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Fish Production in Streams With and Without Natural Broan Trout Populations

Scott Weisinger
University of Pennsylvania

Presented to the Faculties of the University of Pennsylvania in Partial Fulfillment of the Requirements for the Degree of Master of Environmental Studies 2010.

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Abstract
Brown trout (*Salmo trutta*) have been introduced into the waterways throughout the United States, including Pennsylvania, since the 1800's. They may have limited interactions with native fish species in regions where they do not reproduce successfully, but where they do concerns have arisen regarding the impact they have on native species. Are brown trout having a negative effect on the native fish? If so, could they be outcompeting the natives to the point of localized extirpation? This project compared fish communities, densities, biomass and production in two similar stretches of stream in the White Clay Creek, one known to hold brown trout (the East Branch) and the other without (the Middle Branch). Fish in each branch were collected in June and October 2009 using backpack electrofishing equipment to determine species composition and abundance, population densities and community diversity. Fish were aged using scales and further examination revealed biomass and production of the species present. The fish communities within the branches were stable between June and October (Jaccards index = 0.75 for both branches), but differed between branches (Jaccards index = 0.64 in June and 0.58 in October). The stream without brown trout showed much lower density, biomass, and production of most species, which went counter to our hypothesis that fish would show lower levels of these factors in the presence of brown trout. Only the common shiner and longnose dace showed effects in each of these categories while favoring the branch without brown trout over the branch with brown trout. Although the results do show a possible negative correlation between these species and the brown trout, our study design did not allow us to rule out other factors. Also, the fewer number of fish in the Middle Branch as compared to the East Branch leads us to believe that something may be wreaking havoc with the natural balance of this section (e.g. land-use changes, environmental stressors or climatic factors). Continued research regarding brown trout interactions on the East Branch and stream quality of the Middle Branch is highly recommended.

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Scott Weisinger

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Primary Reader: Dr. William Eldridge
Advisor/Secondary Reader: Dr. Sarah A. Willig

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ABSTRACT

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Brown trout (*Salmo trutta*) have been introduced into the waterways throughout the United States, including Pennsylvania, since the 1800's. They may have limited interactions with native fish species in regions where they do not reproduce successfully, but where they do concerns have arisen regarding the impact they have on native species. Are brown trout having a negative effect on the native fish? If so, could they be out-competing the natives to the point of localized extirpation? This project compared fish communities, densities, biomass and production in two similar stretches of stream in the White Clay Creek, one known to hold brown trout (the East Branch) and the other without (the Middle Branch). Fish in each branch were collected in June and October 2009 using backpack electrofishing equipment to determine species composition and abundance, population densities and community diversity. Fish were aged using scales and further examination revealed biomass and production of the species present. The fish communities within the branches were stable between June and October (Jaccards index = 0.75 for both branches), but differed between branches (Jaccards index = 0.64 in June and 0.58 in October). The stream without brown trout showed much lower density,

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INTRODUCTION AND LITERATURE REVIEW

Many species have been intentionally and accidentally transferred around the world. Some of these introduced species have established self-sustaining populations in their new environment. Many introduced species can cause problems for native species and ecosystems. An invasive species is an introduced species that does or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112 (1999) and National Invasive Species Management Plan of 2001). The invasive species which are most successful at establishing in new environments generally have the ability to survive in new environments due to a lack of predators, tolerance to changing conditions and high reproductive rates (NISC 2001). From Canada Thistle *(Cirsium arvense*) and Multiflora Rose (*Rosa multiflora*) in the plant kingdom to the European Starling (*Sturnus vulgaris*) and the Asian Long-Horned Beetle (*Anoplophora glabripennis*) within the animal realm, invasive species wreak havoc on native species, ecosystems and cause significant economic impacts (About NISIC 2009).

Invasive species have the ability to alter individual, population, community, and ecosystem dynamics (Townsend 2003). Native fish and amphibians can be pushed from ideal foraging grounds to less favorable ones, resulting in less efficient feeding or a need to alter prey sources (Simon and Townsend 2003). Invasive species can also carry unknown diseases or alter a population's genetics through hybridization (About NISIC 2009). Negative impacts may be multiplied when habitat modifications favor the introduced species (e.g. non-indigenous species in the Columbia River predating upon migrating US Endangered Species Act listed juvenile Pacific salmon). With habitat loss, dam construction and overfishing adding a new species to an area can cause more trouble. In the Columbia River, it was found that the removal of most non-indigenous species including the walleye (*Sander vitreus*) decreased predation on Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*). This decrease was compounded when native predator management was combined with the removal (Harvey and Karieva 2005).

