EXPLORATION: A HIGH SCHOOL STUDENT'S SUMMER PROJECT IN THE PINE BARRENS

Brandon Li

Skillman, New Jersey

INTRODUCTION

Living for most of my life in Central New Jersey, I have always seen the Pine Barrens as mysterious with the tall pines and tea-colored water (Figure 1) providing a stark contrast to my comparatively boring deciduous suburbs. There's something about life there—the snakes that crawl through the blueberry underbrush, the frogs that croak on the sandy beaches—that seems so alien. Perhaps it's the relentless beauty of the Barrens, the last truly wild place in Jersey. One could spend days wandering the expanse of sand roads, miles from any civilization. On the shore of a blackwater pond, I felt my toes dig into the sand, surrounded by nothing but pine forest, lilies, and a lone Osprey (*Pandion haliaetus*), and for a moment I understood what complete and utter bliss feels like.

The Pine Barrens is spread out over seven counties in the coastal plain of southern New Jersey and is, in many respects, an an alien environment to its surrounding areas. The Barrens is geographically separated from, yet constitutes a large portion of the Atlantic Coastal Pine Barrens Ecoregion, which is not to be confused with *the* Pine Barrens, referring to the one in south Jersey. Its name derives from the environment's sandy, acidic, and nutrient-poor soil. For that reason, it harbors a unique ecosystem found nowhere else in the state. Here, pines dominate the forest, their needles coating the ground and creating a thin layer of soil over sand that would rival the beaches of Cape May in southern New Jersey. All sorts of interesting creatures inhabit this vast expanse, from the beautiful Pine Barrens Tree Frog (*Hyla andersonii*) to the Eastern King Snake (*Lamprepeltis getulus*) to the Southern Bog Lemming (*Synaptomys cooperi*).

What I was interested in, however, were the fishes of the blackwater streams, impoundments, and marshes that crisscross and dot the Barrens. Humates (i.e., fulvic acid) from bog vegetation leach into these waterways, painting the water from a deep orange to near black. Fishes like the Mud Sunfish (*Acantharchus pomotis*), Blackbanded Sunfish (*Enneacanthus chaetodon*), and Pirate Perch (*Aphredoderus sayanus*) call these tannin-stained, acidic waters home. To me, these fishes seemed as alien as the Barrens themselves—a far cry from the Creek Chub (*Semotilus atromaculatus*) and Bluegill (*Lepomis macrochirus*) around my home.

What's so important about the Pine Barrens' fish populations is their isolation from the rest of the Atlantic Coastal Pine Barrens Ecoregion. Historically, the Barrens remained largely uncultivated because its soil was hardly suitable for agriculture. Today, it is under a large habitat degradation risk from rapid urbanization and runoff from surrounding agriculture. The increasing development of land as well as the replacing of forests with houses, farms,

Figure 1. Pine Barrens habitats.

Photos by the author.

Brandon Li is a senior in high school from Central New Jersey, and has a passion for ichthyology, conservation, and art. He is also an avid lifelist angler and a freelance scientific illustrator. His blog, bassonthegolfcourse.blogspot.com, details his fishing adventures, and for any questions, comments, or concerns, he can be reached at li.brandon.y@gmail.com.

Figure 1 (continued). Pine Barrens habitats.

