the nine different sites within the three different rivers. The Surber sampler used a 50-centimeter by 50-centimeter area that was disturbed with a metal stake for 15 seconds down to a depth of 2 cm (Hauer and Lamberti, 1996). The collection of sand, organic matter, rocks and insects were collected in the end of the net for later analysis. Insects were later identified down to family, number of individual were counted, and wet and dry weights were also taken. To calculate the dry weights, sorted samples were placed in pre-weighted tin trays, then incubated at 60$^{o}$C for 14 hours, and reweighed for dry weights.

To evaluate if the means did in fact differ, graphs shows a standard error bar. If two lengths of the error bar overlapped another the results from another standard error from an error bar, the means showed no difference. To compare the entire ecosystem, food webs were created based on text and species collected in each one of the sampling sites.

## RESULTS

River concentrations of nitrate were the highest in the Mashpee River at 24.25 μM, while lowest in the Coonamessett site B at 10.59 μM (table 1). Ammonium was also the highest in the Mashpee site B at a level of 10.06 μM and lowest in the Coonamessett site B at 6.11 μM. Phosphate showed varying levels in each site, but it should also be noted that the levels measured are approaching the lower limits of detection using our methods. Coonamessett site B had the highest levels of phosphate at 1.017 μM. Table 1 also shows that the Coonamessett site C had the highest discharge of 250.9 $L*sec^{-1}$ and the Mashpee site B has the lowest discharge of 117.3 $L*Sec^{-1}$. Data collected from the temperature loggers show the same general trend with the temperature changes across the rivers, seen in figure 2. When one river gets colder, so do the others. But certain rivers seem to be warmer than others. The Mashpee seems to be the warmest of all rivers while the Quashnet and the closed Coonamessett are generally the coldest. When looking at the Coonamessett data, we find that Coonamessett site C is slight warmer than Coonamessett site B.

Forested and restored bogs showed the highest levels of insect biodiversity, with the lowest levels of biodiversity in the abandoned bogs, as seen in figure 3. Fish diversity was highest in the pristine and active bogs, but each site was sampled at a different amount, and this figure only calculates total species found. Figure 4, however, shows the biodiversity per unit effort by taking the total fish species caught and dividing by the total number of traps in each riparian land-use type. This figure shows that diversity was equal in the active and abandoned bogs, while highest in the restored bogs. Fish diversity per unit effort was slightly higher in the pristine rivers than in the active and restored bogs, but lower than the restored bogs.

Total wet weight per site for macroinvertebrates by riparian land-use, as shown in figure 5, is highest in the restored river at 9.476$g/m^2$ and lowest in the abandoned bog at 0.188$g/m^2$. The means calculated are highly variable and show no difference. When wet weights per macroinvertebrates are compared between land-use adjacent to river, as in figure 6, we find that the restored bog has the highest weight per individual macroinvertebrate at 0.0017g/macroinvertebrate. But comparison of the mean with the use of error bars shows no statistical difference in these means. Figure 7 shows the macroinvertebrates per $m^2$ and the means here are also highly variable and did not differ between treatments. Table 2 shows a complete list of families caught along with their abundance per $meter^2$. Figure 19 shows the percent similar Macroinvertebrate families that were compared with the forested river. The land-use with the most similar macroinvertebrate samples was the restored river, followed by the active bog. The restored bog had the lowest percent of similar macroinvertebrates.

Figure 8, 9, 10 and 11 show the frequency of organisms captured. Figure 8 shows the data for the pristine river. The dominant species in this river is the Eastern Brook Trout, followed by the Eastern Silvery Minnow. Species in the lowest concentration are the Blueback Herring, Banded Killifish and the American Eel. Figure 9 shows the collections from the Restored Bogs. Dominate species here are the Fantail Darter followed by the Eastern Brook Trout. Figure 10 shows the dominant species in active bogs to clearly be the Fourspine Stickleback, with other various species to be in very low concentrations, with several species, Banded Killifish, American Eel, Fantail Darter and Chain Pickeral being only caught once. Figure 11 shows the fish collect data for Abandoned bogs with the highest concentration of species being the Fourspine Sticklebacks, with collections of Eastern Brook Trout, American Eel, and Bullfrog tadpoles being the in very low concentrations as well.

Fish weights per unit effort are shown in figure 12. The highest weight per unit effort was found in the abandoned bog and the lowest catch per unit effort was found in the active bogs. The forested river had a slightly higher fish weight per unit effort than the restored river. When comparing the standard error bars, none of these means are statistically different. However, when the individual weights of fish that were captured were compared across rivers, as in figure 13, the forested river and abandoned river had the highest weight at 6.0g/fish and 5.7g/fish, respectfully. The restored river was lower at 4.3g/fish and the lowest was at the active bog at 0.7g/fish. The means between the forested river and the active bogs are statistically different when comparing the error bars. The total fish caught per unit effort is displayed in figure 14, and the greatest fish caught is in the active bogs at 3.7 fish per unit effort. The forested river has a higher fish per unit effort at 1.2 fish per unit effort than the restored river, at 1.0 fish per unit effort. However, the abandoned bog is higher than both the forested and restored river at 1.8 fish per unit effort. Again, using the error bars, means are highly variable and none are statistically different.

Fish condition were compared for the Eastern Brook Trout because the trout's return back to the Quashnet was one of the major goals in restoring the section of the Quashnet site B. Fourspine Sticklebacks were compared because they were the only species that were found in each of the four different riparian land-use types. Figure 15 shows the fish condition for the Eastern Brook Trout. Since no Brook Trout were caught in the active bogs, fish condition cannot be compared for these rivers. Fish condition in the restored bogs was about equal to that of the condition of the forested river. However, the highest condition was found in the Abandon Bogs. But with the error bars plotted, none of these means are statistically different and the data becomes highly variable. Figure 16 compares fish condition for the Fourspine Stickleback. Fish condition was the highest in the restored bogs, but about the same in the forested river, active bogs and abandon bogs.

The amount of Eastern Brook Trout captured was compared to the different land-use riparian land-use types per unit effort in figure 17. The means were highly variable and showed no change between treatment types, except for the active bog, as no trout were caught at all. When each land-use riparian type per unit effort compared with the total amount of fourspine sticklebacks captured, as in figure 18, we found that there were more fourspine sticklebacks present in the active bogs and less in the forested river and restored bogs. Table 3 shows a collection of total fish captured and amounts.

## DICUSSION

The Mashpee has the highest levels of nitrate and ammonium in its waters, and is most likely due to the high density of houses that are present in the watershed. However, we took measurements on two dates in the month of November, and results in all rivers might widely vary between sites. It is known that the active cranberry bogs have a suggested application of 60kg/hectare during the growing season. It is very possible that some of that fertilizer application will run off into the Coonamessett and have a drastic impact on the nutrient concentrations as well as the life that is present in the water system. Discharges between the rivers were very similar, but the physical characteristic of the streams varies between the three rivers. The Mashpee was a fast moving shallow system, the Quashnet was deeper, but was still fast moving. Both sites in the Coonamessett were very deep and slow moving. Also Coonamessett site B had a lower discharge rate than Coonamessett site C, and helps prove that this river is mainly fed by groundwater flow along the river. Interestingly, the water is significantly warmer in the Coonamessett site C than the Coonamessett site B. As the water moves from the Coonamessett, it is exposed directly to the sun because there is no overhanging vegetation to block the light in the active bog site, and is the reason for the increase in temperature between the sites.

Passive fishing methods, such minnow traps, can obtain results measured in catch per unit effort (Murphy, 1996). The most basic assumption is that the CPUE is proportional to stock density and that with increased stock the CPUE will also increase. Using passive methods multiple times, the amount of fish caught in a set of passive gear can be graphed against the frequency of species caught. The frequency catch graphs that result can be compared within a river ecosystem to determine relative species densities. There are also many inherent flaws with passive methods. The fish must be attracted by the bait, negotiate its way into the trap, and remain inside the trap until their removal. These flaws are consistent across the rivers since the same kinds of traps are being used. However, it is important to understand that these flaws makes it an incomplete sample, and that there may be other fish in the river but are unable to be observed. There are also similar problems with my macroinvertebrate samples. While these macroinvertebrate samples are a representative sample of benthic organisms, there might be other species present in the water that were not captured in the sample.

Biodiversity is very different between the land-use types adjacent to the river in macroinvertebrates. One of the more interesting trends is that only some of the species that are found in the Active Bog are also present in the Restored River and the Forested River, such as Amphipoda, Oligochaeta and Mysidae. However, there are various families that are only found in the Forested River and the Restored Rivers, such as Baetidae, Heptageniidae, Leuctridae, Chloroperlidae, Hydropsychidae, Perlodidae, Coleoptera, Elmidae and Lepidostomatidae. These stoneflies, caddisflies and mayflies are generally very intolerant of poor water quality. Their presence indicates that the waters they are found in are generally in good health. However, in the active bogs, other species such as hirudinea can be found in poor water quality. The lack of stoneflies, caddisflies and mayflies and presence of hirudinea may show that the active bogs are in generally poor health. The abandoned bogs only contain species that are most similar to the active bogs as well.

Coonamessett site A and C have both pesticide and fertilizer application on their bogs, and it would be expected that no intolerant species of poor water quality such as the mayflies, caddisflies and stoneflies would be found. But these families of macroinvertebrates are also not found in the Quashnet site A where the cranberry bogs are being maintained, have no fertilizer or pesticide application. While pesticide and fertilizers are not supportive of species that are very sensitive to water quality, their absence suggests that there can be something else that is preventing these species from inhabiting the area. It is possible that the increase light and UV radiation that is able to penetrate the water due to the lack of overhanging vegetation is the reason that they are not present. However, the in-water substrate in active bogs is nothing like the substrate present in the forested sites and restored site. The active bogs were mostly sandy and muddy, while the forested sites and restored site were rocky or consisted of gravel and sand. This might have also contributed to their absence.

There were also no Eastern Brook Trout captured in the active bogs. The Eastern Brook Trout mainly feeds on aquatic insects and terrestrial insects that fall into the water. The lack of the larger and very numerous mayflies, caddisflies and stoneflies that are unable to live in the active bogs remove the major food source from the Brook Trout. Another potential problem for the Brook Trout is that they need a rocky substrate to lay their eggs. This is not present in the active bogs. There are times when the Brook Trout also feeds on some smaller fish, such as very young Fourspine Stickleback. The lack of Brook Trout in the active bogs might help explain why there are so many Fourspine Sticklebacks in the active bogs, as lack of predation has allowed them to become more numerous.