The threats of these organisms to the environment are sometimes overlooked because of the economic benefits afforded to the surrounding communities. Many invasive species were first introduced because they were perceived to provide some benefit (Brock et al. 1991). The perceived benefit of introducing a particular species often leads to considerable debate over whether the benefits outweigh the harm (Brock et al. 1991; Parker et al. 1999). Some organisms are not recognized as invasive species on local or regional registries, but fit the criteria. Ecosystems face many threats besides introduced species, however, and setting conservation priorities requires comparing the risks posed by the various threats (Parker et al. 1999).

Brown Trout (*Salmo trutta*), a native of Europe, have been introduced to waterways throughout the world starting in the 1800s to provide increased fishing opportunities (Kraft et al. 2006). For example, in Southern Chile, brown trout and rainbow trout (*Oncorhynchus mykiss*) were introduced as sport fish and have become the country's most economically important fish due to angling (Soto et al. 2006). In New Zealand and South America they have been found to pose direct threats (predation) and indirect threats (competition and displacement) to the native fish resulting in the decrease in fish diversity and overall abundance (Crowl et al. 1992). Insects are consumed throughout the life cycle of a brown trout, but as they mature they become piscivorous feeders. The piscivorous behavior begins as the fish enters age 2-3 and a reaches a length of 13-17.5 cm. Trout that change to piscivory earlier also mature sooner and have higher growth rates than those that switch later in the life cycle (Jonsson et al. 1999).

Brown trout have been linked to declines in native fish population or altering their distributions. Native fish populations have declined in southern Chile where rainbow and brown trout, which are non-native, account for more than 80% of the biomass in third and fourth order streams (Soto et al. 2006). Research conducted in New Zealand also centered around the premise that introduced brown trout have a caused a decline and fragmented the population of the native River Kokopu (*Galaxias vulgaris*) (Townsend and Crowl 1991). As a conclusion to the study it was stated that "…we have, beyond a reasonable doubt, implicated brown trout as a causal agent" (Townsend and Crowl 1991). A case in Australasia stated, native species that were usually found throughout a stream before trout introductions were restricted to areas above waterfalls. The introduced trout were unable to surmount this obstacle therefore leaving the native species above the waterfalls untouched (Crowl et al. 1992).

Brown trout may impact native species via direct predation, as is suspected with River Kokopu in New Zealand, (Townsend and Crowl 1991), or by out-competing them for resources such as food and breeding locations. A long- term study of Valley Creek, Minnesota showed that brown trout spawned after native brook trout and by using the same grounds caused the disturbance of brook trout redds and ultimately reduced their reproductive success (Waters 1999). The same study by Waters (1999) suggested that brown trout outcompeted brook trout for foraging sites and invertebrate prey due to mean size alone (brown trout grew larger than brook trout).

Brown trout have also been linked to the increase of algal biomass. In experimental stream channels, algal biomass was higher where brown trout resided as opposed to areas with native populations or no fish at all. It was concluded that brown trout reduced the invertebrate grazers that regulated the algae, allowing for the increased biomass (Simon and Townsend 2003).

Brown trout in the United States are defined as a non-indigenous species (Steiner 2000). They were first brought to the United States in the 1880's from Scotland and Germany and have since been introduced to nearly every state (Kraft et al. 2006). Brown trout were introduced, specifically, to Pennsylvania by fisheries managers as a sport fish for recreational angling in 1886 and have become one of the most important fish to sportsmen statewide (Steiner 2000). Brown trout live in clear cool streams where they feed on insects and other fish and can live for 10-12 years. These are often the same rivers and streams that once contained native brook trout. Forestry practices and resulting siltation and increased temperatures reduced brook trout habitat. Forests are coming back, but browns are able to tolerate slightly warmer water and more siltation than brook trout so they colonize first (Steiner 2000).

Where brown trout have been introduced they often alter the native ecosystem in a negative manner. It is suspected that brown trout reduce native fish communities in eastern PA by predation, displacement, and food competition, as they do in other countries (Townsend and Crowl 1991). Native fish communities are also threatened by urbanization and climate change (Horwitz et al. 2008), and in order to help managers it is important to determine the impacts of brown trout so that the threats can be prioritized (Parker et al. 1999). Comparing two similar stretches of stream (one with a self-sustaining population of brown trout and one without brown trout) in the White Clay Creek, we plan to illustrate the possible impact of brown trout on native fish populations. Does the brown trout truly reduce the population densities of native fish, does it cause decreases in biomass and productivity, such that these fish will become locally extinct or is there no correlation at all?

