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Seasonal and Spatial Variation in Biodiversity of Campus Wetlands

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Abstract

My project aimed to identify the species of aquatic vertebrates, especially anurans and salamanders, and macroinvertebrates that inhabit wetlands on the UNC Asheville campus. Many of the wetlands on campus are ephemeral ponds, but two ponds stay wet year-round. My goal was to quantify the species present and compare diversity between ephemeral and permanent ponds. Differences in amphibian diversity were expected, as many amphibian species will not breed in permanent ponds because they contain fish predators. Hurricane Helene impacted campus soon after I began sampling, providing an opportunity to compare diversity before and after this major event. From September 2024 into April 2025, campus ponds were sampled using sweep nets and bucket traps. I recorded the abundance of amphibians and fish and the presence/absence of various macroinvertebrate taxa. Notes about the conditions of the ponds were also recorded, such as fullness and presence of ice that either prevented full sampling or influenced the individuals present. The bucket traps used in the survey yielded two different salamander species, *Ambystoma maculatum* and *A. talpoideum*, as well as tadpoles of several anuran species. Sweep netting revealed the presence of nematodes, snails, and daphnia, as well as damselfly, mayfly, and dragonfly larvae. Surprisingly, there were salamanders present in ponds that contained sunfish. The results of this study provided a foundation that can serve as a baseline to track changes in pond diversity through time as campus land use patterns change.

Introduction

Wetlands cover 116.4 million acres of the conterminous United States (Lang et al. 2024) and provide valuable ecosystem services including flood control, groundwater recharge, water filtration while providing habitat for diverse communities of plants and animals (Mitsch et al. 2015). Upland freshwater wetlands, like those found in western North Carolina, help buffer communities from river flooding, provide water sources for forest-dwelling wildlife, and support numerous rare and threatened species (e.g., Graeter and Hale 2020). Despite their importance, the U.S. Fish and Wildlife Service (USFWS) reported a net loss of 607 thousand acres of freshwater wetlands between 2009 and 2019 (Lang et al. 2024). Such loss highlights the potential importance of constructed wetlands in providing the ecological services one provided by “natural” forest and floodplain wetlands. However, whether constructed wetlands perform these roles as well as natural wetlands may vary extensively by locality and by wetland features. By quantifying biodiversity of constructed wetlands, we can begin to explore how well they serve these roles.

One major factor influencing the biodiversity of wetlands is hydroperiod. Longer hydroperiods are associated with greater biodiversity and trophic diversity (Mdidimba et al. 2021). This increased biodiversity extends to macroinvertebrates, likely due to the increased stability of physical and chemical characteristics in more permanent wetlands. Richness and abundance of amphibian metamorphs also increases with longer hydroperiods (Brooks, 2004). While many pool-breeding amphibians are adapted to irregular hydroperiods, short hydroperiods can be especially problematic for some species (Brooks, 2004). In *Ambystoma talpoideum* (mole salamanders) drying time is known to significantly affect survival and time to metamorphosis (Semlitsch & Wilbur, 1988). It is also documented that bodies that stay full longer allow individuals more time to grow large enough to initiate metamorphosis before drying (Crump, 1989). Larger body size at the time of metamorphosis in amphibians is associated with increased adult survival and reproductive success. Additionally, while ephemeral ponds are not able to support fish, more permanent ponds may contain fish, the presence of which impacts the surrounding biodiversity. The presence of fish has been shown to significantly decrease larval growth and activity, which can also affect metamorphosis (Figiel & Semlitsch, 1990).

Urban ponds typically exhibit lower biodiversity compared to those in natural settings, as urban environments introduce additional stressors such as road traffic, habitat fragmentation, and pollution, that can negatively impact aquatic ecosystems. Road density and traffic volume are also known to limit anuran species richness as well as the distribution of individual species. Specific mechanisms for this effect may include mortality due to collisions, constrained movement, and reduced quality of fragmented habitats (Cosentino, 2014). Another issue is that roads located near wetlands can cause them to be contaminated with runoff, which can have negative effects on inhabitants (Turtle, 2000). Specifically, the survival rate of embryos in *Ambystoma maculatum* (spotted salamanders) are lower for roadside pools, which is a potential effect of deicing salts. These salts may also increase amphibian susceptibility to parasitism (Milotic et al. 2017).

