1987

THE RELATIVE EFFECTS OF AN EXOTIC CHAOBORID SPECIES *(CHAOBORUS AMERICANUS)* AND NATIVE CHAOBORID SPECIES *(CHAOBORUS FLAVICANS* AND *CHAOBORUS TRIVITTATUS)* ON A ZOOPLANKTON COMMUNITY IN A MESOCOSM.

Julie A. Oxler, Department of Biology, University of Notre Dame

ABSTRACT

A mesocosm experiment revealed the varying influences different *Chaoborus* species can exert on a zooplankton community. The native *Chaoborus* species in the mesocosm experiment, *C. flavicans* and *C. trivittatus*, exerted moderate predation pressure on the zooplankton community, controlling the *Daphnia* population and somewhat depleting the copepodite population. The exotic predator, *C. americanus*, exerted heavier predation pressure. In the bags containing *C. americanus*, the *Daphnia* and copepodite populations were depleted, and the *Diaptomus oregonensis* and *Tropocyclops prasinus* populations were controlled. Possible explanations for the increased predation pressure of *C. americanus* on the zooplankton community are differences in the densities of the*Chaoborus* species, different migration behaviors, and the fact that *C. americanus* was an exotic predator.

INTRODUCTION

Chaoborus, major predators on the zooplankton community, are capable of removing up to 40% of the population of certain zooplankton species each day (Fedorenko, 1975). These predation effects may differ dramatically depending on the specific characteristics of the *Chaoborus* predator. Factors such as migration (Fedorenko, 1973) and whether the *Chaoborus* species is a native or exotic predator may play a role in the both the amount of predation and the the type of species preyed upon.

In this experiment the effects of both the native *Chaoborus* species and an exotic *Chaoborus* species on the zooplankton community are studied. During the summer of 1987 a mesocosm experiment was conducted with three sets of bags containing a natural phytoplankton and zooplankton community. To one set of bags the native *Chaoborus* species, *C. flavicans* and *C. trivittatus,* both non-migrating species, were added. To the second set of bags *C. americanus,* an exotic migrating *Chaoborus* species, was added. To study the changes that occur in the zooplankton community when predation is nearly eliminated, no *Chaoborus* were added to the final set of bags.

MATERIALS AND METHODS

Study sites

Peter Lake and Tender Bog are located in the University of Notre Dame's

Environmental Research Center (UNDERC) in Gogebic County, Michigan. The experiment was conducted in Peter Lake and all phytoplankton, zooplankton, *Chaoborus flavicans*, and *Chaoborus trivittatus* used in the experiment were obtained from this lake. *Chaoborus americanus* were obtained from Tender Bog.

Peter Lake is an oligotrophic lake with an area of 2.4 ha and a maximum depth of 19.3 meters. During the summer of 1987 the epilimnion extended down 2.5 meters. The fish community of Peter Lake consists of largemouth bass and minnows. As a result of a fish manipulation experiment conducted in May of 1985, the 2^+ year class of largemouth bass are overrepresented (Carpenter et al, 1987). The *Chaoborus* community in Peter Lake is dominated by *Chaoborus flavicans* but some *Chaoborus trivittatus* are present.

Tender Bog is a darkly stained, acidic (pH 4.2) bog with a maximum depth of 10.0 meters. During the summer of 1987, the dominant organisms found in the bog were *Chaoborus americanus, Diaptomus leptopus*, and *Keratella cochlearis*. No fish were present.

Experimental Design

Nine plastic bags, each four feet in diameter and ten meters deep, were suspended from a wooden frame in the middle of Peter Lake. During the days of June 23, 24, and 25, the bags were prepared as follows: Epilimnetic water from one meter was pumped through a 153 um net into the bags. The net allowed only rotifers to pass with the phytoplankton into the bags. The remainder of the zooplankton community was collected by zooplankton net

tows and subsequently added to the bags. Zooplankton nets with a 153 um mesh were used so that the rotifers would not again be collected in these tows. Enough hauls were taken so that, taking into account the efficiency of the net, the area towed would equal the area of bags at the lake's surface.

Chaoborus were collected and placed in six randomly selected bags. In three of the bags, bags 14, 15, and 17, *Chaoborus* from Peter Lake, *C. flavicans* and *C. trivittatus,* were added. The other three bags, bags 13, 16, and 18, were filled with *C. americanus* from Tender Bog. *Chaoborus* densities were established to mimic the densities found in each *Chaoborus* species' native habitat. To the three remaining bags, bags 2, 8, and 12, no *Chaoborus* were added.

