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Effects of Mosquito Control Chemicals on Aquatic Fauna

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INTRODUCTION

No mosquito abatement districts have ever been organized in Arkansas. Mosquito control efforts have been largely adulticiding operations by either aerial application or ground thermal fogging machines. Practically no chemical applications have been directed at the larval stage in residual water in ditches and depressions from which adult populations arise. Some larviciding with ethyl parathion has been done in ricefields. Although the treatment is very effective in mosquito reduction, voluntary treatment has not been completely successful.

Because relatively little insecticide has been used as a larvicide in Arkansas, it was possible to evaluate the effect of recommended larvicides on non-target organisms in the aquatic environment. A developing mosquito control demonstration program in the rice-producing area provided the study site.

METHODS AND MATERIALS

On the basis of the estimated flight range of the dark ricefield mosquito, four sections were mapped to receive the larviciding chemicals. An additional 1-mile radius was scheduled for treatment of all rice with ethyl parathion. This provided a distance of 2 miles from the center of the treatment area.

Sampling for aquatic fauna was carried out by taking 10 dips with an 8 oz dipper and concentrating the specimens by pouring them through a siphoning device (ADCAS- automatic device for collection of aquatic samples). Excess water was drained off carefully after siphoning was complete and the reduced sample was placed in a baby food jar, marked with date and sample site. At the end of the day, alcohol was added to preserve the specimens. Sampling was carried out before and after treatment on approximately a weekly basis. Control samples were taken at random from outside the treatment areas. Samples were stored and later analyzed in the laboratory, after mosquito-control operations had ceased and personnel were freed to perform this task.

Variable numbers of samples were taken, depending on the availability of standing water. In 1970, 588 samples were collected; in 1971, 277; and 1972, 427. The number of samples decreased as water sources dried up and increased during rainy periods when sample sites were filled. Generally, the same sites were sampled when water was present.

During the first season, treatment was applied almost on a weekly basis to standing water in ditches and to any source which could be found producing mosquito larvae. Later, treatment was applied to sites producing mosquito larvae rather than to all standing water.

The four larvicides used were (1) Abate(R) in the NW section; (2) malathion in the NE section; (3) fenthion (Baytex) in the SE section; and (4) Flit MLO, a petroleum hydrocarbon, in the SW section. Application of these materials was by power sprayer to standing water. The rates used were (1) Abate(R) 4 lb EC - 1.5 oz/gal finished spray; (2) malathion 57% EC - 3.0 oz/gal finished spray; (3) fenthion 4 lb EC - 1.5 oz/gal finished spray; and (4) Flit MLO used directly. Table I shows the dates of application and amounts of larviciding chemicals used; Table II shows the dates and amounts of adulticides used.

Table I. Dates and amounts (gal) of larvicides applied in treatment area at Lonoke, Arkansas, in 1970, 1971 and 1972.

