Potential effects of a warmer and drier climate in the Great Lakes Region on seasonal woodland pool invertebrate communities

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Abstract

Seasonal woodland pools are an important wetland that may be affected by increased evaporation and periods of drought predicted by climate change models. Small, artificial pools were used to model the effect of reduced hydroperiods on seasonal woodland pool invertebrate communities. The artificial pools were seeded with leaf litter from local natural seasonal woodland pools. Hydroperiods were manipulated by manually pumping the water out and refilling the pools. The control pools experienced two two day draw-down events and the experimental pools experienced two eight day draw-down events. The total abundance of invertebrates was significantly fewer in the pools with reduced hydroperiod ($p = .025$). Individual taxa abundance, species richness, and community diversity decreased insignificantly in the pools with reduced hydroperiod. Encouragingly, many of the invertebrates' adaptations allowed them to survive the reduced hydroperiods. However, even with a dry down period of only a week, and with conditions never truly drying out, the invertebrate community was affected. Climate change may intensify these dry periods much more severely and therefore have an even greater impact on seasonal woodland pool invertebrate communities than seen in this investigation.

Introduction

Since the industrial revolution, anthropogenic burning of fossil fuels has caused climate change at a global level. The Intergovernmental Panel on Climate Change models predict that within the next century, mean global temperatures will increase 2-4.5°C and, based on latitude, precipitation patterns will change both in means and extremes (Solomen et al., 2007). In the Great Lakes region, the impacts are already being felt with shorter winters, less lake ice, more frequent storms, and warmer annual temperatures (Kling et al., 2003). Climate change has already affected the functioning of ecosystems and those which depend on the intricate balance of water are particularly susceptible to the impacts.

Wetlands are unique ecosystems that are neither truly aquatic nor terrestrial. Wetlands help to stabilize water levels, cleanse polluted waters, stabilize CO_2, nitrogen, and sulfur levels, and provide habitat for biodiversity (Mitsch & Gosselink, 2000). Climate change will alter the balance the Great Lakes wetlands help provide. Less precipitation, but with more frequent higher intensity storms, may cause temporary flooding, but overall decrease the amount of wetlands. Increases in water temperature will increase water loss by evaporation. Earlier snow melt may decrease the period of inundation of wetlands, especially in those wetlands that are dependent on annual precipitation cycles for their water supply (Kling et al, 2003).

Seasonal woodland pools are a wetland found in the glaciated northeast and are typically small and shallow bodies of water that fill and dry annually. They lack fish and therefore there is minimal predation, making seasonal woodland pools important breeding grounds for amphibians and other organisms. Because of their small, temporary, and variable nature, seasonal woodland pools (also known as vernal pools, ephemeral ponds, seasonal forest ponds, and temporary wetlands) are susceptible to the drier conditions predicted by climate change, yet often are overlooked in traditional wetland literature, research, and legislation (Tiner, 2003; Brooks, 2009).

Climate change and its impact on the hydroperiod (length of inundation) of seasonal forest pools could have direct effects on the organisms that depend on these ecosystems for habitat (Brooks, 2009). Decreased hydroperiods will mean longer periods of desiccation, less time for breeding and maturation, changes in detritus processes, and ultimately possible decreases in biodiversity. Initial research in seasonal woodland pools focused on their importance for amphibians, in particular mole salamanders and the wood frog (Colburn, 2004). However, the largest groups of organisms in seasonal forest pools are insects and other invertebrates (Higgins & Merritt, 1999; Schneider 1999, Colburn 2004).

Invertebrates serve a number of roles in seasonal woodland pools including detritus breakdown, nutrient cycling, and linking primary productivity to higher trophic levels (Wissenger, 1999; Brooks, 2000). Invertebrates of seasonal woodland pools thrive in this unique environment, but also must be able to withstand the variable nature of seasonal woodland pools.

