Effects of Vegetation on the Efficacy of Larval Mosquito (Diptera: Culicidae) Control by a Native Larvivorous Fish

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ABSTRACT: Created wetlands are often planted with vegetation, creating microhabitats suitable for the production of large numbers of mosquitoes. Previous studies have found that wider bands of vegetation reduce the efficacy of *Gambusia affinis*, the mosquitofish, to control larval mosquito populations. This study examines the effects of vegetation patch size on two other predators of larval mosquitoes, backswimmers (Hemiptera: Notonectidae) and arroyo chubs (*Gila orcutti*). The arroyo chub was chosen since it is native to southern California, has a capacity to control larval mosquitoes, and is a species of special concern due to urbanization and to competition with introduced fish. In autumn 2006, twelve ponds at the UC Riverside Agricultural Experiment Station received additions of the bulrush *Schoenoplectus californicus* in one of two arrangements such that twelve 0.1 m^2 (or single plant) plots, four 0.4 m^2 (or four plant) plots and two 0.9 m^2 (or nine plant) plots were present. All twelve wetlands received additions of *Notonecta*. Six wetlands received additions of 30 g of *G. orcutti*. Samples taken through April 2007 showed that wetlands with fish have significantly fewer larval mosquitoes than wetlands with fish. While there was not a significant fish × vegetation plot size interaction, mosquito abundance in the 0.4 m^2 bulrush plots was consistently greater than in the 0.1 m^2 plots; however, mosquito abundance in these two smaller vegetation plots did not differ significantly from that in the largest plots. Samples were taken through the autumn and are currently being processed to assess whether the arroyo chub can provide season-long control of larval mosquitoes.

INTRODUCTION

Wetlands created for water reclamation have become increasingly popular means of reducing nitrogenous compounds in effluent water. These wetlands are often planted with vegetation to improve the stability of the soil, to promote the growth of bacteria and to increase the uptake of excess nutrients. Yet these created wetlands are also a breeding habitat for pestiferous insects such as mosquitoes. Thick stands of vegetation have been found to be detrimental to control by the mosquitofish, *Gambusia affinis*, due to reduced oxygen availability, decreased dispersal and lower prey detection rates (Swanson et al. 1996). Yet vegetation is necessary for the mosquitofish populations because it provides refuge from predation and heat (Walton et al. 1990, Swanson et al. 1996). The effects of vegetation on other predators of larval mosquitoes are unknown. Our study examines the effects of different sizes of vegetation patches on a fish species, *Gila orcutti* (Eigenmann and Eigenmann), and on invertebrate predators, such as *Buenoa* sp. (Hemiptera: Notonectidae). The goals of this study are to provide recommendations on the suitability of the arroyo chub as a replacement for the mosquitofish for mosquito control in riverine wetlands of southern California and to provide additional guidance on planting configurations of emergent vegetation in man-made wetlands situated near human development.

The arroyo chub is a native fish exclusively found in southern California coastal streams. However, due to the effects of urbanization as well as competition with introduced fish such as the red shiner, *Cyprinella lutrensis*, *G. orcutti* has been listed as a species of special concern in the region. Recent work in our lab (Van Dam and Walton 2007) has shown that *G. orcutti* is as effective at controlling larval mosquitoes as *G. affinis* in mesocosms without emergent vegetation. Furthermore, *G. orcutti* is able to withstand higher temperatures than another alternative larvivore to *G. affinis*, the stickleback (*Gasterosteus aculeatus* L.) and may be a preferred biocontrol agent in warmer climates. The efficacy of *G. orcutti* as a mosquito control agent in vegetated, operational constructed treatment wetlands needs to be determined prior to its being recommended as a replacement for *G. affinis*.

Recent studies have also touted the potential use of notonectids as biocontrol agents, but few studies have examined the effectiveness of these invertebrates. Rodriguez-Castro et al. (2006) found that *Buenoa scimita*, a backswimmer common in the Monterrey area of Mexico, was very effective against *Culex quinquefasciatus*, and that the 3rd -5th instars were the most effective at reducing the mosquito population.