Another important factor affecting biodiversity of wetlands is pond size. Intermediate pond sizes have the highest density and diversity of amphibians (Semlitsch et al. 2015). Mechanisms causing this may be the high probability of drying in small ponds, and greater fish colonization and more invertebrate accumulation leading to higher predation rates. Flooding frequency can also influence wetland biodiversity. It is believed that high water velocities in urban streams, which can be caused by flooding, result in decreased larval retention (Barrett et al. 2010). In addition to larval displacement caused by flooding from high precipitation, weather characteristics strongly influence water level changes in vernal pools, with precipitation being the most important factor (Brooks, 2004).

The campus of the University of North Carolina Asheville (UNCA) includes numerous constructed wetlands that serve as filtration systems for water runoff before it reaches Reed Creek. All of the ponds on campus are relatively small, and although their hydroperiods have not been quantified, considerable variation in their hydroperiod has been observed. Two of the wetlands are permanent ponds, while the others are ephemeral. Water levels in these ephemeral wetlands change from week to week, sometimes being dry for up to months at a time. They are located in high traffic areas in an urban campus environment, with all ponds located close to roads. The campus wetlands also sustained a major flooding event after Hurricane Helene hit the area on September 27th, 2024.

The goal of this study is to use regular surveys to collect information on abundance and presence of aquatic vertebrates and macroinvertebrates, and explore the effects of factors including pond fullness, seasonality, and fish presence on the species inhabiting each pond. There has not been any previous extensive sampling of these ponds exploring their biodiversity. Therefore, this study provides baseline biodiversity data against which to compare future biodiversity in the event of changes in land use.

Methods

Study Sites and Sampling Frequency

Sampling was conducted from September 19th, 2024 to April 5th, 2025 at the University of North Carolina Asheville campus in Asheville, North Carolina. Four ponds were sampled (Figure 1). Each was assigned a name to keep track of which body of water individuals were found in. All ponds were near roads running through campus, with two downhill from the Sherrill Center and two located behind residential buildings. Of the uphill ponds, both contained fish. One of these was covered in a layer of duckweed, referred to in this study as Duck (Figure 2A), and the other is referred to as Clear

(Figure 2B). They were estimated to be 0.140 and 0.17 acres, respectively. The two ponds located behind near residential buildings typically dry in the summer months and were also significantly smaller at 0.014 and 0.025 acres. The larger of the two is referred to as Woods (Figure 2C), and the smaller, rounder pond was named Circle (Figure 2D). Sampling for each pond was intended to be done weekly.