Adaptations for surviving in a habitat where water is present only seasonally, but is essential for survival and reproduction, include the ability to aestivate during the dry periods in the summer, temporarily burrowing into dry sediment, and using water as a cue for reproduction. Invertebrates (and other animal species of seasonal woodland pools) may be classified based on their adaptations to pool drying: group 1, overwinter residents through group 4, non-wintering spring migrants (Table 1) (Wiggins, et al., 1980). This classification exists because the main abiotic factor affecting invertebrates in seasonal woodland pools is the hydroperiod (Schneider, 1999; Colburn, 2004, Brooks 2009). As hydroperiod increases, invertebrate diversity increases (Brooks 2000; Batzer, Palik, & Buech, 2004).

	Category	Description	Example organisms seen in study
Group 1	Overwintering Residents	Cannot disperse, adapted to drying	Mollusks, Copepods
Group 2	Overwintering Spring Recruits	Need water for reproduction	Chironomids, Water Mites
Group 3	Overwintering Summer Recruits	Oviposit in dry basin	Mosquitoes
Group 4	Non-wintering Spring Migrants	Leave before dry out, return when wet	

Table 1. Classic classification of seasonal woodland pools based on adaptations to pool drying (Wiggins, et al., 1980).

This study assessed the possible effects of decreased hydroperiods on invertebrate abundance, richness, and community diversity in artificial seasonal woodland pools at the University of Michigan Biostation by creating extended dry periods through the manual removal of water. The majority of previous studies have investigated seasonal woodland pools by comparing natural pools within the same area over extended periods of time. The use of artificial seasonal woodland pools allowed the manipulation of just the hydroperiod and reduction of some of the variability associated with natural seasonal forest pools. I hypothesized that reduced hydroperiod would decrease invertebrate abundance, richness, and community diversity.

Methods

Sixteen artificial woodland pools were constructed in the red maple dominated forest south of the shore of Grapevine Point at the University of Michigan Biological Station in Pellston, Michigan, USA. The pools were placed in natural depressions when possible and lined with an approximately 1.0 x 1.3 m blue Polyethylene tarp. Pools were filled partially with well water and then to capacity with two subsequent rains. Each pool was seeded for organisms with 200 mL of randomly selected, decaying leaf litter from two large, natural seasonal woodland pools on Grapevine Point. The artificial pools therefore started with random populations based on what organisms were in the leaf litter.

Decreased hydroperiods were induced by pumping water out of each pool using a hand pump with a 154 micron zooplankton net as a filter. Each pool was subjected to two dry-down events, with each event having two stages. Pools began with an average depth of 30 centimeters and were drawn-down to a maximum depth of approximately eight centimeters for the first stage and all water being removed for the second stage. Natural evaporation was allowed to take place for the remainder of the dry-down event and any water added by rain was removed by pumping back to the eight centimeter depth. Pools were randomly assigned to the control or experimental group, with eight pools in each group. Control pools remained drawn down for two days (drawn down to eight centimeter on the first day), while experimental pools remained dry for nine days during the first dry down period and eight days during the second dry down period (drawn down to eight centimeters after four days). At the end of each dry-down event, the pools were refilled, once again using well water. Invertebrates were collected were collected at the beginning of the investigation (before the dry-down events) and after a short recovery period after the refilling of the pools for both dry-down events (Table 2).

Day	2 Day Draw-down Pools (Control)	8 Day Draw-down Pools (Experimental)
1	Full, Seeded	Full, Seeded
10	Invertebrate Sample 1	Invertebrate Sample 1, Drawn-down to ~8cm
13	NA	All water removed
17	Drawn-down to ~8cm	NA
18	All water removed	NA
19	Refilled with well water	Refilled with well water
24	Invertebrate Sample 2	Invertebrate Sample 2
26	NA	Drawn-down to ~8cm
28	NA	All water removed
32	Drawn-down to ~8cm	NA
33	All water removed	NA
34	Refilled with well water	Refilled with well water
38	Invertebrate Sample 3	Invertebrate Sample 3

Table 2. Time line of experiment showing progression in both the two day draw-down control pools and the eight day draw-down experimental pools.

