LABORATORY AND FIELD INVESTIGATIONS OF MOSQUITO POPULATIONS ASSOCIATED WITH OXIDATION LAGOONS IN MISSOURI[1]

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INTRODUCTION. Mosquito occurrence in sewage lagoons has been reported by Eads and Mengies (1956), Beadle and Harmston (1958), Rapp (1960), Beadle and Rowe (1960), Rapp (1961), Myklebust and Harmston (1962), and Rapp and Emil (1965). *Culex tarsalis* Coquillett and the *Culex pipiens* complex were considered prolific breeders in certain mid-western sewage lagoons. Other mosquitoes reported less frequently included *Aedes campestris* (Dyar and Knab), *Aedes dorsalis* (Meigen), *Anopheles quadrimaculatus* Say, *Culex erraticus* (Dyar and Knab), *Culex restuans* (Theobald), *Culex salinarius* (Coquillett), *Culex thriambus* Dyar, *Culiseta inornata* (Williston), and *Psorophora confinnis* (Lynch-Arribalzaga).

This investigation was part of a study undertaken to determine the importance of oxidation lagoons as sources of troublesome insect populations in Central Missouri. Previous investigations were concerned with midge production (Kimerle, 1965), chironomid biologies and life histories (Fagan and Enns, 1966) and the predation potential of dytiscid beetles (Roberts *et al.*, 1967). The present study dealt with the relationship of mosquitoes to oxidation lagoons. Specific objectives were to ascertain the mosquito species composition and acquire additional biological data on mosquito behavior in animal waste, municipal, residential, school, slaughterhouse, and trailer court lagoons.

MATERIALS AND METHODS. Two distinct, but related, mosquito populations were investigated, namely, the adult population in the lagoon environs, and the egg raft and larval populations within the lagoons. Standard sampling techniques were employed except for the collection of mosquito egg rafts. Egg rafts were recovered from an artificial oviposition block which was made from "Styrofoam" plastic and measured 18″ x 18″ x 3″. Four openings, each measuring 6″ x 6″ x 3″, were cut in each block and a 2-inch margin was left between the outer edges and between the openings. Two 4½ inch eye-bolts were inserted through the plastic, one on each side of the block to which a 2-foot length of nylon cord (one for each side) was attached with the distal end tied to an eye-bolt embedded in a cement anchor. The total sampling area of the completed oviposition block was 1 square foot.

Egg rafts, larvae, and adult mosquitoes associated with the study lagoons were reared and identified with standard laboratory equipment. Water analyses used were those described in Standard Methods for the Examination of Water, Sewage, and Industrial Wastes (1955). Certain physical and biological characteristics of eight oxidation lagoons included in the study are summarized in Table 1.

RESULTS AND DISCUSSION. The animal waste lagoons were usually too small in size, overloaded, inadequately designed, low in dissolved oxygen content, frequently anaerobic, and poorly maintained. These factors, together with the presence of extensive overhanging and emergent vegetation, created an ideal environment for excessive mosquito production.

The municipal lagoons were adequately designed, well-maintained and seldom anaerobic. Although these lagoons were exposed to a diverse and abundant mosquito fauna, because of their location near woods, fresh water marshes, and various

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TABLE 1.—Summary of data for eight oxidation lagoons; comprising age in years, B.O.D.[a] in pounds per acre per day, size in acres, average depth in inches and incline of bank in inches per foot.

Lagoon[b]	Location and Type	Age	Load	Size	Av. Depth	Bank Incline
1—AW	Humane Society—Primary	4.0	Unk[c]	0.1	21	1.8
2—AW	Swine Farm—Primary	7.0	Unk	0.5	27	5.0
3—AW	Swine Farm—Secondary	4.0	Unk	0.5	40	5.0
4—M	Bear Creek—Primary	8.0	35.0	4.7	42	3.0
5—R	South Drive—Primary	6.0	32.0	0.5	42	4.5
6—SL	Woodhaven—Primary	3.0	17.0	1.0	32	4.8
7—S	Moberly—Primary	6.0	Unk	2.0	38	3.5
8—TC	Pine Grove—Primary	3.5	20.6	1.4	20	2.5

[a] Biochemical Oxygen Demand.
[b] AW (Animal Wastes), M (Muncipal), R (Residential), SL (School Lagoon), S (Slaughterhouse Wastes), and TC (Trailer Court).
[c] Unknown.

streams, mosquito development was limited and restricted to overflow structures and certain effluent areas. The drain devices in which mosquito breeding occurred consisted of four box-like sections arranged at different levels to control the water depth of the lagoon. The absence of flowing water through certain sections created a stable water-air interface well-suited for oviposition. Mosquito egg rafts and larvae were recovered from all negative effluent areas.

