An Experimental Study On the Effects of Climate Change on Primary Consumer Behavior of *Camnula pellucida* in the Field

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ABSTRACT

Grasshoppers of the species *Camnula pellucida* were placed in enclosures in the field over natural vegetation and exposed to different treatments of solar radiation. Grasshoppers were monitored for significant effects of solar treatments on behavior in particular feeding activities. Significant differences in activity rates among treatments were found. The relationship between increased solar radiation and consumption of available food sources enables further understanding of time and amount limited populations within food webs.

INTRODUCTION

It is becoming more evident among ecologists that increased warming patterns across the globe are affecting ecosystem functioning at many levels, including primary production. The implications of these warming patterns are far from being understood or predicted. To predict large scale and long- term affects of global thermal patterns, discovery about individual ecological microcosms must be made. The effects of interactions within different trophic levels and their effect on primary production and nutrient cycling, is one avenue for this discovery.

Primary production may be affected by many different factors within a community. Herbivorous populations are limited by the available plant biomass. Food limited populations are either time or amount limited. Time limited populations are not allotted the time to consume all available resources. If a population is time limited, they have an abundance of food, which will not be depleted so long as they have a time limit for feeding. Amount limited populations are limited by total plant biomass. If a population is amount limited, members of the species have the ability to feed until no resources remain for consumption. Populations, which are time limited, are not limited by the amount of food available, but by the time they have to engage in feeding behavior, due to climate, handling time, predation or other environmental factors. Time or amount limitations, especially in terms of feeding activity, may cause slowing or speeding of nutrient cycling, which affects the amount of primary production in the food web (Belovsky and Slade 2000). Therefore, it is crucial to discover whether a population's food consumption time or amount limited to understand how herbivores affect primary productivity.

Temperature can affect how ectoderms are limited by food in addition to climate, predation, abundance and other abiotic factors. Thermal environmental conditions are often major deciding factors on daily feeding times of ectoderms. Ectoderms, such as grasshoppers, have time constrains on feeding and food processing by ambient radiation and temperature (Chase 1996). Grasshoppers such as *Camnula pellucida*, the clearwinged grasshopper, are inactive at night and active during the day. They rest in sheltered areas, which protect from wind and rain at night, and allow for conservation of body temperature. The grasshoppers begin to climb out of their sheltered places to more open areas only after temperature increases. As temperatures continue to rise, grasshoppers start moving and begin to feed. If temperature rises too high, grasshoppers become stationary. When temperatures are lower at the end of the day, grasshoppers crawl back into sheltered places. Numerous elements of climate, such as temperature and solar radiation, modify daily behavior budgets (Wyoming Agricultural Experiment Station Bulletin 1994). Changes in global temperature may influence whether ectoderms such as grasshoppers are time or amount limited if it effects total available feeding time.

Thus, for ectoderms, time limitations may result from lack of solar radiation, which is required to metabolize and fuel digestion during feeding activities. Cool climate conditions, as in the northern areas of the Upper Peninsular region of UNDERC, most likely lead to time limited grasshopper populations instead of amount limited populations (Laws 2002). As a result of a low temperatures, grasshoppers among these populations are expected to be experiencing maximum feeding times that would result in depletion of food, and cause them to be amount-limited. If time limited grasshopper populations are exposed to warmer conditions, as predicted with global climate change, they should show an increase in available feeding time switch to amount limitation.

One valuable way to test the shift from time to amount limited populations, is to observe the behavioral changes in feeding times of grasshoppers exposed to different temperature regimes. Populations of the grasshopper, *C. pellucida,* an important pest species, along with their plant food source, may be easily manipulated in field enclosures, and are excellent representatives of food chain dynamics (Belovsky and Slade1993, Chase 1996, Laws 2002). Two level food chain enclosures of plants and grasshoppers may be exposed to different temperature manipulations, and then observed for behavioral modifications in them. Changes in behavior would indicate a shift from time to amount limited populations as temperature is increased (Laws 2002). Thus, as temperatures rise feeding time is expected to lengthen. The implications and intensity of global thermal patterns within controlled two trophic level food webs may aid in the prediction of similar implications at higher levels of ecosystem functioning.