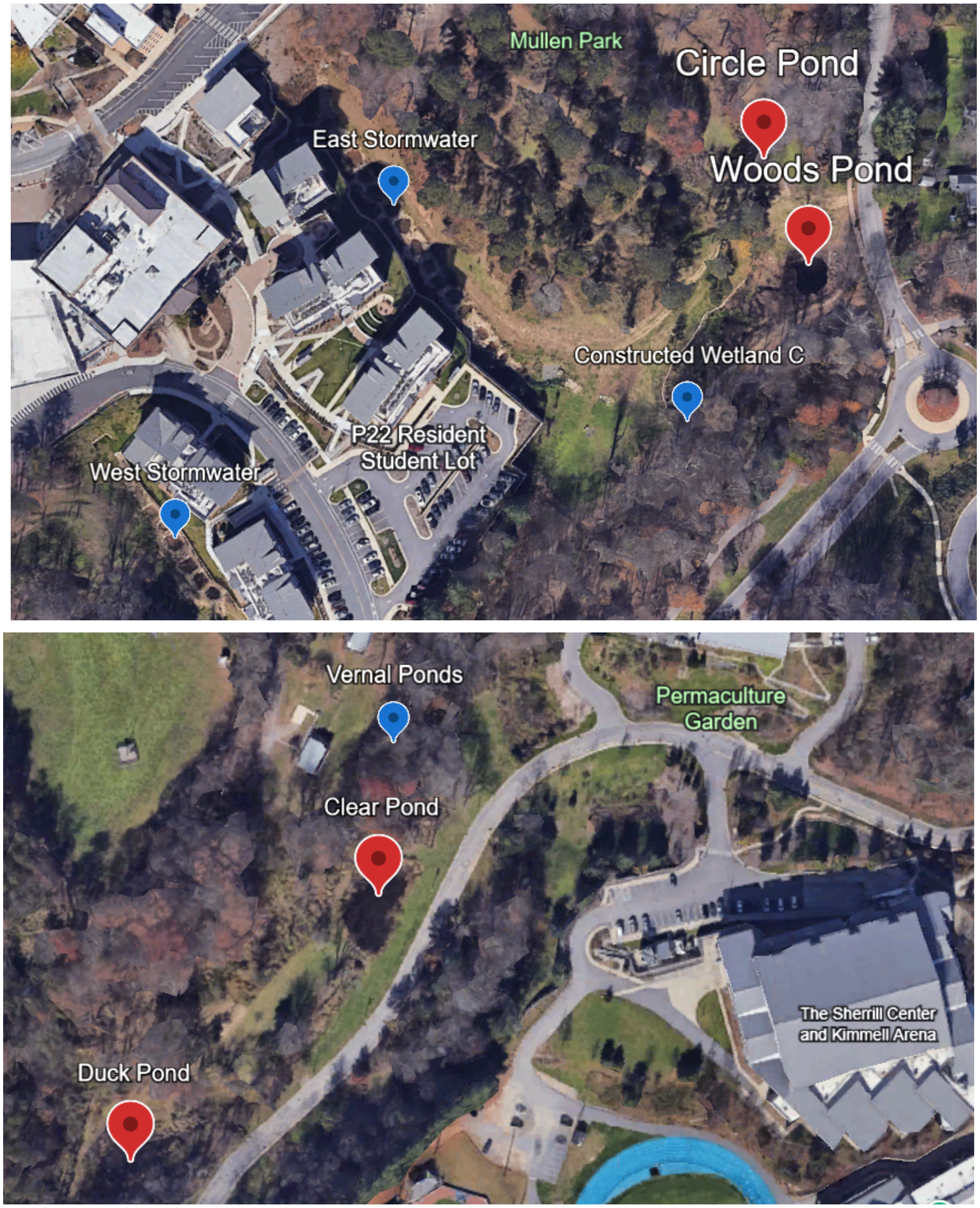

Figure 1. A map of wetlands on the UNC Asheville campus, including the four ponds that were sampled.

Figure 2. The four ponds on the UNC Asheville campus that were sampled during the study. Pictures were taken in April 2025.

Sampling Protocol

The ponds were sampled using two techniques, sweep netting and Ortmann's funnel traps (Figure 3; Drechsler et al., 2010). The funnel traps were used to identify vertebrates present, namely anurans, salamanders, and fish. The sweep netting served to identify macroinvertebrates. Traps used in this study for sampling have angled tubular openings which individuals can swim into, but not easily swim out of. They are also equipped with foam flotation devices and cords used to attach them to the periphery of the ponds. Funnel traps were set weekly for each body of water when conditions allowed. Traps were placed floating in each pond tied to foliage as an anchor. Three were set in Clear and Duck, two in Woods, and one in Circle due to their smaller sizes. Traps were placed in the same area at each time of sampling, except for when conditions required them to be moved, such as thick ice or lower than normal water levels. The traps were collected the next day, and number and species were recorded for each trap on that date, and the animals were released shortly after identification. Notes about the conditions of the ponds were also recorded, such as fullness and presence of ice that either prevented full sampling or influenced the individuals present. Beginning in March, it was also recorded when animals collected were injured.

Sweep netting was done in addition to setting the traps for each body of water. This involved a D frame dip net. Each sampling period, three separate sweeps were done, ensuring that each sweep was in a different location, placing the contents from the pond into one funnel trap that was then examined to identify the macroinvertebrates present, recording only presence/absence for each species. This was also done weekly for each pond.

Data Analysis

Analyses and figures were completed using R (R Core Team, 2025). The abundances of each species were compared by date separately for each pond. All animals collected from traps on the same day were pooled into their respective pond's count. The number of sampling dates on which individuals of each taxon were observed were compared between ponds using a X^2 test.

Figure 3. Ortmann's funnel traps that were used for sampling.

Results

Pond Seasonality
Ponds were intended to be sampled weekly; however, this was not possible during certain periods. Duck and Clear ponds remained full from the beginning of the sampling period in September to April, while Circle and Woods had periods of drying and filling. Woods and Circle ponds were dry from the beginning of the sampling period in September and filled in February. Both dried again in March, with Circle refilling in April, while Woods remained dry until the end of the sampling period in early April. Due to frequent drying there were a total of 4 samples collected from Woods and 3 from Circle. There were also two weeks in January when Clear was partially frozen and only two of three traps were able to be placed. Due to hurricane Helene hitting Asheville on September 27th of 2024, sampling was halted until November 3rd. A total of 2 samples were obtained from Duck and Clear prior to the hurricane and 11 samples after.