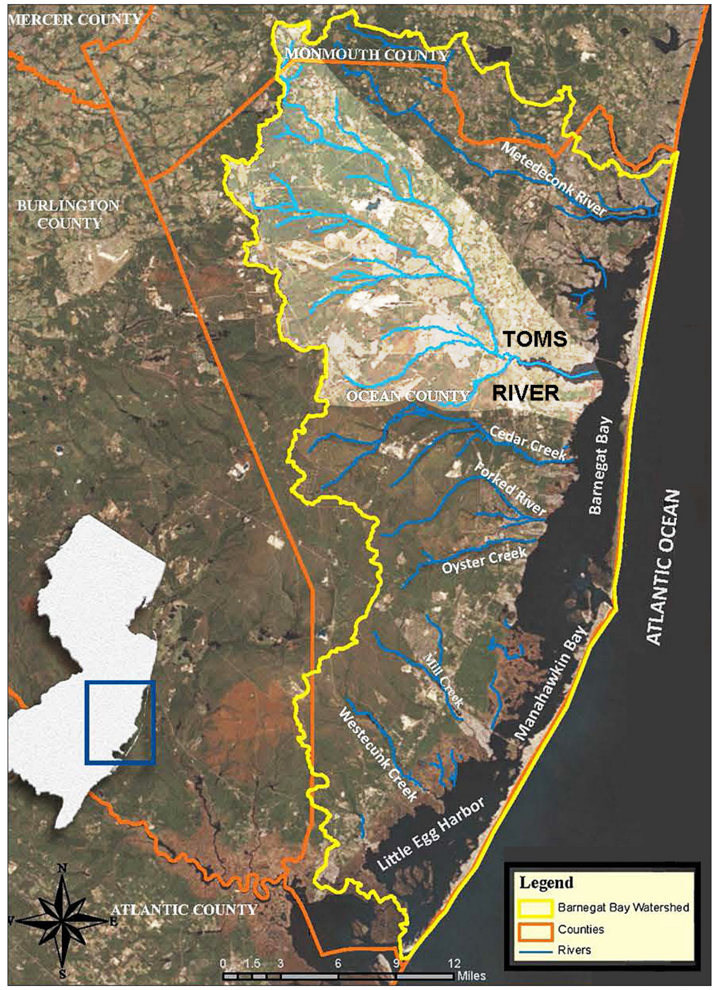

Figure 2. Toms River watershed.

roads, and malls pose a threat to the fragile Pine Barrens habitats. In addition, because of the Pine Barrens' sandy soil, both surface and groundwater are at risk from contamination and alteration of water quality through added nutrients, toxic chemicals, and other pollutants. These factors put the fishes of the Barrens at risk.

In the winter term of my sophomore year, I had the opportunity to submit an independent summer project proposal for a grant from my school, and I leapt upon it, knowing immediately what I wanted to study. Sure enough, my proposal was accepted, and I received a thousand-dollar grant to conduct a project studying the native fish species of the Pine Barrens.

I was ecstatic, but I still had work to do. My project plan underwent changes as summer approached, but in the end, I had come up with a plan to study the relationship between fish species distributions in a single watershed and the hydro-chemical parameters of individual waterbodies.

I focused on the Toms River watershed, a 660 square mile area located in the northeast Pine Barrens and encompassing all of the land and water in Ocean County, as well as parts of Monmouth County, New Jersey. I eventually selected ten sites as judged by various factors, including type of ownership (private vs. public), accessibility, proximity to developed areas, and habitat representation (Figure 2).

METHODS

Fish diversity and density were measured at 10 sites (Figure 3) in 0–4 feet of water along the shore with four methods: dip netting (dip net with ⅛" mesh), seining (4' x 8' Frabill seine net with PVC pipe poles; ⅛" mesh), and observation. Typically, the sampling started with dip netting in heavily vegetated areas. After sufficiently probing, the seine was used to cover a larger, more open expanse of water. Any fishes observed and that could be decidedly identified to the species were recorded as well. All the species collected, as well as observations regarding their abundance were recorded, using the number of each species captured relative to the area surveyed. Each identified species was given a quantification of their population abundance from 0–5, 0 being absent, 1 being 1–5 captures, 2 being 6–10, 3 being 11–15, 4 being 15–20 and 5 being greater than 20. After all recordings/observations were made, every specimen collected was released back into the same body of water, and gear was cleaned to prevent transport of organisms from waterbody to waterbody.

Hydro-chemical parameters of the waterbodies in the Toms River watershed were quantified, including pH and the concentrations of iron, phosphate, total nitrogen or the ratio of nitrate/nitrite (Table 1). In addition, water temperature and transparency at the time of collecting were also measured. The collection time, air temperature, humidity, and barometric pressure were recorded according to weather reporting at each test site.

Table 1. Method and instruments used for measuring hydrochemical parameters.