Zooplankton Collection and Analysis

The bags were sampled at the experiment's inception, after one-half week, and then weekly until the experiment's conclusion on August 13. All zooplankton sampling was conducted at night, soon after sunset. The first sample set was collected using a 9-liter Schindler. Samples were taken every meter, starting at one-half meter. Subsequent sample sets were collected using a small zooplankton net with a 12 cm diameter. Two tows from a depth of ten meters were taken for each sample. On the third collection date, one week following the initial sampling, three of the bags were sampled using both means, the Schindler and the zooplankton net, so that the initial samples could be calibrated to the later samples.

Immediately following collection, the *Conochilus unicornis* colonies were counted since they breakup upon addition of a preservative. Sugared

formalin was then added to to preserve the sample.

The zooplankton samples were counted on a dissecting microscope. The entire sample of *Daphnia* and *Holopedium* were counted while subsets of the remaining zooplankton species were counted. The subsets were counted until the standard deviation was less than ten percent of the mean.

RESULTS

In this preliminary paper only the initial and final sample sets will be compared in order to determine the general changes in zooplankton populations that occurred over the summer. The results from the initial sample of bag 8 and both the initial and final samples of bag 18 are not available since the initial sample of bag 8 was lost and bag 18 broke when it was overfill of water. Differences in the means of sampling, Schindler or zooplankton net, have been taken into account, but differences in the weekly rate of towing cannot be accounted for.

The various *Chaoborus* species exerted dramatically different pressures on the zooplankton communities (figures 1-4). *C. americanus* preyed most heavily on the zooplankton community, limiting both the cladoceran and the copepod populations. It depleted the *Daphnia* and copepodite populations and prevented major population increases in the *Diaptomus oregonensis*, and to some extent, the *Tropocyclops prasinus* populations. The *T. prasinus* populations did rise in the bags containing *C. americanus* but to a lesser extent than occurred in the bags containing the *C. flavicans/C. trivittatus* mixture.

The *C. flavicans/C. trivittatus* mixture, on the other hand, exerted only moderate predation pressure on its native zooplankton community. The *C. flavicans/C. trivittatus* mixture was only able to limit the growth of the *Daphnia* population, while in the bags containing *C. americanus,* the *Daphnia* population was nearly eliminated.. The *C. flavicans/C. trivittatus* mixture did deplete the copepodite populations but again to a much smaller extent than occurred in the bags containing *C. americanus.* The *C. flavicans/C. trivittatus* mixture exerted no detectable influence on the *D. oregonensis* and *T. prasinus* populations. The *D. oregonensis* population rose to nearly equal the final populations found in the bags containing no *Chaoborus* and the *T. prasinus* population rose in each bag to a density greater than the average final density found in the bags containing no *Chaoborus.*

In the bags containing no *Chaoborus*, where the predation on zooplankton was nearly eliminated, the *Daphnia, D. oregonensis,* and *T. prasinus* populations exploded. No trend developed for the copepodite population.

The remaining zooplankton populations that were present in the lake either changed uniformly over all the bags, or developed no trend among the bags with different *Chaoborus* treatments. Nauplii were a major member of the zooplankton community but developed no trend throughout the bag series. *Holopedium gibberum* was initially one of the dominant members of the zooplankton community in all the bags, but by the experiment's conclusion, it was present in small quantities in only three of the bags. *Conochilus unicornis, Mesocyclops edax,* and *Orthocyclops modestus* were also present in the initial samples, but were not counted in any of the final samples. One

Epischura lacustris was present in the initial sample of bag 16. No other *E. lacustris* were ever collected. *Polyphemus pediculus* and *Diaphanosoma birgei* were collected only in the final samples, and then only in minute quantities, less than seven per sample. Other species collected only in the final samples were *Chydorus sphaericus, Ploesoma sp, Polyarthra vulgaris, Trichocerca cylindrica,* and *Euchlanis sp.* No trends developed for the densities of these species in the bags.