MATERIALS AND METHODS

The study took place on the White Clay Creek in Chester County, Pennsylvania during the latter half of 2009. White Clay Creek is in the Piedmont physiographic province and feeds into the Christina River, a tributary to the Delaware River. The Commonwealth of Pennsylvania classifies the East Branch of White Clay Creek as "Exceptional Value", the highest special protection designation for a stream and its watershed against anthropogenic disturbance. In 1998 an Act of Congress designated the White Clay Creek as part of the National Wild and Scenic Rivers System. The White Clay Creek has been the subject of long-term research and monitoring dating back to the 1960's, and periodic fish surveys have been conducted in the East Branch.

We conducted fish surveys at two similarly situated sites on the East Branch and Middle Branch, respectively. The sites were both in 3rd order streams surrounded by mixed deciduous forest. Brown trout had been found in the East Branch of White Clay Creek, but not in the Middle Branch (W. Eldridge, Stroud Water Research Center, personal communication). Over the course of two consecutive sampling efforts, one on each branch, this was to be verified. Fish surveys took place at the beginning of June and again in the middle of October. The downstream end of the East Branch site was located at 39.8647 latitude by -75.7855 longitude, while the Middle Branch was situated at 39.84064 latitude by -75.85021 longitude. These two reaches can be seen in Figures 1 and 2, below.

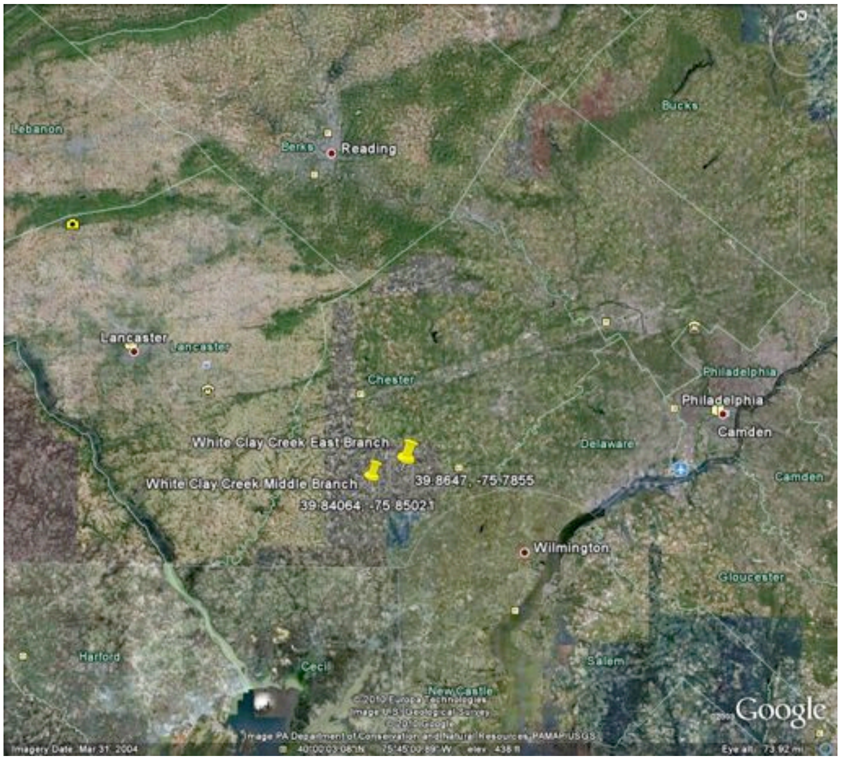

Figure 1: Map of sites in relation to surrounding cities and counties (Photo from Google Earth)

Figure 2: Map of sites' proximity to each other (Photo from Google Earth)

A 50 meter reach in each branch was chosen and included a combination of pools and riffles. The same reach was sampled in the East Branch in both June and October, but in the Middle Branch the sample reach was moved downstream about 100 meters to avoid a hard-to-sample pool. Fish movement into and out of the sample reach was restricted by placing 6 mm mesh nets (Figure 3) across the upstream and downstream ends of the reach. Fish were captured using backpack electrofishing equipment (Smith-Root LR-24 and ETS ABP-3Q-600) as seen in Figure 4.

Figure 3: Mesh net spanning White Clay Creek, PA

Figure 4: Electrofishing backpack

At each site we measured species composition, abundance, density, biomass and productivity. We collected fish from each stretch and estimated abundance using the 3 pass equal effort depletion method (Hayes et al. 2007). All specimens collected were identified to species, weighed, and measured (fork length). Scales were taken from selected size ranges for age determination. Pictures were taken of fish that could not be positively identified in the field and were later identified with a dichotomous key (Kazyak and Raesley 2003). All fish were returned to the stream once the data had been collected. Fish that died during sampling were added to the Stroud Water Research Center research and education collection.

