Journal of the American Mosquito Control Association, 15(1):65–68, 1999

CULTURAL CONTROL OF LARVAL MOSQUITO PRODUCTION IN A FALLOW CITRUS GROVE USED FOR DISPOSAL OF SECONDARY-TREATED SEWAGE EFFLUENT

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ABSTRACT. Larval mosquito production was monitored for 16 months in the furrows of a 13.4-ha citrus grove in east-central Florida used for disposal of secondary-treated sewage effluent. Twenty-one species of mosquito were collected, and the 2 most abundant species were *Culex nigripalpus* and *Aedes vexans.* An unplanned removal of all brush and trees from the site during the study resulted in an overall decline in larval production, but species diversity remained the same.

KEY WORDS Mosquito, Florida, land treatment of wastewater

INTRODUCTION

Citrus production is an important agricultural industry in central and south Florida, USA, with 343,000 ha in production in 1996 (FASS 1996). Irrigation and drainage furrows in citrus groves are productive mosquito habitats in southeastern Florida (Curtis and Frank 1981; Curtis 1985a, 1985b), with most production following episodes of flood irrigation or heavy rainfall that inundates the furrows. *Aedes vexans* (Meigen) is a species whose abundance and distribution has been enhanced by citrus grove habitat, and 14 additional species of mosquitoes have been documented from groves in southeastern Florida (Curtis 1985b).

Because of elevated nutrient levels, human and animal sewage effluents are highly attractive ovipositional sites for some mosquitoes, primarily *Culex* spp. Ponding or impounding of effluents can result in mosquito production (Barr 1957, Steelman and Colmer 1970, Rutz et al. 1980). Whelan (1988) suggested that sprinkler disposal of effluent is an attractive alternative to other methods that may cause mosquito problems. Sprinkler disposal in Australia has been most successful when broadcast over a flat topography with well-drained soils and heavy stands of trees (e.g., *Eucalyptus*). However, Whelan (1994) also cites an example in Australia of failure in mosquito management of overhead sprinkler broadcast of effluent, resulting in ponding and considerable production of *Culex* spp.

In the United States, water reuse has become an increasingly attractive alternative to sewage waste disposal, particularly in areas of chronic water shortage. In Florida, for example, the number of water reuse projects (utilizing secondary- or tertiary-treated effluent) increased from 120 in 1986 to 290 in 1992. In 1992, 8,887 ha of cropland, including 2,290 ha of citrus were irrigated with treated effluent (FDER 1992).

Following a series of severe freezes between 1980 and 1990, more than 220,000 ha of citrus groves were taken out of production in Florida, and the industry has shifted further south in the state (FASS 1996). Many of these abandoned groves have been converted to other agricultural use or residential development, but others have been available for field application of treated sewage effluent. Given this fact and the increasing amount of agricultural usage of treated effluent, mosquito production in these habitats may be of concern.

In this paper, we report on mosquito production over a 16-month period in an abandoned citrus grove in east-central Florida that has been converted to spray field application of secondary-treated sewage effluent.

MATERIALS AND METHODS

The study site was a 13.4-ha (366 × 366-m) citrus grove in southern Brevard County, FL, USA. The grove is typical of that described by Curtis and Frank (1981) and Curtis (1985a, 1985b), with 2 rows of trees separated by an irrigation and drainage furrow. The grove was taken out of production in the mid-1980s, after freezes in the early 1980s, and was converted to spray field application of secondary-treated sewage effluent by a private water company in November 1989. Effluent was broadcast with a traveling agricultural gun with a broadcast radius of 50 m. The gun was moved between 5 discharge pipes spaced regularly throughout the grove. Movement of the gun was at the discretion of the utility operator, and placement was designed to avoid extensive ponding of water. During periods of heavy rainfall the gun was not utilized, and there were short periods when the equipment was inoperable. Some citrus trees were removed to facilitate travel of the gun, but both edges of each furrow remained heavily vegetated with citrus trees and brush.

