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CONTROL OF *AEDES DORSALIS* WITH SUSTAINED-RELEASE METHOPRENE PELLETS IN A SALTWATER MARSH

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ABSTRACT. The efficacy and persistence of sustained-release methoprene (Altosid®) pellets were evaluated in a tidal, saltwater marsh primarily against *Aedes dorsalis*. Pellets were applied prior to marsh inundation at 3.4 kg/ha. They provided >99% control through the July and August high tide series (up to 42 days posttreatment), 86.4% control during the November high tide series (131 days posttreatment) and 66.6% control during the February high tide series (240 days posttreatment). Proportions of partially emerged adults increased over the course of the study, constituting 0, 0.7, 16.2 and 18.9% of the unsuccessfully emerging mosquitoes in July, August, November and February, respectively. Sixty-six percent of the completely emerged mosquitoes from the treated region of the marsh were found dead on the water surface, compared with only 0.7% from the control region. This implies that exposure to low concentrations of methoprene impairs the ability of the completely emergent mosquito to fly.

INTRODUCTION

The salt marsh mosquito, *Aedes dorsalis* (Meigen), is a continual problem in the San Francisco Bay Area and the focus of many mosquito control programs during the spring, summer and fall. *Aedes dorsalis* is a vicious biter, and recently strains of viruses closely related to California encephalitis virus and western equine encephalomyelitis virus have been isolated from a California coastal population of this species (B. Eldridge, unpublished data). *Aedes dorsalis* develops in the vast tidal marshes of the region when they become inundated by high tides exceeding ca. 1.8 m. A series of high tides occurs once or twice a month, and the highest tides occur in the summer and winter. *Aedes dorsalis* develop in the 7 to 14 days following marsh inundation, requiring the inspection and treatment of thousands of hectares of marsh within a relatively short time period.

It would be advantageous to have a mosquito control agent that could be applied prior to marsh inundation and that demonstrates residual toxicity. It would also be desirable to use a selective control agent that has little impact on nontarget organisms because tidal marshes are sensitive ecosystems. Several endangered species, such as the salt marsh harvest mouse, *Reithrodontomys raviventris* Dixon, and the California clapper rail, *Rallus longirostris obsoletus* Ridgway, inhabit regional marshes.

The insect growth regulator methoprene, which inhibits ecdysis of the mosquito pupa to the adult, is a selective mosquito control agent (Miura and Takahashi 1973, Creekmur et al. 1981, Bircher and Ruber 1988). Methoprene is available in several Altosid® formulations, including liquids, briquets and pellets. Both the briquets and the pellets provide residual control, but the briquets are designed to control mosquitoes in small bodies of water (Schoeppner 1978). The sustained-release pellets have, however, demonstrated residual control of mosquitoes in large bodies of water, including irrigated pastures (Kramer and Beesley 1991), experimental brackish ponds (Floore et al. 1990) and grassland depressions (dambos) in Kenya (Linthicum et al. 1989, Logan et al. 1990). In addition, methoprene sustained-release pellets can be applied prior to inundation (Logan et al. 1990, Kramer and Beesley 1991) because the methoprene is protected from ultraviolet radiation by the activated charcoal in the pellets. Because of these attributes, methoprene sustained-release pellets would be an appropriate control agent against salt marsh mosquitoes. The purpose of this study was to evaluate the efficacy and persistence of sustained-release methoprene pellets against *Ae. dorsalis* in a saltwater marsh.

MATERIALS AND METHODS

A 12 ha saltwater marsh on the south shore of the Sacramento-San Joaquin River Delta in central Contra Costa County, California, was divided into treatment, control and buffer regions, located, respectively, in the northern, southern and central portions of the marsh. The treatment region consisted of 3 basins, ca. 0.4, 0.3 and 0.3 ha. The control region was divided into 3 ca. 0.2 ha plots. The dominant marsh vegetation was pickleweed, *Salicornia virginica* Linn. The midday marsh water temperature was measured monthly during the study, and rainfall was measured daily at the laboratory, 5.3 km southeast of the marsh.

Methoprene sustained-release pellets (RF-330 Altosid® pellets, Zoecon Corporation, Dallas, TX) were applied at 3.4 kg/ha to the treatment plots with a hand operated Earth Products Seeder (Earthway Products, Bristol, IN) on July 3, 1991, ca. 4 days prior to inundation. This treatment rate, which was near the minimum label dosage rate of 2.8 kg/ha, has been shown to provide prolonged control of floodwater mosquitoes (Kramer and Beesley 1991). The pellets consisted of 4% methoprene bound with activated charcoal.