MATERIALS AND METHODS

Into each 4-gallon plastic pot, we planted two clumps (3-5 culms/plant) of bulrush (*Schoenoplectus californicus* (C.A. Meyer) Palla) from the Hemet/San Jacinto Water Reclamation Facility. Plants were then trimmed to 1 m from the lip of the pot to facilitate transport. Wetlands were built by placing the plants into 4 x 7 m^2 ponds at the Aquatic Research Facility at the University of California-Riverside Agricultural Experiment Station in Riverside, California. Each wetland had three treatments of vegetation plot size: 0.1 m^2, 0.4 m^2 and 0.9 m^2 plots. A single pot represented the 0.1 m^2 plot, four pots were used to make the 0.4 m^2 plot, and nine pots were used to make the 0.9 m^2 plot. Each wetland received twelve 0.1 m^2 plots, three 0.4 m^2 plots and two 0.9 m^2 plots for a total of 46 plants per wetland. The plants were arranged in one of two different patterns, and each pattern was replicated six times. We stocked each wetland with Corixidae and Notonectidae by placing 12 screens in a wetland in Indio, CA for 7 d, wrapping the screens in moist towels and transporting the screens to Riverside; a screen covered with eggs was placed into each experimental wetland. Six wetlands (3 of each vegetation pattern) were stocked with approximately 30 g of arroyo chubs (hereafter, labeled fish) while the other six were left untreated (no fish). Samples were taken prior to the addition of the fish as well as one week after fish had been added using a 350-ml dip cup. Samples were then taken at monthly intervals during early spring and every two weeks from late spring until autumn. Invertebrates were identified according to Merritt and Cummins (1996) and enumerated. Data were analyzed using SAS 9.1.3.

RESULTS

Wetlands with fish had significantly fewer mosquitoes present than did wetlands without fish, despite starting with equivalent numbers of mosquitoes in October ($p = 0.0094$) (Figure 1). The abundance of immature mosquitoes during early spring was quite still low and variable among wetlands in each of the two treatments; yet, the mean abundance of mosquito larvae in wetlands with fish was about half that in wetland without fish. When larval mosquito numbers were assessed across the all wetlands regardless of the fish treatment, there were significantly more mosquitoes in the 0.4 m^2 plots than in the 0.1 m^2 plots, but neither of these was significantly different from the 0.9 m^2 plots (Figure 2). No significant differences between fish and no fish ponds existed in terms of the macroinvertebrate community as a whole or in any of the other major invertebrate groups captured, including Odonata, Ephemeroptera, and Chironomidae (Diptera).

DISCUSSION

Samples from wetlands containing fish taken through early May contained significantly fewer mosquitoes when compared with no fish wetlands. We believe that this difference in mosquito abundance is due to the presence of *G. orcutti*. Samples taken throughout the summer and autumn are currently being processed to determine if the fish continue to control the larval mosquito populations. Although Rodriguez-Castro et al. (2006) saw a significant reduction in the numbers of mosquitoes with the addition of *Notonecta*, we see that their presence alone does not control mosquitoes as well as the presence of fish. Despite stocking the wetlands with eggs of Notonectidae, very few backswimmers were captured in the samples. This likely is due to the bias of our sampling method. Dipping is biased against capturing fast swimming organisms such as backswimmers (Merritt and Cummins 1996).

It is unclear why immature mosquito abundance in the 0.9 m^2 plots did not differ significantly from the 0.1 m^2 plots, especially when one considers that there is a significant difference in the 0.4 and 0.1 m^2 plots. Dragonfly naiads (Odonata) were significantly more abundant in the 0.4 and 0.9 m^2 plots than in the 0.1 m^2 plots, and it is possible that these helped to control mosquitoes in the largest plots. Further analysis will be done on the samples taken over the summer and autumn.

Based on the trends for mosquito abundance in the samples analyzed to date, we conclude that the arroyo chub shows great promise as a replacement for the mosquitofish in man-made and natural wetlands, especially wetlands associated with rivers of the South Coastal drainage. *Gila orcutti* was able to significantly reduce the abundance of immature mosquitoes in experimental wetlands supporting bulrush. The peak period of annual oviposition by the *Culex* species in Riverside is during June and early July, and we predict that the abundance of immature mosquitoes in the experimental wetlands increased appreciably and these higher abundance levels of mosquitoes should provide a robust examination of the efficacy of *G. orcutti* as a mosquito control agent for wetlands.

