MOSQUITOES ASSOCIATED WITH EVAPORATION-PERCOLATION PONDS IN INDIAN RIVER COUNTY, FLORIDA

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ABSTRACT. Eighteen of 47 wastewater evaporation-percolation ponds in Indian River County, Florida were found to contain mosquitoes. Fourteen mosquito species were identified; *Culex quinquefasciatus* and *Cx. nigripalpus* were the most abundant.

Two holding ponds receiving secondarily treated effluent from activated sludge wastewater treatment plants were sampled weekly for 17 months to determine seasonal mosquito population trends. At both locations, *Cx. nigripalpus* dominated the sampling roughly from mid-June to mid-November and *Cx. quinquefasciatus* was dominant the remainder of the year. *Aedes* and *Psorophora* species were found in the 2 ponds in noticeable numbers only in 2 brief periods after the ponds drained and were reflooded. *Culex* densities are shown to be comparable to another study where nutrient loads were considerably higher.

INTRODUCTION

Evaporation-percolation ponds, also known as holding ponds, are commonly used for disposal of nutrient-rich wastewater. Such ponds have been shown by Beadle and Harmston 1958, Smith and Enns 1967, and Rutz and Axtell 1978, to produce mosquitoes in large numbers. Examination of holding ponds in Indian River County (IRC), Florida, showed *Culex nigripalpus* Theobald and *Cx. quinquefasciatus* Say, to be the most common preadult mosquitoes. *Culex nigripalpus* is the local vector of St. Louis encephalitis (Dow et al. 1964). *Culex quinquefasciatus,* also a vector of St. Louis encephalitis (Subra 1981), is able to transmit *Wuchereria bancrofti* filariasis (W.H.O. 1974), a disease recently detected in Haitian refugees entering South Florida.[1]

Access to some of the holding ponds in IRC is difficult because of their large size and dense surrounding vegetation making ground application of larvicides difficult. To determine which ponds need regular treatment and to gain basic information on mosquito abundance and water quality in these ponds, a series of studies was initiated. The following account reports on the mosquito species found, and for 2 of the ponds, it shows temporal fluctuations in numbers of individuals and gives water quality data.

[1] Memorandum from State of Florida, Dept. of Health and Rehabilitative Services, Office of Entomology, July 15, 1981.

MATERIALS AND METHODS

STUDY SITES. Forty-seven holding ponds were located in IRC varying in surface area from 39 to 3000 m^2. They received one of the following types of wastewater:

1) Secondarily treated effluent from activated sludge wastewater treatment plants servicing mobile home parks, subdivisions, schools and multi-unit apartment or motel complexes.
2) Wastewater runoff from citrus packing houses.

All 47 holding ponds were visited approximately once each month for 12 months and sampled from the edge as randomly as possible for immature mosquitoes (larva or pupa) with a 350 ml dipper. Then, from the 18 ponds found to contain mosquitoes, 2 associated with activated sludge wastewater treatment plants servicing elementary schools and consistently showing high mosquito densities, were chosen for more intensive study. During the study neither pond was treated with larvicides. At times, dense vegetation covered the banks and floating and emergent plants populated the interior of the ponds. Periodic examination of all remaining holding ponds was continued to determine all mosquito species but not to quantify their numbers.

The study sites were:

1) Douglas Elementary School. This pond, which is located in a low socio-economic residential area of IRC is within 100 m of citrus groves and 1.2 km of salt marshes. It measured 3 × 13 m, received discharge from a plant with a 7,570 liter per day capacity, and at peak discharge filled to a depth of 53 cm. An overflow pipe allowed high water levels to flow into an adjacent ditch. Vegetation commonly found on the banks and bottom of this area included *Cyperus notundus* (nut grass), *Commelina longicaulis, Panicum purpurascens* (para grass), *Hydrocotyle spp.* (pennywort), and *Eupatorium spp.* (dog fennel).
2) Clemans Elementary School. The pond for the 18,925 liters per day plant servicing this system measured 3 × 10 m and during peak discharge filled to a depth of 56 cm. An overflow pipe allowed high water levels to flow onto adjacent property. Located adjacent to citrus groves and 1.2 km from salt marshes, the plants found on the banks and pond's interior included *Lemna* spp. (duckweed), *Bidens pilosa* (shepherd needle), *Casuarina* spp. (australian pine), *Melaleuca leucadendron, Eupatorium* spp. (dog fennel), *Eclipta alba, Sporobolus* spp. (dropseed) and *Syntherisma digitatum* (crabgrass).