It was also found that in Coonamessett site C, there were much higher levels of benthic and water column Chlorophyll A, but much lower levels in Mashpee site B and Quashnet site B (Gasarch, 2003). This is expected in the Coonamessett sites because the areas are open for direct sunlight, but is also presents another potential reason for the lack of Brook Trout, mayflies, caddisflies and stoneflies. Each of these organisms is unable to tolerate low oxygen conditions. As nutrients are added to the cranberries, some nutrients will be transported into the water column and promote a bloom of phytoplankton. As the phytoplankton die off, they are consumed by microbes and zooplankton, and in the process, remove all the oxygen from the water. This would select against these low-oxygen intolerant organisms. It also shifted the food webs towards a stronger tendency to algae as the primary producer.

While it was expected to see between all treatment types there seems to be no difference in means in macroinvertebrate weight, weight per macroinvertebrate, fish weight per unit effort and fish captured per unit effort, it was expected to see a difference in the species composition of riparian land-use types, trout abundance per unit effort and fish condition. Both macroinvertebrate and fish samples changed greatly between the land-use sites. Species caught in the forested river were also present in the restored river, but were not present in the active bogs or abandoned bogs. This does provide evidence that restoring a stream after major riparian land use allows it to more closely resemble the its original state, or in this case, the forested river. The fish data that was gathered does not show this trend. Trout condition only showed difference with the active bog because no trout were caught to compare and Fourspine sticklebacks condition showed no difference in their condition. One reason this was surprising is because there were no caddisflies, mayflies or stoneflies caught in the abandoned bogs, which would remove their main food source. It’s unclear what those four Brook Trout were eating that gave them condition that were comparable to the restored bog and forested river since there were no may flies and stone flies captured, and only a few caddisflies in the restored bogs. Trout abundance per unit effort also showed no difference as well. This provides evidence that for fish populations, there is no difference in restoring the bogs than abandoning the bogs. However, there is a difference in the abundance of Fourspine Sticklebacks per unit effort in the restored bog, but not a difference in the abandoned bog when comparing the means to the active bogs. In this measure, it is more certain that the restored bogs are different than the abandoned bogs, and gives support for restoring the bogs.

I believe that this data is slightly misleading because of the decision to group both abandoned bogs together, Coonamessett site B and Quashnet site C. In my sampling of the Quashnet site C, there were no macroinvertebrates collected in the surber sampler, and only one minnow trap collected any fish. The surber sampler is not as important as there was another site that was unable to capture any other insects, Mashpee site C, and might be due to sample site selection within the river. It is the minnow trap is what concerns me the most. The one minnow trap that happened to collect anything was able to capture four Brook Trout and one American Eel, and in my sampling, I was never able to collect that many large fish at once. Without proper reason to throw out the sample, I left that sample in this study. In the Coonamessett site B, I was able to collect macroinvertebrates and fish samples, and both closely resembled data collected in active bogs. This indiscrepancy in the data threw off many of the results. So with this difference seen in the abandoned section of the Quashnet in comparison to the abandoned section of the Coonamessett, that may or may not be the result of random variation, I propose more data is collected on this section.

From the data collected and going strongly off of text, food webs were constructed for each of the land-use adjacent to the river (figure 20, 21, 22 and 23) and showed that the most similar food web to the forested river was the restored river. The Abandoned bog was had a food web that was very different from the forested river and the restored bogs. What is unknown is that there was a very low amount of Caddis flies captured in the abandoned bogs, but no stone flies or may flies, which was determined to be the base of the food web for the Brook Trout, which would leave little food for the Brook Trout and could have lowered the condition of the fish. But this was not the case. It may be that Brook Trout in the abandoned bogs rely more on terrestrial insects for their food source. The reason is that there might be some top down control, that there were so many Brook Trout that they were able to remove all the mayflies, caddisflies and stoneflies in the restored section of the bog. If this were the case, we would expect to find the Brook Trout as the dominant species in the restored bog, but the Fourspine Stickleback is the dominant species. But if the goal would be to have a food web that closely resembles the food web of the forested river, active restoration is key.

But one of the most surprising differences in this study was the lack of difference in total macroinvertebrate wet weight per site. It was theorized that the forested river would have the highest levels because the substrate most resembles a natural system. Without the rocky substrate, it would be much harder to find suitable cover and protection. However, difference macroinvertebrates were found, which shows that there is the same macroinvertebrate weight per site, but these difference macroinvertebrates have different life strategies that allow them to survive without the rocky substrate. This change has affected the upper trophic levels, changing their structure and strategies. Even though there was no difference in the means of total wet weights of macroinvertebrates and change in Macroinvertebrate families, this did not translate into a difference in fish condition in the Brook Trout. There was however a difference in the families of macroinvertebrates collected. This provides difference in macroinvertebrate families support that cranberry bogs should be actively restored rather than abandoned if the goals of the restoration are to shift the macroinvertebrate food web to be more closely resembling the food web of the forested site and move the dominant species from the Fourspine Sticklebacks to the Eastern Brook Trout as it is found in the forested river. Active restoration moves the macroinvertebrates families closer to the families those that are present in the forested river.

There is no noticeable difference each of the riparian land-use types when comparing nutrient concentrations, discharge, wet weight per macroinvertebrate, macroinvertebrate abundance, fish weight per unit effort, wet weight per fish, fish catch per unit effort, fish condition, and Fourspine Sticklebacks per unit effort. Active restoration is only visible when comparing the dominant fish species, Eastern Brook trout per unit effort and macroinvertebrate family types. The only difference found between the forested rivers and the restored bogs was the percent similar macroinvertebrate families with the forested river, upper trophic level food webs and dominant fish species. Difference between the forested river and the abandoned bogs included dominate fish species, macroinvertebrate family types and total macroinvertebrate wet weight per site. This data supports actively restoring cranberry bogs as apposed to abandoning the bogs and allowing succession to take place if the goal is obtaining a river that is closer to the forested river in terms of dominant fish species and macroinvertebrate families. The difference between active cranberry bogs and the forested rivers shows two entirely different ecosystems.

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## FIGURES AND TABLES

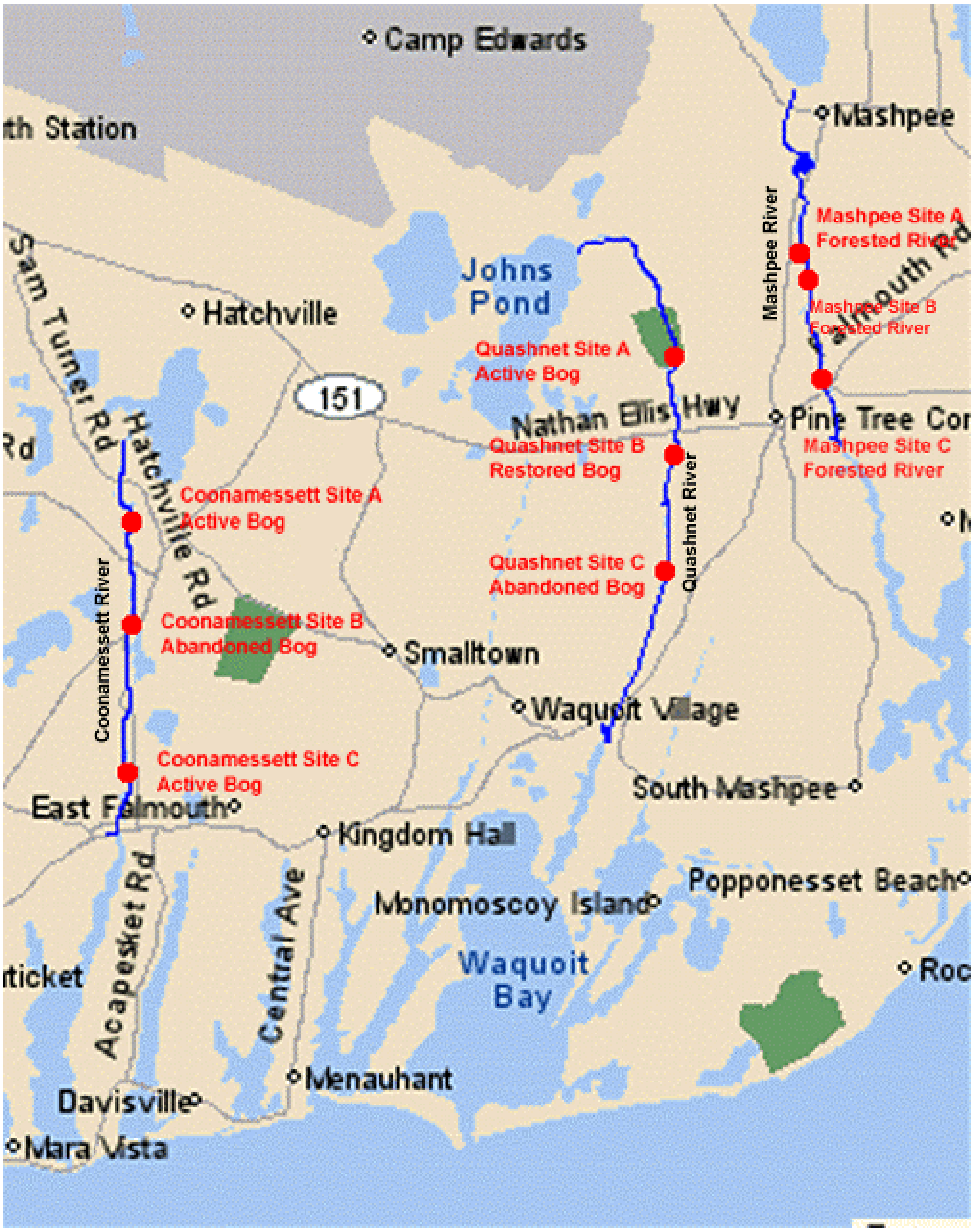


Figure 1-Map of the Southwest section of the cape, Falmouth and Mashpee, MA. Samples sites are on the Coonamessett, Quashnet and Mashpee Rivers. (Yahoo.com, 2003)

Table 1-Physical data gathered from four different sites, each site representing a different land-use adjacent to the river. (*-Data gathered by Gasarch, 2003)

| | Mashpee Site B | Quashnet Site B | Coonamessett Site C | Coonamessett Site B |
|---|---|---|---|---|
| Avg Depth (m) | 0.10 | 0.30 | 0.32 | 0.36 |
| Width (m) | 6.2 | 4.7 | 6.1 | 7.0 |
| Discharge (L/sec) | 117.3 | 194.1 | 250.9 | 119.3 |
| Avg Temp ($^oC$) | 8.8 | 7.8 | 8.4 | 7.7 |
| Nitrate (uM) | 24.253 | 23.029 | 14.470 | 10.588 |
| Ammonium (uM) | 10.060 | 7.973 | 6.515 | 6.109 |
| Phosphate (uM) | 0.855 | 0.730 | 0.908 | 1.017 |
| % Organic * | 1.130 | 2.976 | 0.838 | 0.883 |
| % Organic from Core * | 0.720 | 0.477 | 0.853 | 0.813 |
| Sedimate C:N by weight * | 16.50 | 17.33 | 8.25 | 11.00 |
| Water C:N by weight * | 11.11 | 11.54 | 10.29 | 12.59 |
| Sediment C:N by molar * | 19.25 | 20.22 | 9.63 | 12.83 |
| Water C:N by molar * | 12.97 | 13.47 | 12.00 | 14.69 |
| Sedimate Chl (ug/m2) * | 30884.3 | 11230.7 | 66093.9 | 64821.3 |
| Water Chl (ug/m2) * | -0.6 | -0.1 | 13.8 | 2.5 |