There is not an established protocol to sample invertebrates in seasonal woodland pools. Other typical aquatic sampling methods, such as a zooplankton tow, were not practical because of the small size of the artificial pools. Instead, to sample invertebrates suspended in the water column, a turkey baster was used to remove one liter of water from each pool by running random transects across the diameter just above the leaf litter. The water sample was run through a 153 micron zooplankton net and 125ml of sample was stored in a zooplankton bottle for transfer back to the laboratory. In the laboratory, 70 ml of each sample was filtered again through a 153 micron nytex filter. The filter was then rinsed into a petri dish and the invertebrates were counted using a grid under a dissecting scope at a 3.0x magnification. The size of the filter and the magnification of the scope limited identification to those organisms larger than 153 microns. Invertebrates were classified to family level when possible, but are referred to using the established aquatic invertebrate common name categories. Abundance of invertebrates was then recorded as number of organism per volume of water. Species richness was also recorded.

To sample benthic macroinvertebrates, man-made leaf packs were placed in the pools (Dobson, 1994; Brooks, 2000). Forty-eight leaf packs (three per pool) were constructed, each using ten leaves from the surrounding forest leaf litter. *Quercus rubra, Populus grandidentata, Fagus grandifolia, and Acer rubrum* leaves were included relative to their estimated natural abundance in the area. Each leaf pack was wrapped twice with 15-mm-mesh black plastic garden netting, tied with kite string, and marked with plastic flagging. One leaf pack was collected during each sample: before the first dry-down event, after the first dry-down event, and the last at the conclusion of the second dry-down event. In addition, algae tiles that were present during the last week were collected during the last sample. Both the leaf packs and algae tiles allowed a known surface area to be observed and the number of attached invertebrates recorded. Because only two invertebrate groups were present, the abundance of organisms from leaf packs and algae tiles was added into the data collected with the water column sampling.

Sample three was analyzed for statistical significance using an independent sample T-test after establishing normalcy for abundance, richness, and community diversity using SPSS Statistics 17.0. Abundance was compared between control and experimental groups for both individual invertebrate categories and for the total number of invertebrates counted in each group. Richness, the number of invertebrate groups found in a community, was compared between control and experimental groups. Community diversity was calculated using the Shannon-Weiner index, to account for both richness and evenness within the control and experimental groups. Evenness expresses both richness and the equality of the relative abundance within a community. Community diversity was compared between control and experimental groups.

Results

Four hundred and eighty-four invertebrates were sampled in 16 pools, representing 11 different invertebrate categories. Seven of the invertebrate categories were fairly common, showing up in 40% or more of the pools (Table 3).

Invertebrate Category	% Occurrence
Daphnia	13
Mosquito	88
Copepod	94
Nauplii	63
Mite	44
Nematode	19
Chironomid	88
Rotifer	50
Ostracod	6
Clam	50
Snail	25

Table 3. Percent occurrence of the 11 sampled invertebrate categories in 16 artificial seasonal woodland pools at the University of Michigan Biological Station.

Abundance of total organisms by invertebrate categories did not show any significant difference between the two day draw-down (control) and eight day draw-down (experimental) groups (Figure 1). The five most common organisms (greater than 40 individuals) did show a trend towards fewer organisms in the experimental group, but all had high standard error.