DISCUSSION

Several possible explanations exist for the heavier predation pressure exerted in the bags containing *C. americanus* as compared to the more moderate predation exerted in the bags containing the *C. flavicans* and *C. trivittatus* mixture:

1. *C. americanus* were present in higher densities than the *C. flavicans/C. trivittatus* mixture was (MacKay, personal communication). The *Chaoborus* were present in such varying densities because each bag's *Chaoborus* density was established to mimic the natural density found in the *Chaoborus'* native habitit.
2. *C. americanus* was an exotic predator on the zooplankton community. Some zooplankton species are known to be able to develop specific adaptations to avoid predation by a *Chaoborus* species (Krueger et al, 1981). The zooplankton populations would not have adapted means of avoiding predation by *C. americanus* as they may have for the

Chaoborus species with which they are naturally found, *C. flavicans* and *C. trivitattus*

3. All *C. americanus* instars remain above the thermocline (Fedorenko, 1975) while the fourth instars of both *C. flavicans* (Franke, 1984) and *C. trivittatus* (Fedorenko, 1975) migrate below the thermocline during the daylight hours. In the middle of August, when the final samples were collected, both the *C. flavicans* and *C. trivittatus* populations should have entirely molted to the fourth instar (Von Ende, 1982). *C. flavicans* completed its final molt near the end of July and the *C. trivitattus* population molted to the fourth instar near the end of May (Von Ende, 1982). Thus, both *C. flavicans* and *C. trititttatus* should have begun the migrating behavior by the experiment's conclusion. This migration pattern may have a two-fold effect, both effects contributing to a decrease in predation by the migrating *Chaoborus* species. First, when the *Chaoborus* are in the cool hypolimnion, they may have a slower metabolic rate and may need to consume less than non-migrating species in order to maintain their metabolism. This would result in decreased predation for migrating *Chaborus* species. Secondly, researchers disagree on whether migrating *Chaoborus* prey only in the epilimnion (Kajak et al, 1971) or both in the epilimnion and the hypolimnion (Goldspink, 1971). If migrating *Chaoborus* do prey only in the epilimnion, their predation pressure, as compared to the non-migrating species, would be reduced since they would be spending much less time capturing and consuming prey. Even if the *Chaoborus* do prey in the hypolimnion, the predation

would be limited since few zooplankton species live below the thermocline (Dini, personal communication).

Two factors are present that may have limited the predation pressure of *C. americanus* on the zooplankton communities, especially the *Daphnia* population. When the final samples were collected, the *C. americanus* population was most likely composed of both third and fourth instars in approximately a one to one ratio (Von Ende, 1982). The *C. flavicans* and *C. trivittatus* populations were entirely in the fourth instar (Von Ende, 1982). Since *Chaoborus* larvae consume the majority of their prey while in the fourth instar, the *C. flavicans /C. trivittatus* mixture would have been consuming at its maximum rate since the end of July, when the last *C. flavicans* molted to the fourth instar. The *C. americanus* population would never reach its maximum predation rate during the course of the experiment. Secondly, *Daphnia*, like *C. flavicans* and *C. trivittatus*, migrate below the thermocline during the day (Dini, personal communication). *C. americanus* are in the same area of the water column as *Daphnia* only during the night, while *C. flavicans* and *C. trivittatus* may migrate with the *Daphnia* and be able to consume them constantly. If the migrating *Chaoborus* species do not prey at night, this *Daphnia* migration would not be a factor in the varying predation rates of each species. Both the migrating and non-migrating species would have equal opportunity to encounter the *Daphnia* during the day when both species are preying and are residing in the same waters as all their prey.

Not only the amount of predation varied among the bags, but the species of prey the *Chaoborus* affected also varied. *C. americanus* seemed to

control the *Daphnia*, copepodite, *D. oregonensis*, and *T. prasinus* populations while the *C. flavicans, C. trivittatus* mixture only controlled the *Daphnia* and copepodite populations. Two factors may provide an explanation for these results. First, Schoener hypothesized that as the metabolic rate of a predator increases or as the availability of resources increases, the predator increasingly specializes on the most profitable prey (Schoener, 1971). *C. flavicans* and *C. trivittatus*, as mentioned earlier, may have a greater availability of food per organism because of their lower densities and may also have lower metabolic rates. *C. flavicans* and *C. trivittatus*, thus, may be more able to select their prey and consume primarily *Daphnia* and copepodites. *C. americanus* may exibit less selectivity and consume *D. oregonensis* and *T. prasinus* in addition to *Daphnia* and copepodites. Secondly, as mentioned earlier, *D. oregonensis* and *T. prasinus* may have adapted specific behavioral or morphological characteristics that made them difficult for their native predators, *C. flavicans* and *C. trivittatus*, to capture and/or consume. *C. americanus* may capture or consume its prey in a different manner and thus avoid these adaptations.