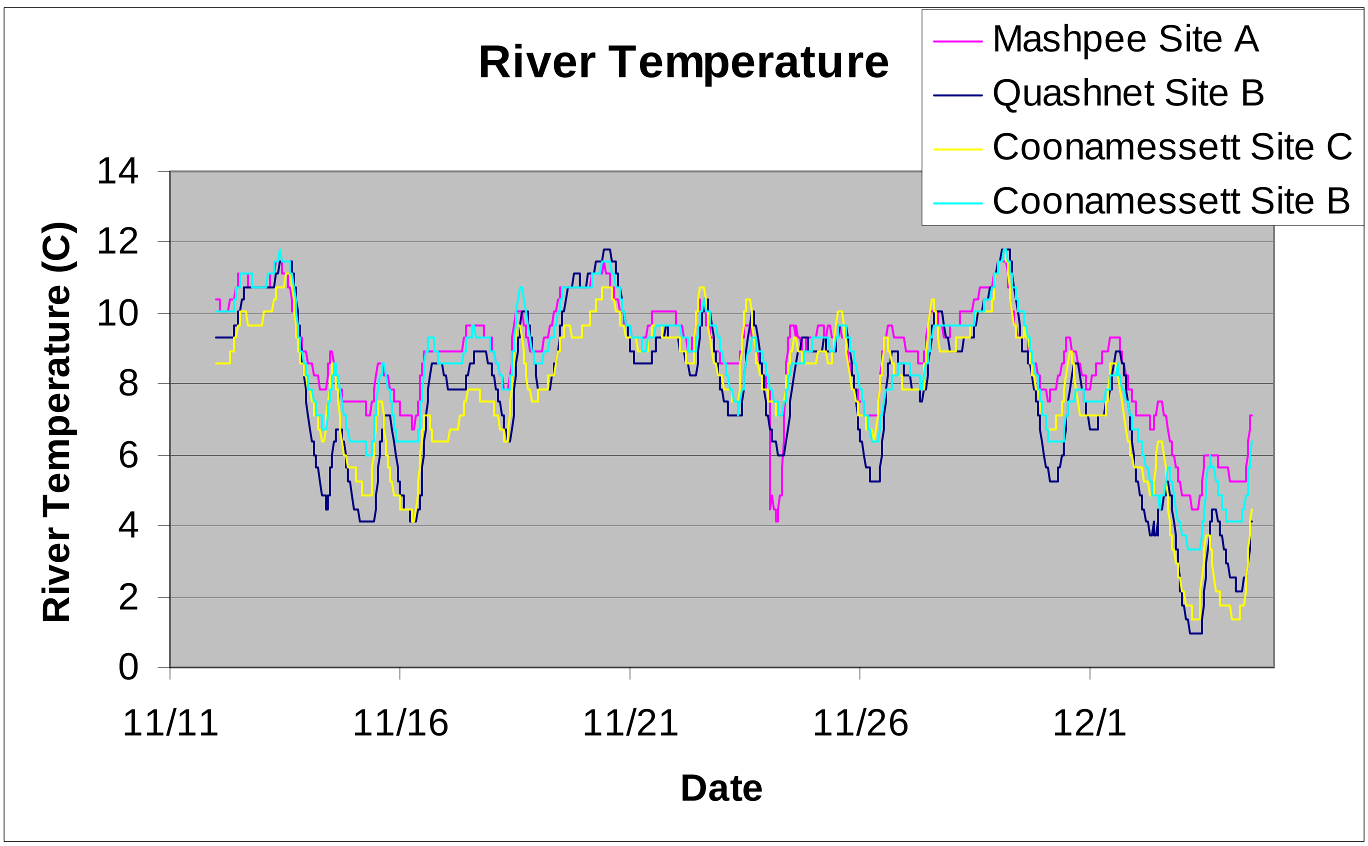


Figure 2-River Temperature gathered from HOBO temperature data loggers.

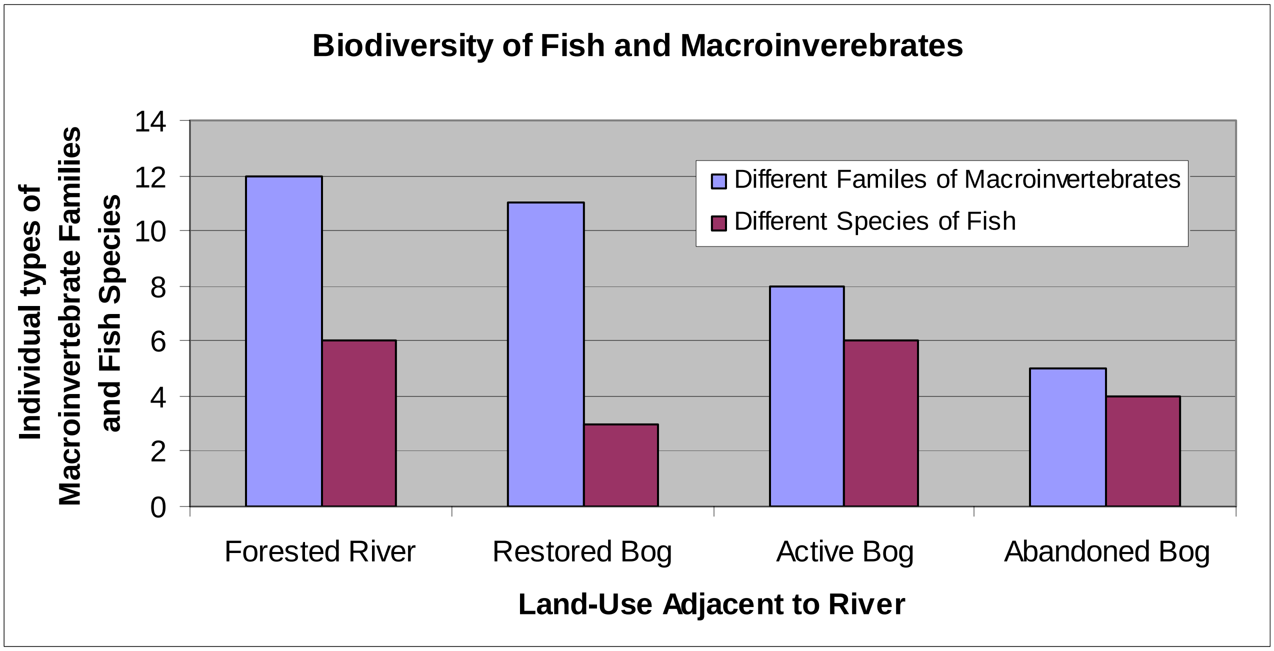


Figure 3-Fish and Macroinvertebrate biodiversity. Fish were identified down to species, macroinvertebrates down to family. Fish Diversity does not take into account for different numbers of traps used in each site.

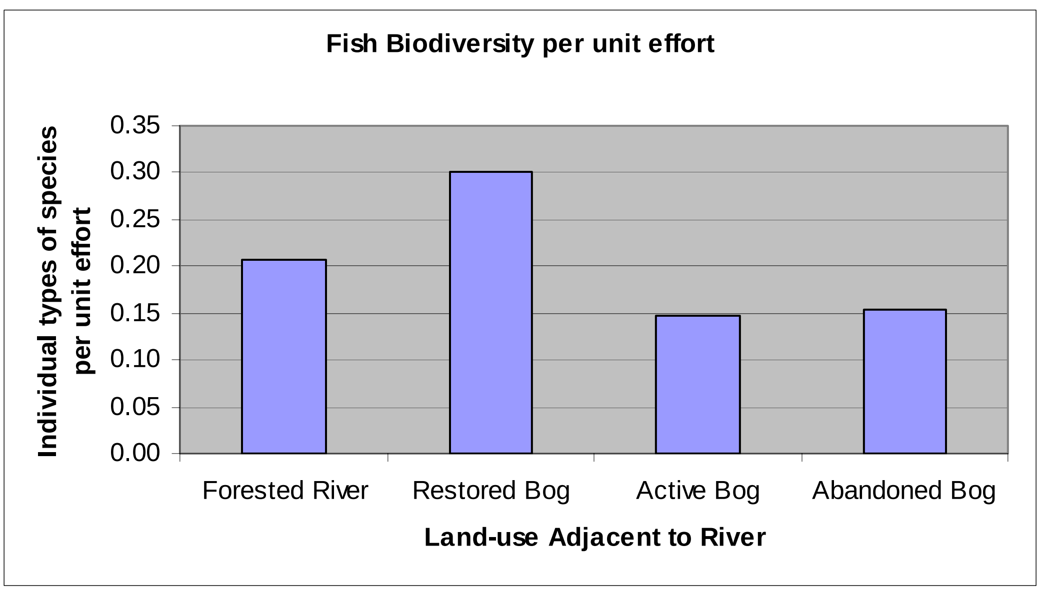


Figure 4-Fish Biodiversity per unit effort takes into account the different number of fish species that were captured, but used different amounts of traps.