MATERIALS AND METHODS

After hatching in the early summer, nymphs of grasshopper *Camnula pellucida,* a common species at UNDERC, were collected. Grasshoppers were transferred to $0.5\mathrm{m}_2$ (basal area), aluminum screen enclosures placed in an old field over natural vegetation. Grasshoppers were stocked in even sex ratios at field densities. Field densities were estimated by observing $0.1\mathrm{m}_2$ quadrates daily for one week, to determine field abundance. Any foreign substrates, such as rock or stone, that may absorb heat and allow grasshoppers to transfer heat to their bodies (Chapman and Joern 1990), which may disrupt the control of radiation, were removed. Spiders and other possible *C. pellucida* predators were removed from cages. Six treatments were created, by altering the amount of solar radiation affecting the enclosures (Laws 2002). Solar radiation was decreased by placing eighty percent shade cloth around the Southeastern sides of the cages for either four or six hours a day. Solar radiation was increased by placing a greenhouse constructed of clear plastic sheeting around the enclosures for four, six or eight hours a day. Finally, a control treatment remained uniform with the ambient environment. Each of the six solar radiation treatments were represented by four replicates which were randomly assigned to enclosures in the field. Inventory on all of the grasshoppers was taken weekly to obtain expected total population counts and measure survival rates.

C. pellucida were observed as nymphs early in the season, and as adults weeks later. Observations took place from 8am to 5pm each day for a three-day span. One replicate of each treatment was observed each day. Each treatment was observed every fifteen minutes throughout the observation period. Behaviors were categorized as feeding, stationary or moving on vegetation, or stationary or moving on the screen. The number of *C. pellucida* engaging in each behavior was observed and recorded during each fifteen minute interval to track any changes or variation among treatments during the day. To ensure human presence did not alter the grasshoppers' activity, the observers waited five minutes before recording any behavior. The observer's presence has appeared in past experimentation as well as in this project, to have little impact on the behavior of the specimens, which allows for assessment and comparisons of activity and feeding time budgets of grasshoppers (Chase 1996).

Behavioral counts were grouped into three two-hour periods (1) from eight am to ten am, (2) eleven am to one pm and (3) two pm to four pm. The data was analyzed using the Kruskal-Wallis test with temperature as the independent variable and the proportion of grasshoppers feeding as the dependent. A linear regression line was plotted for the feeding data against temperature to verify a correlation between feeding activity and solar radiation.

RESULTS

The proportion of grasshoppers feeding during the first observation period between eight and ten am indicates a significant difference between treatments ($p=0.024$, Figure 1). There was no significant difference in feeding time between treatments for the other time periods (p= 0.337, p=0.105, Figure 1).There is a significant difference among treatments in the proportion of *C. pellucida* found stationary on both the screen and the vegetation for the last two observation periods (p= 0.011, p=0.021, Figure 2 and p=0.031,p=0.030, Figure 3). However, the data was not significant for the first time period for proportions of grasshoppers found stationary on both the screen and the vegetation (p=0.108, Figure 2, p=0.105, Figure 3). The difference in the proportion of *C. pellucida* found moving on the screen during the second observation period was only significant between treatments (p= 0.025, Figure 4). The first and third observations for the proportion of grasshoppers found moving on the screen had an insignificant difference among treatments (p=0.660, p=0.167, Figure 4). An insignificant difference among treatments is represented during the first and second observation periods for the proportion of grasshoppers found moving on the vegetation (p=0.171, p=0.284, Figure 5). The final observation period between two and four pm has a significant difference among treatments in the proportion of grasshoppers found moving on the vegetation (p= 0.047, Figure 5).

Time spent feeding is expected to increase with temperature and a linear regression plot was used to determine whether a significant correlation between the length of time spent feeding and solar radiation. The linear regression plot of the proportion of *C. pellucida* feeding vs. treatment was significant only for the first time period (R=0.661, p=0.003, Figure 6). Overall observations of grasshopper feeding were highest in the four-hour sun enclosures. Feeding occurred most frequently in all treatments during the second time period when sun exposure was generally at its maximum. Feeding in the six-hour shade enclosures was at its highest in the middle of the day. The six-hour sun enclosures, however, represented a drop in feeding activity at the prime time of sun exposure in the second time period. Observations of movement on vegetation were most prevalent in the two and four hour shade and greenhouse treatment enclosures of two hours of sun but at the height of the day during the second time period.

