Effects of Anthropogenic Pollution on Gilled Snail Abundance in Stroubles Creek in Montgomery County, Virginia

Introduction

Anthropogenic pollution is a form of contamination created directly by humans from industrial, urban, or agricultural origin. Examples of this are ammonia pollution from farms, pieces of litter left around by people, and pesticide run-off from agricultural fields (Rhind 2009). Pollution production rates have been accelerating with global industrialization efforts and technological advancements (Arihilam and Arihilam 2019). Pollution has reached all aspects of the environment including the air, the soil, and every type of waterway (Rhind 2009). Freshwater ecosystems have been directly affected by anthropogenic pollution for many years (Arihilam and Arihilam 2019). Pollution has direct effects on water quality and biodiversity of species regularly present in these ecosystems (Arihilam and Arihilam 2019). Water quality can be measured with multiple parameters such as pH, dissolved oxygen (D.O.), conductivity, temperature, and visual properties like transparency (Shi et al. 2020). Too high or too low of these measurements can indicate poor water quality. For instance, polluted waterways tend to have lower D.O. measurements (Butcher and Covington 1995) while pH tends to fluctuate in freshwater, but is considered not healthy when the value is lower than 6.0 and higher than 8.0 (Shi et al. 2020). While certain organisms can withstand poor water quality and elevated pollution levels, gilled snails are very sensitive to these aspects of freshwater ecosystems (Bovberg et al. 1982) and may not be not supported in polluted waterways.

Caenogastropoda, also known as gilled snails, are sensitive bioindicators of water quality in freshwater ecosystems (Anyanwu et al. 2019). They are members of the class Gastropoda which inhabit terrestrial, freshwater, and marine environments (Brown and Lydeard 2010). Freshwater gastropods vary in how sensitive they are to pollution due to their mechanism of breathing. Gilled snails breathe by absorbing dissolved oxygen from the water through their gills (Kodani 2021). Since the gills absorb dissolved oxygen, higher dissolved oxygen levels are required for these snails to survive and reproduce abundantly (Anyanwu et al. 2019). Higher dissolved oxygen is supported in warmer temperatures found in the summer and early fall (Butcher and Covington 1995). By gilled snails requiring a higher water quality, this means that gilled snails are more sensitive to pollution (Anyanwu et al. 2019). Due to their sensitivity to pollution, higher gilled snail abundance in creeks and streams demonstrates the pristine qualities of that specific waterway.

Gilled snail abundance in Stroubles Creek will be one indicator of the state of this waterway in the areas it runs through. Stroubles Creek runs through Blacksburg, Virginia into Radford, Virginia where it feeds into the New River (Parece et al. 2010). Both of these towns have been developed heavily in recent years and it is important to recognize the influence anthropogenic pollution has had on the freshwater ecosystems that run through them. Anthropogenic pollution is visually more present in areas near Virginia Tech's campus, such as pieces of litter floating in the water, because of increased anthropogenic development and interaction. Development, such as run-off from roads, might affect D.O. by the removal of shaded vegetation along Stroubles Creek which would cause an increase in water temperature. Warmer water holds less dissolved oxygen due to its solubility being poor in warmer temperatures (Butcher and Covington 1995). Radford and Blacksburg are both of agriculturally-focused origins, but population sizes have increased over time leading to more interaction with Stroubles Creek (Parece et al. 2010). Pollution is likely to be affecting gilled snail populations in Stroubles Creek.

In this study, gilled snail abundance in Stroubles Creek in Blacksburg, VA was measured along the creek from Virginia Tech's College Campus to where it runs through Radford, VA. Water quality measurements and snail abundance are crucial in telling the current state of this ecosystem. My hypothesis is that lower water quality in upstream sites located in Stroubles Creek of Blacksburg, VA will lead to reduced abundance of gilled snails because they are highly sensitive to poor water quality. I predict that abundance will be higher in downstream sites of Stroubles Creek near where it opens into the New River. To test this hypothesis, water quality and snail abundance were measured along the creek ranging across Montgomery County, VA.

Methods

Study Organism

Gilled snails are a member of the class Gastropoda in the invertebrate phylum Mollusca; all of which possess a secreted calcium carbonate shell, a mantle to form the shell, and a strong muscular foot for locomotion (Brown and Lydeard 2010). They often have an elongated conical shell which provides for protection from predators and allows them to store their visceral body mass safely (Brown and Lydeard 2010). There are 46 species of gilled snails found throughout Virginia in 10 families, but some of the most common families are Physidae, Pomatiopsidae, and Pleuroceridae (Dillon 2019).

