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Aquatic Insect Communities in Vernal Ponds: Influence of Habitat Duration

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Abstract

Few studies have been done on what factors contribute to species composition and abundance in vernal ponds. Possible contributors include biotic and abiotic factors. This study attempts to compare specific factors, both biotic and abiotic, to see the influence of these factors on the abundance and diversity of insect species in vernal ponds. Four temporary ponds on the UNDERC property were chosen for the study. Factors that were compared with insect species included the duration of the wet phase of each of the ponds, the similarity index between combinations of the ponds for both species abundance and composition, and functional feeding groups of the species found in the ponds. Other factors were measured for the purpose of characterizing the ponds such as water levels, amount of light the ponds received, water temperature, and water chemistry.

Introduction

Temporary ponds are characterized by a lack of surface water during part of each annual cycle (Ward, 1992). Inhabitants of these temporary water bodies differ from those in permanent aquatic habitats because the former species must be able to adapt to a recurrent dry phase or alternating wet and dry phases. Vernal ponds fill with water from melting snow and spring rains and retain water only until early spring to midsummer (Ward, 1992). There are several characteristics of temporary ponds that distinguish them from permanent ones. These consist of both biotic and abiotic factors. Biotic factors can be such things as differences in reproductive cycles and food niches of species present (Donald, 1971). Abiotic factors can include physical and chemical features such as area, depth, and substratum of the pool (Hamer and Appleton, 1991). Factors such as temperature, pH, dissolved oxygen, water level, and ion concentration all can vary and reach extreme values at different times of the year in temporary ponds. Because of their small size they are usually greatly affected by even small changes in environmental factors.

Not all species can survive on transient water bodies because of the adaptations that they must possess to survive the long dry phases that occur in all temporary ponds. Those species that can adapt, however, usually are present in high number. Lack of fish predation, an abundance of food, and a well-developed pleuston community (Ward, 1992) allow the species that are present to flourish. Therefore, the number of species found in fishless temporary ponds usually is lower than in water with fish, however, the abundance of these species is greater. Worldwide, several groups have been reported to predominate in temporary ponds. These groups include, Hemiptera, Coleoptera, Odonata, Chironimidae, Culicidae, and Ceratopogonidae, and they all exhibit special physiological or life history features that allow them to colonize and survive in these conditions (Williams and Feltmate, 1992). Such features include intense mortality early on the life cycle, rapid development, high rates of maximal population increase, reproduction early in the life cycle and few periods of reproduction, and short life cycles (Williams, 1985).

In all natural environments, life cycles must be temporarily adjusted so the critical stages are in phase with appropriate environmental conditions (Resh and Rosenberg, 1984). It is imperative for inhabitants of temporary ponds to emerge at the optimal time because they must take advantage of the brief, precarious wet phase of the habitat for optimal reproductive success. Variations in climate from year to year can cause the wet phase of the temporary ponds to come about at different times on the season, as well as dry up at different periods. For example, an unusually late spring and hot dry summer can create a very short wet phase in a temporary pond, and an organism must be prepared to complete its life cycle given these adverse conditions. According to Saiah and Perrin (1990), "adaptive phenotypic plasticity" requires temporal variability to be somewhat predictable from environmental cues. Therefore, in order for univoltine species to persist in a temporary pond, individuals in each generation must be able to use environmental cues to synchronize the active part of their life cycle with the optimal conditions of the pond. These environmental cues can be such factors as photoperiod and temperature (Ward, 1991), or even the amount of dissolved oxygen in the surrounding water (Gillett, 1971) which can be used to detect optimal hatching or emergence times.