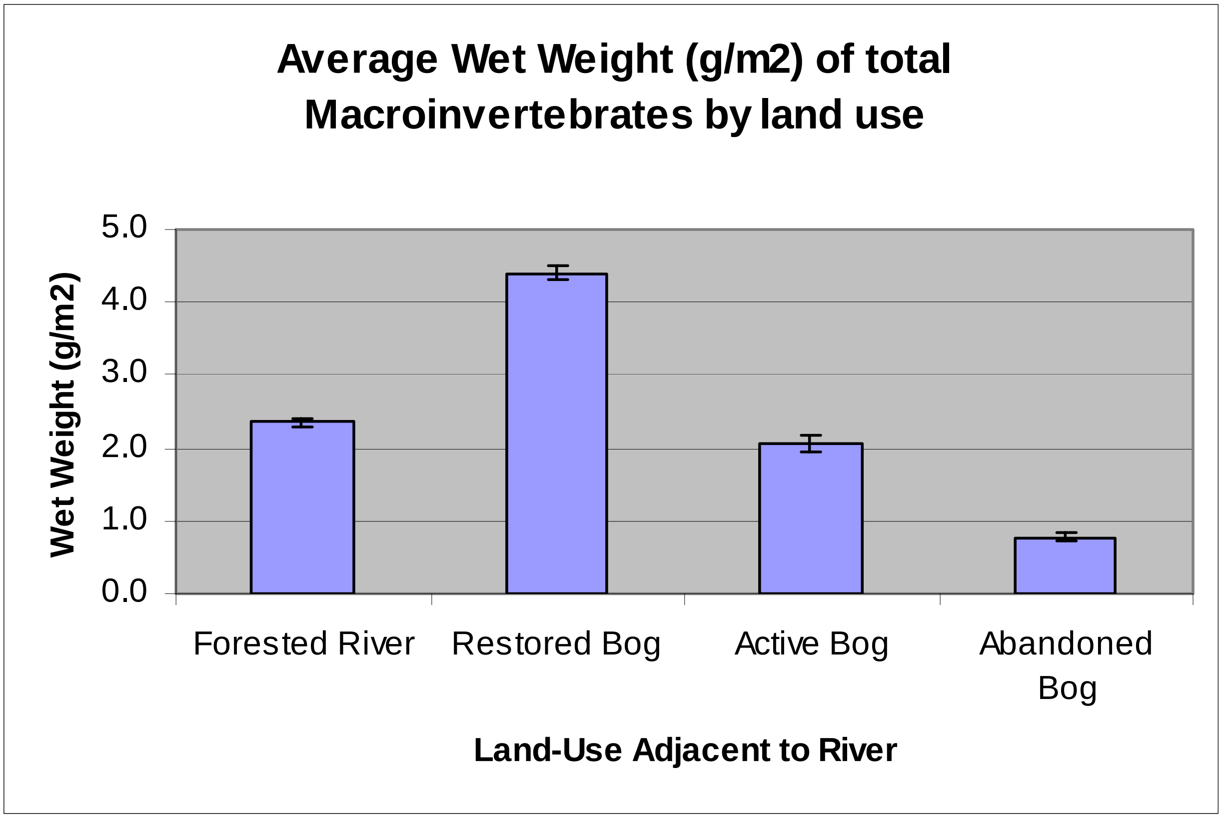


Figure 5-Total wet weights per site of macroinvertebrates and standard error bars. Means show no difference in means between Forested and Active Bogs, but difference between the rest of the land-use adjacent to river

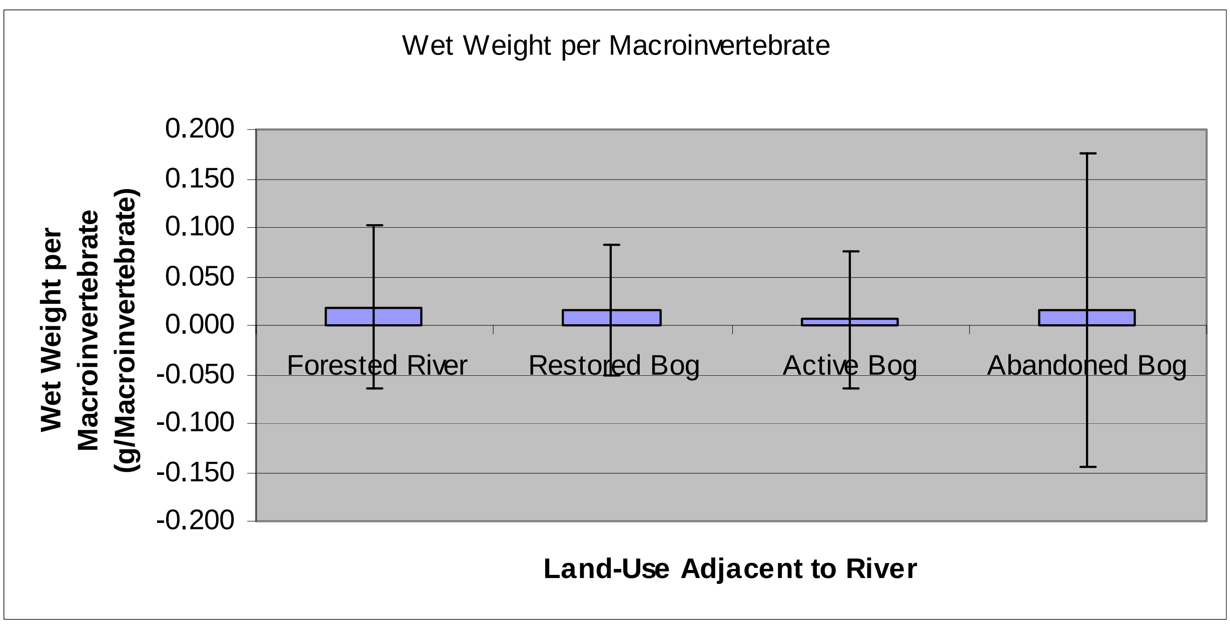


Figure 6-Wet Weight per macroinvertebrate and standard error bars. No difference is shown in the means between the different land-use adjacent to the river.

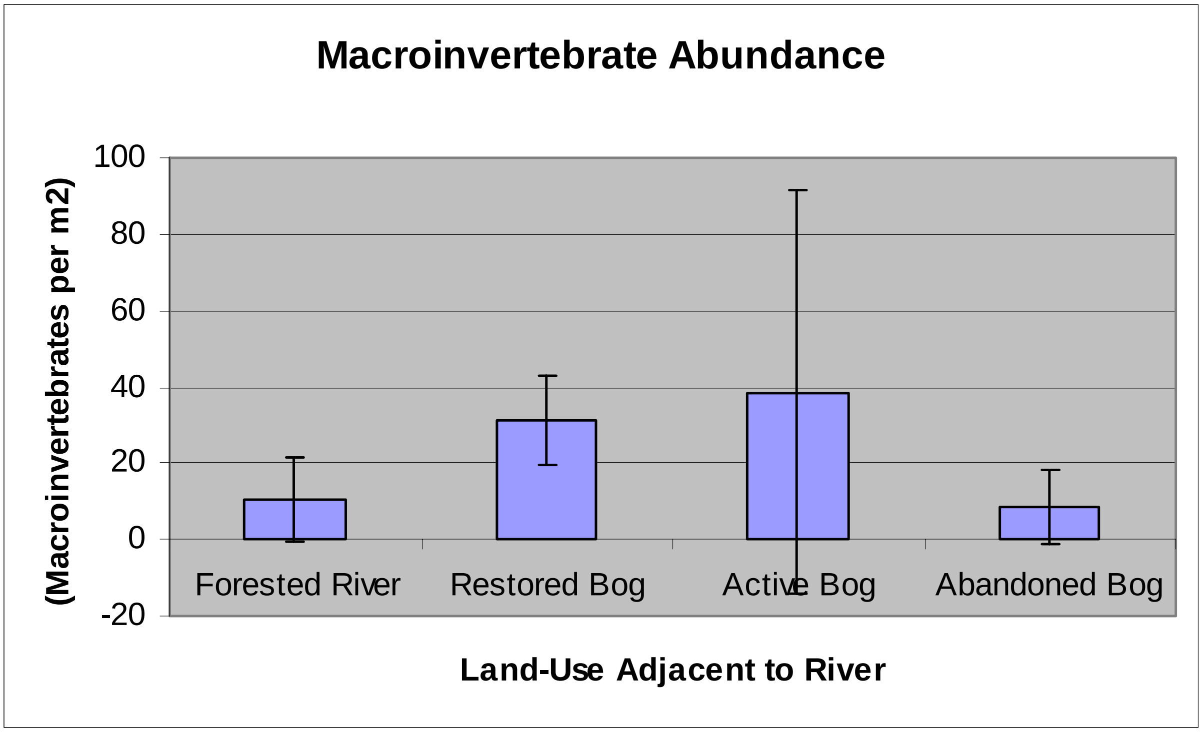


Figure 7-Macroinvertebrate abundance per meter$^2$ and error bars. Means here are highly variable and show no difference.

Table 2-Total list of macroinvertebrates and their abundance per meter$^2$

| | Forested Site | | | Restored Site | | | Active Bog | | | Abandoned Bog | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | Family Name | Individuals/m2 | Site | Family Name | Individuals/m2 | Site | Family Name | Individuals/m2 | Site | Family Name | Individuals/m2 |
| Mash A | Baetidae | 116 | Quash B | Baetidae | 8 | Coon A | Hydracarina | 12 | Coon B | Hydracarina | 20 |
| Mash A | Coleoptera | 4 | Quash B | Elmidae | 8 | Coon A | Amphipoda | 304 | Coon B | Amphipoda | 52 |
| Mash A | Elmidae | 12 | Quash B | Heptageniidae | 4 | Coon A | Hirundinea | 12 | Coon B | Limnephilidae | 4 |
| Mash A | Glossomatidae | 12 | Quash B | Hydracarina | 4 | | | | Coon B | Mysidae | 24 |
| Mash A | Heptageniidae | 12 | Quash B | Hydropsychidae | 12 | Coon C | Corixidae | 44 | Coon B | Oligochaeta | 4 |
| Mash A | Hydropsychidae | 12 | Quash B | Amphipoda | 40 | Coon C | Hydracarina | 12 | | | |
| Mash A | Amphipoda | 36 | Quash B | Lepidostomatidae | 8 | Coon C | Amphipoda | 464 | | | |
| Mash A | Leuctridae | 8 | Quash B | Mysidae | 80 | Coon C | Hirundinea | 44 | | | |
| Mash A | Mysidae | 8 | Quash B | Oligochaeta | 16 | Coon C | Mysidae | 4 | | | |
| Mash A | Oligochaeta | 24 | Quash B | Pertodidae | 8 | Coon C | Oligochaeta | 4 | | | |
| Mash A | Pertodidae | 20 | Quash B | Gastropoda | 20 | Coon C | Gastropoda | 20 | | | |
| | | | | | | | | | | | |
| Mash B | Baetidae | 24 | | | | Quash A | Corixidae | 12 | | | |
| Mash B | Elmidae | 8 | | | | Quash A | Amphipoda | 88 | | | |
| Mash B | Hydropsychidae | 16 | | | | Quash A | Mysidae | 12 | | | |
| Mash B | Amphipoda | 8 | | | | Quash A | Oligochaeta | 12 | | | |
| Mash B | Mysidae | 4 | | | | Quash A | Sialidae | 4 | | | |
| Mash B | Oligochaeta | 44 | | | | Quash A | Gastropoda | 8 | | | |
| Mash B | Pertodidae | 12 | | | | | | | | | |
| Mash B | Phyganeidae | 4 | | | | | | | | | |