Nineteen furrows were present in the study site. Water (from rainfall or spray broadcast) collected only in the furrows and larval production was monitored as follows. Once weekly, 2 furrows on either side of the gun were sampled (total of 4 furrows) as well as the 4 furrows where the gun had most recently been and 4 other furrows elsewhere, wher-

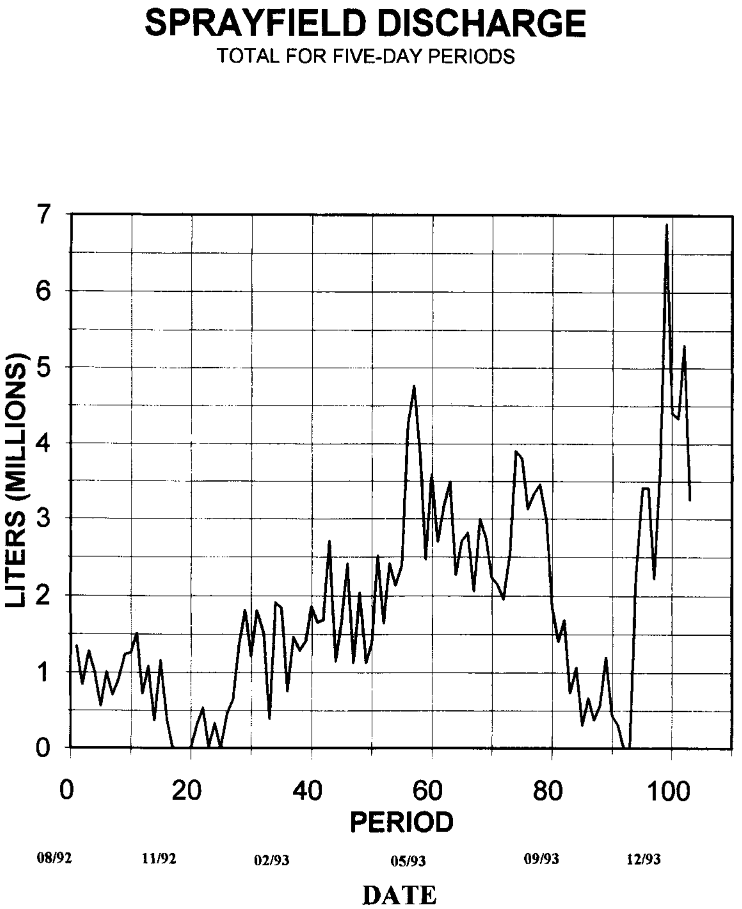

Fig. 1. Effluent discharge in liters × 10^6 for the period August 1, 1992, through December 28, 1993. Totals are for 5-day periods.

ever water was present. A maximum of 12 furrows could be sampled in a sampling event, but on occasion the site was completely dry. Four exceptions occurred late in the study when this weekly schedule was not maintained and also during site modification (see below). A furrow sample consisted of 10 dips with a standard 350-ml larval dipper, with dips evenly spaced throughout available water in the furrow. Each furrow was assigned a number, and all 10 dips from a particular furrow were combined in a jar. Live larvae were returned to the laboratory, identified, and counted. Daily rainfall and spray field discharge records were maintained by the utility company.

The 16-month sampling period commenced in mid-August 1992 and ended in early December 1993. A significant and unplanned alteration of the site occurred from January 30, 1993, to March 30, 1993, when all trees and brush were removed from the field with heavy equipment, leaving the furrows fully exposed. This was done to allow increased broadcast of effluent, and thereafter the field was regularly mowed. Sampling was thus curtailed from December 25, 1992, to April 14, 1993, and was resumed in a substantially altered landscape.

Data on effluent flow rate, rainfall, and larval production were analyzed with chi-square tests and *t*-tests.

RESULTS

Effluent broadcast totaled 188 × 10^6 liters over the entire study period (Fig. 1). Mean daily flow rate of effluent prealteration (August 1992 through January 1993) was 0.17 × 10^6 liters (±SE = 0.09) and postalteration (February through December 1993) was 0.48 × 10^6 liters (±0.22), a significantly greater rate postalteration ($t = -2.96$, df = 15, $P = 0.005$). Rainfall totaled 161.3 cm during the study period. No significant difference occurred in daily rainfall during the 5 months of paired pre- and postalteration periods (August through December 1992 and August through December 1993). Daily rainfall for the 5 paired periods was compared with paired *t*-test for means ($t = -1.18$ to 1.36, df = 28–30, $P = 0.09$–0.48).

Table 1. List of species, number of larvae collected, and number of positive furrows.