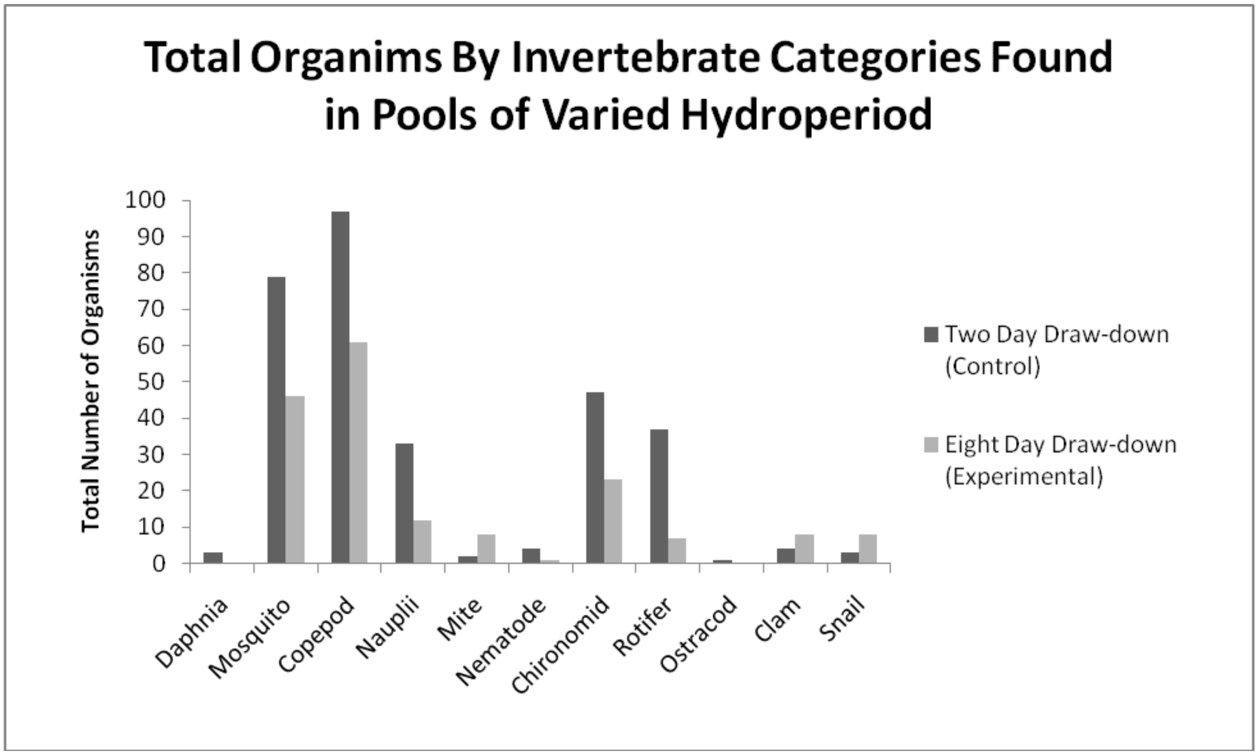

Figure 1. Average number of total number of organisms by invertebrate categories in the two day draw-down control pools group (dark bar) and the eight day draw-down experimental pools group (light bar). Invertebrate groups with more than 40 organisms sampled showed an insignificant trend of fewer organisms in the experimental group.

The control group had an average of 28.2 ± 10.3 total organisms while the experimental group had a total of 16.8 ± 6.0. The control group had almost twice as many total organisms as the experimental group (Figure 2). This difference was significant (t = 2.52, d.f. = 14, p = .025).

