

(Draft copy of report to be published in the 2004 Annual Report of the Resource and Research Planning Division of Delaware Water Gap National Recreation Area)

The Phenology of Macroinvertebrate Communities in Ephemeral Wetland and the Effects of *Ambystoma* spp. Larval Predation in Delaware Water Gap National Recreation Area.

1. Introduction

Ephemeral ponds are isolated aquatic habitats characterized by a cycle of fall or spring inundation and a summer desiccation. The result is a temporally unstable aquatic environment without predators such as fish (Zedler, 2003).

Consequently many amphibian and invertebrate species have developed a unique relationship with these ponds. Amphibian species utilizing ephemeral ponds for breeding include: Jefferson's salamander (*Ambystoma jeffersonianum*), Spring Peepers (*Pseudacris crucifer*), wood frog (*Rana sylvatica*) grey tree frogs (*Hyla versicolor*), pine barrens tree frog (*Hyla andersonii*), and spotted salamander (*Ambystoma maculatum*) (Tesauro, Tiner, 2003). Lacking fish, ambystomid larvae are the top vertebrate predators (Freda, 1983). A diverse group of invertebrates also utilize ephemeral ponds. These taxa often possess certain life-history adaptations that allow them to take advantage of temporary pools (Brooks 2000). Since ambystomids are not always present in these ponds they represent habitat that can be used for a natural experiment to study predation on invertebrate communities.

Variation in vernal pond communities is tied to abiotic factors such as hydroperiod (Brooks 2000), but little is known about how much influence vertebrate predators have. Predator-prey interactions are often studied within the context of trophic relations and community control; the debate over top-down versus bottom-up control. Bottom-up proponents claim that higher trophic levels are controlled by primary productivity, whereas the top-down model holds that consumers and producers are governed by predation (Methratta 2004). The interplay of top-down versus bottom-up forces has been heavily studied in other aquatic systems (Hunter and Price 1992, Power 1992, Methratta 2004, Rosemond 1993), but Batzer (1992) notes that detritus based systems represent a different scenario. Environments such as marshes and ephemeral pools are thought to be rarely limited by resources (Batzer 1992), and therefore do not fit into the traditional trophic model of top-down or bottom-up.

This study had two goals. First, does any indication exist that communities are controlled by amphibian predatory pressure? I hypothesized this could be true if a decrease in abundance was correlated with larval maturation, ergo a decrease in abundance over time. Also I expected a decrease in the ratio of invertebrate predators to non-predator species, or at least a constant ratio, indicating that either competition with ambystomids, or direct predation suppressed populations.

The second aim of the study was to provide natural history data on ephemeral pond phenology.

To address these aims four ponds were selected, each representing a unique combination of habitat characteristics. Ponds were either open or closed canopy, and ambystomid larvae were either present or absent. Each site was sampled bimonthly, samples were then later identified. Using this abundance data, I sought to elucidate patterns within and between each site to determine the influence of salamander predation, and general pond phenology.

2. Study Area

The study area was determined using USGS Leetown Science Center (LSC) data collected on vernal ponds within park boundaries (Snyder, *personal communication*). Data included ambystomid presence data, pond type, vegetation type, topography, and location. Sites were selected that represented each of the four pond types and then visited in March 2004 to determine their feasibility. Because of time constraints, ponds needed to be small, allowing for adequate sampling, while other considerations included ease of access, and the number of ambystomid found at each.

I. 810 – High ambystomid count, closed canopy

This site was located on the southern tip of Pompey Ridge off the southern end of Old Mine Rd. It is part of a series of vernal ponds that run along the top of the ridge. It is surrounded by an Oak and Hemlock forest, and fed by a stream running down the ridge. It remained full throughout the duration of the study. Its benthic material was characterized by a layer of leaf-litter and a deep layer of mud approximately 40 – 50 cm deep. By April 7th Duckweed (*Lemna minor*) had begun to cover the pond, and by April 28th the pond was totally covered. Wood ducks were observed using the pond, and bullfrog tadpoles and bullfrogs were also found at the site. Eighteen ambystomid (most likely *Ambystoma maculatum*) egg masses were counted, and hatched in between April 28th and May 7th. Wood frogs tadpoles were also common and had metamorphosed by the June 9th visit.

II. 758 – High ambystomid count, open canopy.

This site was a deep depression in the middle of an open field area with a scattering of red cedars around it. It was the deepest of the ponds, but by June 23rd was totally dry. The benthos was characterized by a thin layer of mud, and was covered by submerged aquatic vegetation. The pond contained more than a hundred wood frog egg masses, which hatched by April 7th and most had metamorphosed by June 9th. Only 10 spotted salamander egg masses were found, and no larvae were found until May 27th.

III. 277 – No ambystomid larva, closed canopy.

This site was a small depression on a plateau the bottom of a steep slope off Route 209, in between the road and the Delaware River. The benthic material consisted of a layer of leaves and a thin layer of mud before reaching hard soil. It was located in a heavily shaded stand of red maples and dense shrubbery. It had the shortest hydroperiod of any site, and was dry by June 9th. Wood frog egg masses were not found until April 7th, tadpoles had legs by May 28th, but it is unknown if the wood frogs successfully metamorphosed.

IV. 3016 – No ambystomid larva, open canopy.

3016 was characterized by a series of contiguous depressions in a field that formed a large marshy area with islands of grass and sedge. It contained a benthos of mostly dead grass and a 10 – 15 cm layer of mud. Painted turtles were observed in the site and most wood frog tadpoles were found in the western end of the wetland. Tadpoles hatched by April 28th, and fully metamorphosed by June 9th.

3. Materials and Methods

I. Field Collection

Each site was visited and sampled on the same day every other week from March 25th until June 25th. These dates represent the first day of ice out, and total dessication of two of the sites. At each site three composite samples were collected. Composite samples were made by pooling three one meter long D-Frame net sweeps of benthos in a plastic bin. Composite sample were then sorted and picked with tweezers for all invertebrates for ten minutes of effort. As each organism was found, it was put into a labeled collection vial with a 90% ethyl alcohol solution. Ten minutes of effort was chosen because it allowed enough time to sufficiently search each sample while not creating a cumbersome volume of specimens. At the end of sampling at each site, physical data was collected using a YSI Dissolved Oxygen Meter, a YSI30 Specific Conductance meter, and a pHTestr2 by Oaktron. Each meter was calibrated in the morning before sampling with standard solutions. Depth was measured by selecting the deepest point in a pond, and then measuring with a stick from the top of the substrate to the surface. The stick was marked at each site, and then measured using a measuring tape.

II. Laboratory Identification.

Samples were identified in the order they were collected in. Before identification began, each sample was drained, and then placed in a beaker with a fresh 70% ethyl alcohol solution, and its field container was rinsed and cleaned, and refilled with 70% ethyl alcohol. Each sample was keyed out to the lowest taxonomic level possible using a Zeiss .08x to 4x dissecting microscope. As each sample was identified, it was entered into a table recording the abundance of each taxa. The primary key used was Peckcharsky et. al (1990), and a secondary key used was Merritt and Cummins (1996). Microcrustaceans and annelid worms were excluded from the study due to lack of the proper chemicals or equipment for identification.

Data Analysis

The three samples taken on each sampling date for each site were pooled to make a single combined sample for that date. Each genus was also assigned a functional feeding group designation based on the EPA's classification used in its Rapid Bioassessment Protocols, of either gatherer/collector, filter/collector, scraper, shredder, or predator (Barbour, Gerritsen, Snyder and Stribling. 1999, Merritt and Cummins, 1996). Shannon-Weiner diversity indices were calculated for each sample, as well as Sorensen's similarity quotient, and Bray-Curtis similarity index. An explanation of these indices, and the formulas used can be found in Appendix B.