Once all of the physical data had been gathered, the previously mentioned variables were measured and used for analysis. Scales were pressed onto acetate slides and viewed through a microfiche projector to count the number of annuli (yearly rings) for aging purposes (Devries and Frie 1996). All fish were considered born on January 1, fish collected in the year of their birth were age 0 and every annulus present added one year to its age. Every species was broken into age classes and the variables determined for each class individually. Species composition (with the use of a dichotomous key) and abundance were described.

Species composition was used to compare communities, giving an idea of how similar the chosen sites are to each other. This was calculated two different ways: between branches in a specific sampling period and within a branch over time. Jaccard's Index was used for this determination. The formula for Jaccard's Index is:

$$C_j = j/(a + b - j),$$

where j = number of taxa found in both sites; a = number of taxa in Site A; and b = number of taxa in Site B (Li and Li 2006).

Abundance is the total number of individuals of each species from each sampling site. This was determined using maximum-likelihood estimates as shown in Abundance, Biomass and Production (Hayes et al. 2007). The equation for abundance is:

$$\hat{N} = \frac{6X^2 - 3XY - Y^2 + Y\sqrt{Y^2 + 6XY - 3X^2}}{18(X - Y)},$$

where $X = 2n_1 + n_2$; $Y = n_1 + n_2 + n_3$; and n_1, n_2, n_3 are pass 1, pass 2 and pass 3, respectively from the collection sampling.

Using the estimate of abundance, density and biomass were then determined. The density equation is:

$$\hat{D} = \frac{\hat{N}}{A},$$

where $\hat{N}$ = estimated abundance and A = area. Weights were recorded per individual fish for most specimens during sampling. Those not measured were calculated by way of length-weight relationships, and therefore a mean weight was determined for use in biomass. The formula for determining weight based on the length-weight relationship is:

$$\log_{10}(W) = b * \log_{10}(L) - a,$$

where L = length of a fish; a = y-axis intercept; and b = slope. The parameters a and b were calculated by "linear regression of logarithmically transformed weight-length data" that were graphically plotted, slope and y-axis intercept were then determined (Anderson and Neumann 1996). With the mean weight calculated, as above, we continued on with the calculation of biomass. That equation is:

$$\hat{B} = \hat{D} \times \overline{w},$$

where $\hat{D}$ = estimated density and $\overline{w}$ = mean weight of fish in an age class (Hayes et al. 2007).

Finally, production was estimated using the size-frequency method. Therefore, a production value was established for each species on a given date. The equation for this method is as follows:

$$\hat{P} = 0.5c\left[\overline{w}_1\left(\overline{N}_1 - \overline{N}_2\right) + \sum_{k=2}^{c-1} \overline{w}_k\left(\overline{N}_{k-1} - \overline{N}_{k+1}\right) + \overline{w}_c\left(\overline{N}_{c-1} - \overline{N}_c\right)\right]\left(1/CPI\right),$$

where P = production for a given population within a specified interval; $\overline{N}$ = estimated mean density for a specific length-group; $\overline{w}$ = estimated mean weight of individuals in a specific length-group; k = index for length-groups; c = number of length-groups; and CPI = the cohort production interval (Hayes et al. 2007).

Once this data was compiled, a comparison within streams and between the stream with and the stream without brown trout was conducted.

RESULTS

Sampling the East Branch of White Clay Creek allowed us to verify earlier suspicions that brown trout were present within its boundaries. It was also confirmed that brown trout did not reside in the sampled portion of the Middle Branch. We identified a total of 14 species, most of which were found in both branches of White Clay Creek; these species can be seen in Table 1. Jaccard's Index of community similarity was used to evaluate species diversity; there was greater species diversity between sites than there was within a site. Both branches had a value of 0.75 when comparing the sampling from June to the sampling in October. Comparing the East Branch to the Middle Branch during the June sampling resulted in a value of 0.64 and during the October sampling produced a value of 0.58.

Abundance was estimated for many species, where abundance could not be estimated, the total number collected was used for comparisons (Table 1). Four out of the 5 most common species in the East Branch were also among the 5 most common in the Middle Branch. Exceptions were the brown trout, which was found only in the East Branch and the longnose dace, which had a higher rank in the Middle Branch. Further comparison of the East and Middle Branches showed that certain species were restricted in numbers while in the presence of brown trout. Table 1 also shows that rare species were rare at both sampling periods and that these species showed a high variability. For example, the margined madtom and swallowtail shiner were found in small numbers in the Middle Branch, but in the East Branch, where brown trout existed, there was no evidence of either species.