Temporal variation in abundance
Across all ponds, taxa found were mayfly, midge, and damselfly larvae, mole salamanders, spotted salamanders, sunfish (Centrarchidae), daphnia, nematodes, and anurans (Table 1; Figure 4). Of anuran species, larval wood frogs, bullfrogs, and leopard frogs were most abundant. Other anuran larvae were not identified by genus. Of macroinvertebrate taxa, nematodes had the most total occurrences, followed by damselfly larvae then daphnia.

Tadpole abundances throughout the year also varied. There were two major pulses of tadpole abundance for Clear pond, in September of 2024 and February 2025. Pulses of tadpole abundance in Duck were less pronounced.

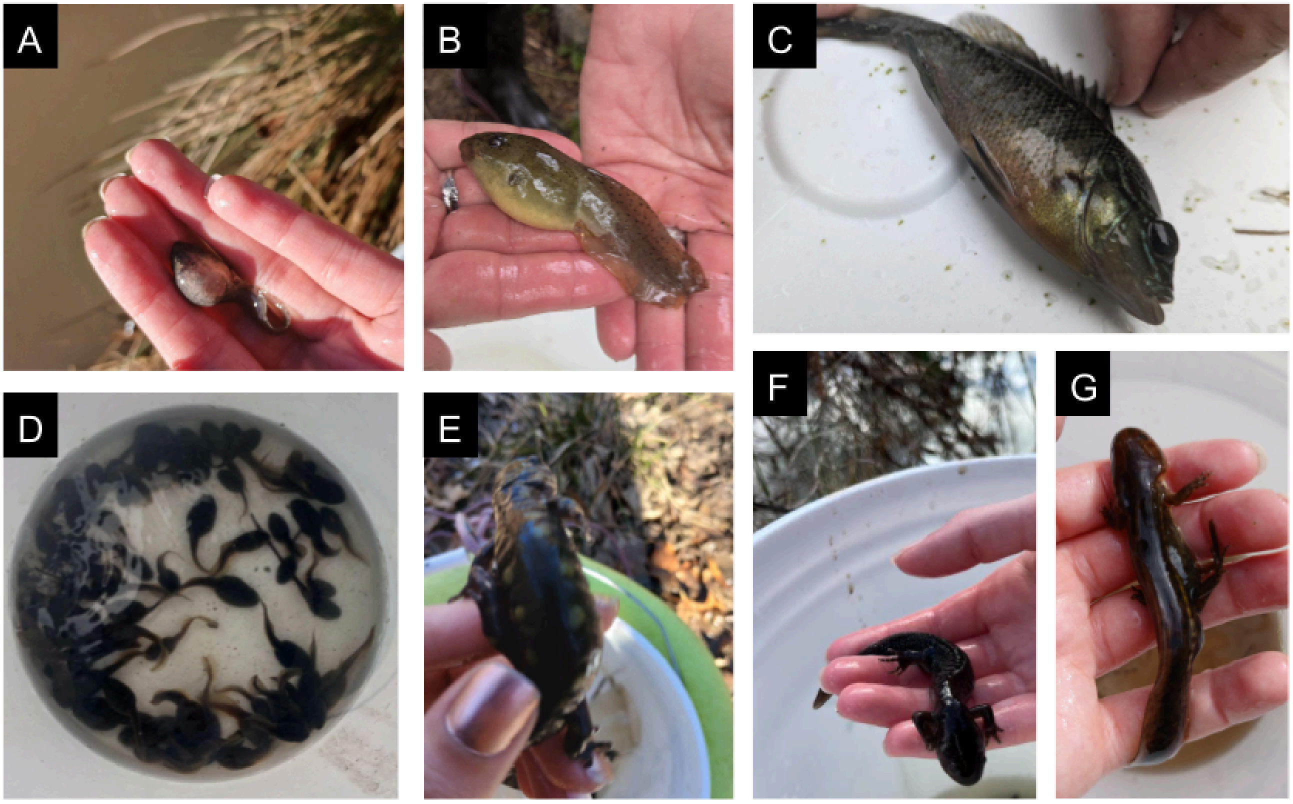

Figure 4. Representative individuals of species captured (A. wood frog tadpole, B. bullfrog tadpole, C. sunfish, D. mixed species tadpoles, E. spotted salamander, F. mole salamander, G. mole salamander).

Table 1. The number of sampling days on which each taxon was observed, separated by pond.