SAMPLING. Both school ponds described above were sampled weekly from the week of February 11, 1980 to July 20, 1981. Samples were not taken the weeks of November 30 and December 7 at Douglas School or the weeks of November 9, November 30 and December 7 at Clemans School. A positive dip was defined as one containing any preadult mosquito. On each visit random sampling from the middle as well as the edges was continued until 10 positive dips or a total of 25 dips had been taken. Exceptions to this technique occurred on June 4, December 29 and April 1 at Clemans School when the pond was dry except for approximately a 1 m diam. puddle remaining at the discharge pipe. On these visits sampling was stopped after 3 positive dips were taken. Immature mosquitoes were taken to the laboratory where larvae were identified. Pupae were allowed to emerge and identified as adults. In February to early May 1980, when samples at Douglas School contained large numbers of larvae, 50% aliquots were identified. During weekly sampling of the 2 ponds, periodic sampling was continued at the remaining 45 ponds.

Between June 1980 and February 1981 measurements of nitrate (NO_3), nitrite (NO_2), organic nitrogen, ammonia nitrogen (NH_4), and total Kjeldahl nitrogen (TKN) were made about monthly at the ponds. Nitrates and nitrites were measured with Hach Low Range Nitrate Test Kit (Model NI-14). Nitrate and nitrite readings were occasionally verified by a water analysis firm. Ammonia nitrogen was measured by the titration method and organic nitrogen by the Kjeldahl method, in both cases using methods from A.P.H.A. (1976). From May 1980 to June 1981, monthly measurements of biochemical oxygen demand (BOD), total suspended solids (TSS) and acidity (pH), which are required of plant operators by the Florida Department of Environmental Regulation, were taken at the point of entry to the treatment plant and again as the water enters the holding ponds. These readings were abstracted from the school systems records (methods described in A.P.H.A. (1976) had been used).

RESULTS

GENERAL SURVEY. Fourteen species of immature mosquitoes were collected from 18 of the 47 ponds surveyed. They were *Aedes atlanticus* (Dyar and Knab), *Ae. sollicitans* (Walker), *Ae. taeniorhynchus* (Wiedemann), *Ae. vexans* (Meigen), *Anopheles crucians* Wiedemann, *An. quadrimaculatus* Say, *Cx. nigripalpus, Cx. quinquefasciatus, Cx. salinarius* Coquillett, *Cx. erraticus* (Dyar and Knab), *Psorophora ciliata* (Fabricius), *Ps. columbiae* (Dyar and Knab), *Ps. howardii* Coquillett and *Uranotaenia lowii* Theobald. *Culex quinquefasciatus* and *Cx. nigripalpus* were encountered with the greatest regularity. The *Culex* species composition in most ponds was similar to that of the 2 school ponds.

DOUGLAS SCHOOL EVAPORATION-PERCOLATION POND STUDY SITE. Of the 755 dips taken at this site, 77.9% were positive for immature mosquitoes; 97,387 preadult mosquitoes were collected with as many as 2,421 in a single dip. The mean number of mosquitoes per dip ($\overline{X}$/dip) for the entire study period was 165.6 and on 15 visits exceeded 300 (Fig. 1). Thirteen mosquito species were found at this site. They were *Ae. atlanticus, Ae. taeniorhynchus, Ae. vexans, An. crucians, An. quadrimaculatus, Cx. nigripalpus, Cx. quinquefasciatus, Cx. salinarius, Cx. erraticus, Ps. ciliata, Ps. columbiae, Ps. howardii* and *Ur. lowii. Culex quinquefasciatus* comprised 93.9% of the total sample and *Cx. nigripalpus* totalled 4.9%. The remaining 11