Measurement (unit)	Instrument and Accuracy/Range	Sampling Location	Replicate
pH	Vantakool digital pH meter at surface; Accuracy: 0.01 pH	at surface	3 readings and average were recorded for each trial
water temperature (°C)	Zacro digital thermometer; Accuracy: 0.1 °C	water depth	3 readings and average were recorded for each trial
water transparency (cm)	Yardstick; Accuracy: 1 cm	up to 5 feet deep of water	3 readings and average were recorded for the last trial
iron (mg/L)	Industrial grade SenSafe Iron Check iron testing strips; Fe+2/Fe+3, test range: 0–5.0 mg/L	at surface	1 measurement; 2 readings. Average was recorded for each trial.
nitrogen (N) or nitrate/nitrite (NO3/NO2) (mg/L)	WaterWorks Nitrate and Nitrite testing strips; 0 to 10 mg/L for NO2 or 0–50 ppm for NO3	at surface	1 measurement; 2 readings. Average was recorded for each trial
phosphate (mg/L)	AquaChek Phosphate Test; 0 to 1000 ppb	at surface	1 measurement; 2 readings. Average was recorded for each trial

Three trials, one at the end of June and two at the beginning of August were attempted. Each trial's data were entered into the dataset as independent entries.

RESULTS

Among the ten tested sites, the pH levels ranged from 4.6 to 6.8, suggesting a generally acidic aquatic environment. The iron level varied from 0 to 0.25 mg/L. Measurements of phosphate and nitrogen were not always quantifiable. All of the nitrogen measurements were below the lowest non-zero value on our test, 0.15 mg/L, and most were zero. There was no further analysis on the levels of phosphate and nitrogen. Air temperature ranged from 23° to 29.6° C with a mean of 25.6° C. Water temperature ranged from 22.5° C to 31.0° C with a mean of 26.2° C. The air pressure encompassed a narrow range of 29.9 to 30.1 inHg. The measurements were generally consistent between the three trials conducted at each test site. As the study was conducted throughout summer, these conditions should represent a typical summer environment in the Toms River watershed.

Figure 3. Ten sites selected in the study area.

Figure 4. Representative fish species found in study area from top left across and down: Mud Sunfish, Banded Sunfish, Bluespotted Sunfish, Blackbanded Sunfish, juvenile Bluegill, Pumpkinseed, Pirate Perch, Banded Killifish, and Creek Chubsucker.

In this study, a total of 15 fish species was found at ten testing sites (Figure 4). The species are as follows: Bluespotted Sunfish (*Enneacanthus gloriosus*), Banded Sunfish (*E. obesus*), Blackbanded Sunfish, Mud Sunfish, Pumpkinseed (*Lepomis gibbosus*), Bluegill, Largemouth Bass (*Micropterus salmoides*), White Crappie (*Pomoxis annularis*), Creek Chubsucker (*Erimyzon oblongus*), Pirate Perch, Golden Shiner (*Notemigonus crysoleucas*), Banded Killifish (*Fundulus diaphanus*), Chain Pickerel (*Esox niger*), Yellow Bullhead (*Ameiurus natalis*), and Swamp Darter (*Etheostoma fusiforme*). Using previous biological surveys in the area, the species found followed expectations, suggesting the collecting methods were comprehensive and the findings can be generalized to the greater Toms River watershed.

Species that were significantly more abundant in a pH lower than 5.5 included Bluespotted Sunfish, Banded Sunfish, Blackbanded Sunfish, Mud Sunfish, Creek Chubsucker, Pirate Perch, Golden Shiner, Chain Pickerel, and Swamp Darter. The abundance of Bluespotted Sunfish has a clear inverse relationship with pH. That of Banded Sunfish does as well, although the deviation from the trend is greater. Blackbanded Sunfish were found to be more abundant at a lower pH, but the difference in abundance at a lower versus higher pH is less than the other two *Enneacanthus* species. Mud Sunfish were only observed in waterbodies with a very low pH. Similar to the Mud Sunfish, Pirate Perch were only collected from low pH water. Creek Chubsucker, on the other hand, had great abundance in most waterbodies, although they were only slightly more abundant in waterbodies with lower pH. Golden Shiner were only found in lower pH waterbodies. While Chain Pickerel were found in greater abundance in lower pH, their abundance was low across the board. Swamp Darter only occurred in low pH water (Figure 5).