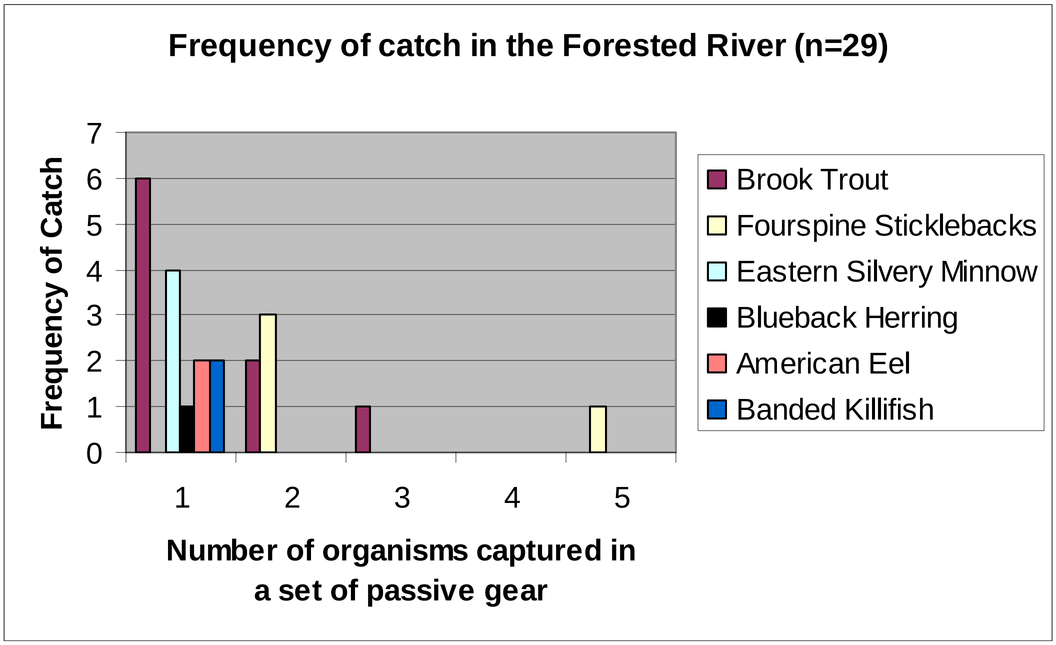


Figure 8-Catch per unit effort in the Forested River. The dominant species is the Brook Trout. (29 traps in total)

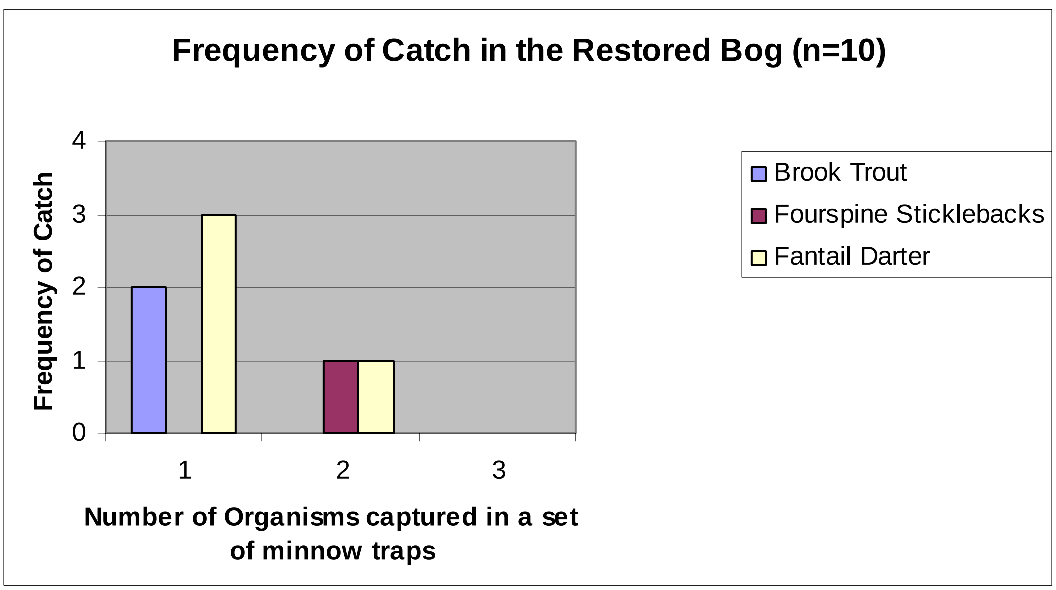


Figure 9-Catch per unit effort in the restored bog. The dominant species here is the Fantail Darter. (10 Traps in total)

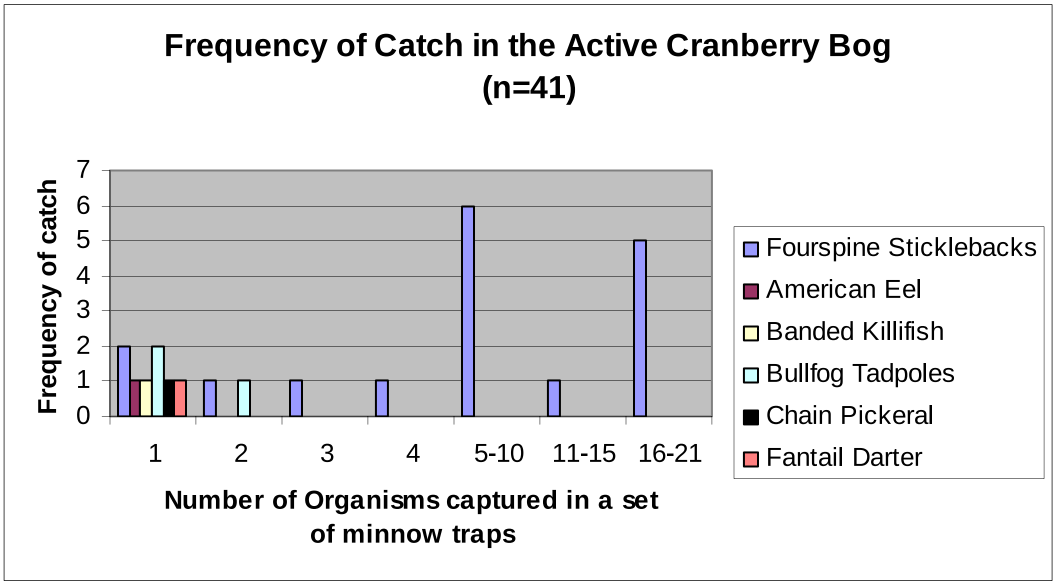


Figure 10-Catch per unit effort in the active bogs. The dominant species here is the Fourspine Stickleback. (41 traps in total)

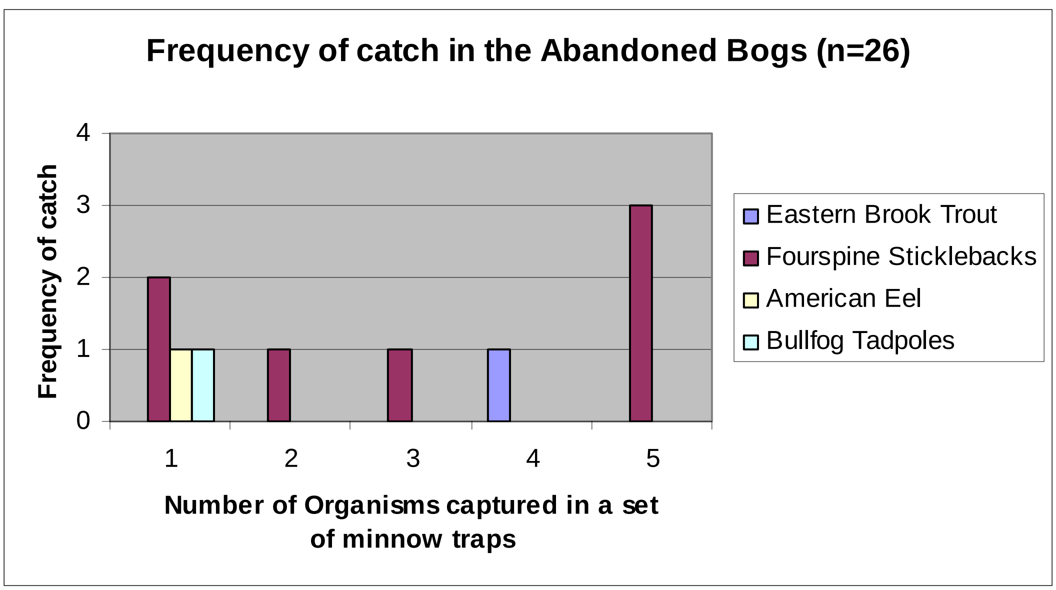


Figure 11-Catch per unit effort in the abandoned bogs. The dominant species here was the Fourspine Stickleback. (26 traps in total)

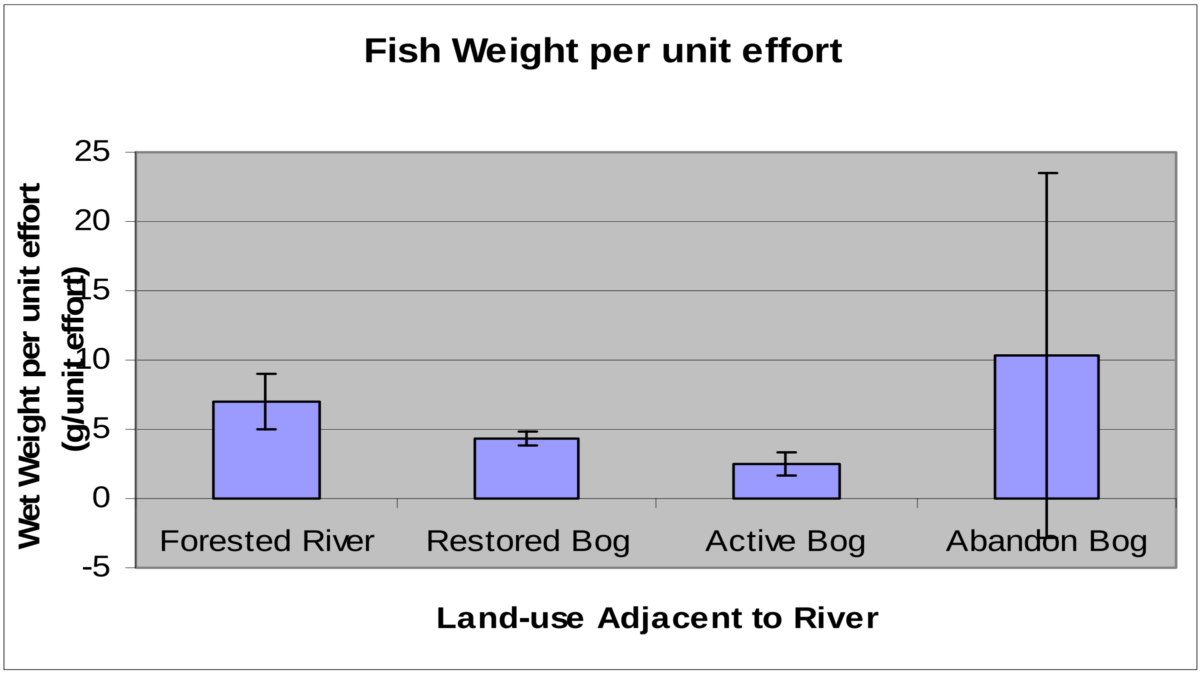


Figure 12-Fish Weight per unit effort plotted with error bars. There is no difference between the means.