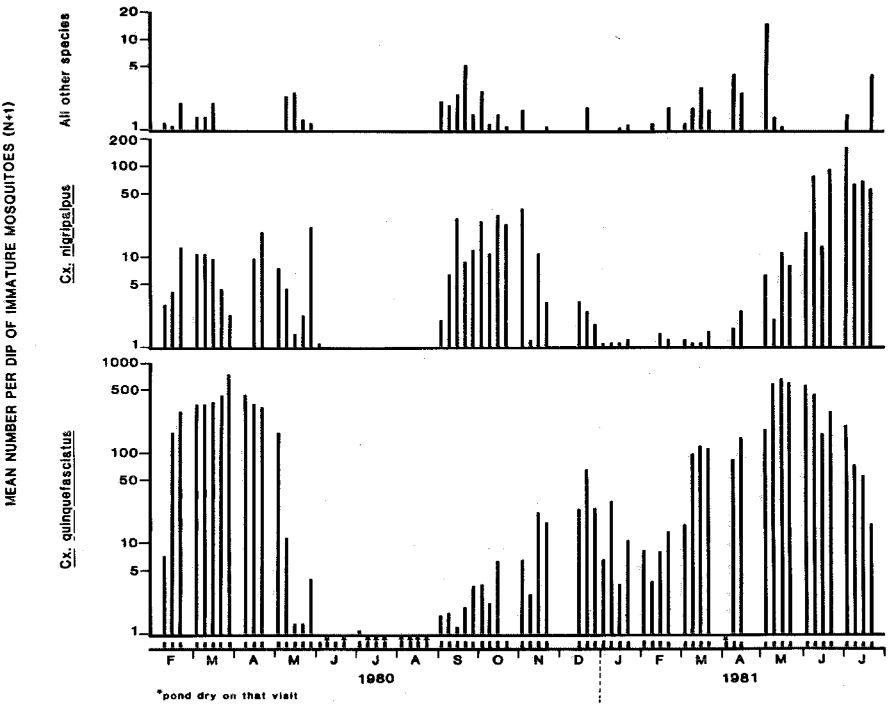

Fig. 1. Mean number per dip of immature mosquitoes at Douglas School pond.

species totalled 1.2% of the population and on only 8 occasions made up more than 10.0%.

Culex quinquefasciatus dominated the sampling from early February until mid-May averaging 93.0% and again from mid-November to mid-July 1981 averaging 94.2%. In the interim (from mid-May to mid-November 1980), *Cx. nigripalpus* dominated, averaging 73.8%. Although *Cx. quinquefasciatus* comprised 66.6% of the July 1, 1980 sample, the sample was biased since only 3 mosquitoes were captured.

Culex salinarius formed only 0.2% of the total sample and more than 1.0% on only 6 occasions. *Culex erraticus* individuals were collected in insignificant numbers.

Floodwater mosquito species were collected in significant numbers during two periods after the ponds drained and reflooded. During the weeks of September 1 through September 15, *Ps. columbiae* and *Ae. taeniorhynchus* totalled 6.2% and 1.2% respectively of the total population. *Aedes vexans* averaged 11.3% of the sample during the weeks of April 12 through April 27. Although present, *Ae. atlanticus* and *Ps. howardii* comprised an insignificant part of the collection.

CLEMANS SCHOOL EVAPORATION-PERCOLATION POND STUDY SITE. Of the 894 dips taken at this site, 58.9% were positive for preadult mosquitoes; 20,236 preadult mosquitoes were collected with a maximum of 624 in a dip. The $\overline{X}$/dip for

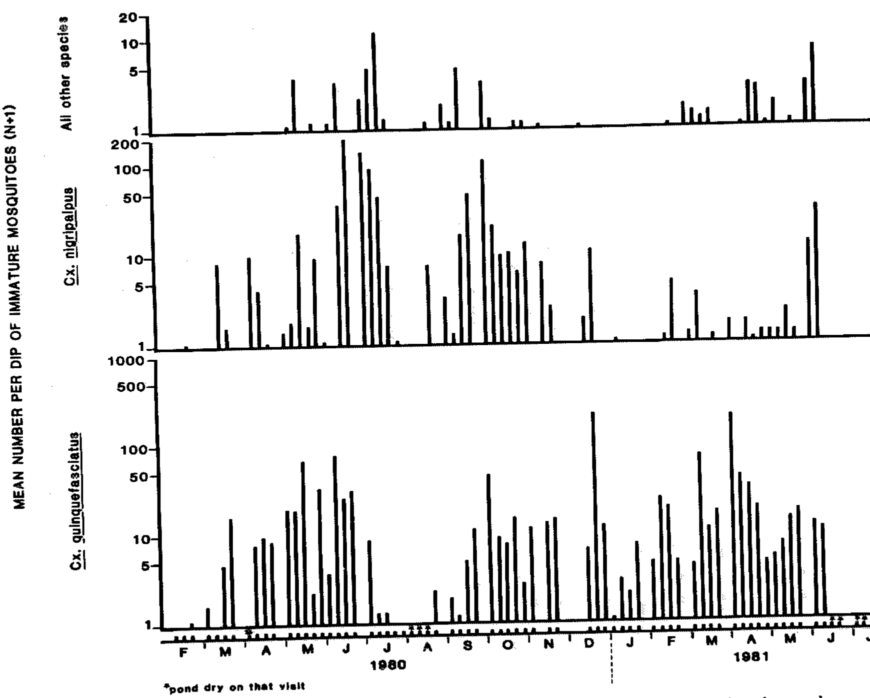

Fig. 2. Mean number per dip of immature mosquitoes at Clemans School pond.