	Pond			
	Clear	Duck	Circle	Woods
Spotted salamander (*Ambystoma maculatum*)	0	0	1	0
Mole salamander (*A. talpoideum*)	0	2	0	0
Adult bullfrog (*Lithobates catesbeianus*)	0	1	0	0
Tadpole	9	9	2	1
Centrarchidae juvenile	1	2	0	0
Damselfly larvae (Odonata)	0	3	0	0
Dragonfly larvae (Odonata)	0	1	0	0
Mayfly (Ephemeroptera)	1	1	1	0
Nematode (Nematoda)	2	3	1	1
Daphnia spp.	0	1	1	0
Midge larvae (Diptera)	0	1	0	0

Fish were present both before and after the hurricane (September 27, 2025), as were tadpoles, nematodes, mayfly larvae, and damselfly larvae (Table 1). There was also likely an influence in abundances due to the filling of ponds caused by the hurricane, as Circle and Woods ponds were not full until after it hit. After the hurricane, there was a substantial decrease in macroinvertebrate species observed. Mayfly larvae, nematodes, and daphnia were not observed again until April.

In total, more tadpoles were found in Clear than in Duck, with 351 compared to 122. Clear also contained the highest tadpole count in one sampling period with a highest count of 79 tadpoles compared to Duck's 24.

Circle and Woods both had few occurrences of tadpoles and no fish. An adult spotted salamander was found once in Circle in February, and mole salamanders were found twice in Duck in January. Mole salamanders have a breeding season that occurs between December and March, which is aligned with these findings (Scott et al. 2013). Spotted salamanders have breeding seasons in late winter and early spring. Spotted salamander egg masses were also found in Circle. No salamander species were observed in Woods or Clear.

Other species found in or near the ponds were ducks, great blue and green herons, red shouldered hawks, doves, and other bird species, as well as a brown water snake and a deceased snapping turtle. These were not systematically sampled but are important to note as many may be predators or otherwise affect the ponds as part of the surrounding ecosystem.

Despite these differences in abundance, there was no significant difference among ponds in taxon occurrence, measured as the number of sampling dates on which each taxon was observed ($X^2 = 32.379$, $df = 30$, p-value = 0.3501).

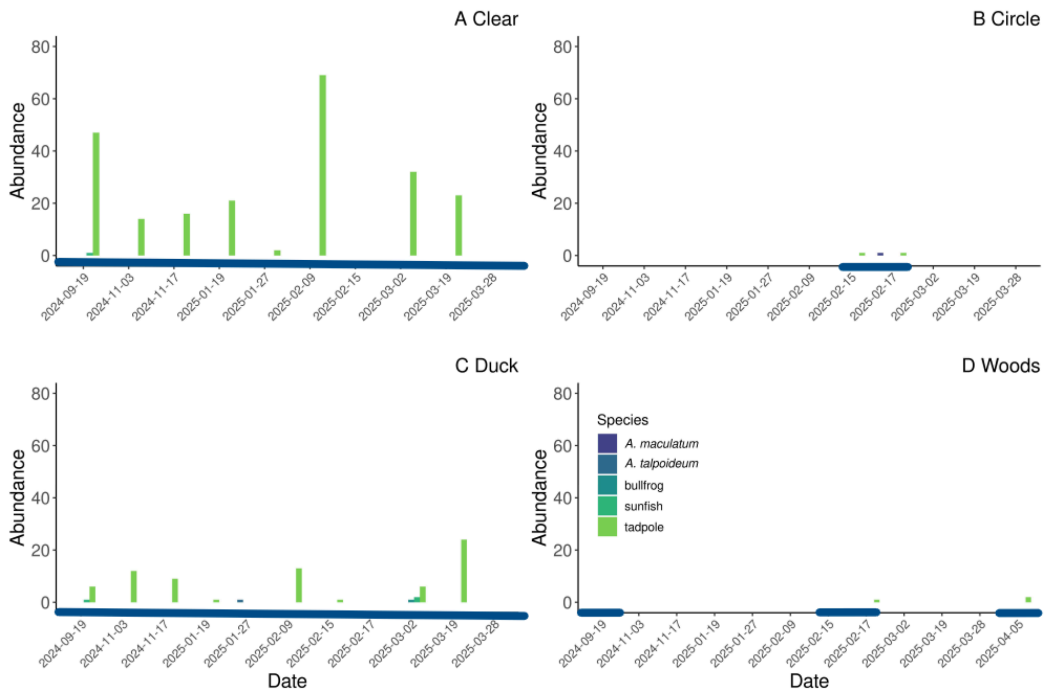

Figure 5. Abundances of each species per sampling date for each pond. Horizontal line below bars indicates wet periods.