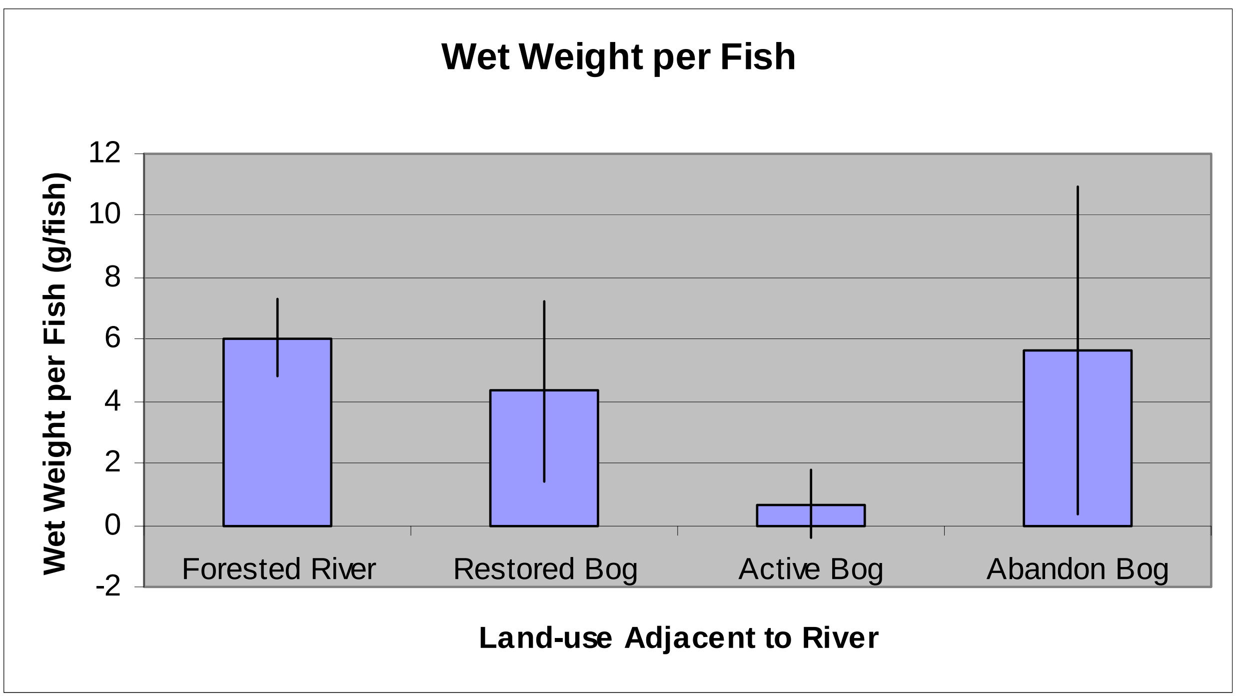


Figure 13-Wet weight in grams per fish captured and standard error bars. There is a difference in means between the forested river and the active bog.

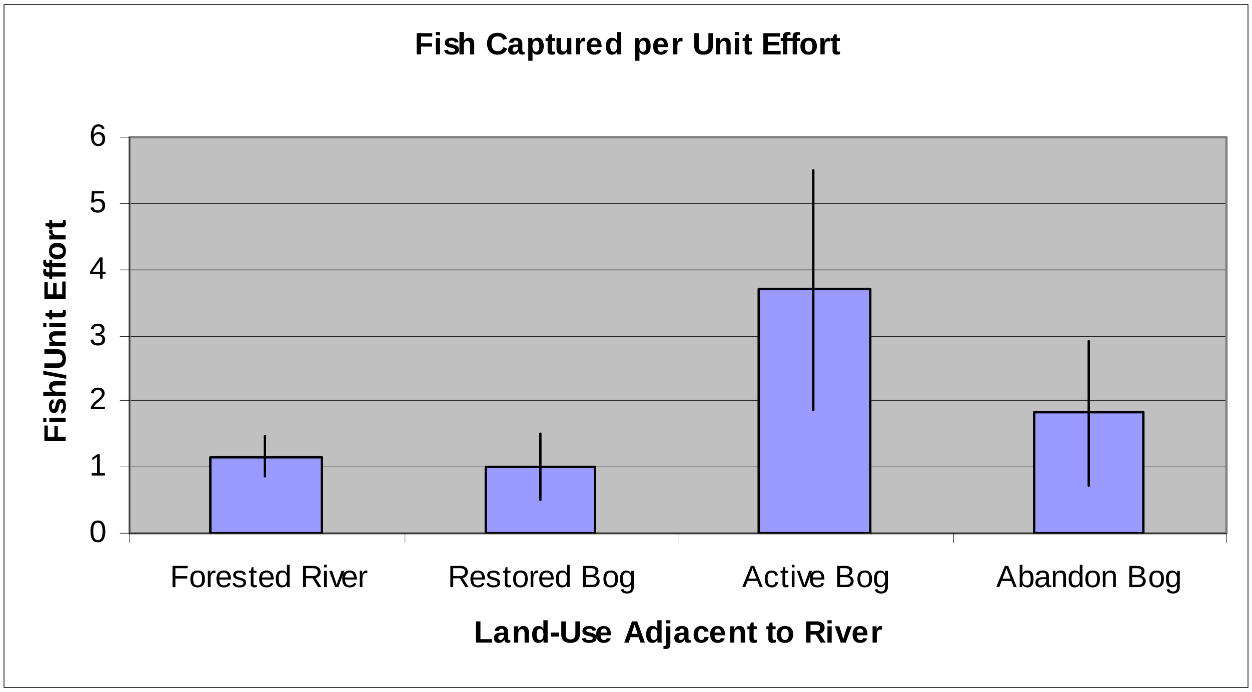


Figure 14-Fish Captured per unit effort and standard error bars. Means are highly variable and show no difference.

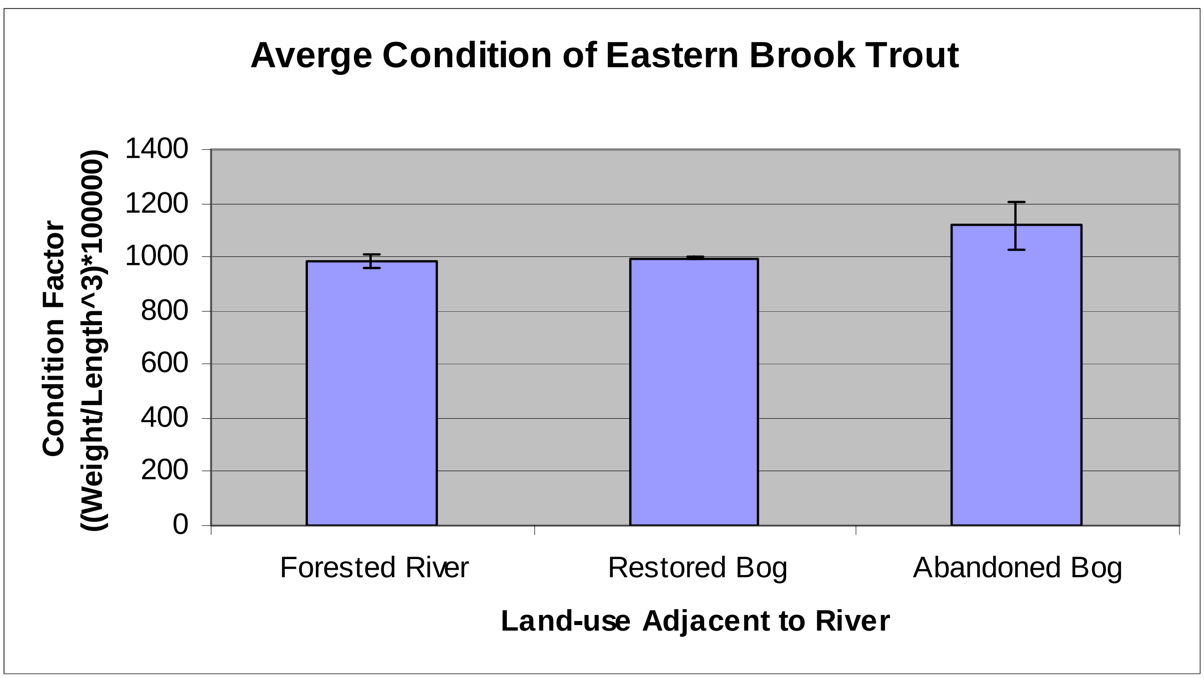


Figure 15-Average condition of the Eastern Brook Trout along with standard error bars. Means are highly variable and show no difference.

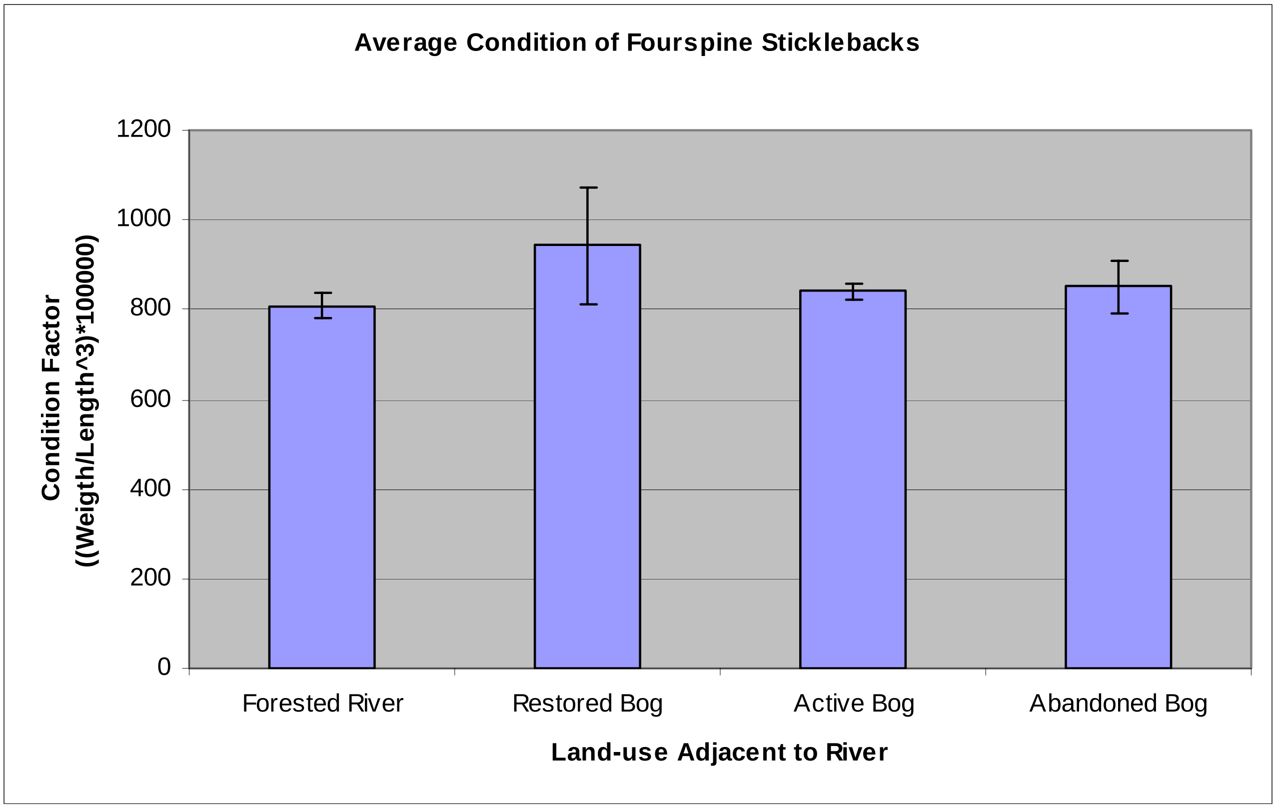


Figure 16-Average Condition of the Fourspine Sticklebacks along with standard error bars. Means are highly variable and show no difference.