DISCUSSION

The *C. pellucida* seemed to be moving up the screens most during the start of the observation period and were not as noticeable during the height of the day, the second observation period, on the screens but were moving back down on the screens toward the end of the observation period. Thus, UNDERC populations act in accordance with the theory that grasshoppers begin to climb out of their sheltered places to more open areas only after temperature increases and as temperatures continue to rise, start moving and begin to feed. If temperature rises too high, grasshoppers become stationary, accounting for the less notable activity during the second observation period at the height of the day. The combination of the highest temperatures of the day with additional greenhouse treatments trapping heat may have provided the maximum radiation required for grasshoppers to become sedentary and unable to perform metabolic functions such as feeding activities. Four and six hour shade treatments had the highest frequency of grasshoppers stationary on the screens during all time periods. This may be due to the lowered solar radiation, which causes grasshoppers to spend more time basking in an attempt to increase body temperatures. Increasing body temperature will allow the *C. pellucida* to perform metabolic functions such as feeding. The two-hour shaded enclosures had the highest frequency of grasshoppers found stationary on the vegetation throughout the day also, perhaps, due to lower temperatures, which increases necessary basking time. High temperatures seem to impact the level of grasshopper activity. As solar radiation increased with treatments so to did the amount of feeding behavior observed within the *C. pellucida* populations. This trend was only significantly represented during the first observation period, which suggests increased solar radiation does not impact grasshopper feeding behavior during the last two observation periods but allows them to begin feeding sooner during the initial observation period. Lengthened total feeding time suggests that grasshopper populations at UNDERC may shift from time to amount limited.

The species *Camnula pellucida*, or clearwinged grasshopper is a pest to grains and grasses. Early in the summer, populations of *C. pellucida* are devastating to crops such as spring wheat. Grass areas of 2,000 square miles have been ruined by outbreaks of these clearwinged grasshoppers. Reduction of Kentucky bluegrass yield by 5.1 pounds per acre for each nymphal grasshopper per square yard has been shown by cage plot tests on native grasslands of interior British Columbia. A reduced yield of 1 pound per day over 1 acre resulted from an infestation of one young adult per square yard. Infestations also preferentially feed on vegetable crops of peas, cabbage, lettuce, and onions (Wyoming Agricultural Experiment Station Bulletin 1994). Therefore, if increased temperatures allow grasshoppers to begin feeding sooner, lengthening total feeding time, global climate change may significantly increase the efficiency of this important species.

ACKNOWLEDGMENTS

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1: six hours of shade, 2: four hours of shade, 3: ambient conditions, 4: two hours of greenhouse treatment,, 5: four hours of greenhouse treatment, 6: six hours of green house treatment