Emergence of *Ae. dorsalis* was monitored after 4 of the high tide series between July 1991 and February 1992. Maximum tidal heights for the 4 series occurred on July 10, August 8, November 5 and February 16, and measured 2.2, 2.1, 1.9 and 2.0 m, respectively (NOAA 1990). The marsh was inundated for at least 2 wk after each peak tide. During each tide series, larvae were allowed to develop in the marsh until most of the population reached the pupal stage. A minimum of 150 immature mosquitoes were collected with a standard (400 ml) dipper from each of the treatment and control plots, except in July when the third treatment plot was not sufficiently inundated, and no mosquitoes could be collected from that plot. During the July high tide series, the number of mosquitoes per dip was recorded. Immature mosquitoes were brought to the laboratory, and 100 pupae were separated from each sample. The pupae were placed in containers with marsh water from the collection plot and put in emergence cages. Adults were counted, identified and sexed as they emerged.

Emergent adults were categorized as: 1) completely emerged and flying, 2) completely emerged and dead on the water surface, 3) partially emerged with the tarsi still attached to the pupal case, or 4) partially emerged with the abdomen and part of the thorax remaining in the pupal case. Partially emerged adults are indicative of low but effective growth regulator concentrations (Mulla 1991). Numbers of dead pupae in each container were counted when no live pupae remained in the sample.

The percent mortality was calculated as the number of pupae not completely emerging/number of pupae in the sample (n = 100) × 100. Mortality rates (arcsin transformed) between the treatment and control plots were compared with Student's t-test (P < 0.05). Proportions (arcsin transformed) of completely emerged, non-flying adults (number adults found dead on the water surface/number of adults completely emerged × 100) from the treatment and control plots were also compared using Student's t-test (P < 0.05).

RESULTS AND DISCUSSION

Aedes dorsalis was the only mosquito species found in the marsh following the July, August and November tide series. Following the February high tide series, 33% of the emergent adults were *Ae. dorsalis*, 49% were *Ae. squamiger* (Coq.) and 18% were *Culiseta inornata* (Williston). During the July high tide series, there was an average of 6.7 immature mosquitoes per dip (SD = 9.1, range = 0 to 44). Water temperatures ranged from about 24°C in midsummer to 5°C in midwinter. There was no rainfall from July–September and ca. 27.2 cm from October–February.

The percent mortality of *Ae. dorsalis* (plus *Ae. squamiger* and *Cs. inornata* during the February tide series) in the methoprene-treated and control plots is given in Table 1. During the July and August tide series, emergence was minimal, with pupal mortality exceeding 99%. In November, pupae were collected 131 days posttreatment, and the mortality rate was 86.4%. In February, 240 days posttreatment, the mortality rate was 66.6%.

Laboratory mortality of pupae collected from the control region of the marsh never exceeded 5%. During each tide series, the percent mortality in the methoprene-treated plots was significantly higher than in the control plots.

The proportions of pupae collected from the methoprene-treated plots that emerged completely, partially, or died prior to emergence are shown in Fig. 1. In November and February, there were higher proportions of partially emerged adults with their tarsi still attached to the pupal case than with their abdomen still attached (9.9 vs. 5.6%, and 8.1 vs. 4.4% in No-

Table 1. Efficacy of 4% methoprene pellets against saltmarsh mosquitoes[1] in a tidal marsh

High tide cycle	Days posttreatment[2]	Percent mortality[3] ± SD	
		3.4 kg/ha	Control
Jul.	10	99.8 ± 0.3	3.2 ± 1.9
Aug.	42	99.3 ± 0.7	4.7 ± 3.3
Nov.	131	86.4 ± 4.9	3.6 ± 2.1
Feb.	240	66.6 ± 19.9	2.1 ± 0.8

[1] Exclusively *Aedes dorsalis* except in February, when *Ae. squamiger* and *Culiseta inornata* also present.
[2] Number of days between treatment and date immature mosquitoes collected.
[3] Number of pupae not completely emerging/number of pupae in sample (n = 100) × 100.