Species	No. collected	No. positive furrows
Culex nigripalpus	7,680	148
Aedes vexans	1,698	80
Psorophora columbiae	340	71
Uranotaenia sappharina	106	35
Aedes atlanticus	83	19
Anopheles crucians	65	31
Anopheles quadrimaculatus	65	41
Culex pilosus	61	23
Psorophora ciliata	59	23
Aedes infirmatus	44	9
Aedes taeniorhynchus	27	6
Anopheles sp. (unidentified)	15	10
Culex sp. (unidentified)	13	3
Culex restuans	11	6
Psorophora ferox	9	5
Culex erraticus	9	6
Psorophora howardii	6	2
Uranotaenia lowii	6	4
Culex peccator	3	3
Anopheles georgianus	2	2
Anopheles bradleyi	1	1
Total	10,303	534

A small number (n = 28) of *Culex* and *Anopheles* were collected as pupae and could not be identified. A total of 10,303 larvae of 21 species were collected over the sampling period (Table 1). Table 1 also shows the number of positive furrows for each species, that is, the total number of furrows in which each species was found. The most abundant species collected was *Culex nigripalpus* (Theobald) (n = 7,680), followed by *Ae. vexans* (n = 1,698). Larval production peaked in September 1992, but declined thereafter, with a significant reduction after site alteration (January 30, 1993) (Fig. 2).

Meaningful comparison of mosquito production pre- and postalteration requires examination of the same time frames. Prealteration, there were a total of 24 sampling events, 17 of which (August 20 through December 9, 1992) can compare with a similar time frame in the postalteration period (July 21 through December 8, 1993). Eighty-one furrows were sampled in the 17 sampling events of the prealteration period, and 129 furrows were sampled in the corresponding postalteration period, reflecting the greater amount of effluent broadcast during this portion of the postalteration period.

During the entire prealteration period, 148 furrows were sampled and 137 were positive for larvae. In the entire postalteration period, 260 furrows were sampled, of which 125 were positive, a significant decrease (χ^2 = 16.1, df = 1, $P < 0.0001$).

The 2 most abundant species collected reflect the overall differences pre- and postalteration. In the 17 prealteration sampling events, 5,522 *Cx. nigripalpus* were collected; only 799 were collected in the corresponding postalteration period. Likewise, 615 *Ae. vexans* were collected prealteration and 172 were collected postalteration. On the basis of larvae per dip, *Cx. nigripalpus* were collected at a mean of 3.99 (±6.18) per dip prealteration and 0.53 (±0.92) postalteration, a significant difference (t =

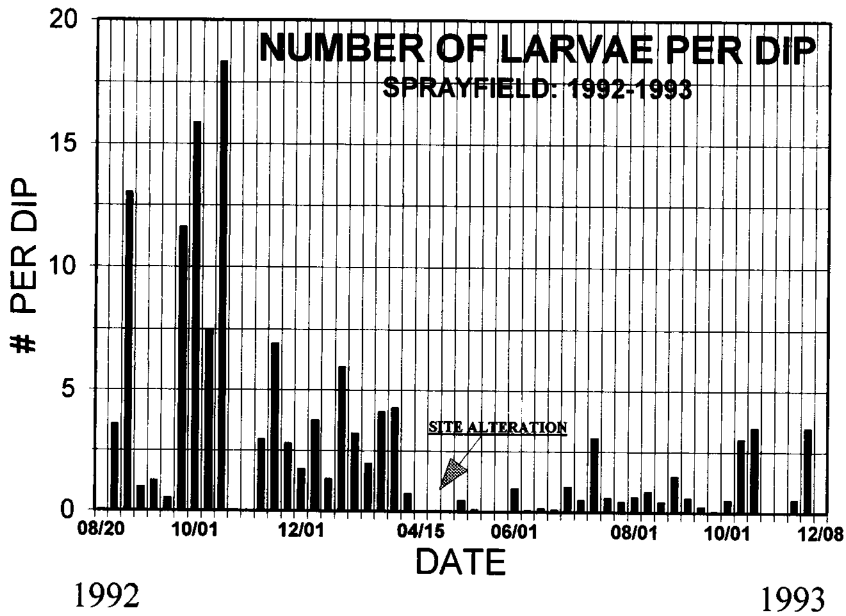

Fig. 2. Number of larvae per dip in 55 sampling events for the period August 20, 1992, through December 8, 1993.