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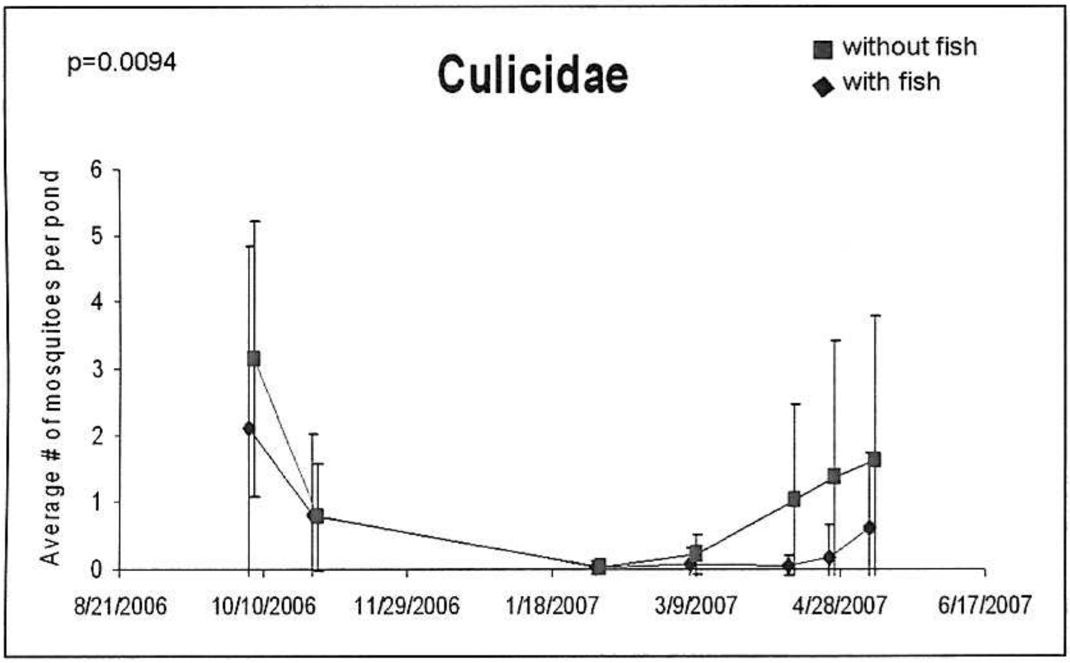

Figure 1. Average number of mosquitoes caught per pond in fish and no fish ponds. Bars represent 1 standard deviation.

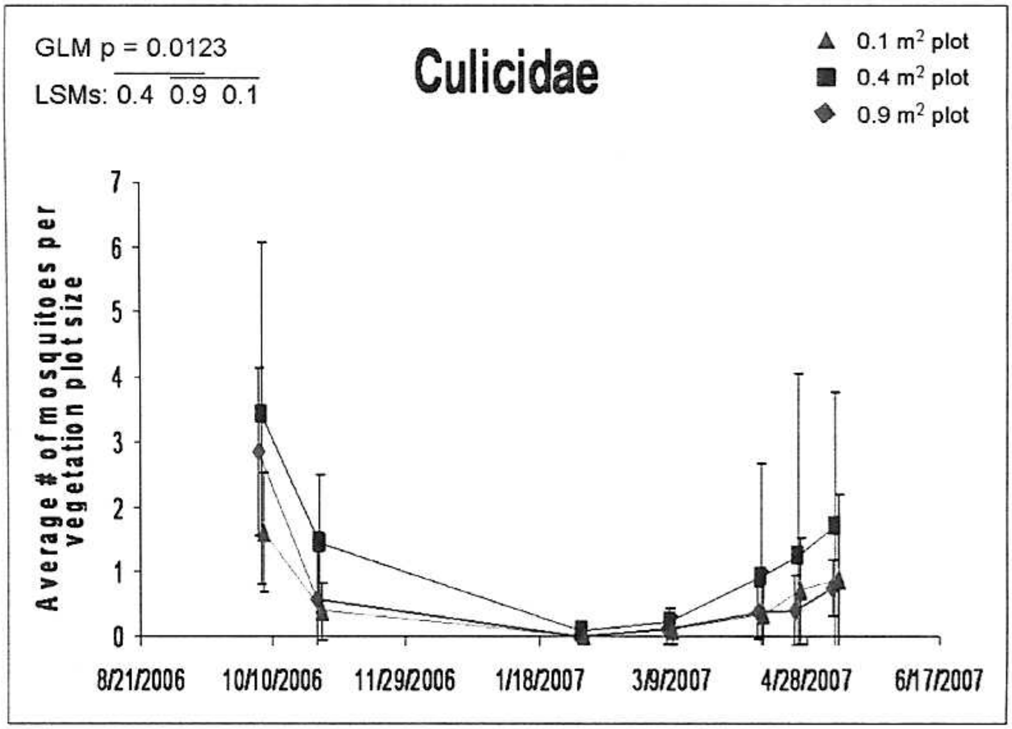

Figure 2. Average number of mosquitoes caught per pond per vegetation plot size. There were significantly more mosquitoes in the 0.4 m^2 plots than in the 0.1m^2 plots; however, mosquito abundance in the 0.9 m^2 plots was not significantly different from either smaller plot size. Bars represent 1 standard deviation.

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