4. Results

I. Between Site Comparison

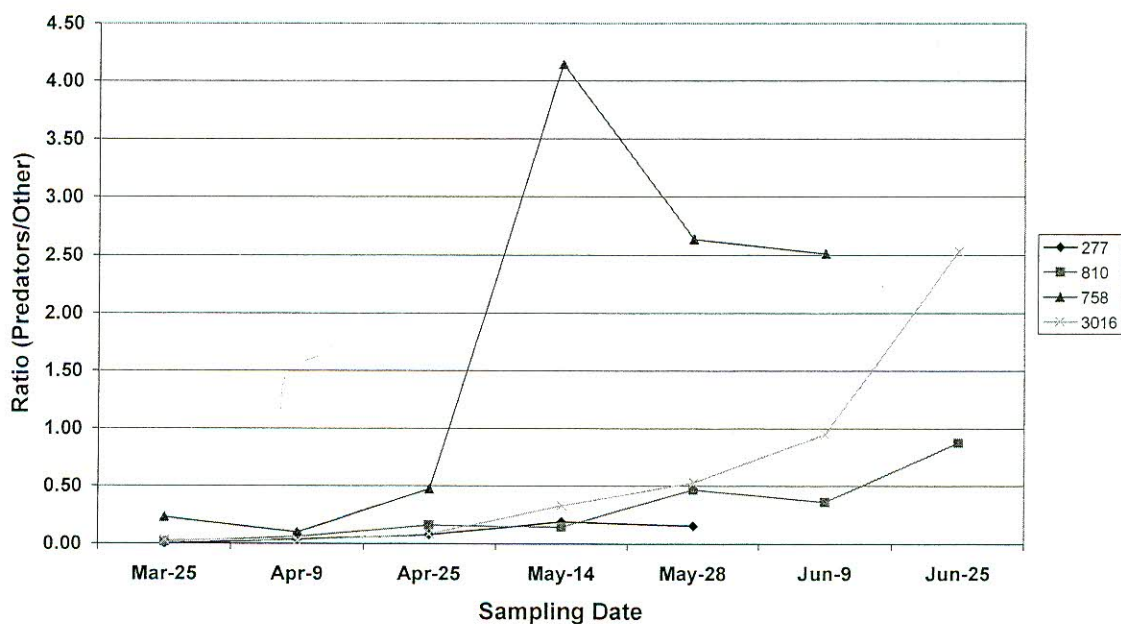
Three of the sites had similar physical characteristics. Sites 810, 277, and 3016 all had similar pH and dissolved oxygen levels. All three had large inputs of allochthonous detritus, whereas site 758 was deep and open, with submerged aquatic vegetation spread across the pond floor (Table 1).

Table 1.
2004 Seasonal Means of Physical Vernal Pond Data

Site	Depth (cm)	Air Temp (C°)	Water Temp (C°)	pH	Dissolved Oxygen (mg/L)	Conductivity (µmhos/cm)
810	55.67	19.35	14.22	5.98	3.54	55.52
758	100.92	20.33	21.38	8.32	11.27	179.35
277	35.35	18	15.65	6.05	3.03	109.56
3016	37.748	22	17.02	6.26	1.72	201.72

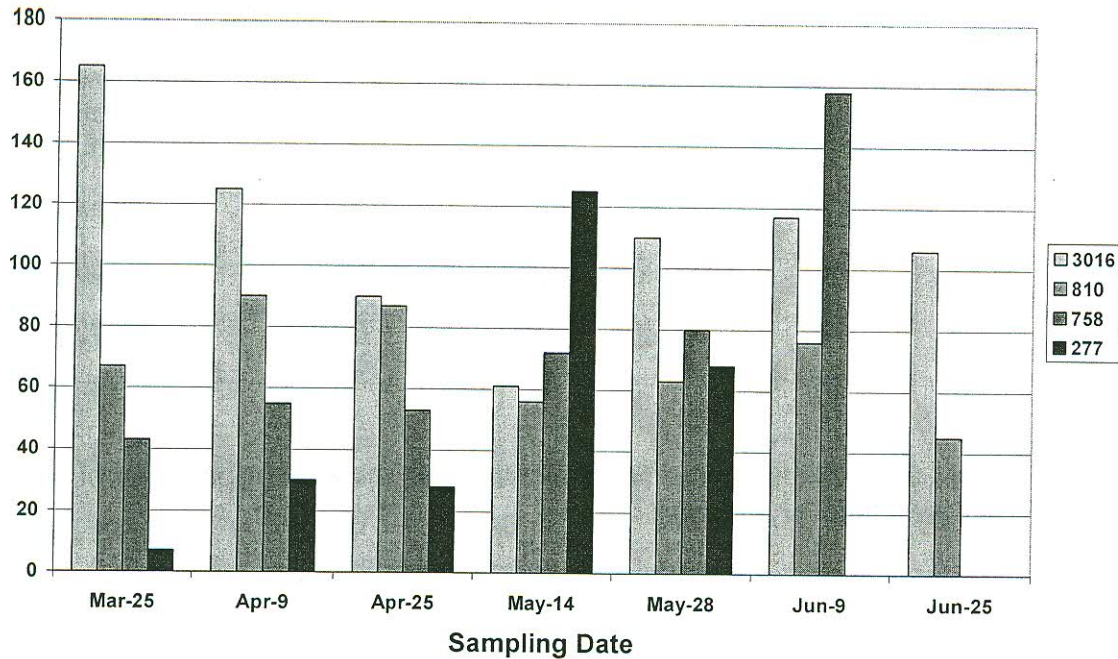
Similar trophic relationships were found between all the sites regardless of ambystomid presence or absence.

Figure 1. Ratio of Predators to all Other Trophic Classification at Each Sampling Date



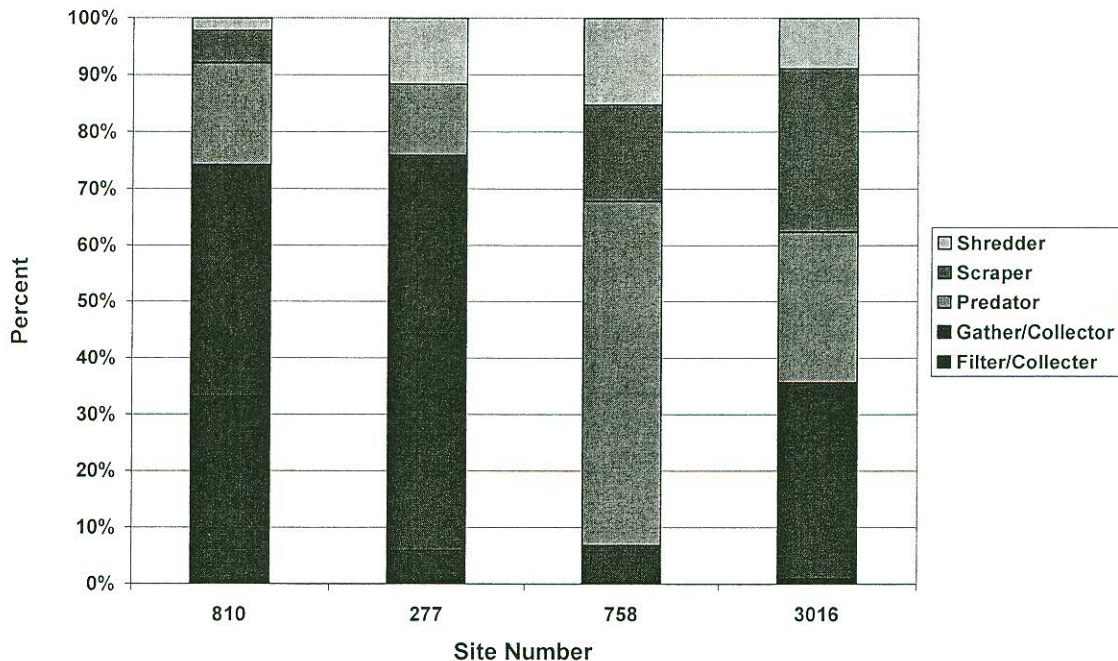
The ratio of predators to all other functional feeding groups increased with each sample taken (Figure 1).