the entire study period was 38.3 and on 5 visits exceeded 100 (Fig. 2). The 12 mosquito species found at this site were *Ae. taeniorhynchus, Ae. vexans, An. crucians, An. quadrimaculatus, Cx. nigripalpus, Cx. quinquefasciatus, Cx. salinarius, Cx. erraticus, Ps. ciliata, Ps. columbiae, Ps. howardii* and *Ur. lowii*. *Cx. quinquefasciatus* comprised 55.3% of the total collection and *Cx. nigripalpus* formed 42.0%. The remaining 10 species formed only 2.7% and made up more than 10.0% of the sample on only 7 occasions.

Culex quinquefasciatus was the most common mosquito species from early February to mid-June 1980 (79.5%) and again from mid-November until early June 1981 (89.9%). *Culex nigripalpus* dominated from mid-June until mid-November (72.1%) and again in early June 1981 when their numbers again exceeded 50% of the sample. *Culex salinarius* individuals formed only 0.3% of the total population and made up more than 1.0% of the total only 11 times. Although occasionally present, *Cx. erraticus* larvae were found in very low numbers.

Floodwater species formed only 2.2% of the total sample. *Psorophora columbiae, Ps. ciliata* and *Ae. taeniorhynchus* were collected during the weeks of September 1 through September 15 amounting to 22.2%, 1.8% and 75.9% respectively. Between the weeks of April 12 through April 27, *Ae. vexans* averaged 13.5%. *Psorophora howardii* were found in insignificant numbers.

Although never present in large numbers, other mosquito species collected at both study locations were *An. crucians, An. quadrimaculatus* and *Ur. lowii*. *Anopheles* spp. were collected during 9 months of the year, absent only in April, August and September. *Uranotaenia lowii* were collected in May through July and September through November. When present, these combined species generally totalled less than 5.0% of the sample. However, on one occasion at the Douglas School pond when the total sample size was small (50 mosquitoes), these species combined totalled 70.0% of the population.

The Clemans School plant appeared slightly, but not significantly, more efficient than the Douglas School plant at reducing BOD and TSS. NO_2, NO_3, NH_4, organic nitrogen, TKN, BOD, TSS and pH did not differ significantly between the 2 ponds as determined by the *t*-test.

DISCUSSION

This survey, which shows the occurrence of a large number of mosquito species in local holding ponds, differs from studies of wastewater retention areas in other parts of the country where much lower levels of mosquito diversity have been shown (Myklebust and Harmston 1962, Smith and Enns 1967, Shroyer and Siverly 1970, Rutz and Axtell 1978). Some species not commonly associated with wastewater systems in the literature (i.e. *Ae. sollicitans, Ae. taeniorhynchus, Ps. ciliata* and *Ps. howardii*) were collected in these IRC ponds. The study also shows a seasonal reversal in abundance of *Cx. quinquefasciatus* and *Cx. nigripalpus*.

Culex quinquefasciatus is generally found in more highly polluted water than is *Cx. nigripalpus*. Studies have shown some water rich in organic carbon (Sinha 1976, Rutz and Axtell 1978, Rutz et al. 1980), TKN (Rutz and Axtell 1978, Rutz et al. 1980), ammonia nitrogen (Hagstrum and Gunstream 1971, Sinha 1976), nitrate (Hagstrum and Gunstream 1971, Rutz and Axtell 1978) and phosphate (Sinha 1976) to provide attractive habitats for *Culex* mosquitoes. Certain proteins and the metabolites of some bacteria have been shown to be a *Culex* ovipositional stimulus as well (Ikeshoji et al. 1967). Secondarily treated wastewater or agricultural runoff, such as the effluent retention areas examined in this study, can contain some or all of these factors (Table 1).

Data from the Douglas and Clemans School ponds reveal some water quality characteristics different from another study examining mosquitoes in wastewater systems. In field pilot-scale swine and poultry waste lagoons in North

Table 1. Water quality data for 2 evaporation-percolation pond study sites (N = number of samples).