Although there have been several autecological studies conducted in temporary water bodies (Tejedo, 1993, Holopainen and Oikari, 1992; Hornbach and Denekak, 1991; Hann and Lonsberry, 1991; Grainger, 1991; Hamer and Appleton, 1991; Saiah and Perrin, 1990), factors determining species composition of these communities are not well understood. Recent studies on plant and animal species composition in temporary water bodies have been done in vernal pools in California, where wet winter produce shallow puddles ranging in size from a few meters to many hundred yards across Baskin, 1994). Results from these studies are still premature, but the data has suggested some interesting points. According to the article by Baskin, in some cases, the species distribution seems related to the physical and chemical parameters of a pool: high alkalinity and turbidity in one pool versus neutral pH and clear water in another. In some cases temperature appears to be most influential. And yet in others, it is the duration of the wet phase (pool longevity), because some species are quicker to develop than others. Simovich, one of the researchers on the California vernal pools, says that there are several predictions for why species may be present in one pond and not another, even with similar water chemistry. These include competition with another species, or it could be that historically, the species never reached the pool. Another important finding by the researchers so far has been that the pool size as well as the effect of the length of time the pools hold water (pond duration) may have a large effect on species present in the pools. They hypothesize that if the pool is larger, there are more habitats that they can subdivide... and of the pool lasts longer, there can be short-lived species coming in first and being replaced by other species later (Baskin, 1994).

A rigorous study of animal communities in 1992 demonstrates that these ecosystems are home to 60 known endemic species of plants and invertebrates found nowhere elso on the planet, as well as 127 rare, threatened, or endangered plants (Baskin, 1994). It is estimated that somewhere between 93 and 97% of vernal pools in California have already been lost, so the biodiversity is only a small fraction of what it once was in the original habitat. This fact demonstrates the importance of studying these little understood ecosystems before it is too late.

The objective of this study is to look at the differences in species in different vernal ponds and relate those differences to the pond duration. This study will first compare the insect species in two short duration ponds and compare that to species found in two long duration ponds. This will hopefully demonstrate the importance of wet phase duration on species composition. In order to assess the importance of food type and nutrient availability on species diversity and location, the functional feeding groups of the species in the long duration and short duration will be compared. Then the similarity of each of the four ponds will be calculated on the basis of species found in each to assess exactly how much they differ in relation to one another. And finally, the similarity between the first two sampling dates and the last two sampling dates for each site will be calculated to see of the species present in the short duration ponds are under greater pressure to get their life cycle completed, therefore growing, developing, and emerging faster than the species present in the ponds that dry up later in the season, and therefore showing less abundance towards the end of the summer.

Materials and Methods

Site Selection:

There are 31 temporary ponds on the UNDERC property that have been studied by Dr. George B. Craig and associates for approximately 25 years. From a list of the 31 ponds on the property, three ponds were chosen and classified on the basis of size, depth, water chemistry, amount of tree canopy over the water surface, and type of material making up the benthic layer. The other pond chosen for this study was one that has not been previously studied by Dr. Craig, but is still located on the property. This will be called Site 32.

Site 5: This sampling site is a relatively small pond (surface area=40.8 m^2) with well defined margins. Large maple trees hang above, giving the pond heavy canopy and shading it from direct sunlight almost all day. The benthic region is composed primarily of a layer of leaf detritus covering a dense heavy dirt bottom. The pond was fairly deep, with a depth of approximately 2.5-3 feet.

Site 32: This sampling site is similar to 5 in appearance. It also has heavy canopy consisting of primarily large maple trees and is a bit bigger and deeper than Site 5 (surface area=42.5 m^2, approximate depth=4 feet). The benthic region, like Site 5, is composed primarily of leaf detritus, but was observed to not have as much dirt underneath the leaf layer.

Site 6: This sampling site is much larger than Sites 5 and 32 (surface area= 1653 m^2), and is exposed to direct sunlight for most of the day. The pond does have many trees around the perimeter of the water surface, such as aspen and small maple, but few of them hang directly over the water surface. This pond has lots of grassy plants and typha growing throughout the pond, and the benthic region is composed of mostly moss and grass, with little to no dirt or mud. The pond has many small, segregated pools throughout and varies in depth from 1-4 feet.

Site 16: This site appears similar to site 6 in the fact that it is rectangularly shaped and relatively large in size (surface area= 702 m^2). It also receives direct sunlight for most of the day and therefore has grassy plants and typha growing up through the water surface. The benthic region differed from Site 6 in that it has more dead grass, but still contained mostly mosses and little to no mud or dirt.