In this study competitive interference appears to be less important than predation in structuring the zooplankton community. Vanni (1987) in his experiment also found that the effects of competition are dwarfed by the effects of predation in zooplankton communities. In the bags containing *C. americanus*, where the *Daphnia* population, was nearly eliminated, the copepodite population decreased and the *D. oregonensis* and *T. prasinus* populations respectively remained constant or only increased slightly compared to the substantial population increases that resulted for these

species in the bags containing *C. flavicans* and *C. trivittatus.* The increased predation of these species seems to have overcome the decreased competition and limited their growth. Secondly, in the bags containing no *Chaoborus* where the *Daphnia* populations increased up to twenty-five-fold, the *D. oregonensis,T. prasinus,* rotifer, and, to some extent, the copepedite populations all increased, contrary to what one would expect if competition were playing a major role.

Several zooplankton populations died out uniformly throughout the bags. *C. unicornis, M. edax,* and *O. modestus* were absent from all the final samples. The native *Conichilus, M. edax,* and *O. modestus* in Peter Lake had also died out by the middle of August when the final samples were collected. *H. gibberum,* initially a dominant member of the zooplankton community, also died out uniformly throughout the bags. *H. gibberum* is known to not survive well in mesocosms (MacKay, personal communication). The*Chydorus sphaericuus, Ploesoma sp., Polyarthra vulgaris,* and *Trichocerca cylindrica* populations all increased uniformly from the initial to the final sampling periods. These trends were no followed in the native populations of Peter Lake. Most likely these species increased because of a bag effect.

LITERATURE CITED

CARPENTER, S. R., J. F. Kitchell, J. R. Hodgson, P. A. Cochran, J. J. Elser, M. M. Elser, D. M. Lodge, D. Kretchmer, X. He, and C. N. von Ende. 1987. Regulation of lake ecosystem primary productivity by food web structure in whole-lake experiments. Ecology 68: in press.

FEDORENKO, A. Y. 1973. Instar and species-specific diets in two species of *Chaoborus.* Limnol. Oceanogr., 20: 238-249.

_____. 1975. Feeding characteristics and predation impact of *Chaoborus* (Diptera, Chaoboridae) larvae in a small lake. Limnol. Oceanogr., 20: 250-258.

FRANKE, CHRISTIAN. (Inst. Allgemeine Zool, Koenigin-Luise-Str. 1-3, D-1000 Berlin 33, W. Ger.) 1984. A model for the buoyancy of the larvae of *Chaoborus flavicans* (Diptera, Chaoboridae). Zool. Beitr., 28(2): 231-252.

GOLDSPINK, C. R., and D. B. C. SCOTT. 1971. Vertical migration of *Chaoborus flavicans* in a Scottish loch. Freshwater Biol. 1: 411-421.

KAKAK, Z., and B. RANKE-RYBICKA. 1970. Feeding and predation efficiency of *Chaoborus flavicans* Meigen (Diptera, Culicidae) larvae in eutrophic and dystrophic lake. Pol Arch. Hydrobiol. 17: 225-232.

KRUEGER, DONALD A. and STANLEY I. Dodson. 1981. Embryological induction and predation ecology in *Daphnia pulex*. Limnol. Oceanogr., 26: 219-223.

SCHOENER, T. W. 1971. Theory of feeding strategies. Annu. Rev. Ecol. Syst. 2: 369-404.

VANNI, MICHAEL J. 1987. Effects of food availability and fish predation on a zooplankton community. Ecological Monographs, 57: 61-88.

VON ENDE, CARL N. 1982. Phenology of four *Chaoborus* species. Environmental Entomology, 11: 9-15.

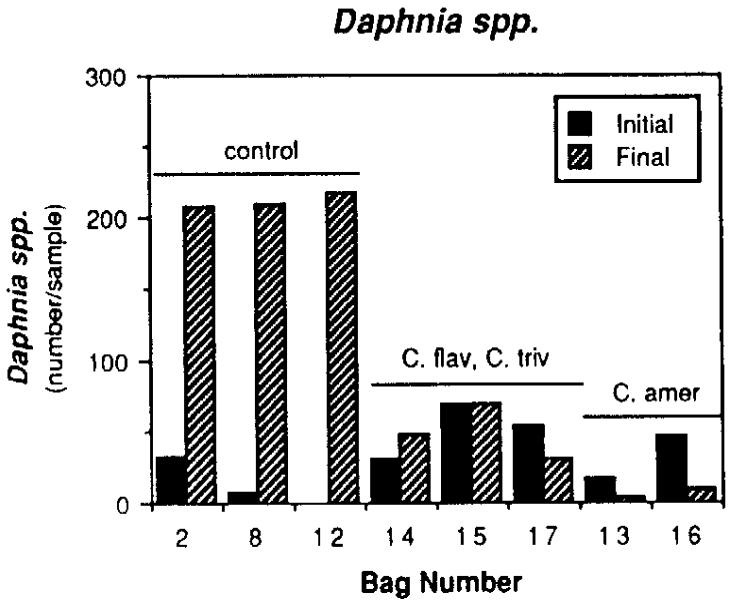

Figure 1. Number of *Daphnia* collected in each sample of the initial and final sample sets