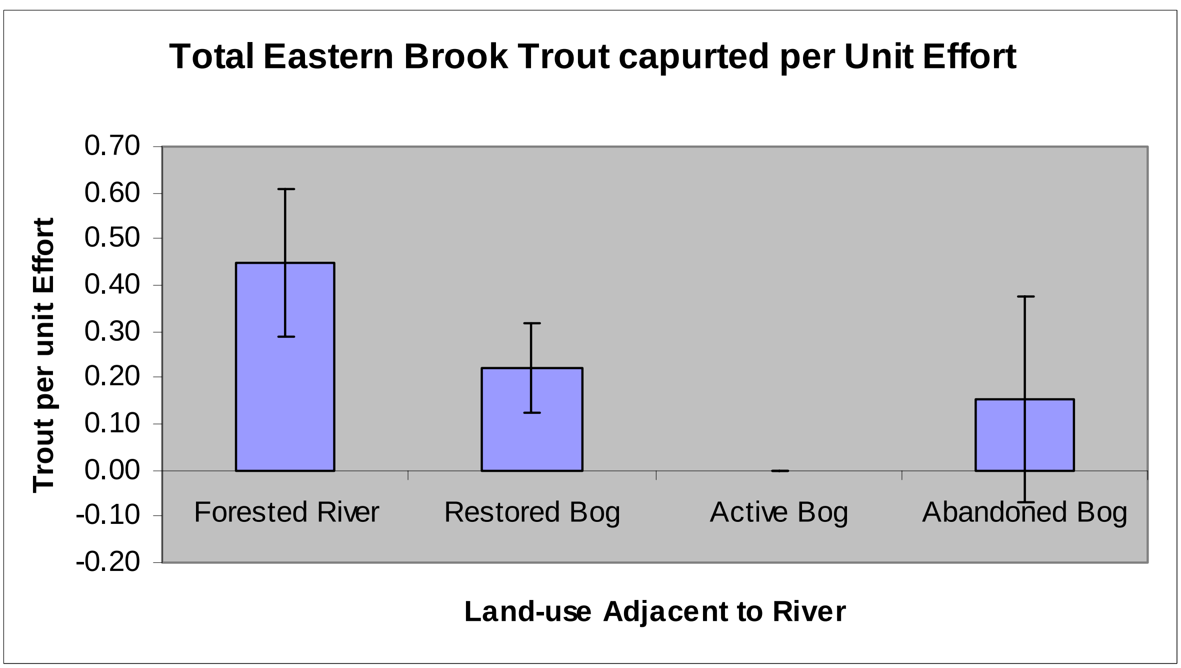


Figure 17-Eastern Brook Trout captured per unit effort and standard error bars. Means are highly variable and show no difference.

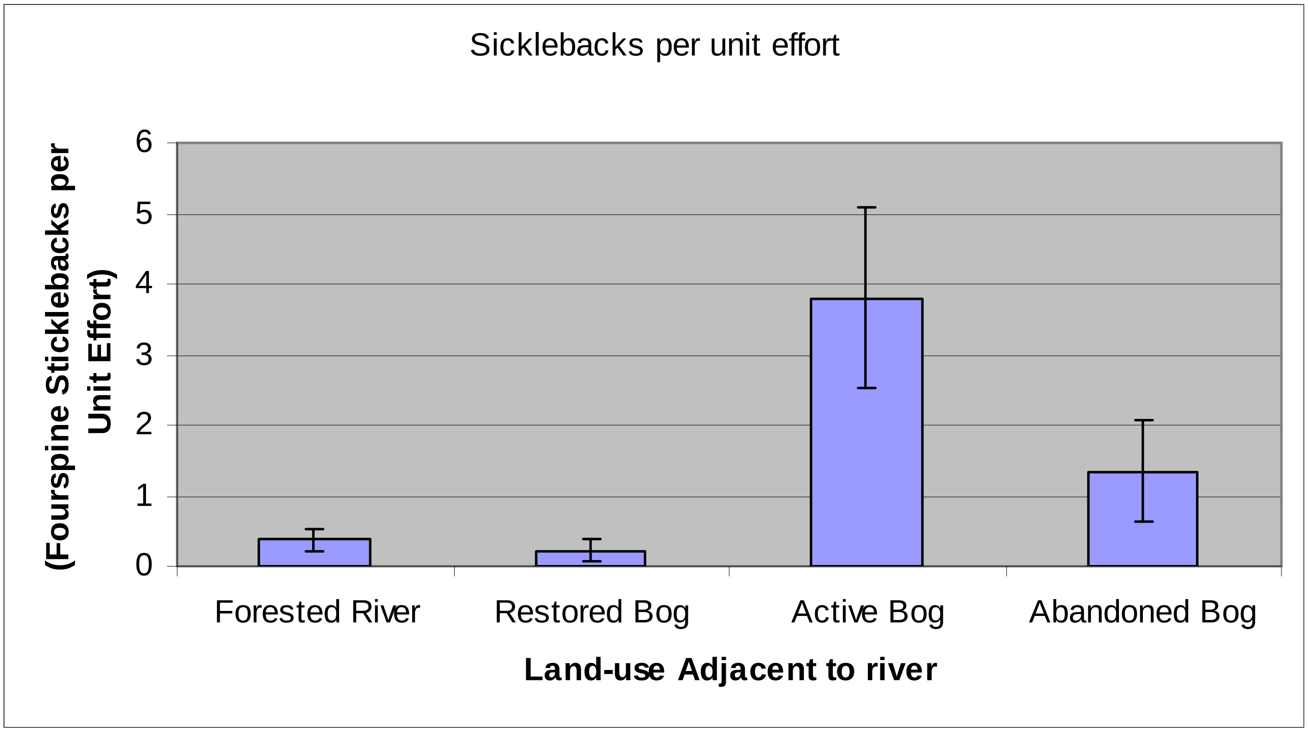


Figure 18-Sticklebacks captured per unit effort and standard error bars. There is a difference in means between the active bog and the forested river and active bog and restored bog.

Table 3-Total fish captured and amounts of fish captured.

| | Forested River | Restored Bog | Active Bog | Abandoned Bog |
|---|---|---|---|---|
| Brook Trout | 13 | 2 | 0 | 4 |
| Fourspine Sticklebacks | 11 | 2 | 155 | 34 |
| Eastern Silvery Minnow | 4 | 0 | 0 | 0 |
| American Eel | 2 | 0 | 1 | 1 |
| Blueback Herring | 1 | 0 | 0 | 0 |
| Banded Killifish | 2 | 0 | 1 | 0 |
| Fantail Darter | 0 | 5 | 1 | 0 |
| Bullfog Tadpoles | 0 | 0 | 4 | 1 |
| Chain Pickeral | 0 | 0 | 1 | 0 |

Figure 19-Percent similar Macroinvertebrate families with that of the Forested River

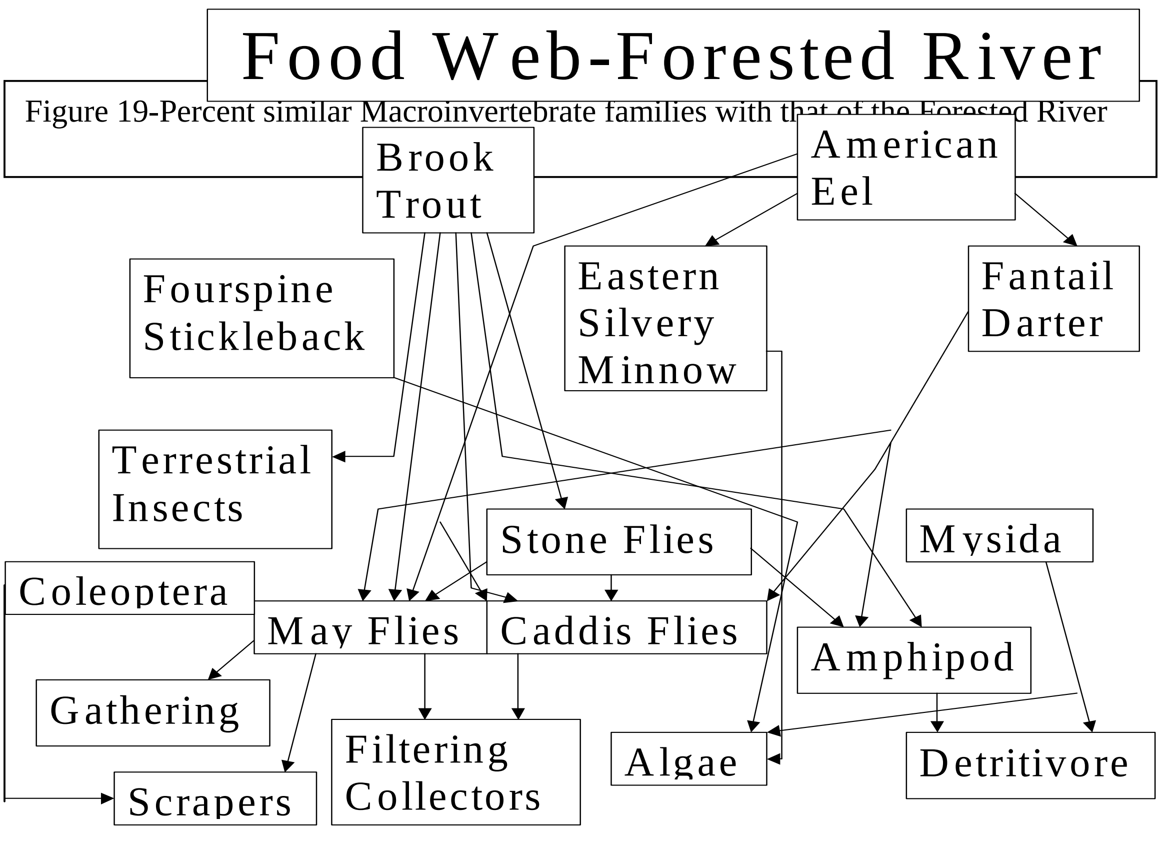


Figure 20-A food web created from text and species found in the river for the forested river