Invertebrate Sampling

Samples were taken from each of the four sites at four times during the summer (5-22-94, 5-28-94, 6-8-94, and 6-21-94). A 6x6x9 in^3 Eckman Grab was used to sample the benthic material. The volume of each sample was 5300 ml or 324 in^3. Five replicate samples from each site were taken to insure a complete survey of the pond was being taken. While sampling, an attempt was made to take samples at completely random locations throughout the ponds. The benthic samples were sifted once on the site and preserved in 75% alcohol. In the lab, the samples were again sifted, using a 500 micron sieve and then split in half once they were completely sifted. Because the samples were halved to extract the insects, the number of insects per Eckman Grab was calculated by multiplying the observed number of insects by two. Only members of the family Chironimidae were identified and analyzed, due to limited time. At the time of sampling, water temperature, photometer readings and water levels were also measured.

Results

Table 1 shows the results of the water chemistry test performed on samples from each site. It can be seen that Sites 5 and 32 (the two short duration sites), were more similar to each other by way of amount of phosphate present and pH, but not in color or amount of nitrate present in the water. The measured values for water temperature (Table 2), photometer readings (Table 3), and water levels (Table 4) are also shown.

The mean number of organisms per Eckman Grab in both the long and short duration ponds was calculated, and the results are shown in Figure 1. A factorial ANOVA was conducted and the obtained F value (df=1, n=797, p<.05) showed that the difference was statistically significant. The mean number of organisms in the long duration ponds (u=2.9/324 in^3) was clearly greater than the mean number of individual organisms in the short duration ponds (u=.3/324 in^3).

For the next test, one species was chosen that was found on both short and long duration ponds and the abundance of individuals in both types was compared. The species chosen was Chironimidae orthocladiinae *bryophaenocladius sp.* A factorial ANOVA was again conducted, and the obtained F value (DF=1, n=797, p=.002) shows that the number individual *bryophaenocladius sp.* per Eckman grab was significantly larger in the long duration pond (u=8.125/324 in^3) than the short duration pond (u=0.40/325 in^3).

To calculate the similarity, the SIMI equation was used:

$$\frac{\sum_{i=1}^{n} P_{ih}\, P_{ik}}{\sqrt{\sum_{i=1}^{n} P_{ih}^{2}}\ \sqrt{\sum_{i=1}^{n} P_{ik}^{2}}}$$

Table 1: Water chemistry values from pond samples taken on 6-7-91. Tests that were run were color (PtCo color), phosphorous (mg/l of PO_4^{3-}), pH, and nitrate (mg/l). The values given are the averages of the three trials with the ranges in parentheses.

	Color	PO_4^{3-} (mg/l)	pH	NO_3^-
Site 5	329 PtCo (319-337)	1.71 mg/l (1.52-2.06)	6.40 (6.39-6.42)	1.3 mg/l
Site 32	508 PtCo (506-512)	0.623 mg/l (0.60-0.64)	6.17 (6.16-6.19)	1.8 mg/l
Site 6	over range	0.177 mg/l (0.17-0.18)	5.37 (5.36-5.38)	2.3 mg/l
Site 16	424.3 PtCo (423-425)	0.057 mg/l (0.05-0.09)	5.08 (5.07-5.09)	1.7 mg/l

Table 2: Water temperature of vernal ponds taken at the time of each sampling period and one additional time. Values given in degrees Celcius.

	5-22-94	5-28-94	6-8-94	6-21-94	7-8-94
Site 5	14	16	14	18	20
Site 32	16	16	15	19	18.5
Site 6	19	18	18	21	23
Site 16	19	19	18	20	21.5

Table 3: Light meter readings taken at each site at the time of sampling (in μm).

	5-22-94	5-28-94	6-8-94	6-21-94
Site 5	20.24	26.55	152.2	28.77
Site 32	40.07	29.42	103.6	23.64
Site 6	1570	1646	503.8	1693
Site 16	1626	1660	962.3	1741
Time	10:00 AM	10:45 AM	12:30 PM	4:30 PM

Table 4: Changes in water levels measured at each site at the time of sampling and one additional time. Water level is taken to be 100% at first sampling date.