Study Site

Data were collected along Stroubles Creek which covers a distance of 9.2 miles in Montgomery County, VA (Parece et al. 2010). This creek flows into the New River and is a part of the Mississippi River Basin (Parece et al. 2010). The habitat for the majority of Stroubles Creek is characterized by shaded vegetation growing along the edge of the creek. Ten sites were chosen along the creek to provide coverage of all the types of environments that could affect gilled snail abundance (see figure 1). Sites one and two were chosen to represent where the creek runs through Radford, VA near the New River and is surrounded by natural areas rather than a college campus (figure 1b). Sites three and four were selected to be at the mouth of the Duck Pond on Virginia Tech's campus (figure 1c). Sites five and six represent the area in between the campus and where the creek runs along farmland owned by Virginia Tech (figure 1c). Sites seven and eight were selected to represent where the creek runs along the cow farms near the Campbell barns (figure 1d). Sites nine and ten were chosen to be where restoration efforts are currently in place from Virginia Tech near the Foxridge Collegiate Apartment Homes of Blacksburg. Due to the importance of these efforts, data were collected immediately upstream of the restoration site to preserve water quality in the monitored portion of the creek.

Figure 1: Map showing all ten sites where abundance was measured along Stroubles Creek (a), location of sites 1 and 2 (b), location of sites 3-6 (c), location of sites 7-10 (d)

Study Design

I followed guidelines for freshwater snail monitoring suggested in O'Sullivan (2011). At each of the ten sites, five one meter by one meter plots (N = 50 plots total) were established with a tape measure and flags to provide consistent areas of gilled snail abundance. The plots were spaced out two meters apart from each other. This process was repeated until all plots had been set up. Each plot was thoroughly examined and each snail was picked up to clarify the identification as a gilled snail. Snails were visually identified by their longer conical shells and all snails within each plot were counted to estimate abundance in the area. Prior to and directly after measuring snail abundance, water quality measurements were taken at each plot and the two measurements were averaged together. I measured pH, dissolved oxygen (mg/L), conductivity (µS/cm), and temperature (C^{o}). These measurements were taken with the water quality meter kit from Sper Scientific Direct (Model Number 850086) and the dissolved oxygen meter kit from Sper Scientific Direct (Model Number 850081DOK). The pH meter was submerged ~10 centimeters underwater until a stable value was read on the screen. The same process was repeated for temperature and conductivity. To provide a stable reading for dissolved oxygen (D.O.), a slight velocity with the probe was created if there was not enough flow in the site. After each measurement, the pH probe was submerged in distilled water to bring the reading back to neutral and avoid influencing the next measurement. To control for weather effects on water quality, this data was only collected on days with no precipitation within 24 hours of collection. Any acidic rain would have negatively affected this data and provided skewed values. Sites one, two, and seven were sampled on October 11, 2021. Sites three, four, five, and six were sampled on October 17, 2021. Sites eight, nine, and ten were sampled on November 7, 2021.

Data Analysis

Data was analyzed using R (version x64 4.1.1). The software packages "lme4" (Bates et al. 2015), "ggplot2" (Wickham 2016), "viridis" (Garnier et al. 2021) and "dplyr" (Wickham et al.

2021) were used for this analysis. A histogram was used to assess the distribution of gilled snail abundance data. It was determined by the histogram that the distribution was non-normal. To test the effects of water quality on gilled snail abundance in Stroubles Creek, I used a generalized linear mixed model with the Poisson distribution. Snail abundance was the response variable. pH, temperature, conductivity, and dissolved oxygen were all fixed effects. Site was a random effect.

Results

Stroubles Creek was shown to have varying gilled snail abundance. Sites one and two had a very high abundance of gilled snails compared to the other eight sites (Figure 2). The average abundance was ~30 snails per plot at site one and ~26 per plot at site two (Figure 2). There was a significant negative effect of conductivity on snail abundance across all ten sites (z-value: -2.86, p-value: 0.0042; Figure 3). Dissolved oxygen had a significant positive effect on snail abundance across all ten sites (z-value:5.56, p-value: 2.65e-08; Figure 4). Dissolved oxygen and conductivity were shown to have an inverse relationship (correlation of fixed effects: -0.941; Figure 6).