Figure 2. Abundance at Each Sampling Date



Abundance data in Figure 2 displays a bimodal distribution for sites 810 and 3016, while 758 and 277 showed a steady increase.

Figure 3. Overall Feeding Group Composition at Each Site



A breakdown of each site by functional feeding groups in reveals strong similarities between sites 277 and 810, both with high numbers of collectors, and a low number of predators (Figure 3). Site 758 had a high number of predators, and 3016 represented an intermediate, with the most even distribution of feeding groups.

Site 3016, with an open habitat, and a long hydroperiod also had the greatest species richness and abundance (Table 2).

Table 2. Taxa Abundance, Richness and Diversity for Each Site

	810	758	3016	277
Abundance	484	461	774	258
Richness	28	41	57	11
Shannon-Weiner Diversity	2.72	3.99	3.92	1.74

The distribution of taxa richness among different orders was almost uniform in relative proportions across all sites (Table 3).

Table 3. Taxa Richness in by Order for Each Site

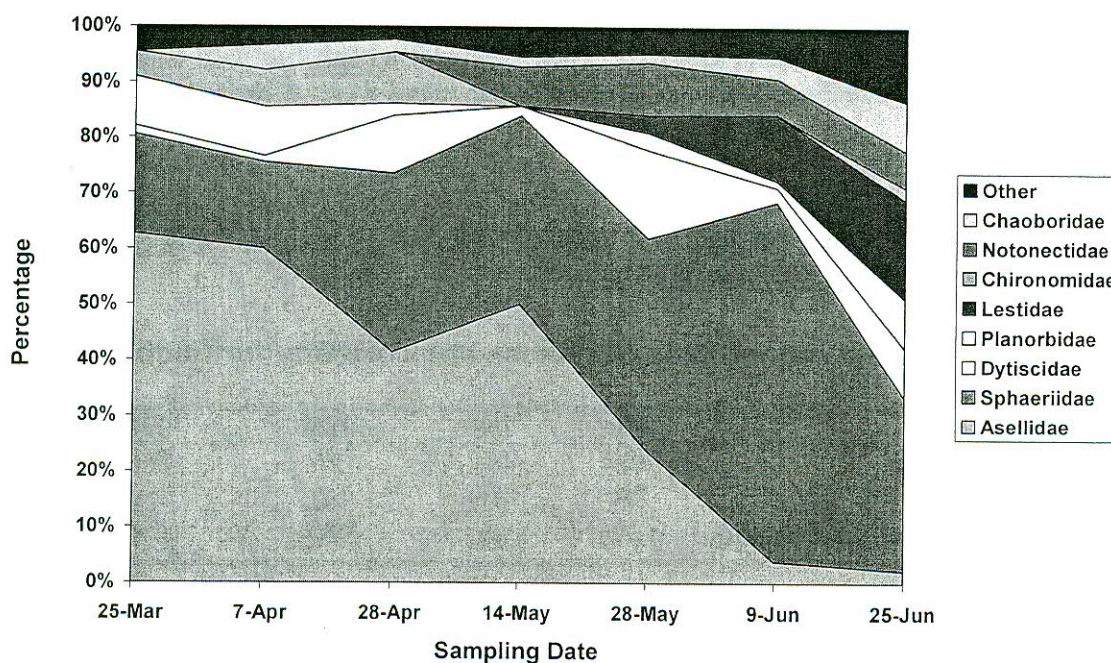
	758	810	3016	277
Coleoptera	15	11	26	4
Odonata	6	5	7	0
Diptera	5	2	7	3
Hemiptera	7	2	6	1
Basommatophora	2	6	5	0
Tricoptera	2	2	2	2
Acariformes	1	1	3	0
Ephemeroptera	1	0	3	0

In all of the sites, Coleoptera had the greatest richness. Odonata, Diptera, and Hemiptera, all had richness levels which were reasonably similar to each other. The two ponds with the longest hydroperiods also saw the greatest richness in Basommatophora.

I. **810 – High ambystomid count, closed canopy**

The large amount of detritus found in 810 is reflect a population that is overall dominated by collectors.

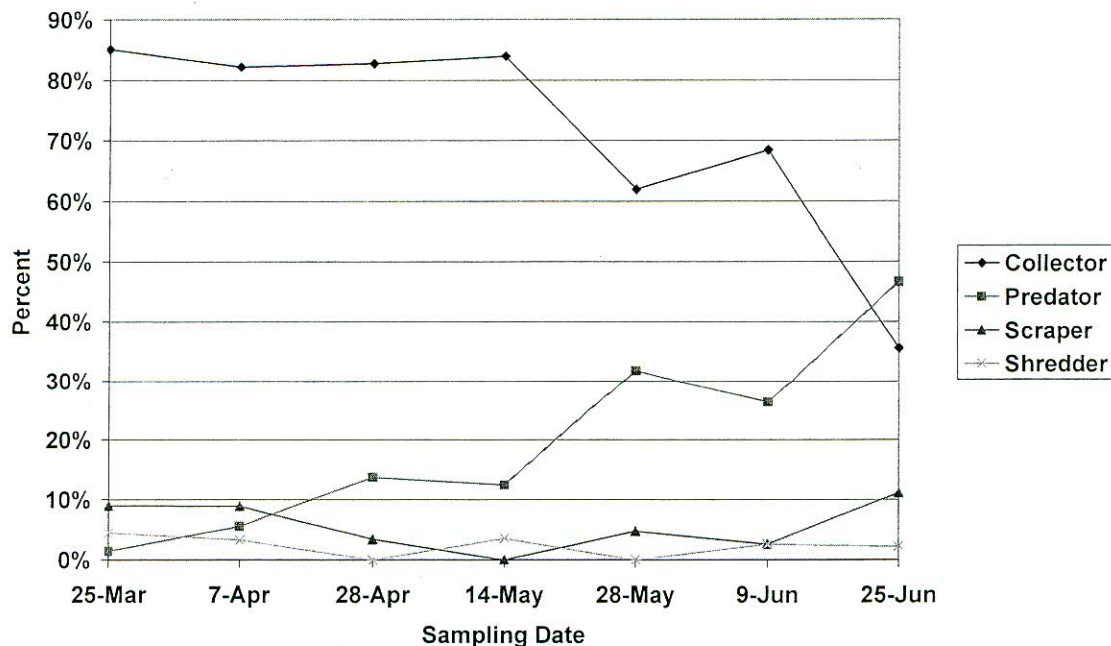
Figure 4. Site 810 Percent Composition by Family



The two families representative of collectors consistently made up at least 60% of the total population (Figure 4). While this figure shows site composition by family over time, the two largest families were represented by only a single taxa each: in *Asellidae* the genus *Caecidotea*, and in *Sphaeriidae*, the genus

Musculium. Overall individuals from these two taxa represented 70% of the total organisms found. The isopod *Caecidotea* had a high abundance from the first sample, but numbers quickly decreased during each successive sampling date, while the fingernail clam *Musculium* kept relatively steady numbers throughout the study period. This site also showed the least amount of drying, and on the last sampling date of June 25th, it was by far the most full, that combined with the presence of bullfrog tadpoles indicate that it may not dry out every year.