Table 1: Abundance of fish species collected (per 50m reach) at two sampling periods in the East Branch and middle branch – White Clay Creek (WWC), PA.

Species / Abundance		East Branch of WCC		Middle Branch of WCC	
Common Name	Scientific Name	6/2/2009	10/14/2009	6/3/2009	10/15/2009
American brook lamprey*	*Lampetra appendix*	18	9	24	2
American eel*	*Anguilla rostrata*	2	3	2	0
Blacknose dace	*Rhinichthys atratulus*	75	131	109	141
Bluegill*	*Lepomis macrochirus*	1	0	0	0
Brown trout	*Salmo trutta*	59	30	0	0
Common shiner	*Luxilus cornutus*	1	0	11	4
Creek chub	*Semotilus atromaculatus*	32	53	10	41
Cutlips minnow	*Exoglossum maxillingua*	28	43	11	7
Longnose dace	*Rhinichthys cataractae*	0	3	17	22
Margined madtom*	*Noturus insignis*	0	0	2	3
Rosyside dace	*Clinostomus funduloides*	120	132	53	11
Swallowtail shiner	*Notropis procne*	0	0	6	0
Tessellated darter	*Etheostoma olmstedi*	56	18	26	4
White sucker	*Catostomus commersoni*	39	45	36	0

* indicates total number caught, otherwise abundance was estimated using the three-pass depletion method

Most species were broken into age classes and density was described for each of these age classes as well as total density of each species. Although discrepancies were noted, especially in the Middle Branch, under most circumstances a species having a high density in June also had a high density in October. Total density can be seen in Table 2, but descriptions of specific Age class densities are discussed. Age class 0, those born in the year of sampling, showed variations in these densities between stream branches. Where brown trout are present the young of some other species have a tendency to have lower densities therefore recruitment may also be lower. The density for age 0 (June sampling) in the East Branch of the common shiner was 53 fish/ha, whereas the same age in the Middle Branch was 190 fish/ha. A similar occurrence can be seen for the longnose dace during the October sampling with the East Branch having 160 fish/ha while the Middle Branch had 799 fish/ha. The blacknose dace not only showed a difference in the Age class 0, but also in the Age class 1. June sampling of the East Branch at Age 0 resulted in a 710 fish/ha density and at Age 1 resulted in a 2,506 fish/ha density. The corresponding density for the Middle Branch at Age 0 was 1,381 fish/ha and at Age 1 was 3,535 fish/ha.

Table 2: Density (fish/ha) of fish species collected at two sampling periods in the East Branch and Middle Branch – White Clay Creek (WWC), PA.

Density	East Branch of WCC		Middle Branch of WCC	
Species	6/2/2009	10/14/2009	6/3/2009	10/15/2009
Blacknose dace	4037	7023	5194	5521
Brown trout	3148	1579	---	---
Common shiner	53	---	524	149
Creek chub	1718	2817	465	1614
Cutlips minnow	1504	2281	529	277
Longnose dace	---	160	810	877
Rosyside dace	6393	7056	2490	438
Swallowtail shiner	---	---	286	---
Tessellated darter	2997	915	1233	157
White sucker	2086	2430	1701	---
Total Density per Sampling	21936	24262	13231	9033
Total Density per Site	46198		22265	
Density in fish/ha	Total	→	68462	

In addition to the variations between the branches as shown above there were also differences within the East Branch. Table 2 shows brown trout densities dropping by half from June to October, from 3,148 fish/ha to 1,579 fish/ha. As brown trout density was dropping the blacknose dace density elevated from 4,037 fish/ha to 7,023 fish/ha and creek chub increased from 1,718 fish/ha to 2,817 fish/ha. Also on the rise was the cutlips minnow density, increasing from 1,504 fish/ha to 2,281 fish/ha. Longnose dace which were not caught at all in the first sampling were found during the October sampling with a density of 160 fish/ha. Finally, Rosyside dace increased from 6,393 fish/ha to 7,056 fish/ha and white sucker increased from 2,086 fish/ha to 2,430 fish/ha. Although it is only speculation that brown trout could cause such an effect over the course of one season, it does show a possible connection. Graphical representation can be seen in Figure 5; all but the tessellated darter show an increase in density on the East Branch while brown trout density decreased.