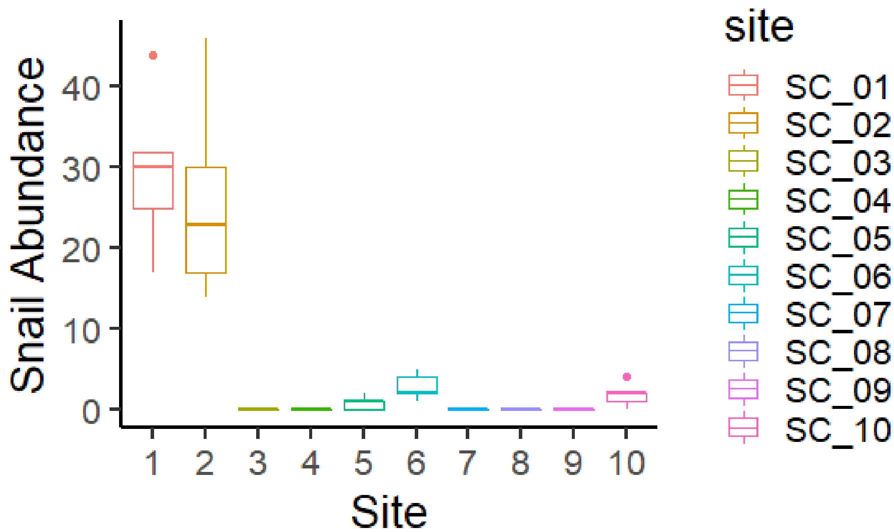

Figure 2: Gilled snail abundance along Stroubles Creek at each site (e.g. SC_01, SC_02, etc.)