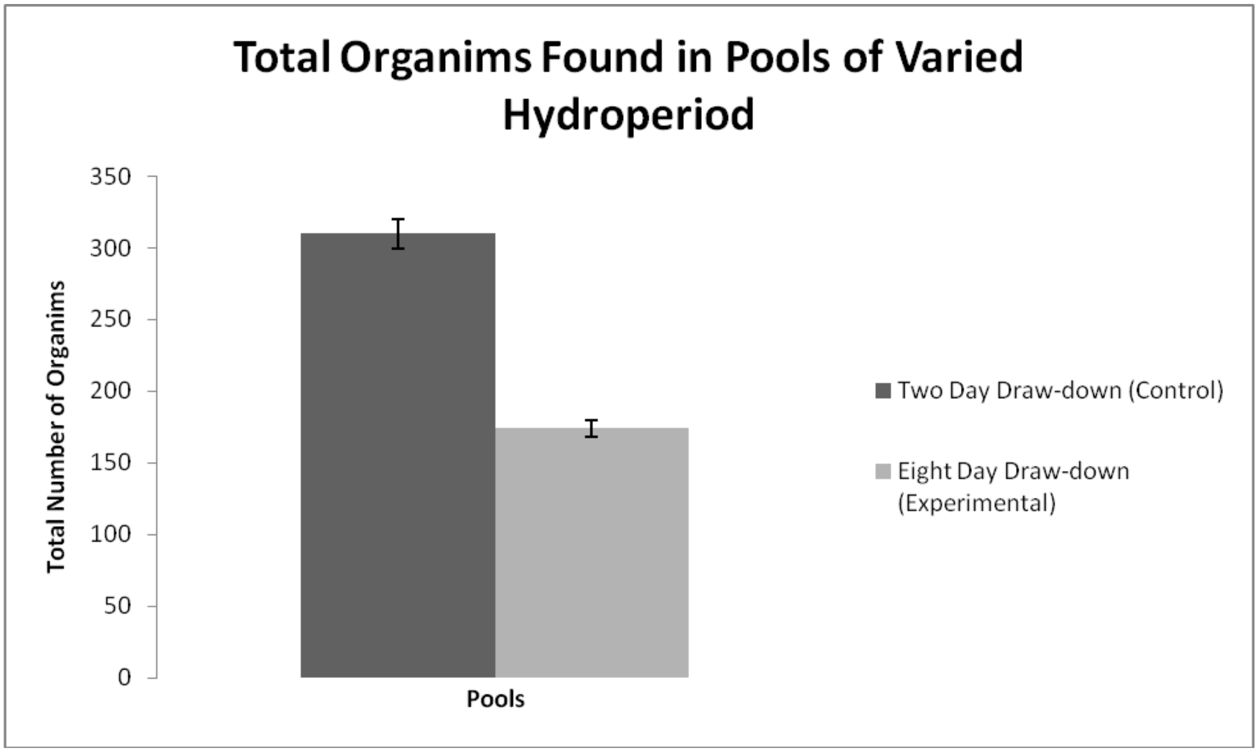

Figure 2. Average number and standard error of total number of organisms in the two day draw down control pools group (dark bar) and the eight day draw-down experimental pools group (light bar). The experimental had significantly fewer total organism (p = 0.025).

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The control group had an average species richness of 5.9 ± 2.17 while the experimental group had an average of 4.5 ± .92. This difference was not significant (t = 1.65, d.f = 14, p = .1) (Figure 3).

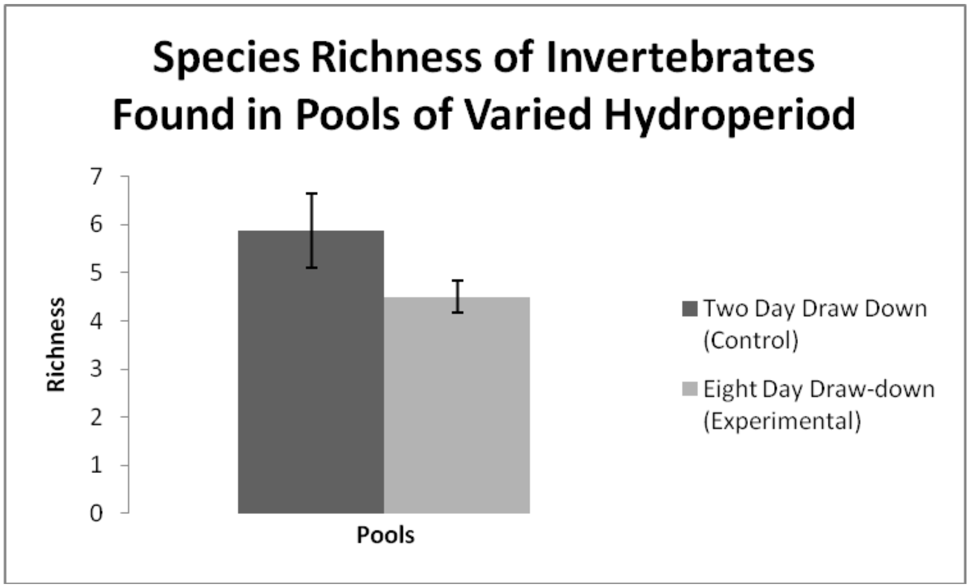

Figure 3. Average species richness and standard error in the two day draw down control pools group (dark bar) and the eight day draw-down experimental pools group (light bar). Richness was insignificantly less in the experimental group.