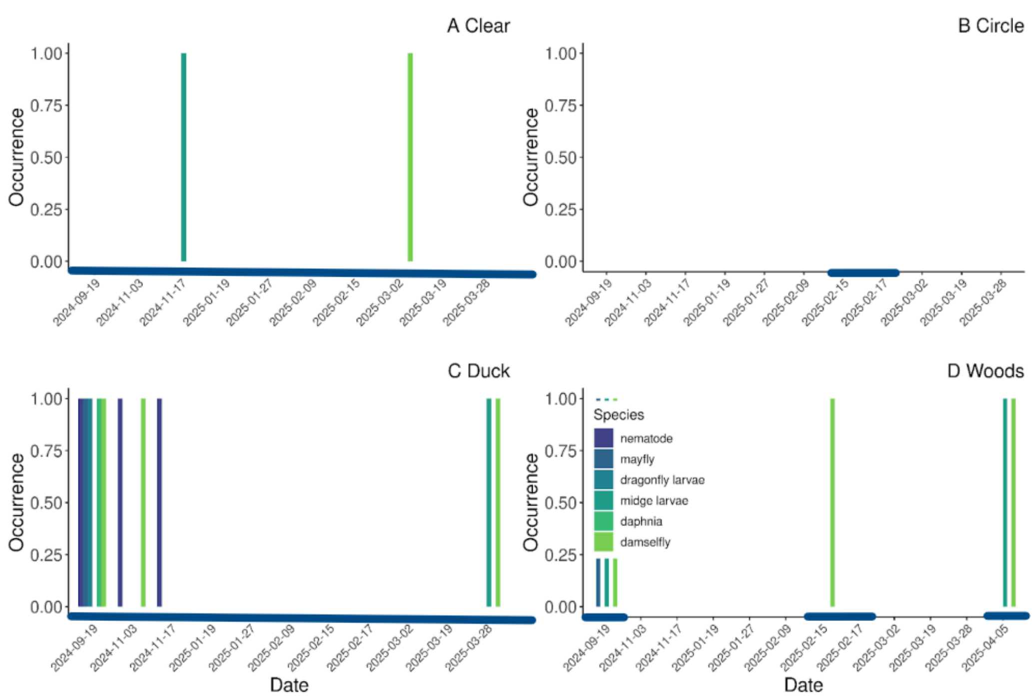

Figure 6. Occurrences of each species per sampling date for each pond. Horizontal line below bars indicates wet periods.

Discussion

Clear and Duck ponds were more permanent, while Circle and Woods were ephemeral with many dry periods. The permanence of Clear and Duck allowed for the presence of fish. Permanency of wetlands affects survivorship and reproductive success. Early drying results in high mortality, caused by the inability of larvae to grow enough to successfully initiate metamorphosis. The growth rate of larvae also decreases as ponds dry (Semlitsch, 1987).

Due to frequent drying of Woods and Circle ponds, it would be useful to continue sampling these ponds in particular to allow for more data to be collected. The current limited sampling data makes it difficult to draw accurate conclusions.

There were two pulses of high tadpole abundance in Clear, both in September and February. This is likely partially due to breeding times. Bullfrogs and leopard frogs, many of which were found earlier in the sampling period, breed in fall which could explain the first pulse in September. Wood frogs breed in winter or early spring, which could explain the second pulse in February as many tadpoles found were wood frogs (Brooks, 2004).

The decline could also be an effect of the hurricane, as high water velocity can reduce retention (Barrett et al. 2010). After the initial pulse in September, which occurred eight days before the hurricane, there was a decline in tadpole abundances, with some sampling days collecting as few as zero tadpoles.

Another reason for the drop off might be that the tadpoles were not detectable because they weren't high in the water column. Due to the floating design of the traps, they will not capture animals that stay near the bottom of the water. This may limit the capture of tadpoles in cold weather, when they are likely to be less active. (Drechsler et al., 2010)

The University of North Carolina Asheville campus wetlands have been found to be important breeding grounds for amphibians due to the abundance of anurans and the presence of two salamander species, spotted and mole salamanders. Vernal pools like those on the UNCA campus are essential to amphibians as transitional habitats between aquatic and wetland areas (Zedler, 2003). These pools are especially sensitive to disruptions from human activity and climate change, so the preservation of such habitats is crucial (Ammar, 2024). This should be considered moving forward when tracking changes in biodiversity through time and planning for future land use.

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