	Surface Area	5-28-94	6-8-94	6-22-94	7-4-94	7-20-94
Site 5	40.8 m^2	100%	75.4%	40.0%	*0%	30.0%
Site 32	42.5 m^2	100%	71.1%	* 0%	36.6%	35.2%
Site 6	1653 m^2	100%	76.0%	46.0%	*0%	19.5%
Site 16	702 m^2	100%	66.1%	33.3%	*0%	54.3%

* indicates that ponds hit a low point in water level, then rainfall increased level again

Table 5: SIMI values calculated for site versus species.

	Site 5	Site 32	Site 6	Site 16
Site 5	1.00	0.396	0.328	0.042
Site 32	0.396	1.00	0.676	0.128
Site 6	0.328	0.676	1.00	0.683
Site 16	0.042	0.128	0.683	1.00

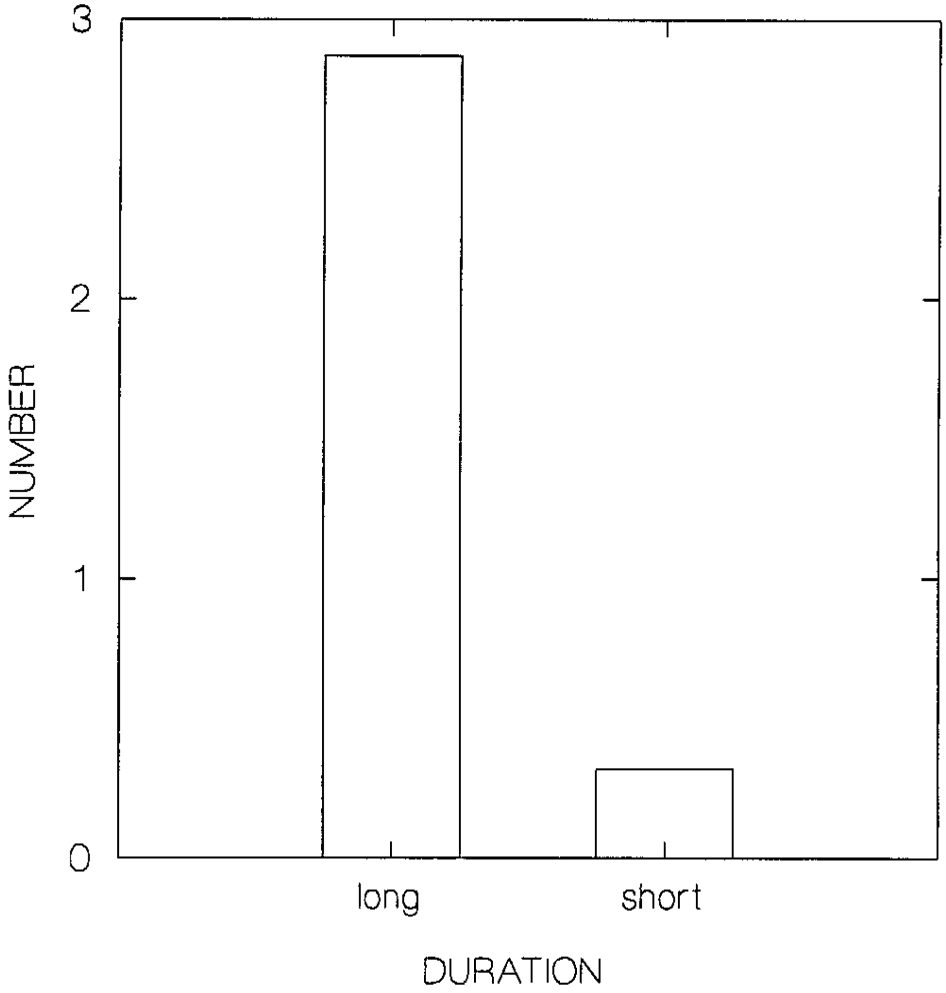


Figure1: The number of organisms found per Eckman grab in long duration ponds (μ=2.9) versus short duration ponds (μ=0.3).

The calculations were done by hand, and the results of the SIMI calculations for Site versus species are seen in Table 5. The most similar ponds to each other were Site 6 and Site 16(SIMI=0.683), both of the short duration ponds . This means there was a 68.3% similarity in the species found in those sites. The ponds least similar to each other were Site 32 and Site 16 (SIMI=0.128), one long duration and one short duration pond.