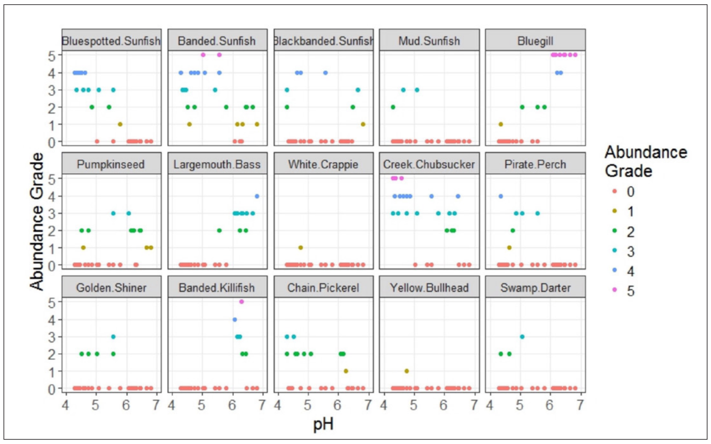

Figure 5. Distribution of fish species by pH level.

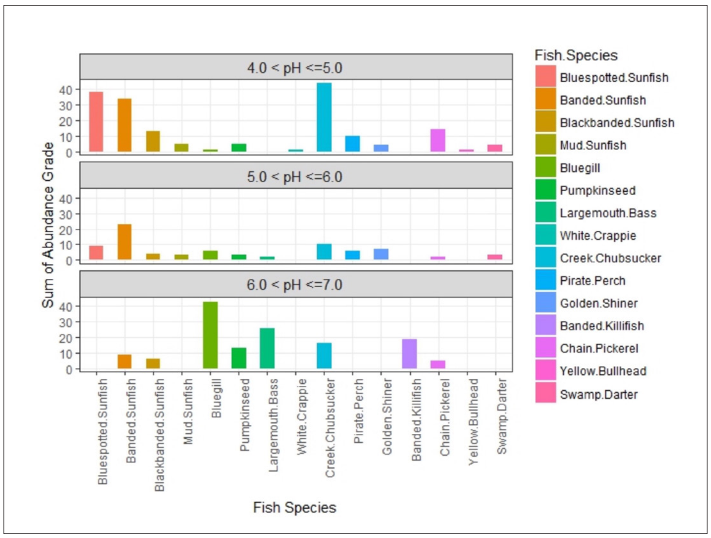

Figure 6. Sum of each species' abundance grades by site and grouped by three pH ranges.