The control group had an average of 1.1 ± .12 on the Shannon-Wiener diversity index while the experimental group had an average of 1.5 ± .11 (Figure 4). This difference was not significant (t = 1.018, d.f. = 14, p = .3).

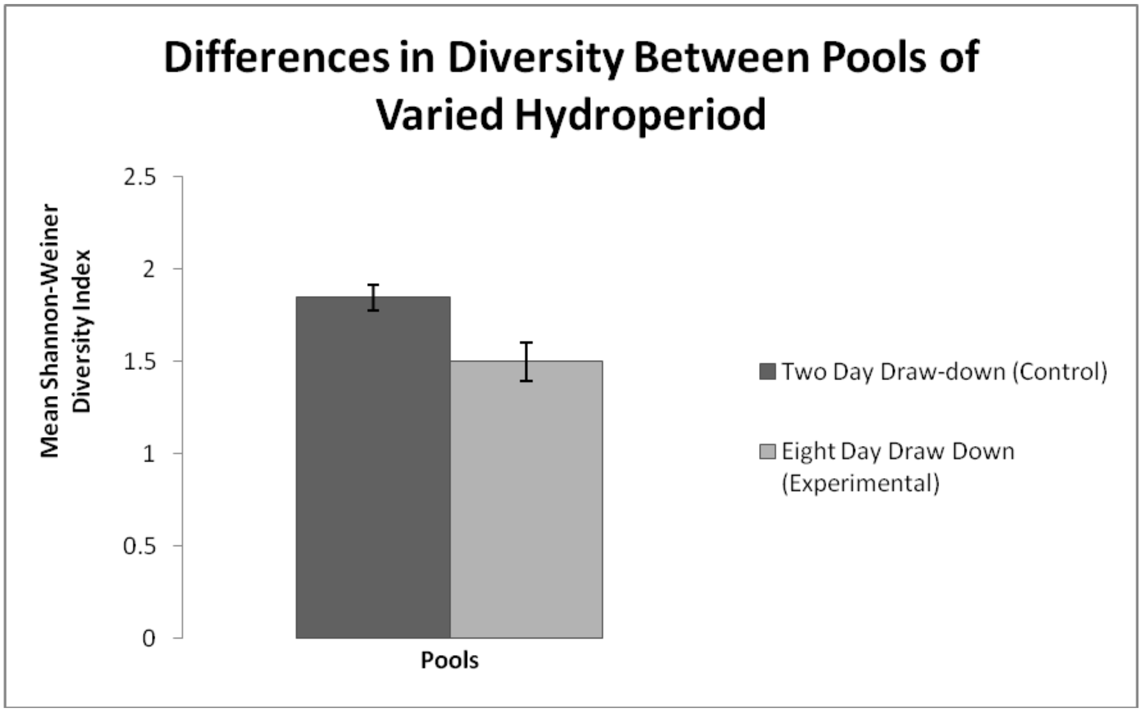

Figure 4. Average Shannon-Wiener index and standard error in the two day draw-down control pools group (dark bar) and the eight day draw-down experimental pools group (light bar). Biodiversity was insignificantly less in the experimental group.

Discussion

Seasonal woodland pools show a wide variation in their duration and amount of water present. The goal of this investigation was to examine the effect of drying down artificial seasonal woodland pools for a duration of days. Due to the method of removing water by pumping and continual rainfall during the investigation, the leaf litter in the artificial pools stayed damp. Therefore the results discussed model a system in which there are short hydroperiods followed by periods of no water, but still damp conditions (Figure 5).