FEEDING

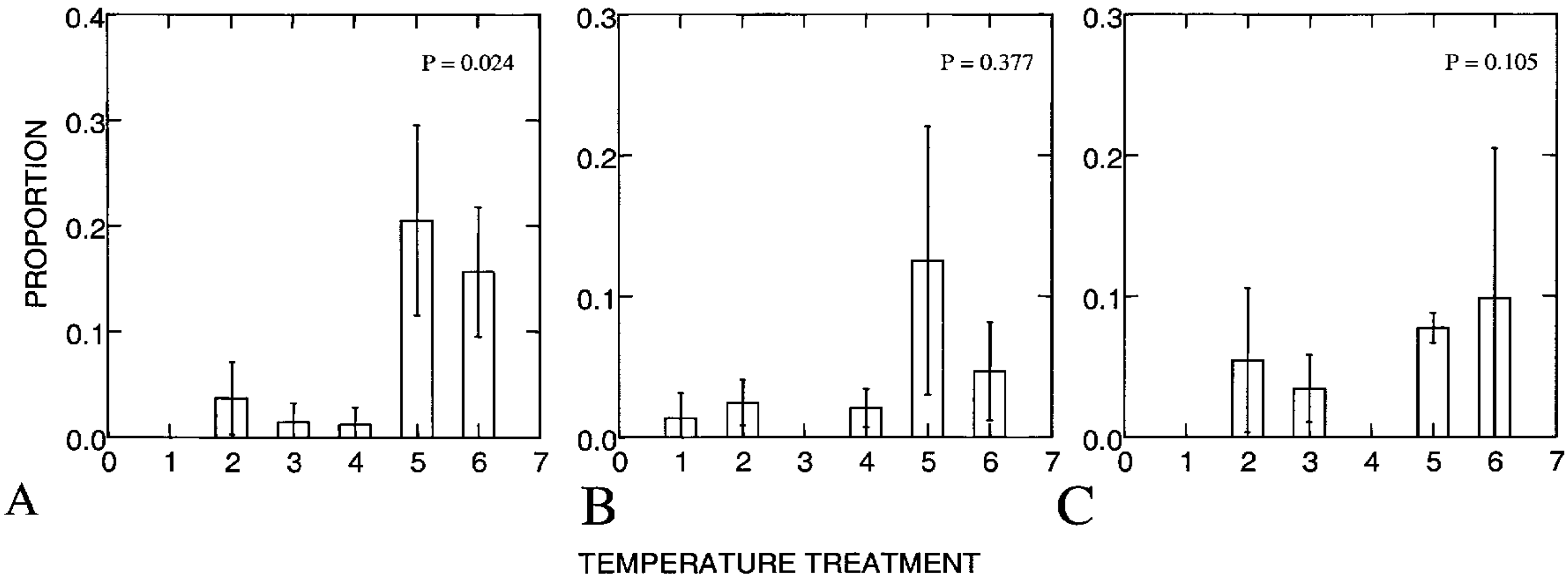

Figure 1: Proportion of *C. pellucida* feeding A: 8:00 – 10:00am, B: 11:00 – 1:00pm, C: 2:00 – 4:00pm

1: six hours of shade, 2: four hours of shade, 3: ambient conditions, 4: two hours of greenhouse treatment,, 5: four hours of greenhouse treatment, 6: six hours of green house treatment