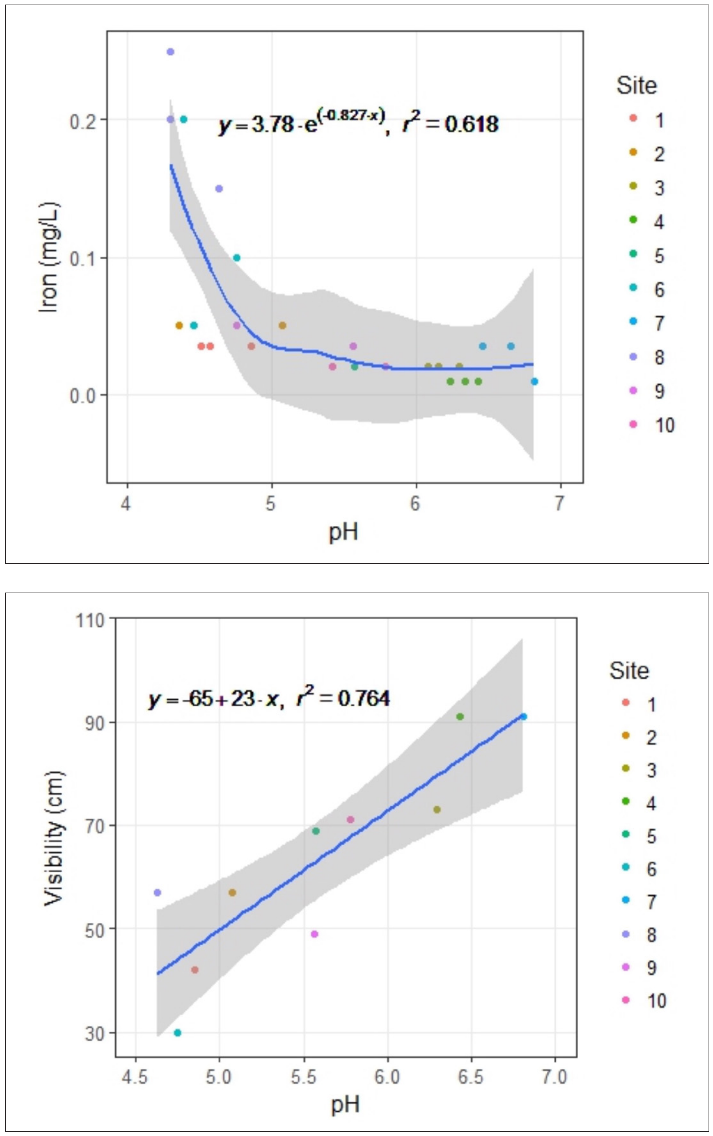

Figure 7. Top: Correlation between iron concentration level and pH level. Bottom: Correlation between water visibility and pH level.

Species that were significantly more abundant in a pH higher than 5.5 included Bluegill, Pumpkinseed, Largemouth Bass, and Banded Killifish. The abundance of Bluegill was extremely high at higher pH waterbodies, having a clear direct relationship with pH. While Pumpkinseeds were more common in water with higher pH, correlation between pH and abundance was not as strong as that of Bluegill. Largemouth Bass had a similar trend to Bluegill, and Banded Killifish were only found in waterbodies with relatively high pH (Figure 6).

While both White Crappie and Yellow Bullhead were found in a lower pH waterbody to have established a significant correlation.

While the major focus of this work is to correlate hydro-chemical parameters with fish species distributions, it is also interesting to note that there was a strong correlation between both the iron concentration level present in the water and the transparency with pH. As pH level goes higher, the water gets less acidic, iron concentration goes down in a nearly exponential decay fashion. Due to the correlation between both the iron concentration level and transparency with pH, there was no separate analysis in this work relating iron level or transparency with the fish population distributions (Figure 7).

DISCUSSION

This work identified 15 fish species in the shallow waters of the Toms River watershed. The main species of interest were Bluespotted Sunfish, Banded Sunfish, Blackbanded Sunfish, Mud Sunfish, and Pirate Perch—to a lesser extent, Creek Chubsucker and Swamp Darter as well. That is because, in New Jersey, these species are unique to the Pine Barrens and are vulnerable to habitat degradation. On the other hand, species such as Bluegill, Largemouth Bass, Pumpkinseed, and Banded Killifish are widespread and common throughout the state.

The dominance of Bluegill, a more common species, over other unique sunfish species in higher pH water was apparent. For example, in Site 7, Bluegill, Banded Sunfish, and Blackbanded Sunfish were all present, but the abundance of Bluegill compared to that of the two *Enneacanthus* species was astounding. A similar trend was found across the board. As the pH increased in the study, Bluegill began to coexist with unique Pine Barrens species that fill the same niche in the aquatic ecosystem, such as the *Enneacanthus* species, Mud Sunfish, etc. When that occurred, the abundance of those more unique species dramatically decreased in most situations. However, in the absence of Bluegill (generally in the lower pH waterbodies), those species flourished. In this study, it was found that Bluegill significantly outcompeted other vulnerable species where both coexisted. In every site with a pH above 6.0, Bluegill were found. In fact, in water with a pH above 6.0, Bluegill were by far the single most abundant species.

The correlation between Bluegill dominance over other sunfish species and higher pH may be due to the optimal pH range as well as the habits of Bluegill. While Bluegill can supposedly tolerate water with a pH as low as 4.0, their optimal range is 6.5–8.5. In their optimal pH range, Bluegill are repeat spawners, meaning that they reproduce multiple times each year. On the other hand, *Enneacanthus* species are much less prolific spawners even in their optimal pH range. In addition to spawning habits, Bluegill also hold a distinct advantage over the other non-*Lepomis* sunfish species in the Pine Barrens due to size and aggressiveness. The maximum recorded length for a Bluegill is 41.0 cm, while specimens are more commonly found at 19.1 cm. Compared to, for example, Bluespotted Sunfish, which has a maximum length of 9.5 cm and a common length of 7.0 cm, Bluegill are less vulnerable to predators due to their size advantage. The other *Enneacanthus* species are of similar size to the Bluespotted Sunfish, with the exception of the Blackbanded Sunfish, which is a bit smaller. In addition to their larger size, Bluegill have been observed to be much more aggressive than the other species, which means that they would tend to outcompete the other sunfish where Bluegill have a large population, especially since they occupy the same niche in the Pine Barrens ecosystem. It should be noted that Bluegill are not native to the Pine Barrens nor New Jersey in general, but they have been widely introduced across the United States and are now found in most waterbodies throughout New Jersey. The dominance of Bluegill over the more unique Pine Barrens species is particularly alarming due to the vulnerability of those more unique sunfish.