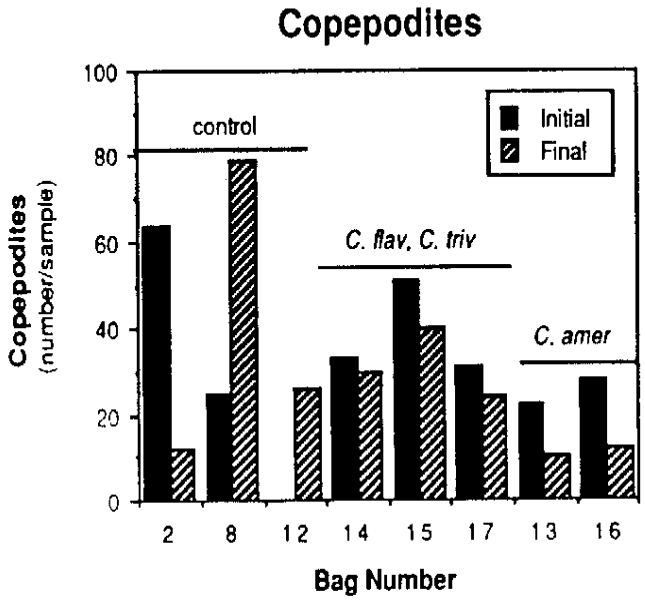

Figure 2. Number of copepodites collected in each sample of the initial and final sample sets.

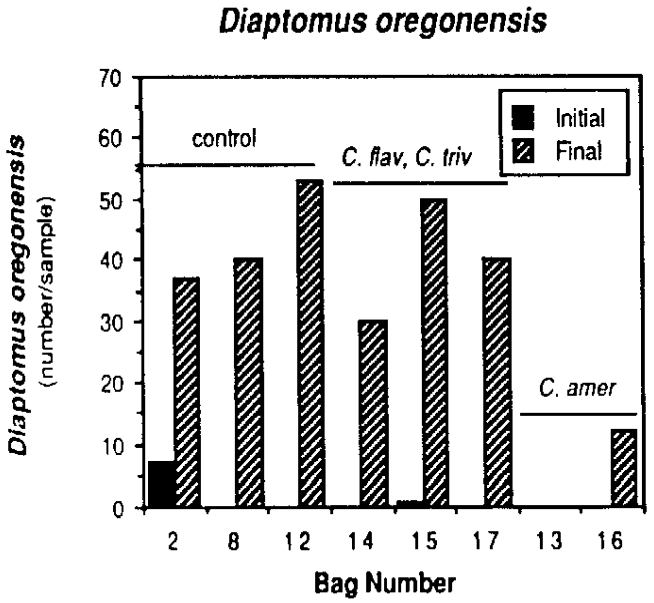

Figure 3. Number of *Diaptomus oregonensis* collected in each sample of the initial and final sample sets.

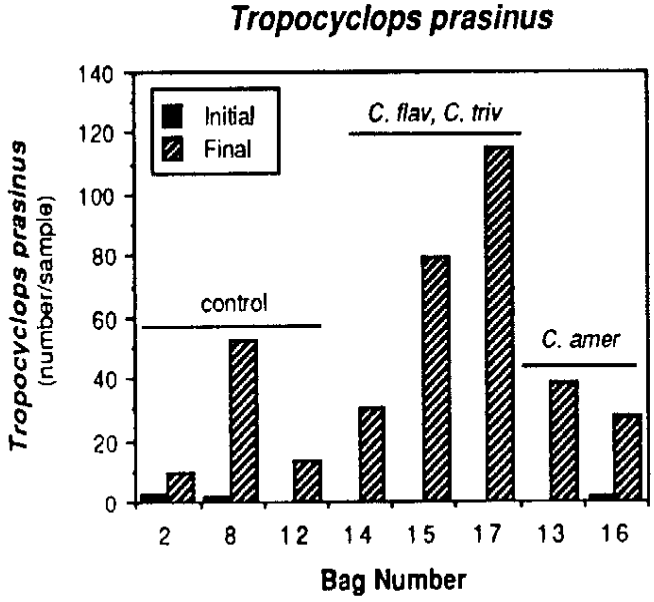

Figure 4. Number of *Tropocyclops prasinus* collected in each sample of the initial and final sample sets.