STATIONARY-SCREEN

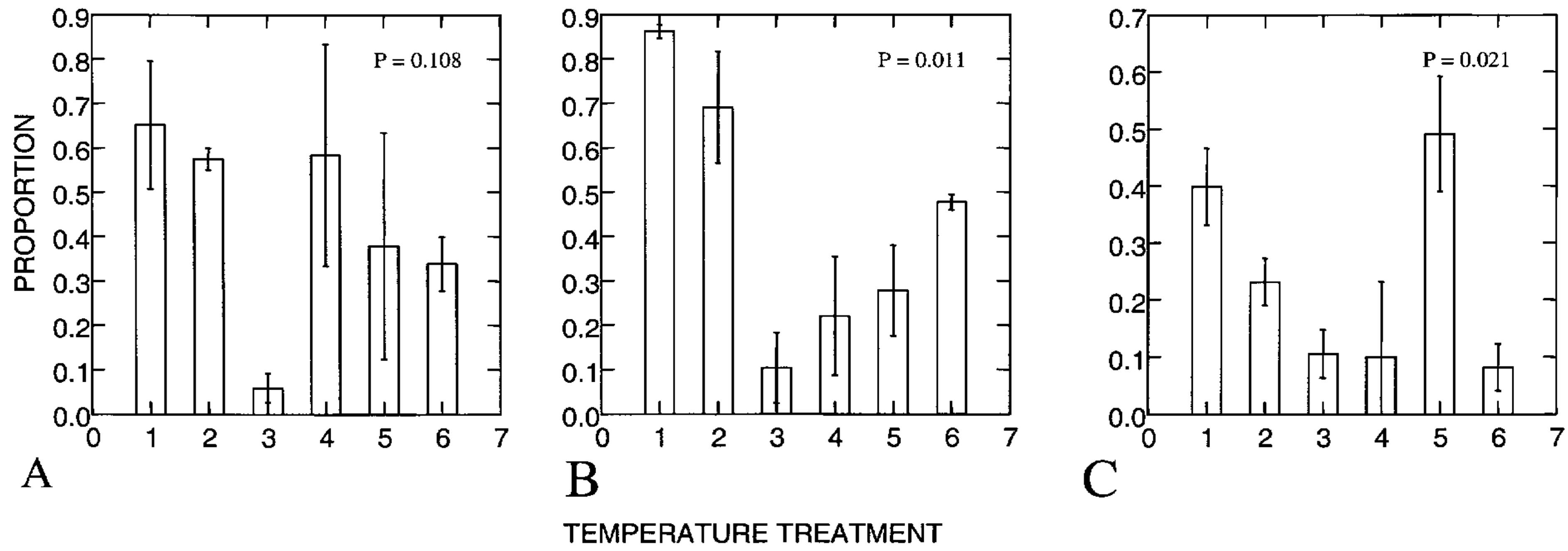

Figure 2: Proportion of *C. pellucida* found stationary on the screen; A: 8:00 – 10:00am, B:11:00 – 1:00pm, C: 2:00 – 4:00pm

1: six hours of shade, 2: four hours of shade, 3: ambient conditions, 4: two hours of greenhouse treatment,, 5: four hours of greenhouse treatment, 6: six hours of green house treatment

STATIONARY-VEGETATION

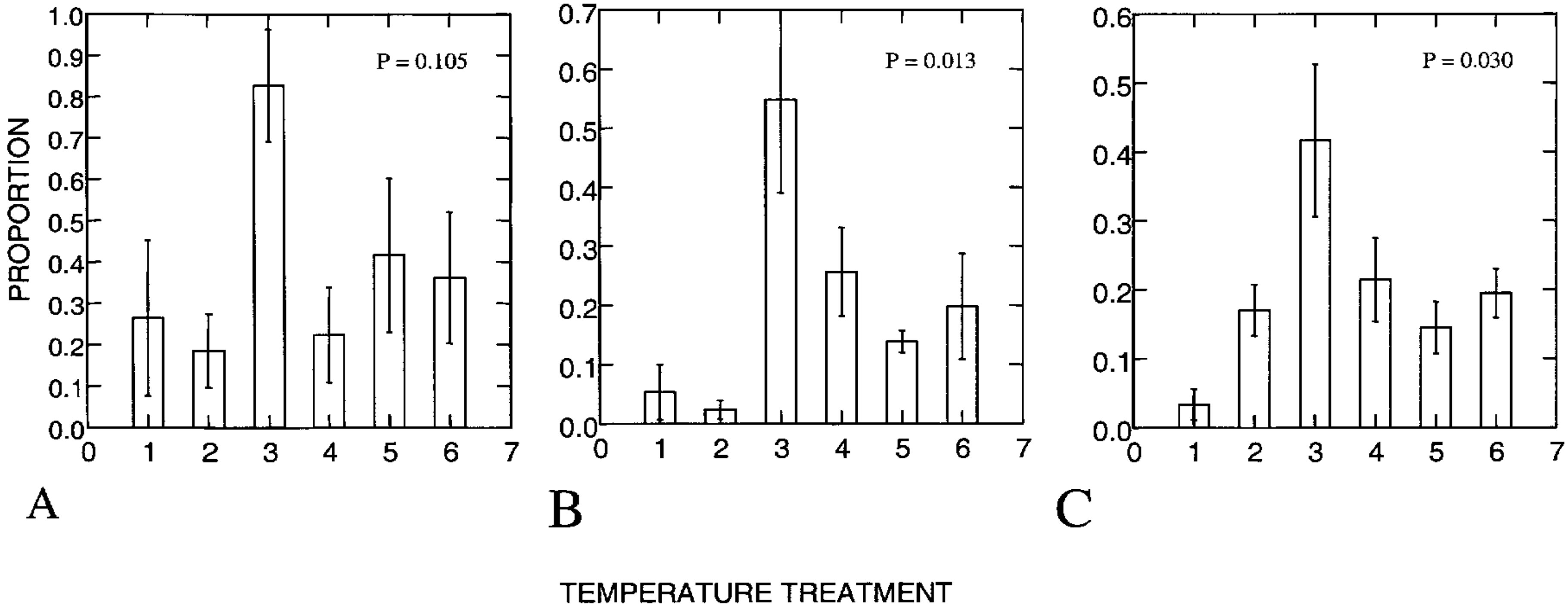

Figure 3: Proportion of *C. pellucida* found stationary on the vegetation; A: 8:00 – 10:00am, B:11:00 – 1:00pm, C: 2:00 – 4:00pm