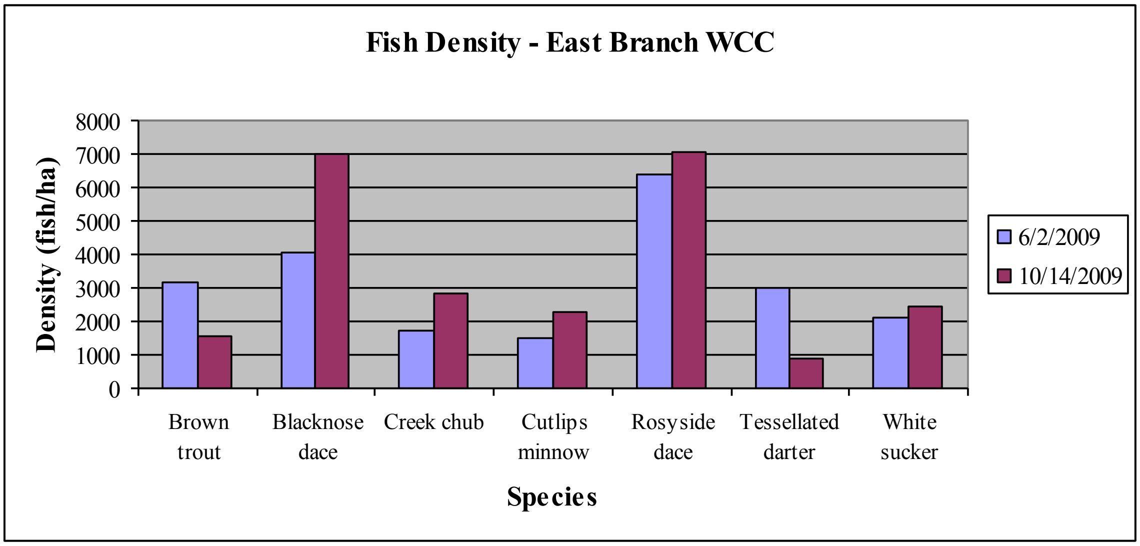

Figure 5: Density of fish species in the East Branch of White Clay Creek (WCC), PA from 6/2/09 and 10/14/09 (only species that occurred in both sampling periods are present)

The breakdown of ages for each species also gave insight as to how long each species was living in their respective stream branch; Table 4 shows a maximum age class for each species/sampling date. For low density species found at both sites, the maximum age observed was lower in the presence of brown trout. For example in the East Branch, where brown trout resided, the common shiner and the longnose dace never made it past Age 0, which could indicate a disappearing species. Yet in the absence of the brown trout the common shiner lived to Age 2 and the longnose dace lived to Age 3, reaching a reproductive age.

Biomass allowed us to look at the total weight of a species per area of stream; this can be seen in Table 3. Even though the total biomass of the East Branch was significantly higher than that of the Middle Branch, a couple of species had a higher individual biomass on the Middle Branch. Such was the case of the blacknose dace, at Age 0 and 1 the biomass was higher in the Middle Branch than in the East Branch during the June sampling. The same was true of the white sucker at Age 2 and 3. The white sucker could quite possibly be the dominant species in the East Branch as well as the Middle Branch if brown trout did not inhabit that area. In the June sampling of the East Branch, brown trout consisted of 44% of the total biomass and white sucker made up 26%. Yet, in the Middle Branch where brown trout were not present, white suckers made up 57% of the total biomass.

Table 3: Biomass (kg/ha) of fish species collected at two sampling periods in the East Branch and Middle Branch – White Clay Creek (WWC), PA.

Biomass	East Branch of WCC		Middle Branch of WCC	
Species	6/2/2009	10/14/2009	6/3/2009	10/15/2009
Blacknose dace	8.739	12.550	9.324	8.032
Brown trout	84.154	99.600	---	---
Common shiner	0.035	---	2.418	0.913
Creek chub	13.458	18.923	1.294	11.288
Cutlips minnow	10.929	16.217	3.966	0.848
Longnose dace	---	0.197	2.202	1.145
Rosyside dace	18.727	25.208	6.164	2.052
Swallowtail shiner	---	---	0.669	---
Tessellated darter	5.481	1.390	1.708	0.312
White sucker	49.573	54.063	37.286	---

Biomass in kg/ha

Brown trout production on the East Branch of White Clay Creek was significantly greater than any other species with the exception of the white sucker. In fact brown trout production was 4-5 times higher than all other fish, again excluding the white sucker. Although the biomass of the Middle Branch as compared to the East Branch was considerably lower there were some species that still had greater production values in the Middle Branch as shown in Table 4. The production of blacknose dace in the Middle Branch was almost double that in the East Branch, 5.270 kilograms/hectare/year and 2.605 kilograms/hectare/year, respectively. Similarly, the tessellated darter's production was 0.868 kilograms/hectare/year in the Middle Branch and only 0.219 kilograms/hectare/year in the East Branch. Production of the common shiner and the longnose dace on the Middle Branch was 1.122 kilograms/hectare/year and 0.314 kilograms/hectare/year, respectively, yet on the East Branch no production level was able to be calculated due to the extremely small population size captured.