The single residential lagoon studied contained emergent and overhanging vegetation, was overloaded, frequently anaerobic, and seemed ideally suited for excessive mosquito production. Egg raft, larval, and adult mosquito populations, however, were quite limited. Macro- and micro-predators were abundant within the lagoon, and their activities may have been instrumental in reducing the density of mosquito populations. The effluent of this lagoon discharged into a small drainage ditch that extended for approximately 200 yards through a densely populated residential section. Extensive mosquito breeding occurred in this habitat throughout the season.

The school lagoons were well-designed, lightly loaded, used only for a nine-month period, and were devoid of extensive emergent and overhanging vegetation. The biological behavior of these lagoons contrasted sharply with that of other lagoons. Anaerobic conditions frequently occurred, but were not caused by the usual factors, i.e., overloading, inadequate design, etc. The anaerobicity was caused by the rapid growth of duckweed (*Lemna minor* L.) over the lagoon surface. Eventually, the heavy growth of duckweed caused high algal mortality and may have served as a physical deterrent to ovipositing mosquitoes.

Slaughterhouse lagoons were well-designed and relatively free of vegetation. Extensive mosquito breeding was caused indirectly by an inadvertent discharge of waste waters laden with excessive fats. The direct phytotoxic effects on algae precluded photosynthesis and the lagoon became anaerobic, attractive to female mosquitoes, and the interspaces of the floating, dead algal mats soon contained large numbers of mosquito egg rafts and larvae.

Trailer court lagoons were often overloaded, but proper design and excellent maintenance precluded extensive mosquito breeding. The effluent areas of these lagoons, however, were often sources of large numbers of mosquitoes.

The most annoying and abundant adult mosquitoes in the lagoon environs were the *C. pipiens* complex, *A. punctipennis, C. erraticus,* and *A. trivittatus.* Adults of the *C. pipiens* complex, *A. punctipennis,* and *C. salinarius* were omnipresent in all lagoon environs, but *C. salinarius* adults were never abundant. *C. erraticus* and *C.*

tarsalis adults were observed in the environs of every lagoon also except for one trailer court. *C. erraticus* adults were present from June through October (peak abundance during August) and readily attacked human bait while *C. tarsalis* adults were observed infrequently from August through November and were never taken in human biting collections.

C. inornata adults occurred in all lagoon environs except certain municipal and trailer court lagoons. The seasonal distribution and biting behavior of this mosquito was unique in comparison to the other mosquitoes associated with the lagoons. *C. inornata* was the first species to appear in the lagoons and was the last species to be collected in late fall. Adults were present from May through June, virtually absent during July and August, and reappeared again in September and October. Adults were frequently identified from biting collections during the spring and early summer, but not during the terminal portion of their cycles, i.e., September through October.

Mosquitoes recorded less frequently included *A. canadensis, A. triseriatus,* and *A. vexans*. *A. canadensis* were present during early spring and summer while other *Aedes* species were recorded from June through November. *A. trivittatus* was the most abundant flood-water mosquito in the lagoon environs, and was recovered only from diurnal biting collections. *A. quadrimaculatus* and *P. ferox* adults were occasionally taken.

The number of egg rafts and larvae recovered from certain lagoons is summarized in Table 2. Five species, including *A. punctipennis, C. pipiens* complex, *C. salinarius, C. tarsalis,* and *C. inornata* were recovered from eight lagoons. Of the 7,821 egg rafts recovered from April through August, 7,715 were identified as the *C. pipiens* complex, 79 *C. inornata,* and 27 *C. tarsalis*. *A. punctipennis* eggs and *C. salinarius* egg rafts were not found during the investigation. The majority of the egg rafts were recovered from the animal waste lagoons, with the least number of egg rafts occurring in the school lagoons.