1: six hours of shade, 2: four hours of shade, 3: ambient conditions, 4: two hours of greenhouse treatment,, 5: four hours of greenhouse treatment, 6: six hours of green house treatment

MOVING-SCREEN

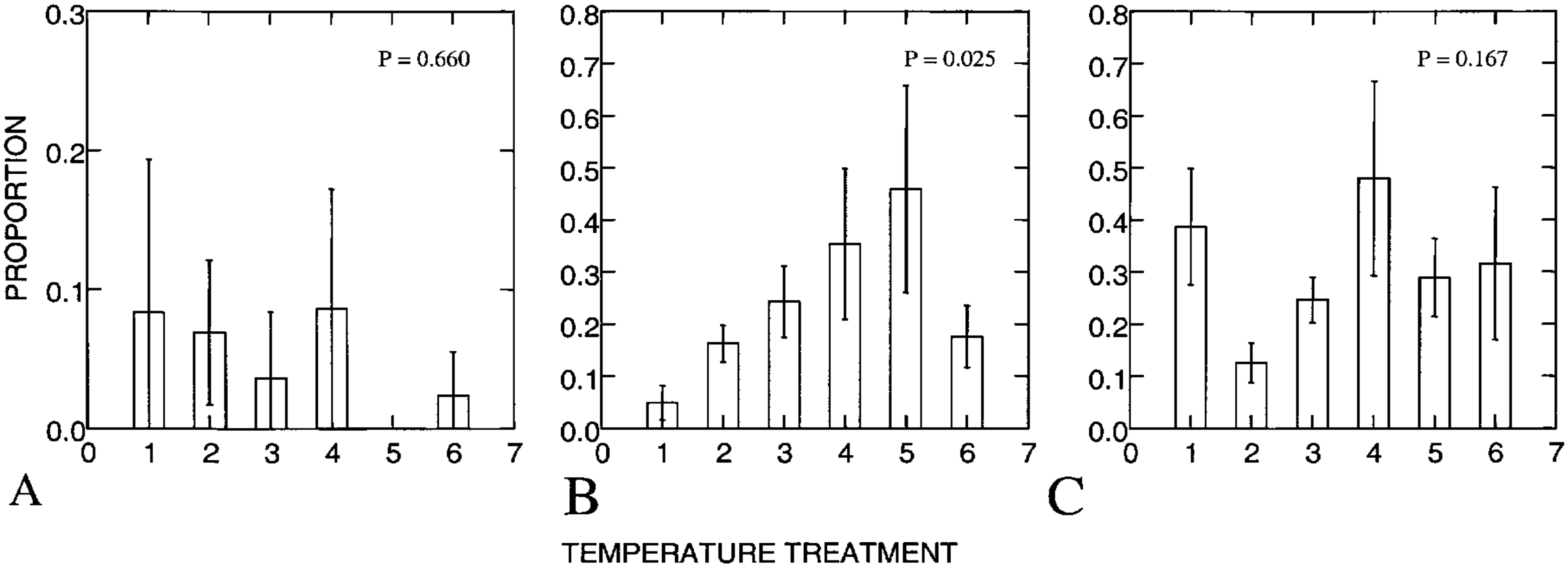

Figure 4: Proportion of *C. pellucida* found moving on the screen; A: 8:00 – 10:00am, B:11:00 – 1:00pm, C: 2:00 – 4:00pm

1: six hours of shade, 2: four hours of shade, 3: ambient conditions, 4: two hours of greenhouse treatment,, 5: four hours of greenhouse treatment, 6: six hours of green house treatment