2.28, df = 32, P = 0.01). For *Ae. vexans,* the prealteration mean was 0.78 (±1.85) per dip and the postalteration mean was 0.19 (±0.61), a nonsignificant difference (t = 1.23, df = 32, P = 0.11). When the complete data set was analyzed for these 2 species, a highly significant difference was found between pre- and postalteration means for *Cx. nigripalpus* (3.21 ± 5.36 prealteration and 0.41 ± 0.86 postalteration) (t = 2.88, df = 53, P = 0.003). *Aedes vexans* were collected at means of 1.01 (±1.95) prealteration and 0.15 (±0.47) postalteration, and there is a significant difference (t = 2.38, df = 53, P = 0.01) in this complete data set.

DISCUSSION

Although our data cannot account for differences between sites, addition of treated effluent to citrus furrows appears to enhance mosquito species diversity over nontreated groves. Curtis (1985b; unpublished data) reported 15 species from a several-year study of citrus groves, and our findings supplement this list by several species, particularly in the addition of 3 species of *Anopheles.* Although water quality in the furrows was not monitored, the broadcast effluent had mean values for the following nutrients during the entire study period (Florida Cities Water Co., personal communication): total nitrogen, 10.04 ppm; total phosphorus, 0.41 ppm; and nitrate, 5.92 ppm.

The unfortunate site alteration prevented long-term monitoring of seasonal changes in production and diversity, the original goals of the study. However, this disruption did allow examination of another hypothesis, that cultural control can greatly affect mosquito production in such fallow citrus groves. Although many environmental variables can affect mosquito production, the decrease in production following site alteration, in spite of consistent rainfall patterns and higher effluent flow rates in the postalteration period, indicates that the physical removal of the vegetation may have been the dominant factor.

The two indicator species chosen (*Cx. nigripalpus* and *Ae. vexans*) represent floodwater and permanent-water breeding species, and both declined significantly following alteration. This decline in productivity is also reflected in the significant decrease in number of positive furrows postalteration. The presence of more water on the site following alteration perhaps should have been reflected by a shift in floodwater vs. permanent-water species, but this was not the case. During the entire prealteration period, 19 species were collected, 9 floodwater and 11 permanent-water. Postalteration, 18 species were collected, 7 floodwater and 11 permanent-water.

Our data suggest that fallow grove furrows irrigated with sewage effluent are an attractive oviposition site for mosquitoes. However, cultural control by tree and brush removal may reduce mosquito production in the furrows.

ACKNOWLEDGMENTS

Sincere gratitude is expressed to Florida Cities Water Company, Barefoot Bay Division, for support of this study. Thanks also to D. B. Horst for assistance in data compilation.

REFERENCES CITED

Barr, A. R. 1957. The distribution of *Culex pipiens pipiens* and *Culex pipiens quinquefasciatus* in North America. Am. J. Trop. Med. Hyg. 6:153–165.

Curtis, G. A. 1985a. Habitat selection strategies of mosquitoes inhabiting citrus irrigation furrows. J. Am. Mosq. Control Assoc. 1:169–173.

Curtis, G. A. 1985b. Environmental induced periodicities in citrus grove mosquitoes, pp. 211–221. *In*: L. P. Lounibos, J. R. Rey and J. H. Frank, eds. Ecology of mosquitoes: proceedings of a workshop. Florida Medical Entomology Laboratory, Vero Beach, FL.

Curtis, G. A. and J. H. Frank. 1981. Establishment of *Aedes vexans* in citrus groves in southeastern Florida. Environ. Entomol. 10:180–182.

Florida Agriculture Statistics Service (FASS). 1996. Commercial citrus tree inventory. Orlando, FL.

Florida Department of Environmental Regulation (FDER). 1992. Reuse inventory. Tallahassee, FL.

Rutz, D. A., R. C. Axtell and T. D. Edwards. 1980. Effect of organic pollution levels on aquatic insect abundance in field pilot-scale anaerobic animal waste lagoons. Mosq. News 40:403–409.

Steelman, C. D. and A. R. Colmer. 1970. Some effects of organic wastes on aquatic insects in impounded habitats. Ann. Entomol. Soc. Am. 63:397–400.

Whelan, P. 1988. Mosquito breeding and sewage treatment in the Northern Territory. J. Aust. Water Wastewater Assoc. 15:34–37.

Whelan, P. 1994. Sewage effluent dispersal and mosquito breeding. Australian Department of Health and Community Services, Casuarina, NT, Australia.