The SIMI equation was also used to compare the similarity for the first sampling dates versus the last sampling dates for each site. The results for this test are shown in Table 6. All four sites had relatively high similarity (0.633-0.935), which shows that the species did not change drastically throughout the sampling period for each site.

Functional feeding groups for each species of Chironimidae are given in Table 7. The similarities are compared between long and short duration ponds in Figure 2. There is a large number of collector-gatherers in the long duration ponds (y=562), whereas the short duration ponds are inhabited mostly by predators (y=179). Scrapers and herbivores were present in small numbers in some of both types of ponds.

Conclusions

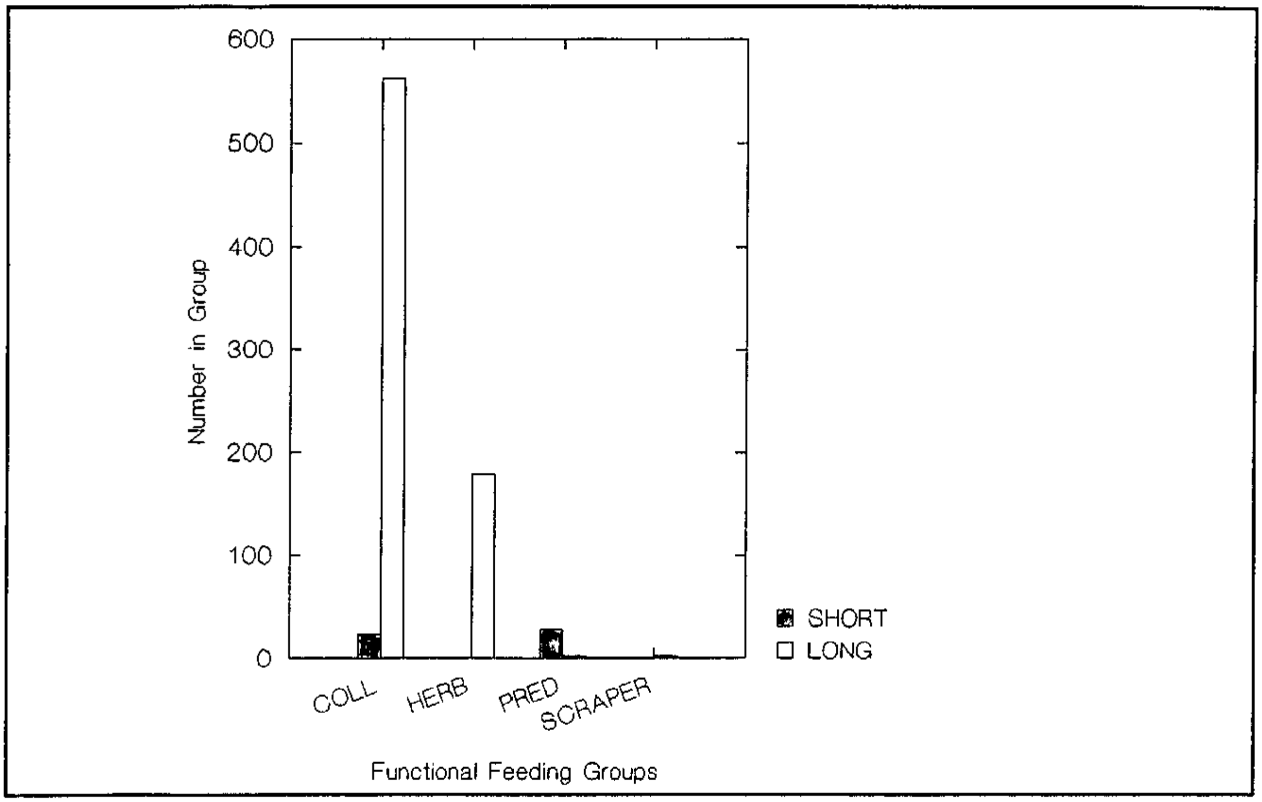
The tests run in this study were done for the purpose of comparing species diversity and abundance in vernal ponds. A comparison of the mean number of organisms in the long duration and short duration ponds was found to be statistically significant ($p<.05$). The data found that the short duration ponds have more diversity in species of Chironimidae found (7 species) than the long duration ponds (5 species). This finding contradicts the early conclusions from the California vernal pool studies

Table 6: Similarity between species found in first two versus second two sampling dates for each sampling site.