Figure 5. Site 810 Functional Feeding Group Composition

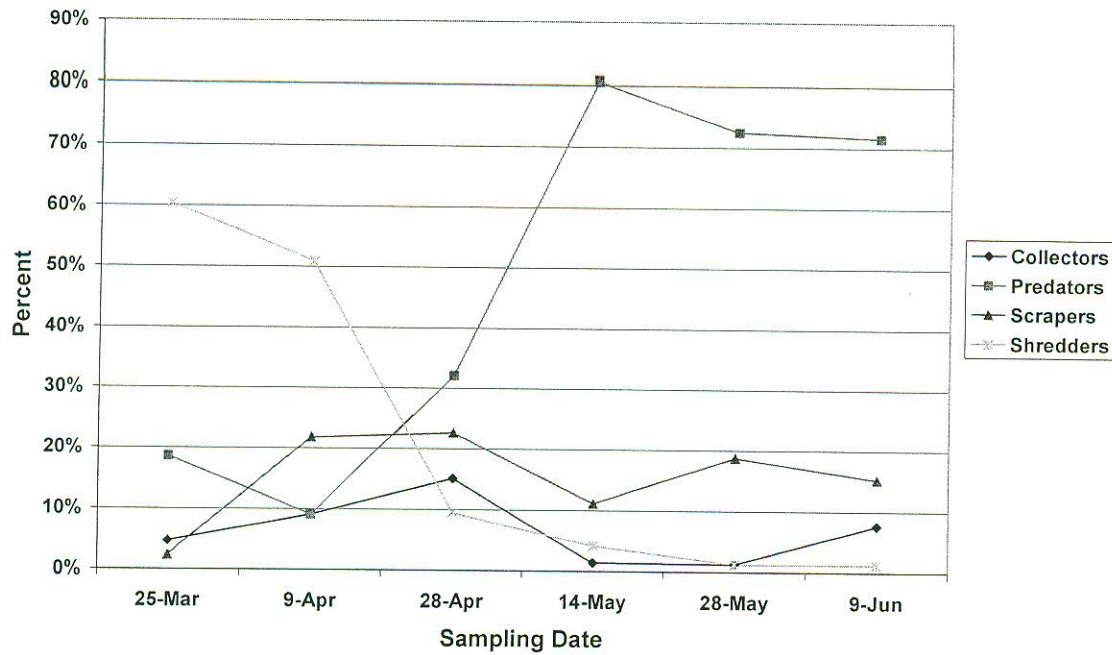


There was an inverse relationship between collectors and predators, though collectors as a group remained dominant until on the last sampling date (Figure 5). Also this decline in collectors correlates to the decline in isopods in Figure 4.

II. 758 – High ambystomid count, open canopy.

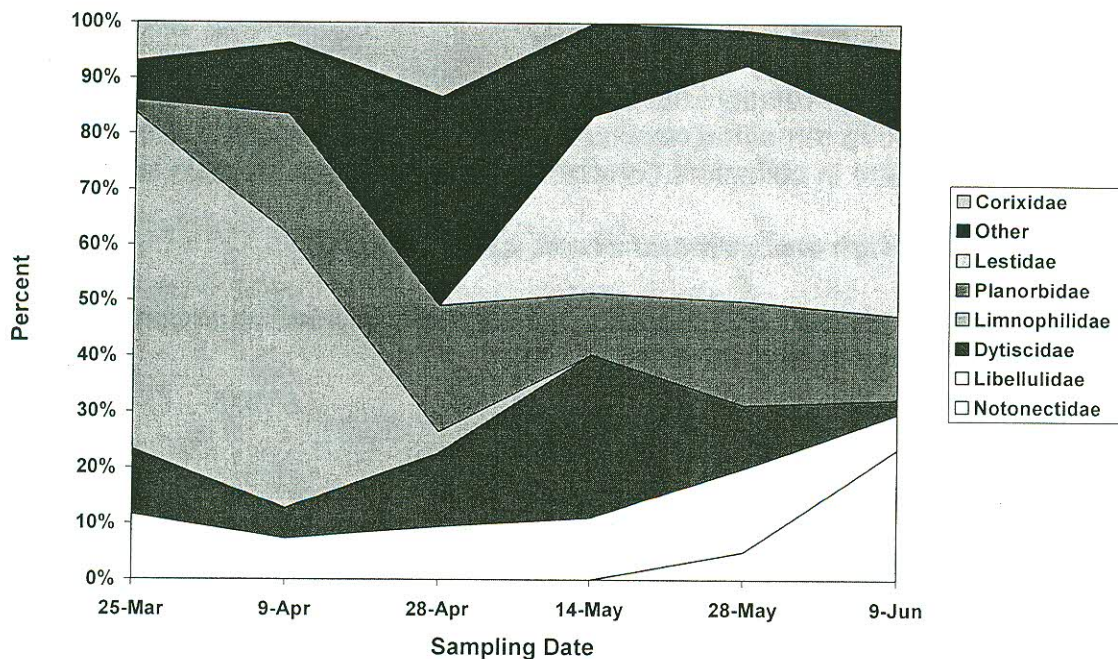
Site 758 was the deepest of the ponds, but surprisingly dried up second fastest, with a last sampling date of June 9th.

Figure 6. Site 758 Functional Feeding Composition



It was also the only site with submerged aquatic vegetation initially had a large population of shredders (Figure 6). As this population declined, there was also a sharp increase in predators.

Figure 7. Site 758 Percent Composition By Family

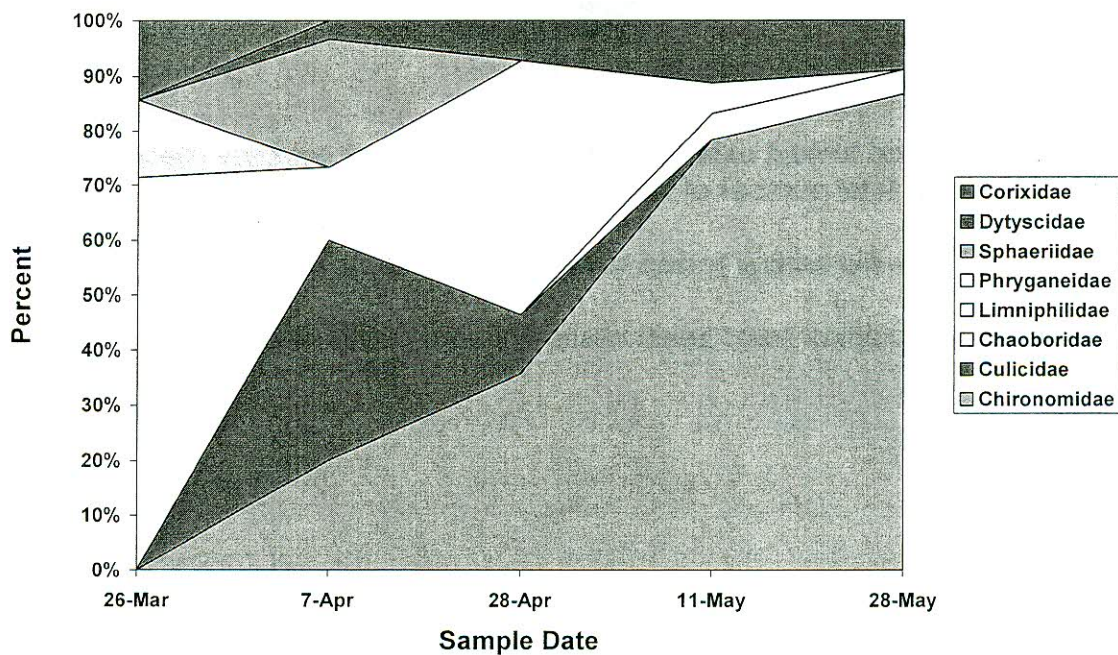


Comparing Figure 6 with Figure 7, one can see the relationship between the decline of collectors and the decline of the caddisfly family *Limnephilidae*, and the rise in predators with the rise in the damsel fly family *Lestidae*. Again this sharp decline in collectors, and corresponding increase in predators is the result of single taxa. By the last sampling date of June 9th, almost no water remained in the pond, and organisms that had previously used the partially submerged grass at the ponds edges for cover could no longer do so, resulting in a high density of individuals at the center of the puddle that remained. This most likely explains the sudden increase in the genus of backswimmer, *Notonecta*. This site is also the only location where fairy shrimp were found.