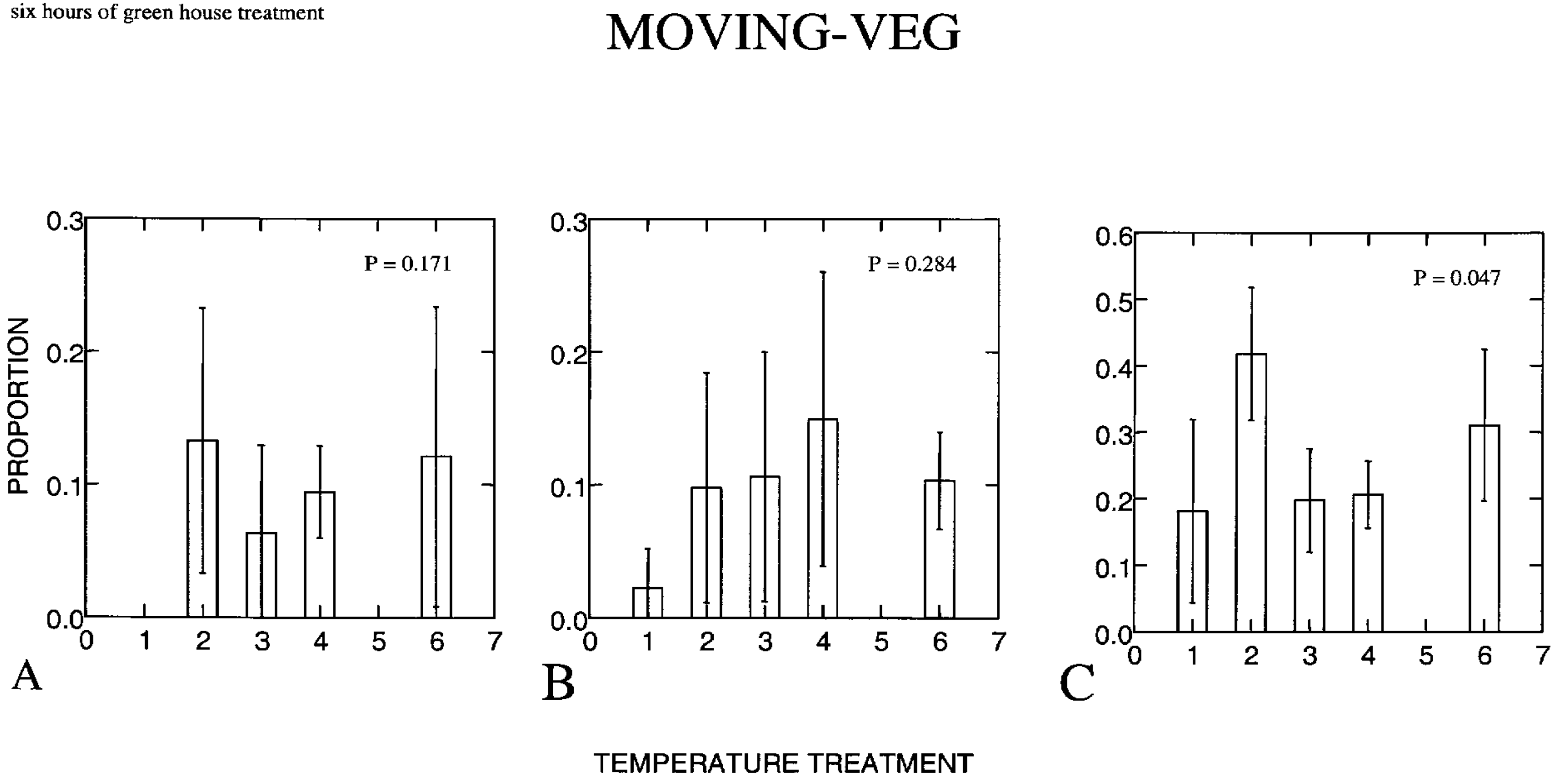

Figure 5: Proportion of *C. pellucida* found moving on the vegetation; A: 8:00 – 10:00am, B:11:00 – 1:00pm, C: 2:00 – 4:00pm