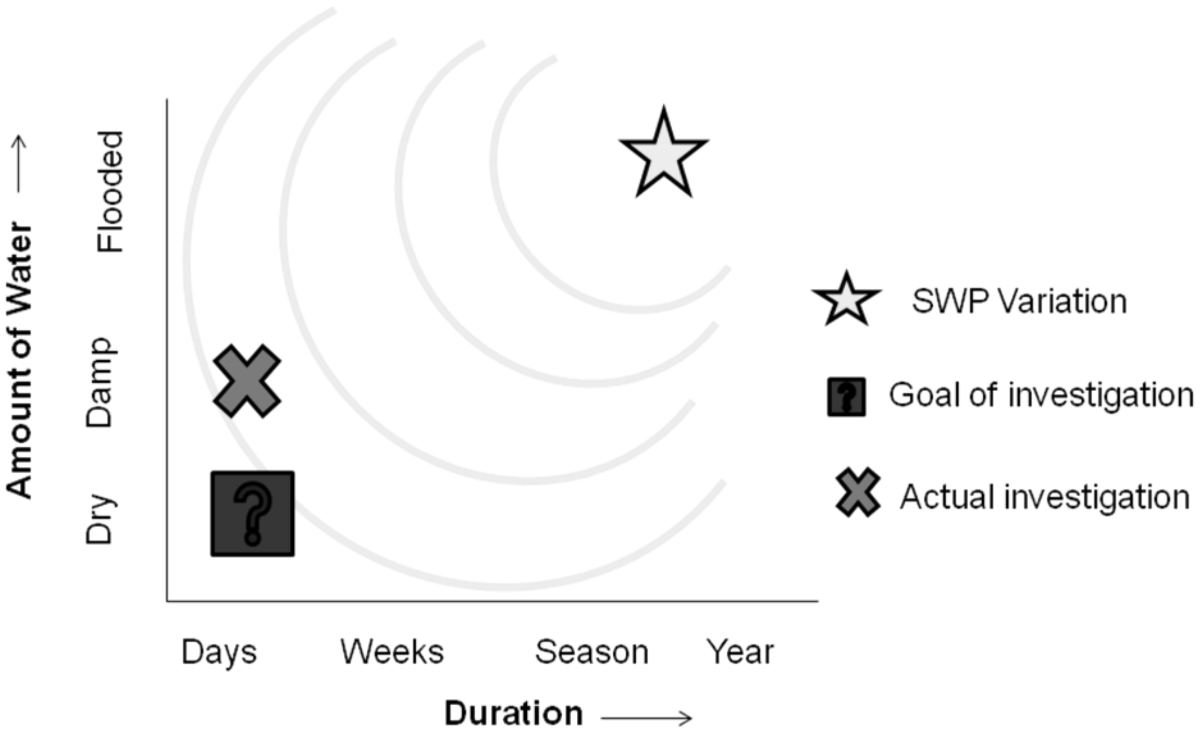

Figure 5. Seasonal woodland pools (SWP) show a wide variation in their duration and amount of water present (star and radiation). The goal of this investigation was to examine the effect of drying down artificial SWPs for a short duration (question mark). Due to the method of removing water by pumping and continual rainfall, the artificial pools stayed damp.

Abundance of individual organisms by invertebrate categories did not show any significant difference between the eight day draw-down (control) and two-day draw-down (experimental) groups. Of the eleven invertebrate categories present in the artificial pools, five categories had greater than 40 individuals. Although each of these categories had a high standard error, there was a trend showing that there were more organisms in the control group, while there were fewer organisms in the experimental group. There were 22% fewer copepods, 26% fewer mosquitoes, 34% fewer chironomids, 47% fewer naupliis, and 68% fewer rotifers in the experimental pools than in the control pools. This suggests that although these invertebrates can survive two eight day dry-down events, it does inhibit their ability to grow and reproduce. In short period ponds, species that are desiccation- resistant such as mosquitoes, copepods, daphnia, and rotifers have been shown to be more resilient in response to dry periods (Schneider, 1999). This is consistent with the findings in seasonal woodland ponds of Minnesota that the same taxa were dominant regardless of pool hydroperiod (Batzer, et al., 2004). Snails and clams both had more individuals in the experimental group than in the control group. These invertebrates were not detected until the third sampling, perhaps needing time to establish a population in the artificial pools. The increased number of snails and clams in the experimental pools may also be explained by their ability to enter an aestival phase. These organisms find refuge by burrowing into the sediment (in this case leaf litter) and becoming dormant during dry periods (Colburn, 2004). The removal of water from the artificial pools by pumping and the continual rainfall during the investigation caused the leaf litter to always be damp, providing a hospitable refuge for the snails and clams.