In addition to Bluegill, another species prompting concern is the Largemouth Bass. Like the Bluegill, Largemouth Bass are an introduced species in New Jersey. Adult Largemouth Bass have an almost entirely piscatorial diet, competing with the native Chain Pickerel. Although Chain Pickerel are widespread throughout the state, an abundance of another large predator provides increasing threat to those species unique to the Pine Barrens. Like the Bluegill, Largemouth Bass were found most abundant in less acidic waterbodies.

The study also found that Pumpkinseed, another smaller and less aggressive member of the *Lepomis* genus, followed a similar trend to Bluegill, although to a much lesser extent.

Creek Chubsucker were common across the board, most likely due to their large range of tolerance for pH as well as their unique benthic niche in the Pine Barrens ecosystem. Banded Killifish were only found in higher pH waterbodies, suggesting their pH tolerance does not extend to below 6 (Figure 6). Both Mud Sunfish and Pirate Perch are primarily nocturnal species. Low collection numbers for both, due to their tendency to hide deep in cover during the day, may mean that no conclusive conclusions can be drawn about their relationship with hydro-chemical parameters in the Pine Barrens, even though all found were in relatively low pH waterbodies. Contrary to expectation, due to the pervasiveness of the species, a few Golden Shiners were found mostly in lower-pH waterbodies. Expectations were that they would be mostly found in higher pH water. Those captured were suspected to be most likely the results of bait releases.

Also quite interesting is the apparent strong correlation between the iron concentration, water transparency, and pH. The Pine Barrens is known to have relatively high amounts of iron in its waterways compared to other waterbodies in New Jersey. The Pinelands Alliance notes that the water in the Pine Barrens is acidic under "natural conditions," and it seems high iron and low transparency are found in the natural state of the characteristic blackwater streams of the Barrens. However, their relationship to the acidity of the water is still unknown. Historically, bog iron has been mined from the water there. The water transparency measured is not due to turbidity, but rather to the natural black-brown, so called "tea-colored" water. That water color is suspected to be caused by the high iron content, as well as natural humates like tannin, which drain from bogs into blackwater streams (which most of the sites are man-made impoundments of). Thus, it follows that transparency and iron should have a negative correlation, which was found in the study. However, my review of the literature did not find previous quantitative reporting of the iron and pH levels in the Pine Barrens, suggesting that this work could be the first one attempting to quantify such a relationship.

CONCLUSION

The results from this study indicate that there are distinct relationships between the water's pH and iron level, and the fish species distribution in the Pine Barrens. The findings also suggest that changes in the hydro-chemical parameters, such as neutralization of acidic water, can allow the proliferation of more dominant fish species, disastrously affecting the populations of unique, more vulnerable ones. New Jersey species unique to the Pine Barrens, such as the Blackbanded Sunfish, which is currently threatened by habitat loss and competition from invasive species, are less abundant in higher pH water and where they coexist with non-native species. This information can help create a greater understanding of the long-term effects of habitat change on the piscatorial community of the Pine Barrens and even help determine policies to help preserve the biological purity of the Barrens.

This independent summer project was a great learning experience, and I am quite thankful that I have this affinity for fishes, otherwise it might have become quite tiring. And although that concludes the project portion of my time, the Barrens had so much more to offer. As an avid angler and one who occasionally dabbles in herping, I enjoy microfishing and catching a variety of reptiles and amphibians. Relaxing on the beaches of impoundments and the wilderness so close to urban life was a plus. The Pine Barrens is truly a strange and wild place; I can only hope that it stays that way.