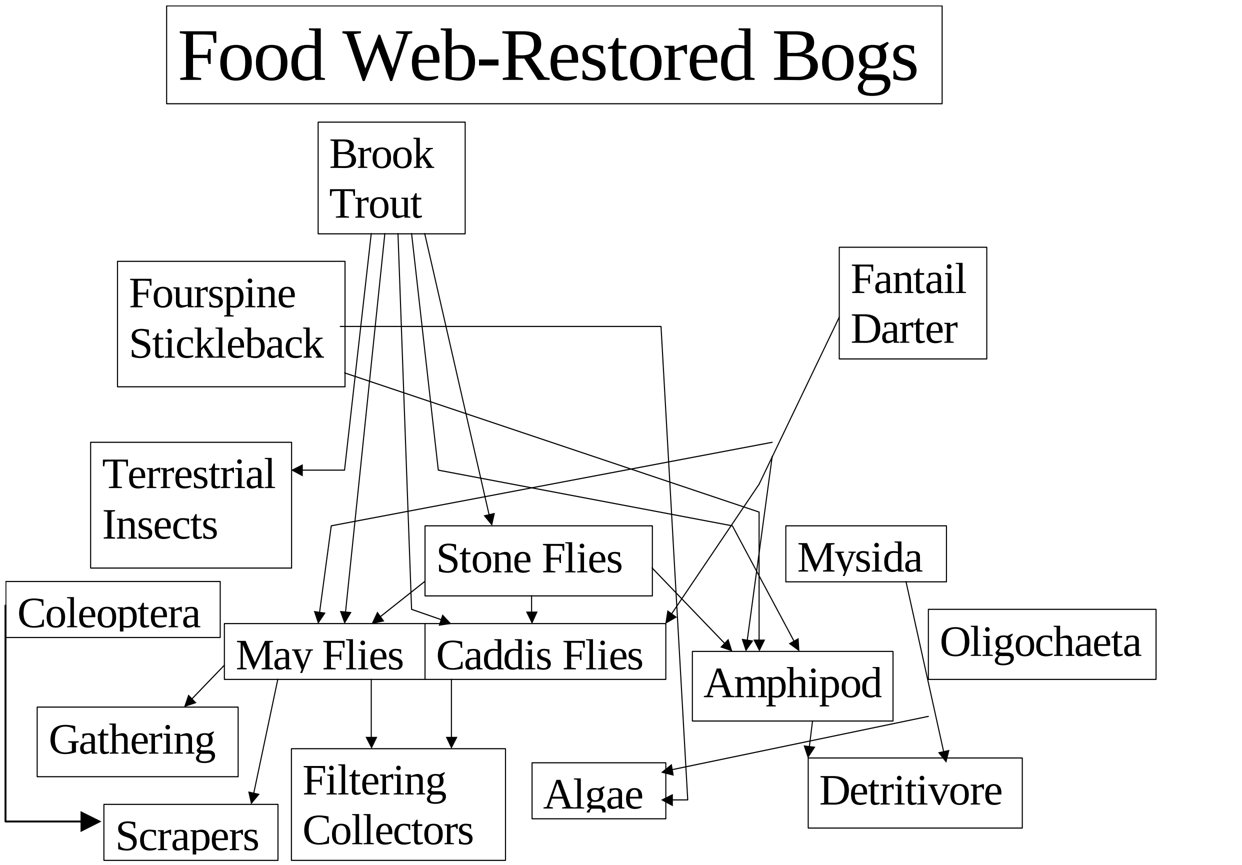


Figure 21- A food web created from text and species found in the river for the restored bog

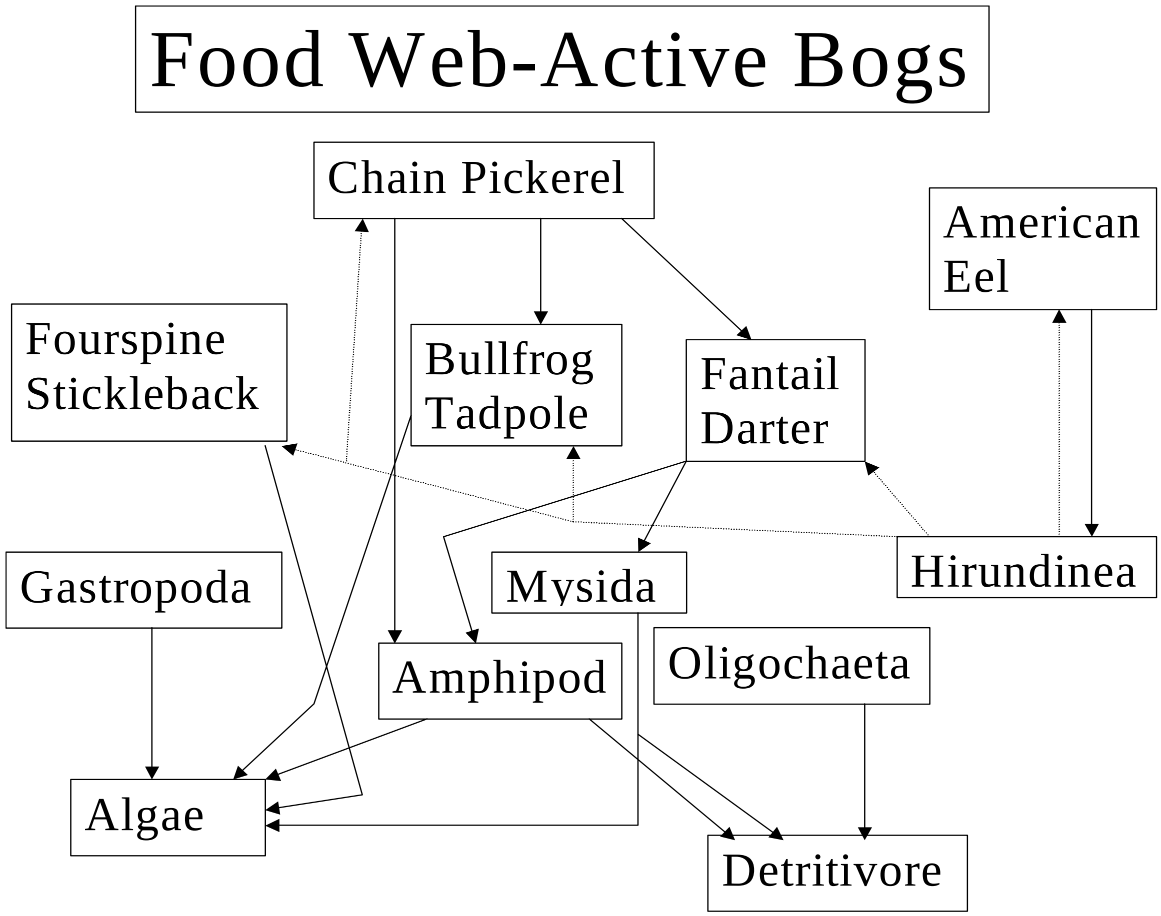


Figure 22- A food web created from text and species found in the river for the Active Bog

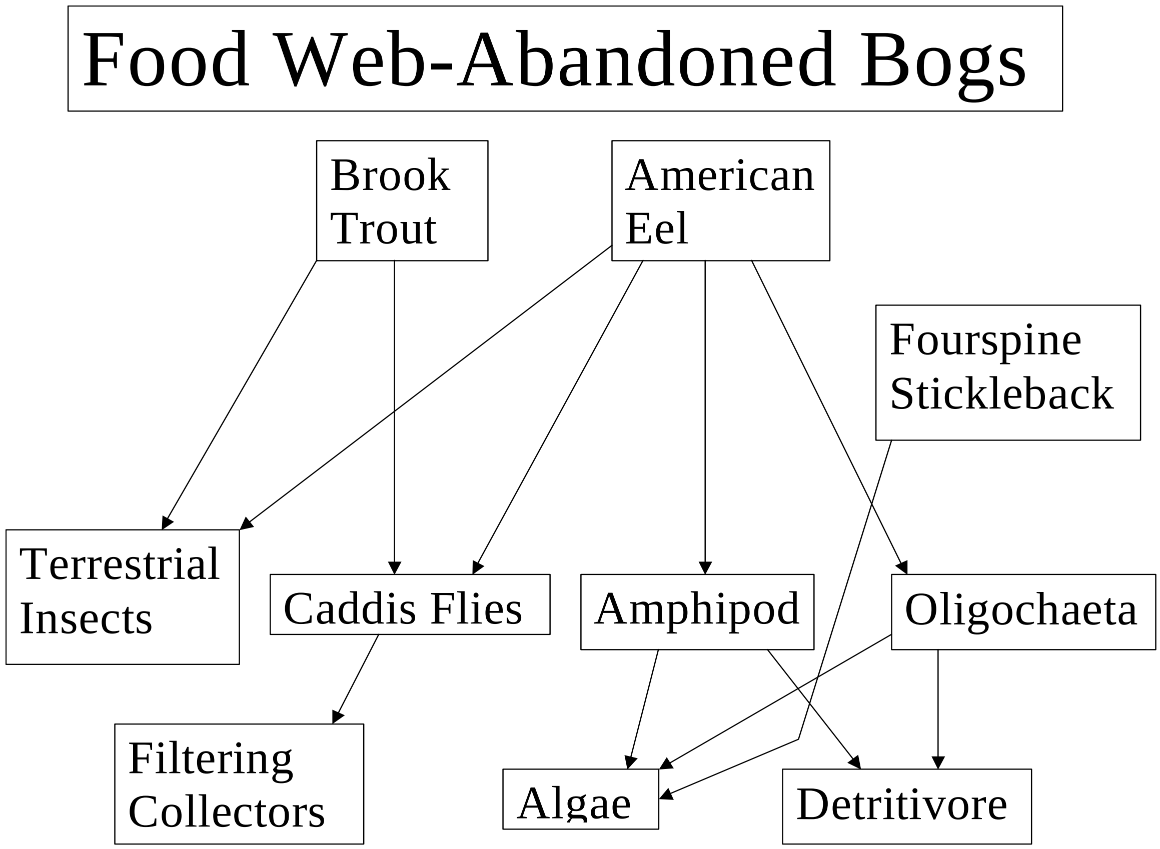


Figure 23- A food web created from text and species found in the river for the Abandoned Bog