III. 277 – *No ambystomid larva, closed canopy.*

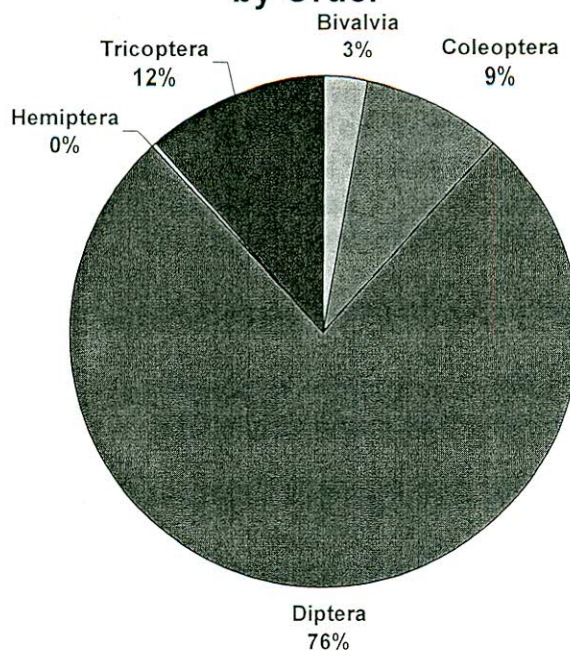
With the shortest hydroperiod, it was dry by the June 9th sampling date, the lowest diversity of organisms was found at this site.

Figure 8. Site 210 Percent Composition By Family



Early on it was dominated by caddisflies in the family *Limnephilidae*, but this is misleading since only seven individuals were collected during the first sampling (Figure 8). Soon it was heavily populated by dipteran larva in *Culicidae* and *Chironomidae*.

**Figure 9. Site 277 Percentage of Total Abundance
by Order**



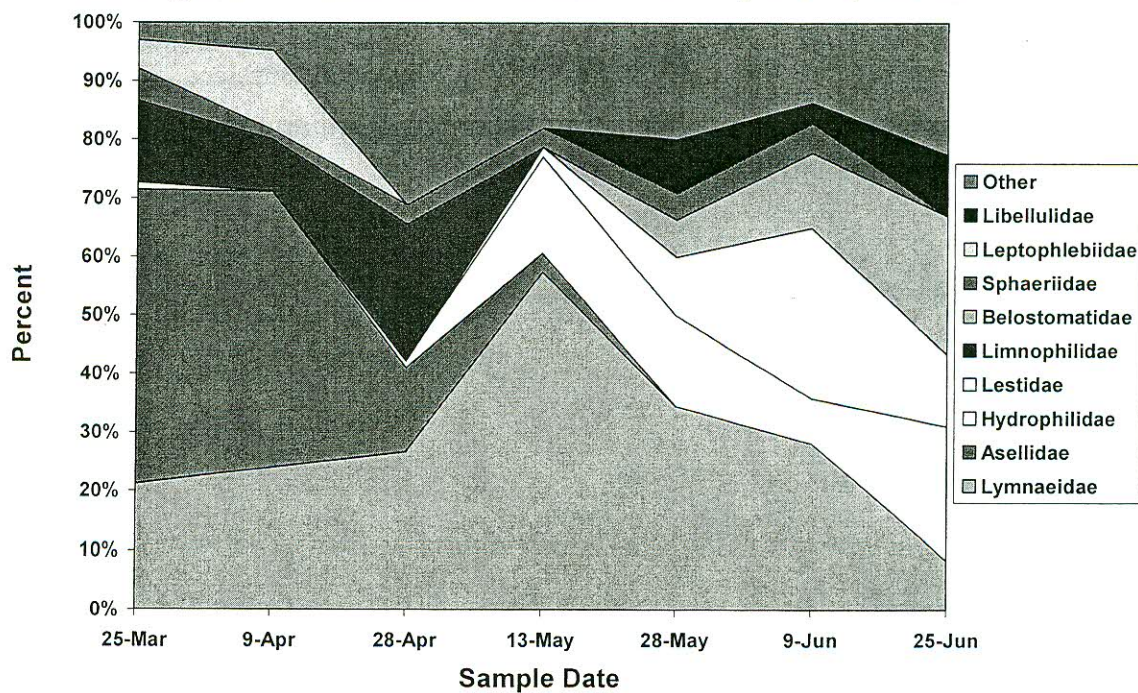
This site was used almost exclusively by Dipterans, and they made up more than 75% of the total number of taxa found (Figure 9).

IV. 3016 – No ambystomid larva, open canopy.

The same phenological trend seen in site 758 and 810 is observed here as well.

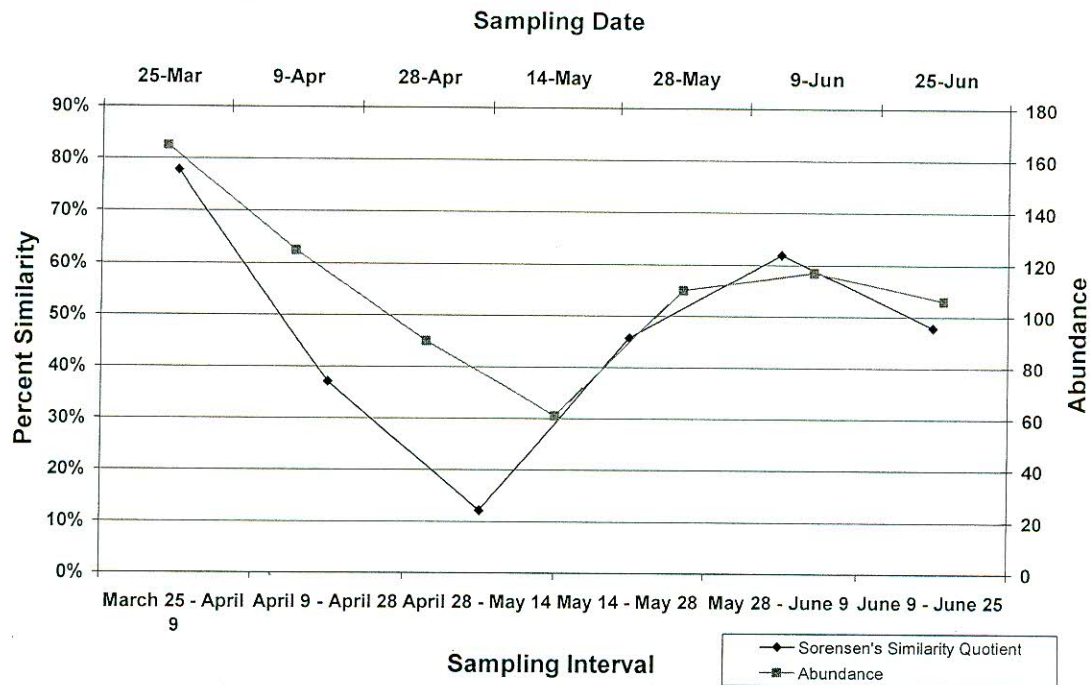
Sampling Date	Collector (%)	Predator (%)	Scraper (%)	Shredder (%)
25-Mar	60	3	21	15
9-Apr	62	2	25	10
28-Apr	39	8	28	23
13-May	8	24	59	4
28-May	20	31	31	1
9-Jun	10	48	35	1
25-Jun	13	71	8	0