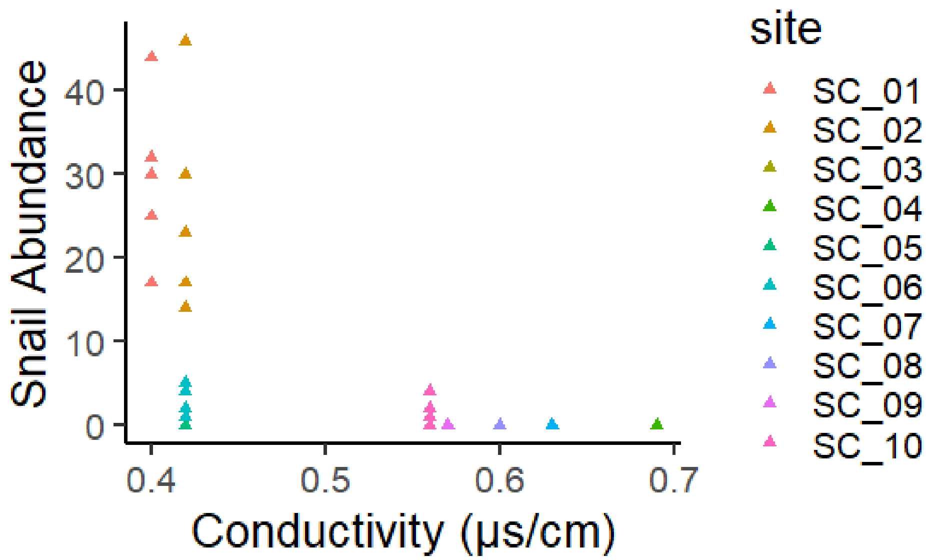

Figure 3: Effect of conductivity on snail abundance in Stroubles Creek, VA

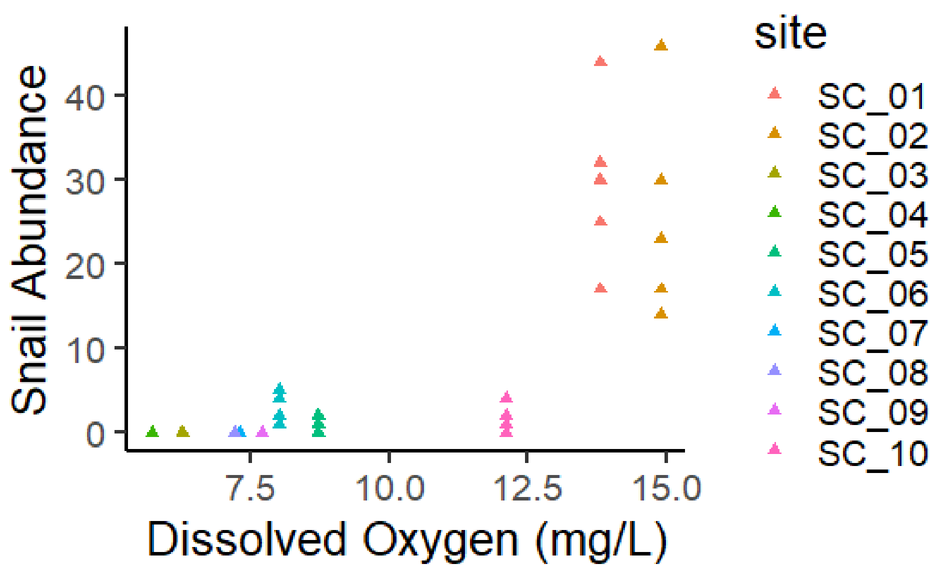

Figure 4: Effects of dissolved oxygen on snail abundance in Stroubles Creek, VA

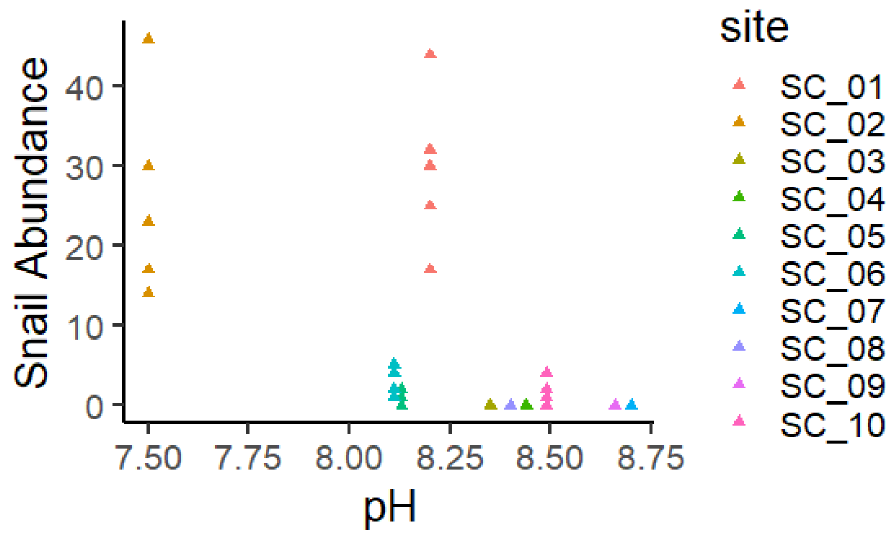

Figure 5: Effects of pH on snail abundance in Stroubles Creek, VA

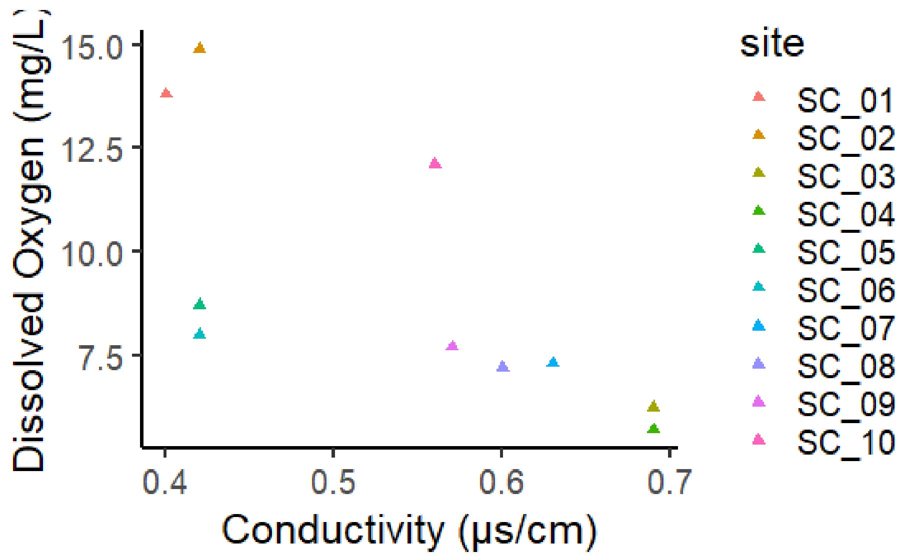

Figure 6: Dissolved oxygen vs conductivity--This graph shows the inverse relationship between conductivity levels and dissolved oxygen

pH had a marginally significant effect on abundance (p-value 0.059; Figure 5). Gilled snails were abundant in a range of pH of 7.5-8.5 (Figure 5). Temperature had a strong negative effect on abundance (z-value: -2.64, p-value: 0.0084).