Site	SIMI
Site 5	0.906
Site 32	0.753
Site 6	0.935
Site 16	0.633

Table 7: Functional feeding groups for each species of Chironimidae found.

chironimini chironomus sp.	collector-gathers/ shredder-herbivore
chironimini phaenopsectra sp.	collector-gathers/ scrapers
chironimini polypedilum sp.	collector-gathers
orthocladiinae bryophaenocladius sp.	collector-gathers
orthocladiinae nanocladius sp.	collector-gathers
orthocladiinae psectrocladius sp.	collector-gathers/ shredder-herbivore
tanypodinae pentaneurini monopelopia sp.	predators
tanypodinae pentaneurini larsia sp.	predators
tanypodinae pentaneurini procladius sp.	predators
tanypodinae pentaneurini pentaneura sp.	predators



<u>Figure 2:</u> Number of individual organisms found of each functional feeding group in short duration ponds versus long duration ponds.

sited in the article by Baskin (1994), that state longer duration ponds house more species. This difference could be attributed to several possibilities. The ponds chosen as the long duration sites in this study could have had particuarly harsh conditions compared to the ponds in the California studies. On the other hand, the short duration ponds chosen in this sudy could have been uncharacteristically mild in their physical conditions. It is difficult to make such predictions in regards to why these differences occurred because no extensive data has been published yet in the California studies.

The data does agree with the California vernal pool studies in regard to the size of the ponds compared to the number of species found there. Both are showing that larger ponds have more species than smaller ponds. The data from this study agrees with this hypothesis because the short duration ponds (Site 6 and 16) have a much larger surface area (and also more species) than the long duration ponds (Site 5 and 32). This is due possibly to the greater number of microhabitats available in the larger ponds.

The question of whether the functional feeding groups found at each site were related to the pond duration, is an important question to address because it deals with the food sources present. The results show that over 75% of species found in the long duration ponds were collector-gatherers. This is significant if the type of food available in these types of ponds is taken into account. The leaf detritus itself is not very nutrient rich, however, because all of the leaves are dead, there is fungus and bacteria growing on them. This is a good food source for the insects and agrees with the type of feeding that they would be demonstrated if this were the case. On the other hand, the short duration ponds get plenty of sunlight, so it is possible that photosynthesis is taking place, and the plants present below the surface of the water are not dying. This was supported by the fact there was very little detritus on the bottom of the shallower, short duration ponds. Because there is not much dead matter in this area, not as much fungus and bacteria will be present on the benthic matter, decreasing the chance that the insects are using this as a major food source.

Of the species found in the short duration ponds, over 50% were classified as predators in their functional feeding group. There were various worms, zooplankton and other small insects observed in the samples of the short duration ponds, possibly supporting the hypothesis that these predators feed on other midges, worms, and pleuston, which is typical of this functional feeding group (Merritt and Cummings, 1993).

The tests for similarity of species composition in the vernal ponds had mixed results, some agreed with the proposed hypothesis and others contradicted it. The highest similarity was found between both short duration ponds (SIMI=0.683 for Site 6 and 16), which would support the hypothesis that pond duration is a major contributing factor in species composition. However, there was also a strong similarity between Site 6 and 32 (SIMI=0.676), which was not expected because one is a short duration and the other is a long duration pond. Also the similarity between both of the long duration ponds, Site 5 and 32, was not very high (0.396) compared to the other SIMI values. These results imply that pond duration itself is not the most important or the only factor contributing to species composition.

The similarity tests on each site for the first two sampling periods and the last two sampling periods in species composition was shown to have strong results- all SIMI values were between 0.633 and 0.935. The high SIMI values demonstrate that the species found in the beginning of the summer were similar to those found in the same sites later on. According or the proposed hypothesis, the species found later on in the season should have been similar in the long duration ponds, but not in the short duration ponds because the short duration ponds should have fewer number of species types. This was not the case. The short duration ponds (SIMI=0.633 and 0.935) had comperable similarity values to the long duration ponds (SIMI=0.735 and 0.906).

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