Figure 11. Site 3016 Percent Family Composition



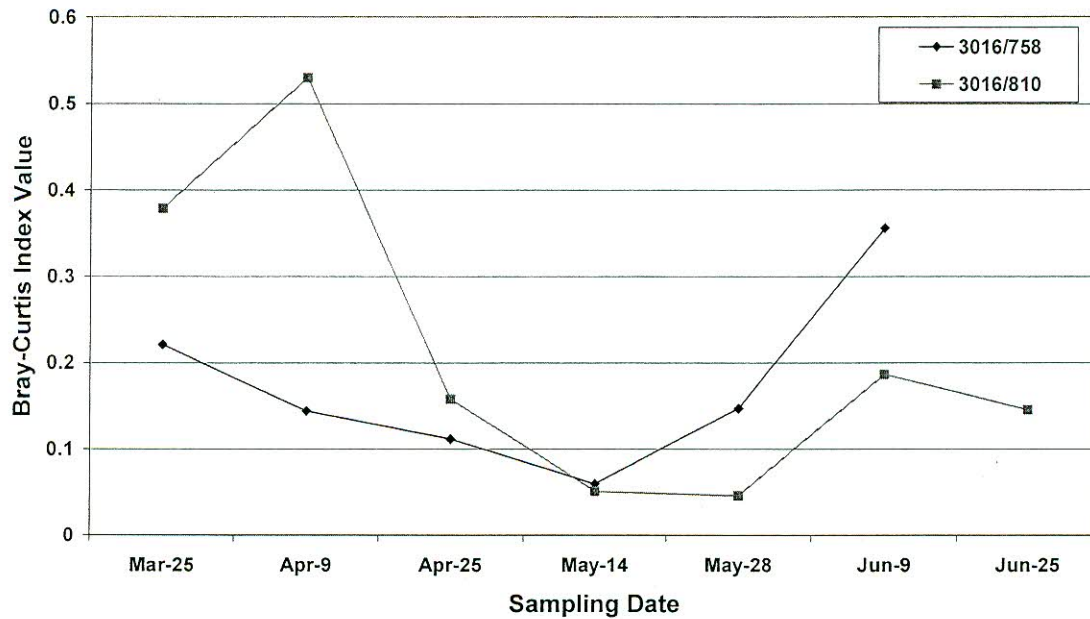
This decline corresponds to the trends in family composition (Figure 11). A decline in the collector, the isopod *Caecidotea* (family *Asellidae*), and shredder *Limnephilus* (family *Limnephilidae*), ends at the same time most predator species begin to arrive, represented by the families *Lestidae*, *Belostomatidae*, and *Libellulidae*. By May 28th sampling date though, barely macroscopic isopods began to appear at the site, presumably the progeny of the generation that had declined during the spring. Also, site 3016 consistently had the highest levels of diversity, as well as having the highest abundance and richness.

Figure 12. Sorensen's Similarity And Abundance



Another phenomenon observed was a correlation between abundance and similarity between each sampling date (Figure 12).

Figure 13. Bray-Curtis Similarity Index Comparing Sites 3016 and 758 and Sites 3016 and 810



This site represented a pond that was open and grassy, but contained large amounts of detritus. Bray-Curtis similarity values for 3016 compared to sites 758 and 810 were calculated at each sampling date (Figure 13). An initial high similarity to site 810 is seen, but as the season progresses a shift in similarity occurs. This again corresponds to the shifts in family composition and functional feeding groups, seen in Figures 11 and 12.

5. Discussion.

I. The effect of salamander larva on invertebrate populations.

Salamander predation had negligible effects on the macroinvertebrate population. Freda (1983) found that larval *Ambystoma maculatum* preyed exclusively on cladocerans and copepods during early development, and then diversified as they matured, consuming isopods, odonates, and coleopterans. Therefore predator populations would have been expected to decline towards the end of each ponds cycle as larval salamander hatched and matured. The expected decline could have been the result of direct predation or competition. Instead a constant rise in predator populations was seen. An overall decline in abundance was not seen either, instead it steadily increased in site 758, which had ambystomid larva. No measure of ambystomid density was taken though, and it is impossible to know just how many larvae actually matured, and what densities were actually competing and predating in each site.

II. Pond phenology

Ponds all displayed similar phenology except site 277. Phenology was characterized by an initially high population of primary consumers, either shredders or collectors, followed by a steady decline in those feeding group members, and a subsequent increase in predators. The transition occurred between the April 28th date and the May 14th date, and is clear not just in figures showing functional feeding groups, but also in the family composition. In fact, there is almost no overlap between the major primary consumer taxa and predators, indicating that the corresponding decline and rise are not the result of predation, but differential life-history adaptations. This pattern of succession is most clear in the two open sites, 3016 and 758.

The two taxa that are most well represented in the early stages of the ponds are the caddisfly *Limnephilus spp.*, and the isopod *Caecidotea spp.* Wissinger et al. (1996) noted that caddisflies will lay their eggs at the end of the summer in an autumnal basin, and then the eggs will hatch during fall inundation and overwinter. This would explain high presence of *Limnephilus spp.* immediately after ice out. In fact, some were found during initial sampling efforts in early March when I broke through ice to take samples. Many of the ephemeral ponds within the park are autumnal (Snyder, personal communication), so the presence of overwintering individuals is not surprising. *Caecidotea spp.* most likely overwinter as well given their steep population decline by early summer and the appearance of larval isopods observed in June. The trend of overwintering primary consumers emerging or completing their life cycle before the arrival of predators indicates that perhaps these individuals have evolved life histories to take advantage of the predator free period in these ephemeral habitats.

Community structure seems organized by pond hydroperiod, surrounding landscape features, and initial resource availability. The influence of hydroperiod can be seen in site 277. The large population of two Dipteran families, *Culicidae* and *Chironomidae* and few other organisms, is likely the result of the pond's short hydroperiod. This has been the case when hydroperiod has been studied in other ephemeral wetlands as well (Brooks, 2000). All the other ponds which had correspondingly longer hydroperiods followed similar phenological trends. In the ponds with more similar hydroperiods, surrounding landscape features and initial resource availability were the determining factors. Previous studies have had similar results, such as de Szalay and Resh (2000) finding that different emergent vegetation composition in seasonal marshes effected community assembly. Site 758, with high primary productivity in the form of submerged aquatic vegetation had a markedly different community than either 3016 or 810 with large amounts of detritus. As time progressed, and the communities changed, the variable driving successional patterns appeared to be landscape variables. Both 758 and 3016 were in fields, with a tall grass perimeter, and after May 14th nymphs and larva of *Belostomatidae*, *Lestidae*, and *Libellulidae* became common. Meanwhile, site 810 had far fewer representatives from these groups.

Evidence of the influence of these two factors acting on the three sites is most easily seen on Figure 13. Bray-Curtis similarity was calculated between all the sites at each sampling date. Site 3016 and 810 are initially quite similar, and as they both approach May 14th, similarity declines, at that date, site 758 and 3016 become more similar, and that increases until 758 dries up on June 9th. The May 14th sampling date represents the transition period when primary consumers complete their life cycle, and predator larva or nymphs begin to appear.

There was no indication that ambystomid presence effected a given ponds community structure. Hydroperiod played a large role in community assembly, especially evident in the low diversity and Dipteran dominance in site 277. Many of the predator taxa are univoltine (Merritt and Cummins, 1996), and oviposit during the summer and have overwintering eggs, if ponds have a short hydroperiod they will not be filled when egg laying occurs, and taxa will be absent the following season. Ponds of similar hydroperiod followed similar phenology, with the initial community determined by resource availability, followed by a successional pattern controlled by landscape features. Interacting with these abiotic factors was organism life history, with primary consumers maturing or completing their life cycle before they are vulnerable to predation. Butler (1984) points out that attributing seasonal variation in emergence to competitive interactions is problematic when based solely on observations of coincidental timing. Yet, the synchronization of predator and consumer appearances within each site regardless of differences in physical characteristics points to the possibility of a causal relationship. Further research is needed in order to provide quantitative information regarding the initial conclusions of this report. With a larger sample size and controlled variables, Some future questions might be: how much influence surrounding habitat has on community assembly versus the type of resources available in the ponds and how does year to year variation in pond hydroperiod affect community assembly? Also, is there a causal relationship between the timing of consumer emergence and predator larval and nymphal maturation? Only with further controlled study and larger sample size could these questions be answered.

