DIURNAL ZOOPLANKTON DISTRIBUTION IN RELATION TO AQUATIC VEGETATION IN A TROPICAL MARSH

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Abstract. Aquatic vegetation in freshwater systems can affect zooplankton distribution. Varying complexities of underwater structure may provide zooplankton with different levels of protection from visual planktivores. We hypothesized that zooplankton density in the Laguna Palo Verde freshwater marsh would be higher beneath aquatic plant communities with the most complex underwater structure. We sampled zooplankton beneath three common aquatic plants. Zooplankton were most dense under floating mats of chorizo, which had the most complex underwater structure. Zooplankton populations were less dense under water-lily and water hyacinth, both of which had less underwater structure than chorizo. Conservation strategies aimed at maintaining trophic diversity in the marsh should further examine the ecological impact and consequences of the exotic water hyacinth.

Key words: Eichhornia crassipes, *exotic species, freshwater marsh,* Neptunia plena, Nymphaea *spp., root structure, zooplankton density*

INTRODUCTION

Zooplankton distribution in freshwater systems is often related to the presence and type of aquatic vegetation (D. Chiavelli, pers. comm.). During the day, zooplankton tend to be more abundant in patches of vegetation than in open water to hide from visual planktivores (Carson et al. 1995, D. Chiavelli, pers. comm.). The complexity of underwater structure may also influence zooplankton distribution by creating habitats with different levels of protection from visual predators.

Three types of floating vegetation that differ in their underwater structure occur in the Laguna Palo Verde marsh: *Neptunia plena* (chorizo, a mimosoid legume), *Nymphaea* spp. (water-lily), and *Eichhornia crassipes* (water hyacinth). While both water-lilies and water hyacinth occur in distinct patches, chorizo typically co-occurs with *Utricularia gibba, Ceratophyllum muricatum,* and sedges. We hypothesized that zooplankton density would vary under different vegetation types with more zooplankton under plant communities with the most complex underwater structure.

METHODS

We sampled three patches each of chorizo, water-lily and water hyacinth on 9 January 1998, in Laguna Palo Verde, a mostly freshwater marsh in Palo Verde National Park, Costa Rica. We took two replicate samples at each of the nine patches, and assessed underwater structure of each vegetation type in the field. We used a tube sampler to collect zooplankton from directly beneath vegetation mats, each of which were 4 - 9 m^2 in area. We carefully spread the vegetation (to minimize agitation), then lowered a collecting tube 30 cm into the water and capped it with a rubber stopper at one end. We used a second rubber stopper to seal the tube, removed the tube from the water, and filtered the sample (738 cm^3) through 110-µm mesh. The contents were washed into sample vials and all crustacean zooplankton were later identified under dissecting microscopes and counted. An ANOVA with a Tukey test for multiple comparisons ($\alpha = 0.05$) was used to test the effect of vegetation on the density of each taxon and on total zooplankton density.

RESULTS

The three vegetation types differed in the complexity of their underwater structures. Water hyacinth occurred in a dense mat on the surface, beneath which was open water free of stems. The water-lily had large floating leaves rooted to the marsh substrate by a slender stem. Chorizo, and associated species, combined to form a dense surface mat extending 20 cm down into the

TABLE 1. Mean crustacean zooplankton densities (number / liter) in each vegetation type.

Zooplankton Taxon	Mean ± SE Chorizo	Water Lily	Water Hyacinth	$F_{2, 6}$	P
Calanoid	7.22±1.74	3.19±1.03	0.68±0.46	3.77	0.087
Cyclopoid	17.83±3.84	1.36±0.70	2.26±0.29	11.25	0.009
Diaphanosoma	3.61±2.28	0.68±0.46	1.80±0.29	2.04	0.21
Chydorid	9.49±3.83	1.12±0.46	3.83±1.73	4.02	0.078

water column. This mat consisted of a tangle of underwater stems and sausage-sized roots.

Total zooplankton density differed significantly among our three patch types ($F_{2,6}$ = 14.28, P = 0.005). Zooplankton were significantly more abundant under chorizo than under water hyacinth or water-lily (P < 0.05; Fig. 1). Zooplankton density did not differ significantly between patches of water hyacinth and water-lily (P > 0.05; Fig. 1). We recognized four crustacean zooplankton taxa: cyclopoid copepods, calanoid copepods, chydorids, and *Diaphanosoma* (Sididae). Aquatic mites were also present, but not counted. All taxa occurred in all three patch types. All were more abundant under chorizo (Table 1), but only cyclopoid copepods showed a significant effect of habitat ($F_{2,6}$ = 11.25, P = 0.009; Table 1).

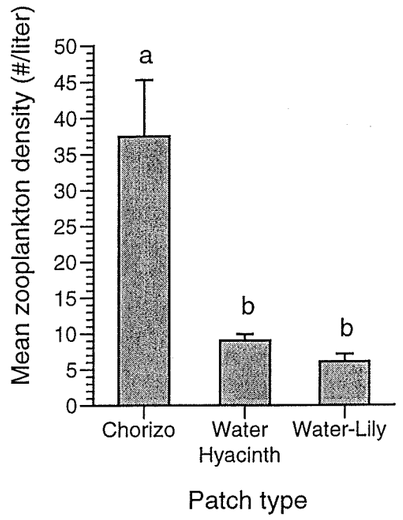

FIG. 1. Mean zooplankton densities across three habitat types of aquatic plants in the Laguna Palo Verde marsh. Bars with different lowercase letters were significantly different.

DISCUSSION

Zooplankton density in Laguna Palo Verde varied with the structural complexity of aquatic vegetation. Chorizo had more complex underwater structure than either water-hyacinth or water-lily, and the water column beneath it contained the highest zooplankton density. This suggests that chorizo communities may provide zooplankton with more daytime refugia from visual predators than water hyacinth or water-lily. Because we did not measure predation directly, it is possible that other factors, such as differential food availability associated with various aquatic plants, affect zooplankton distribution. These alternative mechanisms could be tested by manipulating light availability and underwater structure and measuring the effects on both food availability and zooplankton density.

Diel vertical and horizontal migration of zooplankton have been shown repeatedly to be a tradeoff between feeding efficiency and predator avoidance (D. Chiavelli pers. comm). Previous studies in the Palo Verde marsh have shown that zooplankton migrate to open water areas at night, where they can feed on high phytoplankton populations with reduced threat from visual predators (Dums and Gilbertsen 1997). During the day, zooplankton hide from visual planktivores in darker environments despite the reduced abundance of phytoplankton. In lakes without visual predators, zooplankton do not exhibit this migratory behavior; instead they remain in areas of high phytoplankton abundance throughout the day. These findings support the hypothesis that predator avoidance is the mechanism responsible for differences in zooplankton associated under different communities of aquatic vegetation.

Regardless of the mechanisms, our results indicate that the recent invasion of the Palo Verde marsh by water hyacinth could reduce zooplankton abundance. In the past century, water hyacinth has invaded many areas beyond its native range in lowland tropical South America, and it is now one of the most widespread of invasive aquatic plants (Barrett 1983). Possible consequences of reduced zooplankton abundance include: (1) increases in the algal populations that support zooplankton, and (2) decreases in bird, fish, and insect populations that are supported by the zooplankton. Increases in algae could increase amounts of decaying matter at the bottom of the marsh. The increased respiration rates associated with increased decaying matter could result in anoxia, with immediate catastrophic effects on many marsh organisms. Efforts to prevent the invasion and expansion of water hyacinth should be considered in management strategies.

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