Table 4: Production (kg/ha/yr) and maximum ages (yrs) of fish species in the East Branch and Middle Branch – White Clay Creek (WWC), PA.

Production	East Branch of WCC		Middle Branch of WCC	
Species	Prod.	Max Age	Prod.	Max Age
Blacknose dace	2.605	2	5.270	2
Brown trout	49.799	5	---	---
Common shiner	---	0	1.122	2
Creek chub	5.754	5	4.021	4
Cutlips minnow	8.175	3	0.713	2
Longnose dace	---	0	0.314	3
Rosyside dace	12.070	3	2.759	3
Swallowtail shiner	---	---	---	1
Tessellated darter	0.219	2	0.868	2
White sucker	44.385	5	---	3

Production in kg/ha/year

DISCUSSION

Sampling of both sections of the White Clay Creek resulted in the identification of 14 species including our target species, the brown trout. The two stream reaches were similar in cover, size, surrounding land-use, temperature, etc., but brown trout were not present on the Middle Branch, as anticipated, allowing for a confident comparison based on these characteristics. We hypothesized that brown trout would negatively affect species within the East Branch, but based on our study and results, we noticed that fish were less abundant and density was lower in the Middle Branch as opposed to the East Branch. The Middle Branch was not quite as diverse as the East Branch, and also showed much lower numbers of many species present. There was also less community complexity in the stream without brown trout. Common shiner, blacknose and longnose dace were more abundant while creek chub, cutlips minnow and rosyside dace were less abundant in the community without brown trout.

On the East Branch, brown trout did not represent the highest abundance or density, but it did have the greatest biomass and production. In the presence of brown trout, several species showed lower densities in the lower age classes, specifically age 0, in the East Branch, showing a possible decrease in their recruitment. Also, there were a couple of species that did not live past age 0 (possibly representing a dying species) on the East Branch and yet were able to thrive in the Middle Branch. Finally, production of a few species was higher on the Middle Branch, but not measurable (due to very small catch size) on the East Branch. Two fish, the common shiner and the longnose dace, fall into each of these categories, and therefore appear to be the most affected species and may be losing a foothold in the East Branch.

Our study design accurately measured abundance, biomass, production, etc. Therefore differences between the communities in the two branches may not be due to brown trout. Possible causes of the Middle Branch's lower capacities range from land-use change or habitat degradation to climatic change or environmental contamination. Alternatively, it may be that brown trout stimulate production in other species by releasing them from competition. We saw fewer benthic species in the East Branch, and these may directly compete with other fish in the community.

The project design was adequate for determining species composition and related information.However, to actually lay blame on the brown trout as a causal agent to the reduction of other species, different methods would be superior. Our project was based on the overall question that brown trout were negatively affecting other fish species on the East Branch. Another way to determine this is to look at the interspecific interactions between two species. Enclosures are set up to manipulate fish combinations and exclude outside interference. Combining brown trout with one other species allows the investigator to measure interactions between fish as well as their affect on invertebrate organisms. One such study concluded that the brown trout out competes the slimy sculpin (*Cottus cognatus*) causing slowed growth; brown trout did not appear to affect the benthic macroinvertebrate populations (Ruetz et al. 2003).

Another study design to look at the effects of brown trout on the stream ecosystem and its inhabitants involves food webs and trophic cascades. The ecosystem production budget experiment allows for a look into the effect of one fish species on invertebrate production, thereby decreasing food resources for other species. A study from New Zealand used the trophic cascade design to see if brown trout had such an effect. It was determined that brown trout caused a top-down production control by consuming 100% of the invertebrate production (Huryn 1998).

That said it is the opinion of this investigator that research should be continued and different methods employed. In the event that research is not continued, this stream should be reverted to its historical species composition. That would include the removal of the brown trout and replacement with its related native species, the brook trout.

WORKS CITED

About NISIC – What is an invasive Species? Modified 8/24/2009. USDA – National Invasive Species Information Center. Visited 12/11/2009. http://www.invasivespeciesinfo.gov/whatis.shtml.

Anderson, R.O., and R.M. Neumann. (1996) Length, Weight, and Associated Structural Indices. In: *Fisheries Techniques - Second Edition* (eds. Murphy B.R., Willis D.W.), pp. 447-?. American Fisheries Society, Bethesda, Maryland.

Brock, R., T. Crisman, W. Courtenay, and V. Nilakantan. (1991) The ecological effects of exotic species in North American lakes. *Hydrology of Natural and Manmade Lakes* 206: 95-104.