	Douglas School			Clemans School		
	N	Range	X±S.D.	N	Range	X±S.D.
NO_2[a]	7	0.0–1.3	0.4±0.5	10	0.0–2.1	0.2±0.7
NO_3[a]	7	0.6–46.7	14.3±16.7	10	0.0–34.7	6.8±14.0
NH_4[a]	9	0.0–27.1	9.8±10.8	9	0.0–26.9	11.4±11.1
Organic N[a]	9	0.0–1.7	0.2±0.6	9	0.0–0.0	0.0±0.0
TKN[a]	9	0.0–27.1	9.9±11.0	9	0.0–26.9	11.4±11.1
TSS[a]	15	2–90	16.7±21.2	15	1–40	10.9±11.0
BOD[a]	14	5–130	26.4±35.1	14	3–32	11.4±7.7
pH	15	6.9–7.4	7.1±0.2	14	6.8–7.4	7.1±0.2

[a] Expressed in parts per million.

Carolina in 1975, Rutz and Axtell (1978) showed mosquito abundance to be affected by the level of organic pollution as well as by the degree of vegetation and/or floating debris. Optimal mosquito production in poultry waste lagoons (approximately 300 immature mosquitoes per dip) occurred at a TKN level of 165 ppm while maximum mosquito abundances in swine lagoons (approximately 220 immature mosquitoes per dip) corresponded to a TKN level of 174 ppm. Table 1 shows that at the 2 study sites in IRC, the TKN levels were considerably lower ($\overline{X}$ values of 9.9 and 11.4 ppm and not exceeding 27.1 ppm) but mosquito densities were comparable.

Although overall the seasonal species composition pattern was similar between the 2 IRC study sites, slight temporal discrepancies occurred. At Clemans School, *Cx. nigripalpus* dominated the sample from mid-June until mid-November 1980. In 1981, onset of dominance was also in mid-June (Fig. 2). At Douglas School in 1980, *Cx. nigripalpus* became dominant in mid-May and persisted until early November while in 1981 onset of dominance was delayed until mid-July (Fig. 1).

Even though the dominant periods for *Cx. quinquefasciatus* and *Cx. nigripalpus* were similar at both school ponds, the reasons for this differ. By comparing mean number of mosquitoes per dip between dominant versus non-dominant periods, it can be shown that there was a significant difference for *Cx. quinquefasciatus* at Douglas School ($t = 3.80$, $p < 0.0001$, $df = 59$) and for *Cx. nigripalpus* at Clemans School ($t = -5.04$, $p < 0.0001$, $df = 61$) but not for *Cx. quinquefasciatus* at Clemans School and for *Cx. nigripalpus* at Douglas School. It seems that at Douglas School, dominance by *Cx. quinquefasciatus* was due to a real increase in their numbers, not to a decrease in *Cx. nigripalpus* numbers. In contrast, at Clemans School, dominance by *Cx. quinquefasciatus* seems due to a decrease in *Cx. nigripalpus* numbers. The reasons for this difference and difference in time of onset and termination of dominance are unclear.

Aedes taeniorhynchus and *Ae. sollicitans* inhabit salt-marshes in IRC (Provost 1968). *Aedes atlanticus, Ae. sollicitans, Ae. vexans, Ps. ciliata, Ps. columbiae, Ps. howardii,* and *Cx. nigripalpus* occur in citrus groves in IRC (Curtis, personal communication). Both types of habitat occupy extensive areas in IRC and both occur in proximity to some of the ponds studied. *Aedes taeniorhynchus* and *Ps. columbiae,* which were collected at both study sites in noticeable numbers when school opened in late summer 1980, are prevalent species in summer and early fall when heavy rainfall stimulates their development. In 1981, south Florida experienced an extreme drought, forcing citrus grove owners to crown-flood irrigate producing huge populations of *Ae. vexans* (Curtis, personal communication), followed in April by *Ae. vexans* becoming a sizable component of the species composition of both school ponds. Although rarely present in them, the occurrence of floodwater mosquito populations in holding ponds is a phenomenon due to synchrony of the presence of large numbers of adult floodwater mosquitoes in conjunction with the draining and reflooding of the ponds.

In IRC, production of mosquitoes from evaporation-percolation ponds is small in comparison to other aquatic habitats. However, because the 2 major species occurring there are disease vectors with both possibly playing an integral role in any future St. Louis encephalitis outbreaks, and since ponds are close to residential areas, the monitoring and control of mosquito populations in this habitat is important. Moreover, increasing residential development and the relatively new and growing use of marshes as effluent retention areas is expanding the possible wastewater mosquito habitats in southeast Florida.

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