1: six hours of shade, 2: four hours of shade, 3: ambient conditions, 4: two hours of greenhouse treatment,, 5: four hours of greenhouse treatment, 6: six hours of green house treatment

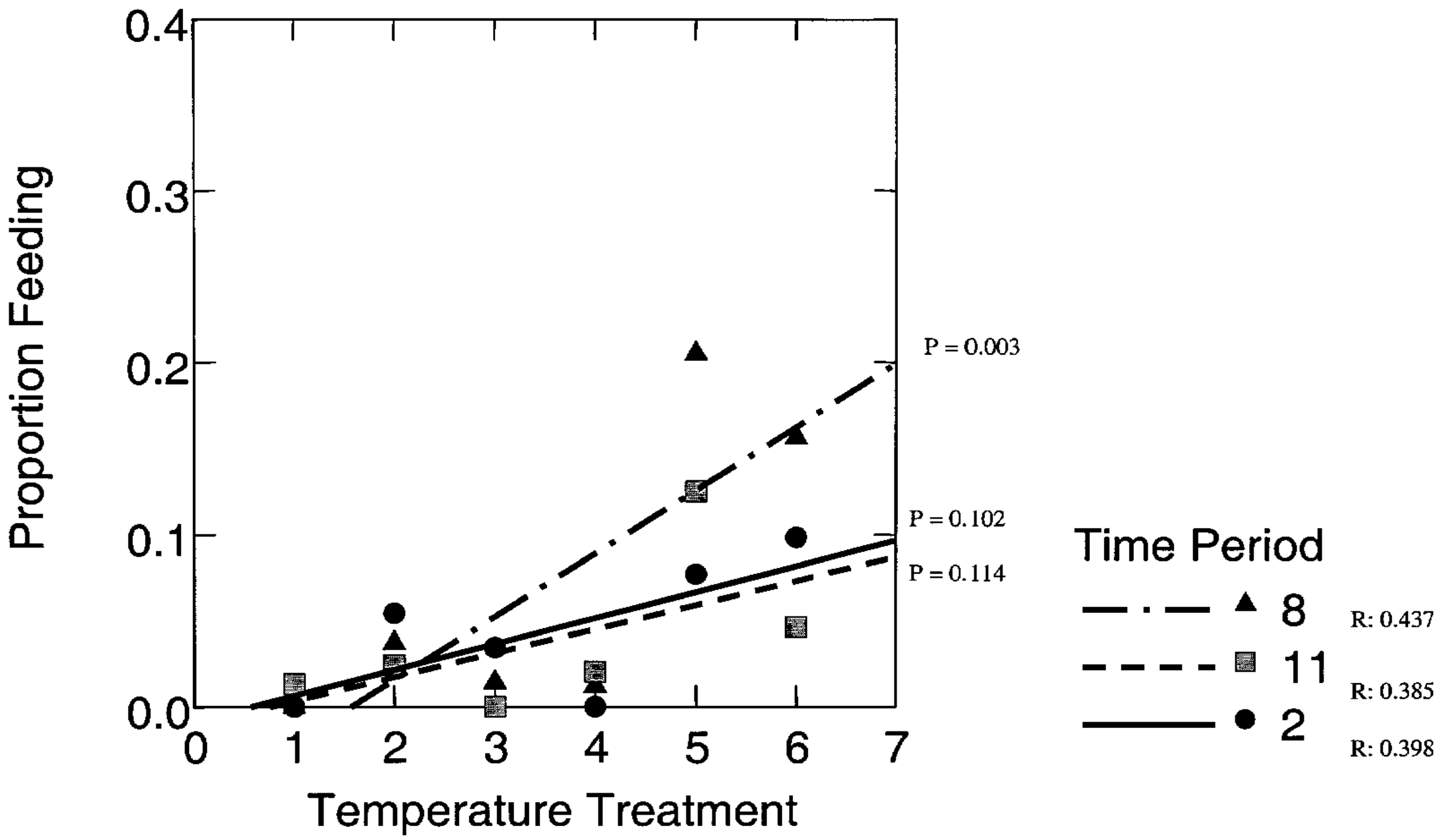

Figure 5: Proportion of *C. pellucida* found feeding at different time periods