Larval data were comparable to egg raft data except that *A. punctipennis* and *C. salinarius* larvae were recorded only from a swine farm lagoon. Approximately 98,200 larvae were counted and, of this number, 97,362 larvae were identified as the *C. pipiens* complex, 679 *C. inornata,* 111 *C. salinarius,* 41 *C. tarsalis,* and 7 *A. punctipennis.*

SUMMARY. Previous investigations had considered the presence of emergent and/or overhanging vegetation as the single most important factor favoring mosquito production in oxidation lagoons. The results of this investigation indicate that the magnitude of mosquito production may depend primarily on one or more of several additional factors including density of vegetation, types of wastes, dissolved oxygen content, available food, and presence of parasites and predators. Mosquito production was further enhanced, indirectly, by certain phytotoxic wastes that killed algae, caused them to float in large mats, and thus provided an ideal oviposition site.

Frequent anaerobicity apparently favored mosquito production except in the school lagoons. The interference with photosynthesis and the resultant high algal mortality was brought about by the surface-sealing effects of duckweeds. Mosquito breeding was virtually eliminated under these conditions. Additional reduction in mosquito populations may have been caused by the activities of parasites and predators.

The characteristic mosquito population associated with the lagoons consisted of 12 species, of which only 5 were found breeding within the lagoons proper.

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TABLE 2.—Number of egg rafts and larvae recovered from selected oxidation lagoons in Missouri from April–August, 1965–66.

Lagoon [a]	Number of Egg Rafts and Larvae/Month										Total	
	April		May		June		July		August			
	Rafts	Larvae	Rafts	Larvae	Rafts	Larvae	Rafts	Larvae	Rafts	Larvae	Rafts	Larvae
1—AW *	17	23	5	41	11	61	NS	NS	NS	NS	33	125
2—AW	35	NS	43	NS	3,580	176	1,444	19,223	1,033	42,356	6,135	61,755
3—AW	0	NS	0	NS	128	9	213	1,419	697	33,267	1,038	34,695
4—M	NS	NS	15	NS	173	149	15	52	40	82	243	283
5—R	4	NS	6	NS	41	142	14	190	21	175	86	507
6—SL *	3	0	5	0	11	21	0	0	0	0	19	21
7—S *	NS	NS	15	47	25	81	11	53	NS	NS	51	181
8—TC	8	NS	25	NS	51	37	53	175	79	421	216	633

[a] See Table 1 for explanation of AW, M, R, SL, S and TC.
* —1965 data; all other 1966.
NS—Not sampled.

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THE EGG-LAYING HABITS OF *AEDES AEGYPTI* (LINNAEUS) IN CENTRAL TEXAS[1]

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INTRODUCTION. Until recently, larval survey and adult resting and biting collections have been the only means of sampling an *Aedes aegypti* population. Measurement of *Ae. aegypti* populations by adult resting and biting collections is productive only in areas where this species is very abundant. Larval surveys are effective only when rainfall or other moisture is sufficient to flood eggs previously deposited in artificial containers. Recognizing the need for a surveillance method of detecting this species at low population levels, Fay and Perry (1965) at the Technical Development Laboratories in Savannah, Georgia, attempted to develop an attractive egg-laying site. The selection of an egg-laying site was based on female *Ae. aegypti* preference for texture, color, and shape of container, as well as the odor and taste characteristics of the contents. Based on the work of Fay and Perry and the additional studies of the Aedes aegypti Field Research Station at Perrine, Florida, an attractive oviposition site was successfully developed.

This oviposition site, or ovitrap, consists of a black, tapered, pint jar containing one inch of water; a two-dram vial containing reagent grade ethyl acetate as an attractant; and a hardboard paddle, the oviposition site.

The egg-laying site developed by Fay and Perry was employed in the present study, conducted in central Texas, to determine the effects of temperature and rainfall on the ovipositional behavior of *Ae. aegypti*. In addition, a limited test was conducted comparing results of ovitraps operated with and without the ethyl acetate attractant. This study was made during the period of June 23 to November 21, 1966, in an area in Austin, Texas, known to have a heavy infestation of *Ae. aegypti*.

METHODS. Larval surveys were made on June 2, 1966, and July 7, 1966, to determine the degree of infestation in the study area. In all, 203 premises were inspected.

[1] From the Aedes aegypti Eradication Program, National Communicable Disease Center, Public Health Service, U. S. Department of Health, Education, and Welfare, Austin, Texas.