Acknowledgements.

I'd like to thank Rich Evans for his tireless patience with all of my questions no matter how inane, Al Ambler for allowing me the time and freedom to conduct this work, Craig Snyder for providing the initial data sets on vernal ponds in the park, and everyone else at the Delaware Water Gap R&RP office who was kind enough to listen to my animated discussions about the project and help me with editing this report.

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Appendix A.

Raw Abundance Data

810 – High ambystomid count, closed canopy

Order	Family	Genus	25-Mar	7-Apr	28-Apr	14-May	28-May	9-Jun	25-Jun	Total
Acariformes	Hydryphantidae	Hydryphantes				1				1
Basommatophora	Lymnaeidae	Pseudosuccinea columnella			1		1			2
Basommatophora	Lymnaeidae	Radix auricularia						1		1
Basommatophora	Physidae								1	1
Basommatophora	Planorbidae	Planorbella trivolis group	6	8	2		2	1	2	21
Basommatophora	Planorbidae	Promenetus exacuus							2	2
Coleoptera	Dytiscidae	Acilius					1			1
Coleoptera	Dytiscidae	Agabus							1	1
Coleoptera	Dytiscidae	Deronectes					1			1
Coleoptera	Dytiscidae	Dytiscus	1		1	1	2	1	3	9
Coleoptera	Dytiscidae	Hydroporus		1	9		1			11
Coleoptera	Dytiscidae	Laccophilus					5			5
Coleoptera	Dytiscidae	Matus						1		1
Coleoptera	Halplidae	Peltodytes						1	1	2
Coleoptera	Hydrophilidae	Cymbiodyta							2	2
Diptera	Chaoboridae	Chaoborus		4	2	1	1	3	4	15
Diptera	Chironomidae		3	6	8				1	18
Hemiptera	Belostomatidae	Belostoma						1		1
Hemiptera	Notonectidae	Notonecta				4	6	5	3	18
Isopoda	Asellidae	Caecidotea	42	54	36	28	15	3	1	179
Odonata	Aeshnidae	Aeshna					1		1	2
Odonata	Lestidae	Lestes					2	9	8	19
Odonata	Libellulidae	Leucorrhinia					1			1
Odonata	Libellulidae	Sympetrum							1	1
Tricoptera	Limnophilidae	Limnophilus				2		1		3
Tricoptera	Phryganeidae	Ptilostomis	3	3						6
Veneroida	Sphaeriidae	Musculium	12	14	28	19	24	49	14	160
Abundance			67	90	87	56	63	76	45	484
Richness			6	7	8	7	14	12	15	27
Shannon-Wiener Index			1.67	1.87	2.11	1.78	2.77	1.97	3.25	2.72
Dominance			0.44	0.40	0.30	0.37	0.22	0.44	0.15	0.25

758 – High ambystomid count, open canopy.

Order	Family	Genus	25 – Mar	9 – Apr	28 – Apr	14 – May	28 – May	9 – Jun	Totals
Acariformes	Hydrachnidae	Hydrachna				1			1
Anostraca	Chirocephalidae	Eubbranchipus			1				1
Basommatophora	Planorbidae	Gyraulus		2				8	10
Basommatophora	Planorbidae	Planorbella trivolis group	1	10	12	8	15	16	62
Coleoptera	Dytiscidae	Acilius				4			4
Coleoptera	Dytiscidae	Agabus	4		3	1			8
Coleoptera	Dytiscidae	Coptotomus		1	1	5	1	4	12
Coleoptera	Dytiscidae	Deronectes		2		1	3		6
Coleoptera	Dytiscidae	Dytiscus			1	3			4
Coleoptera	Dytiscidae	Hydroporus				2			2
Coleoptera	Dytiscidae	Ilybius			1				1
Coleoptera	Dytiscidae	Laccophilus				5			5
Coleoptera	Dytiscidae	Laccornis	1		1				2
Coleoptera	Dytiscidae	Liodessus					1		1
Coleoptera	Dytiscidae	Rhantus					4		4
Coleoptera	Gyrinidae	Dineutus			1				1
Coleoptera	Halplidae	Peltodytes		1	3		1	2	7
Coleoptera	Hydrophilidae	Berosus			2	3		2	7
Coleoptera	Hydrophilidae	Tropisternus						1	1
Diptera	Ceratopogonidae	Probezzia			1				1
Diptera	Chaoboridae	Chaoborus		1		1	1		3
Diptera	Chironomidae		2	4	7				13
Diptera	Culicidae	Aedes			1				1
Diptera	Stratiomyidae	Odontomyia				1			1
Ephemeroptera	Baetidae	Callibaetis					1	12	13
Hemiptera	Belostomidae	Belostoma				2	1	3	6
Hemiptera	Corixidae	Callicorixa	1						1
Hemiptera	Corixidae	Hesperocorixa	2	2	6		1	7	18
Hemiptera	Corixidae	Sigara			1				1
Hemiptera	Gerridae	Gerris						2	2
Hemiptera	Naucoridae	Pelocoris						1	1
Hemiptera	Notonectidae	Notonecta					4	37	41
Isopoda	Asellidae	Caecidotea		1					1
Odonata	Coenagrionidae	Enallagma	1		4		1		6
Odonata	Coenagrionidae	Nehalennia				1			1
Odonata	Lestidae	Lestes				23	34	53	110
Odonata	Libellulidae	Leucorrhinia	4	3	4	2			13
Odonata	Libellulidae	Libellula	1	1	1	4	1		8
Odonata	Libellulidae	Sympetrum				2	11	10	23
Tricoptera	Leptoceridae	Trienodes				3			3
Tricoptera	Limnephilidae	Limnephilus	26	27	2				55
Abundance			43	55	53	72	80	158	461
Richness			10	12	19	19	15	14	41
Shannon-Wiener Diversity			2.12	2.5	3.7	3.5	2.7	2.88	4
Simpson Dominance			0.39	0.29	0.11	0.1	0.2	0.19	0.11

277 – No ambystomid larva, closed canopy.

Order	Family	Genus	25-Mar	9-Apr	28-Apr	14-May	28-May	Taxa Total
Diptera	Chaoboridae	Chaoboris	0	0	0	6	3	9
Diptera	Chironomidae	Chironomidae	0	6	10	98	59	173
Hemiptera	Corixidae	Hesperocorixa	1	0	0	0	0	1
Diptera	Culicidae	Aedes	0	12	3	0	0	15
Coleoptera	Dytiscidae	Acilius	0	0	0	13	6	19
Coleoptera	Dytiscidae	Deronectes	0	1	0	0	0	1
Coleoptera	Dytiscidae	Dytiscus	0	0	0	1	0	1
Coleoptera	Dytiscidae	Ilybius	0	0	2	0	0	2
Tricoptera	Limnephilidae	Limnephilid	5	4	13	7	0	29
Tricoptera	Phryganeidae	Ptilistomis	1	0	0	0	0	1
Veneroida	Sphaeriidae	Sphaerium	0	7	0	0	0	7
Abundance			7	30	28	125	68	258
Richness			2	5	4	5	3	11
Shannon-Wiener Diversity			1.15	2.03	1.66	1.11	0.69	1.75
Dominance			0.55	0.27	0.36	0.63	0.76	0.47

3016 – No ambystomid larva, open canopy.