Crowl, T.A., Townsend C.R., McIntosh, A.R. (1992) The impact of introduced brown trout on native fish: the case of Australasia. *Reviews in Fish Biology and Fisheries* 2: 217-241.

Devries, D.R., and Frie R.V. (1996) Determination of Age and Growth. In: *Fisheries Techniques - Second Edition* (eds. Murphy B.R., Willis D.W.), pp. 483-?. American Fisheries Society, Bethesda, Maryland.

Harvey, C. J., and P. M. Kareiva. (2005) Community context and the influence of non-indigenous species on juvenile salmon survival in a Columbia River reservoir. *Biological Invasions* 7: 651-663.

Hayes, D.B., Bence J.R., Kwak T.J., Thompson B.E. (2007) Abundance, Biomass and Production. In: *Analysis and Interpretation of Freshwater Fisheries Data* (eds. Guy C.S., Brown M.L.), pp. 327-374. American Fisheries Society, Bethesda, Maryland.

Horwitz, R. J., T. E. Johnson, P. F. Overbeck, T. K. O'donnell, W. C. Hession, and B. W. Sweeney. (2008) Effects of riparian vegetation and watershed urbanization on fishes in streams of the mid-Atlantic piedmont (USA). *Journal of the American Water Resources Association* 44: 724-741.

Huryn, A. D. (1998) Ecosystem-level evidence for top-down and bottom-up control of production in a grassland stream system. *Oecologia* 115: 173-183.

Jonsson, N., T. F. Næsje, B. Jonsson, R. Sakagård, and O. T. Sandlund. (1999) The influence of piscivory on life history traits of brown trout. *Journal of Fish Biology* 55: 1129-1141.

Kazyak, P., and R. Raesley. (2003) Key to the freshwater fishes of Maryland. Maryland Biological Stream Survey, Annapolis, Maryland.

Kolar, C. S., and D. M. Lodge. (2002) Ecological predictions and risk assessment for alien fishes in North America. *Science* 298: 1233-1236.

Kraft, C.E., D.M. Carlson, and M. Carlson. (2006) *Inland Fishes of New York (Online)*, Version 4.0. Department of Natural Resources, Cornell University, and the New York State Department of Environmental Conservation.

Li, H.W. and J.I. Li. (2006) Role of Fish Assemblages in Stream Communities. In: *Methods in Stream Ecology* (eds. Hauer, F.R., Lamberti, G.A.), pp. 489-514. Academic Press (Elsevier), Burlington, Massachusetts.

National Invasive Species Council. (2001) Meeting the Invasive Species Challenge: National Invasive Species Management Plan. 80 pp.

Parker, I. M., D. Simberloff, W. M. Lonsdale, K. Goodell, M. Wonham, P. M. Kareiva, M. H. Williamson, B. Von Holle, P. B. Moyle, J. E. Byers, and L. Goldwasser. (1999) Impact: Toward a framework for understanding the ecological effects of invaders. *Biological Invasions* 1: 3-19.

Ruetz, C. R., A. L. Hurford, and B. Vondracek. (2003) Interspecific interactions between brown trout and slimy sculpin in stream enclosures. *Transactions of the American Fisheries Society* 132: 611-618.

Simon, K. S., and C. R. Townsend. (2003) Impacts of freshwater invaders at different levels of ecological organization, with emphasis on salmonids and ecosystem consequences. *Freshwater Biology* 48: 982-994.

Soto D, Arismendi I, Gonzalez J, et al. (2006) Southern Chile, Trout and Salmon Country: Invasion Patterns and Threats for Native Species. *Revista Chilena De Historia Natural* 79: 97-117.

Steiner, Linda. (2000) *Pennsylvania Fishes (book online)* Chapter 16-Trout and Salmon: Family Salmonidae. http://fishandboat.com/pafish/fishhtms/chap16.htm#brontrt.

Townsend, C.R. (2003) Individual, Population, Community, and Ecosystem Consequences of a Fish Invader in New Zealand Streams. *Conservation Biology* 17: 38-47.

Townsend, C. R. (1996) Invasion biology and ecological impacts of brown trout Salmo trutta in New Zealand. *Biological Conservation* 78: 13-22.

Townsend, C. R. and Crowl, T. A. (1991) Fragmented population structure in a native New Zealand fish: an effect of introduced brown trout? - *Oikos* 61: 347-354.

Waters, T. F. (1999) Long-term trout production dynamics in valley creek, Minnesota. *Transactions of the American Fisheries Society* 128: 1151-1162.

W. Eldridge, Stroud Water Research Center, personal communication.