Abundance of total organisms did show a significant difference between the eight day draw-down (control) and two-day draw-down (experimental) groups. The control group had almost twice as many total organisms as the experimental group. This further supports that two eight day dry-down events can decrease the population numbers within a seasonal woodland pool invertebrate community. Species richness did not show a significant difference between the control and experimental groups, but there was a trend of less slightly less species richness in the experimental group. Previous studies have shown that reduced hydroperiod decreases both species abundance and richness. In seasonal forest ponds of varying hydroperiod in Massachusetts, the number of macroinvertebrate taxa has been shown to be fewer in pools of short hydroperiod and more in pools of longer hydroperiod (Brooks, 2000). Taxon richness decreased as average number of days flooded (shorter hydroperiods) decreased in 66 seasonal woodland ponds in Minnesota (Batzer, et al., 2004). High standard error and the low number of invertebrate categories that were seeded into the artificial pools may have contributed to the insignificant richness findings.

Although overall numbers changed significantly between the control and experimental groups, the eight day dry-down event did not appear to significantly change the overall community composition between the eight day draw-down (control) and two-day draw-down (experimental) groups. Community diversity was calculated with the Shannon-Weiner index and there was a slight trend of less biodiversity in the experimental pools. Once again, high standard error and the low number of invertebrate categories that were seeded into the artificial pools may have contributed to insignificant richness findings.

This study of seasonal woodland pools was unique in its attempt to use artificial pools as models that would allow direct manipulation of hydroperiod rather than observations of natural variation. Although the findings of this investigation were not significant, they did support the trend of less invertebrate abundance, richness, and biodiversity found in other investigations of natural seasonal woodland pools and may be useful for future study with the appropriate modifications. The results may have been affected by a number of factors in our methods that could be addressed in the future. Allowing ample time after seeding is necessary to ensure that the populations added to the artificial pools have acclimated themselves to the new habitat. In this investigation, the first dry-down event occurred only ten days after the invertebrates had been introduced, which may not have been ample time for them to establish stable populations. Ensuring that the artificial pool communities fully represent the invertebrates found in the local natural seasonal woodland pools is also essential for the model to be accurate. There were a number of invertebrate categories that were absent in the artificial pools that are commonly found in seasonal woodland pools, including: fairy shrimp, flatworms, annelids, beetles, caddisflies, mayflies, damselflies, dragonflies, midges, and water bugs (Wiggins, 1980; Colburn 2004).

Climate change in the Great Lakes predicts increased evaporation and more days of drought. The intent of this investigation was to mimic the predicted scenario and its possible effects on seasonal woodland pool invertebrate communities. The method of pumping water out of the pools and the continual rain did not allow the pools to ever become fully dry. However, even with the pools remaining damp, and the damp periods lasting less than a week, the investigation was still able to detect changes in the invertebrate community. It is plausible to assume that if seasonal woodland pools are subjected to more thorough drying and/or longer periods of drought, that reduced hydroperiods will have a much greater impact on the invertebrate community.

Even with the limitations of artificial pools, and while investigating seasonal woodland pools on the extreme end of their duration continuum, there was a trend that reduced hydroperiods can affect the abundance, richness, and biodiversity of seasonal woodland pool invertebrate communities. It is encouraging to note that because of the inherent variable nature of seasonal woodland pools, many of the organisms already possess adaptations to help them survive during dry periods. Climate change, however, may intensify these dry periods past the invertebrates' current threshold of tolerance. This investigation suggests that the variable nature of seasonal woodland pools supports the need for more research on how decreased hydroperiod may affect seasonal woodland pool invertebrate communities.

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