Order	Family	Genus	25-Mar	9-Apr	28-Apr	13-May	28-May	9-Jun	25-Jun	Totals
Acariformes	Hydrachnidae	Hydrachna							1	1
Acariformes	Hydrodromidae	Hydrodroma			1					1
Acariformes	Hygrobatidae	Hygrobates					3			3
Basommatophora	Lymnaeidae	Fossaria	35	30	24	35	38	33	9	204
Basommatophora	Physidae			1		1		3		5
Basommatophora	Planorbidae	Gyraulus						3		3
Basommatophora	Planorbidae	Planorbula armigera			1			1		2
Basommatophora	Planorbidae	Promenetus exacuus					1			1
Coleoptera	Dytiscidae	Deronectes				1				1
Coleoptera	Dytiscidae	Hydaticus					1		1	2
Coleoptera	Dytiscidae	Hydroporous					3	1	4	8
Coleoptera	Dytiscidae	Acilius	1		1					2
Coleoptera	Dytiscidae	Ilybius							1	1
Coleoptera	Dytiscidae	Laccophilus							1	1
Coleoptera	Elmidae	Stenelmis						1		1
Coleoptera	Gyrinidae	Dineutus				1				1
Coleoptera	Halplidae	Peltodytes				2	1	1		4
Coleoptera	Hydrophilidae	Anacaena							5	5
Coleoptera	Hydrophilidae	Berosus					1			1
Coleoptera	Hydrophilidae	Enochrus			1		12	5	11	29
Coleoptera	Hydrophilidae	Helophorus						1		1
Coleoptera	Hydrophilidae	Hydrobius	2			5			4	11
Coleoptera	Hydrophilidae	Hydrochara				2	2	2		6
Coleoptera	Hydrophilidae	Hydrochus				1	1		1	3

Coleoptera	Hydrophilidae	Tropisternus				2	1	1	3	7
Coleoptera	Scirtidae	Elodes							1	1
Coleoptera	Scirtidae	Scirtes			1		4	1		6
Coleoptera	Noteridae	Hydrocanthus						1		1
Coleoptera	Dytiscidae	Agabus		2	1					3
Coleoptera	Dytiscidae	Dytiscus				1				1
Diptera	Chironomidae				1				1	2
Diptera	Culicidae	Aedes			7					7
Diptera	Dixidae	Dixella			8					8
Diptera	Sciomyzidae						2	1	1	4
Diptera	Stratiomyidae	Odontomyia				1	7		1	9
Diptera	Tabanidae	Hybomitra			1					1
Diptera	Chaoboridae	Chaoborus	2	1						3
Ephemeroptera	Baetidae	Callibaetis						1	1	2
Ephemeroptera	Leptophlebiidae	Leptophlebia	8	17						25
Ephemeroptera	Siphonuridae	Siphonurus			2					2
Hemiptera	Belostomatidae	Belostoma					7	12	23	42
Hemiptera	Belostomatidae	Lethocerus						3	2	5
Hemiptera	Corixidae	Hesperocorixa			1			1		2
Hemiptera	Gerridae	Gerris			1			1	5	7
Hemiptera	Notonectidae	Notonecta							3	3
Isopoda	Asellidae	Caecidotea	83	59	13	2				157
Megaloptera	Corydalidae	Chauliodes							1	1
Odonata	Aeshnidae	Aeshna							2	2
Odonata	Coenagrionidae	Enallagma			2					2
Odonata	Coenagrionidae	Nehalennia				4				4
Odonata	Lestidae	Lestes				1	11	34	13	59
Odonata	Libellulidae	Leucorrhinia					1			1
Odonata	Libellulidae	Libellula					3			3
Odonata	Libellulidae	Sympetrum					6	4	11	21
Tricoptera	Limnophilidae	Limnephilus	23	11	21					55
Tricoptera	Phryganeidae	Ptilostomis	2	2						4
Veneroida	Sphaeriidae	Sphaerium	9	2	3	2	5	6		27
Abundance			165	125	90	61	110	117	106	774
Richness			9	9	18	15	20	22	24	57
Shannon-Wiener Diversity			2.09	2.10	3.13	2.50	3.39	3.16	3.81	3.91
Simpson Dominance			0.32	0.31	0.16	0.35	0.16	0.18	0.10	0.13

Appendix C.

List of Common Names by Family

Order	Family	Common Name
Acariformes	Hydrachnidae	Water Mite
Acariformes	Hydrodromidae	Water Mite
Acariformes	Hydryphantidae	Water Mite
Acariformes	Hygrobatidae	Water Mite
Anostraca	Chirocephalidae	Fairy Shrimp
Basommatophora	Lymnaeidae	Pulmonate Snail
Basommatophora	Physidae	Pulmonate Snail
Basommatophora	Planorbidae	Pulmonate Snail
Coleoptera	Dytiscidae	Predaceous Diving Beetles
Coleoptera	Elmidae	Riffle Beetles
Coleoptera	Gyrinidae	Whirligig Beetles
Coleoptera	Haliplidae	Crawling Water Beetles
Coleoptera	Hydrophilidae	Water Scavenger Beetles
Coleoptera	Scirtidae	Marsh Beetles
Coleoptera	Noteridae	Burrowing Water Beetles
Diptera	Ceratopogonidae	Biting Midges
Diptera	Chironomidae	Midges
Diptera	Culicidae	Mosquitoes
Diptera	Dixidae	Dixid Midges
Diptera	Sciomyzidae	Marsh Flies
Diptera	Stratiomyidae	Aquatic Soldier Flies
Diptera	Tabanidae	Horse and Deer Flies
Diptera	Chaoboridae	Phantom Midge
Ephemeroptera	Baetidae	Small Minnow Mayflies
Ephemeroptera	Leptophlebiidae	Pronggilled Mayflies
Ephemeroptera	Siphonuridae	Primitive Minnow Mayflies
Hemiptera	Belostomatidae	Giant Water Bugs
Hemiptera	Corixidae	Water Boatmen
Hemiptera	Gerridae	Water Strider
Hemiptera	Naucoridae	Creeping Water Bugs
Hemiptera	Notonectidae	Back Swimmers
Isopoda	Asellidae	Isopod, Pillbugs, Sowbugs
Megaloptera	Corydalidae	Dobson fly, Fish fly
Odonata	Aeshnidae	Darners
Odonata	Coenagrionidae	Narrowwinged Damselflies
Odonata	Lestidae	Broadwinged Damselflies
Odonata	Libellulidae	Common Skimmers
Tricoptera	Leptoceridae	Longhorned Case Maker Caddisflies
Tricoptera	Limnephilidae	Northern Case Maker Caddisflies
Tricoptera	Phryganeidae	Giant Case Maker Caddisflies
Veneroida	Sphaeriidae	Fingernail Clams

Appendix B.

Ecological Index Formulas Used

Index Name	Formula	Description
Shannon – Wiener Diversity	$H' = - \sum_{i=1}^S \frac{n_i}{N} \times \log_2 \left(\frac{n_i}{N} \right)$ N = total number of individuals S = number of different species ni = number of individuals in sample i	Based on information theory, considers both abundance and richness. The greater the number, the greater disorder in the sample, and ergo greater diversity.
Simpsons Dominance	$\sigma = \sum_{i=1}^S \left(\frac{n_i}{N} \right)^2$ N = total number of individuals S = number of different species ni = number of individuals in sample i	Can be interpreted as the probability that any two randomly chosen individuals will be the same.
Sorensen's Similarity Quotient	$Q/S = \frac{2j}{(a+b)} \times 100$ a is the total number of species in sample #1, b is the number of species in Sample #2, and j is the number of species common to both samples.	Measures similarity only of richness, not abundance. Interpreted as a percent of taxa that two samples have in common.
Bray-Curtis Similarity	$BC_{1,2} = \frac{2 \times \sum \text{Max}(n_{1i}, n_{2i})}{\sum n_{1i} + \sum n_{2i}}$ n1i = number of individuals in sample I n2i = number of individuals in sample II	Measures similarity both in terms of richness and abundance.

Ephemeral Wetland Study Site Location



Overview Map