Discussion

This study was conducted to examine the effects of anthropogenic pollution on water quality in Stroubles Creek and how this relationship is demonstrated through gilled snail abundance. It was found that gilled snails are more abundant in downstream sites of Stroubles Creek toward Radford, VA. It was also found that water quality was much better in downstream sites. Water quality and gilled snail abundance were shown to have a direct relationship through this data. Specifically, D.O. and conductivity were two predictor variables that helped confirm this relationship (Figure 2). This supports the hypothesis because upstream sites had less gilled snail abundance due to worse water quality.

These findings are consistent with those found in Anyanwu et al. (2019) in that gilled snails need a higher dissolved oxygen concentration in the water. Higher dissolved oxygen concentrations were found in sites closer to the New River where less anthropogenic interaction has occurred with Stroubles Creek (Figure 4). Seeing snails present in a range of pH from neutral to slightly basic was consistent with results from the studies done in O'Sullivan (2011), Anyanwu et al. (2019), and Shi et al. (2020). Since snails were found in varying pH, it was found that pH was marginally significant in affecting snail abundance as a fixed effect. Conductivity having a negative effect with abundance was a pattern also found in Anyanwu et al. (2019). These patterns are important for future research done on gilled snails as bioindicators and also for restoration efforts in Stroubles Creek.

The most noteworthy caveat to the results seemed to be temperature's effect on gilled snail abundance. Temperature varied because of the time of year this study was conducted. It was conducted over the fall season from late October to mid November. Sites one, two, three, four, five, six, and seven were sampled on warmer days in mid-October (~18.3°C). Sites eight, nine, and ten were sampled on colder days in early November (~4.4°C). Because of this, time seems to be a confounding variable in the measurement of water temperature. While temperature is related to dissolved oxygen concentrations, this relationship cannot be proved in this study because of the variability in sampling dates. Warmer weather led to higher average water temperature in sites tested throughout October. Future studies on gilled snail abundance should be done in a season of consistent air temperature so that water temperature also remains consistent. Another caveat was that many of the predictor variables (D.O., conductivity, pH, temperature) were strongly correlated, so distinguishing which one influenced abundance the most is hard with this data. Additional data collection farther downstream in Stroubles Creek closer to the New River could further support my hypothesis and possibly help identify which predictor variables affect abundance the most.

These results are important for understanding the effects of pollution on freshwater ecology. Anthropogenic pollution has been becoming a greater problem in recent years in freshwater ecosystems. Climate change has been occurring simultaneously and has caused changes in the biodiversity of macroinvertebrates in these ecosystems. Sensitive macroinvertebrates play a large role as indicators of water quality. Pristine water quality should be preserved to maintain high populations of sensitive macroinvertebrates in freshwater ecosystems. This can be done through conservation and restoration efforts of endangered streams, creeks, rivers, etc.

The current Virginia Tech restoration efforts in Stroubles Creek start near the Foxridge Collegiate Apartment Homes of Blacksburg and are limiting access to the public in order to improve water quality and eventually remove Stroubles Creek from Virginia's impaired waterways. These efforts are being led by Dr. W. Cully Hession and the StREAM lab. Water quality restoration in Stroubles Creek seems to be working because gilled snail abundance increased at the beginning of the restoration sites as I collected data further downstream. With the change in abundance, this shows that anthropogenic pollution has a greater effect toward Virginia Tech's campus.

Overall, this study has shown significant effects on how water quality not only affects macroinvertebrate populations, such as gilled snails, but that it affects conservation efforts and how ecologists go about achieving them. As climate change progresses and human civilization introduces more anthropogenic pollution to the natural world, freshwater ecosystems and the species that inhabit them must be conserved.

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