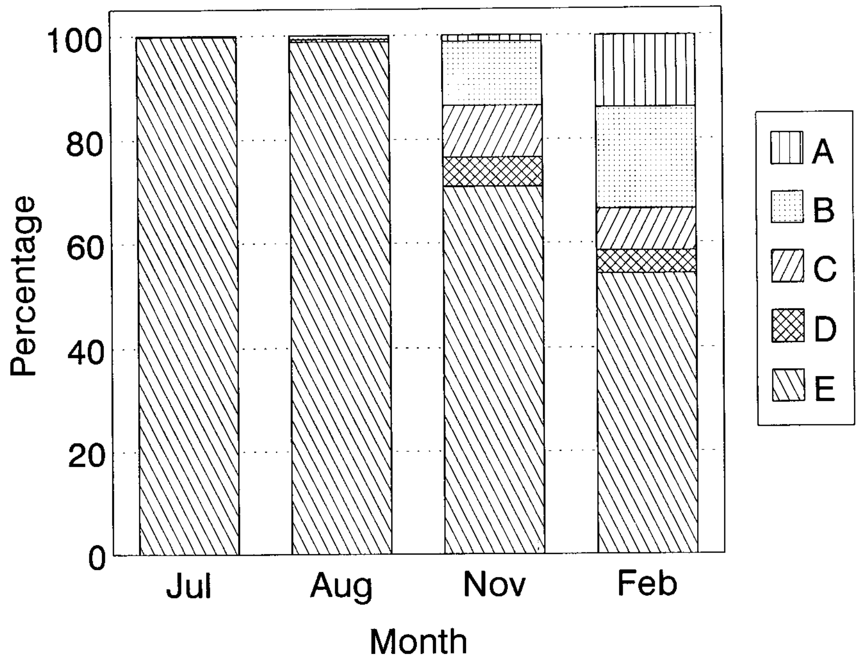

Fig. 1. Proportions of methoprene-treated pupae with complete, partial or no emergence. A) Completely emerged and flying adults, B) completely emerged adults found dead on the water surface, C) partially emerged adults with tarsi still attached to pupal case, D) partially emerged adults with abdomen and part of thorax remaining in pupal case, and E) no emergence (dead pupae).

vember and February, respectively). The proportions of partially emerged adults/total number of unsuccessfully emerging mosquitoes (i.e., dead pupae plus partially emerged adults) were 0, 0.7, 16.2 and 18.9% during the July, August, November and February high tide series, respectively. Therefore, the proportion of partially emerged adults increased over the course of the study, indicating a decrease in the concentration of methoprene in the marsh.

None of the adults that emerged from pupae collected from the control plots had body parts still attached to the pupal case. Among those emergent mosquitoes, only 0.7% were found dead on the water surface, compared with 66.0% of the mosquitoes emerging from pupae collected from the methoprene-treated plots. This significant difference suggests that exposure to low concentrations of methoprene impairs the ability of completely emergent adults to fly. In addition, the increased proportion of emerged and flying adults from November to February (8.5 to 41.7% of completely emerged mosquitoes, Fig. 1) implies that as methoprene concentrations continued to decrease, greater numbers of emergent adults were able to fly. No physical abnormalities were observed among the completely emergent adults previously exposed to methoprene. Self et al. (1978) and Floore et al. (1990) attributed the immediate death of completely emergent adults to methoprene and included these in their mortality rate calculations.

This study was conducted for 240 days posttreatment, but the marsh was inundated only periodically, after high tide series and during the winter rainy season. Based on observational data, the marsh was wet during about 40% of the study period. Because methoprene is released only when inundated, its efficacy is prolonged when habitats are periodically dry. It would be erroneous to conclude that the growth regulator provided >66% control of mosquitoes for 240 days. The number of days during which a habitat will potentially be inundated needs to be considered when determining the potential residual effectiveness of methoprene.

The divergence in mortality rates among the 3 treatment plots following the February tide series illustrates the importance of the inundation period. Plot one was lower in elevation than plot two, which was lower than plot three. Consequently plot one was consistently wetter than two, and three was the driest. In February, mortality rates in plots 1–3 were 46.0, 68.0 and 87.5%, respectively. Therefore, the driest region of the marsh had the greatest mortality. This pattern was also apparent in November, when mortality rates in plots 1–3 were 81.2, 87.1 and 91.0%, respectively.

In conclusion, sustained-release methoprene pellets applied at 3.4 kg/ha to a tidal, saltwater marsh provided excellent control (>99%) of *Ae. dorsalis* through 2 high tide series, and continued to adversely affect mosquito populations throughout the 8 months of the study.

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