	NE Abate 4EC			SE Fenthion 4EC			NW Malathion 57% EC			SW Flit MLO		
Date	70	71	72	70	71	72	70	71	72	70	71	72
6-01	-	-	-	-	-	-	-	-	-	-	-	35
6-02	-	-	-	-	-	75	-	-	-	-	60	-
6-03	-	-	-	-	30	-	25	-	-	-	-	-
6-04	-	-	-	60	55	-	-	-	-	60	-	-
6-05	60	-	75	-	-	-	-	-	75	-	-	-
6-07	-	10	-	-	45	-	-	-	-	-	-	-
6-08	-	40	-	-	-	-	-	-	-	-	-	-
6-09	-	-	-	-	-	-	-	72	-	-	-	-
6-11	-	70	-	-	-	-	-	-	-	-	-	-
6-15	-	-	-	-	-	-	25	-	-	19	-	-
6-16	-	-	-	75	40	-	-	-	-	-	-	-
6-17	20	-	-	-	-	-	-	-	-	-	55	-
6-22	-	-	-	-	-	-	-	65	-	-	13	-
6-23	-	42	-	-	-	-	-	-	-	-	-	-
6-25	-	-	-	-	80	-	-	-	-	-	-	-
6-28	-	-	-	-	-	75	-	-	-	-	-	-
6-29	-	-	-	-	-	-	25	-	-	30	-	-
6-30	25	-	-	55	-	-	-	-	75	-	-	-
7-01	-	-	-	-	-	-	-	85	-	-	70	-
7-05	-	-	75	-	-	-	-	-	-	-	-	35
7-06	-	-	-	-	-	75	-	-	75	-	-	-
7-07	-	-	-	-	69	-	-	-	-	-	-	-
7-08	-	50	-	-	-	-	-	80	-	-	22	-
7-09	-	-	-	-	-	-	67	-	-	63	-	-
7-10	-	-	-	105	-	-	-	-	-	-	-	-
7-13	37	-	-	-	-	-	-	-	-	-	-	-
7-16	-	-	-	-	-	-	35	-	-	70	-	-
7-17	-	-	-	185	-	-	-	-	-	-	-	-
7-20	70	-	-	-	-	-	-	-	-	-	-	-
7-21	-	15	-	-	30	-	-	52	-	-	-	-
7-27	-	-	-	-	62	-	-	15	-	-	-	-
7-28	50	-	-	-	-	-	-	-	-	-	-	-
7-29	-	-	-	-	-	-	-	70	-	-	-	-
8-03	-	-	75	-	-	75	68	-	75	51	-	-
8-04	30	-	-	92	-	-	-	-	-	-	-	-
8-05	2.5	-	-	-	-	-	-	-	-	-	-	-
8-09	-	-	-	-	-	-	-	-	-	-	17	-
8-10	-	-	-	-	85	-	-	-	-	-	-	-
8-11	150	-	-	-	-	-	-	-	-	-	-	-
8-12	-	-	-	165	-	-	-	-	-	-	-	-
8-13	-	-	-	-	-	-	-	-	-	49	-	-

Table II. Gallons of insecticide concentrates applied against adult mosquitoes in 1970, 1971, and 1972, Lonoke, Arkansas.

Aerial Applications

Date	Fenthion 4EC 1970	1971	1972
6-19	15.00	-	15.00
6-25	-	15.00	-
7-02	15.00	-	-
7-07	-	-	15.00
7-10	15.00	-	-
7-17	15.00	-	-
8-14	15.00	-	-

ULV Applications

Date	Malathion* 1970	1971	1972
6-02	-	-	3.00
6-04	2.00	-	-
6-06	-	-	3.00
6-09	4.00	-	-
6-12	2.50	-	-
6-15	1.75	7.00	3.00
6-16	-	-	3.00
6-17	4.00	-	3.00
6-18	-	8.00	3.00
6-22	3.50	2.00	-
6-23	-	-	3.00
6-24	3.00	-	-
6-26	2.50	-	3.00
6-28	-	-	3.00
6-30	-	4.00	-
7-01	-	4.00	3.00
7-02	-	3.13	-
7-05	-	3.20	-
7-08	3.50	3.25	-
7-09	-	15.00(Dibrom)	-
7-10	-	-	3.00
7-11	-	3.90	-
7-12	-	4.20	-
7-13	4.50	2.50(Dursban)	-
7-14	-	1.90(Dursban)	3.00
7-15	-	15.00(Dibrom)	-
7-16	-	1.90(Dursban)	-
7-19	-	4.00	-
7-20	1.30	2.50	-
7-21	-	2.00	3.00
7-26	-	3.50	-
7-27	-	3.00	-
7-28	-	4.00	-
8-02	-	4.50	-

Table II. (Continued)

Date	1970	1971	1972
8-09	-	-	3.00
8-11	1.50	-	-
8-17	4.25	-	3.00
8-22	-	-	3.00
8-26	2.50	-	-

*Except where indicated.

LITERATURE REVIEW

As early as 1919, studies on Anopheles quadrimaculatus (Say) were being conducted in the area of Lonoke by Geiger et al. (1919), who stated that an infestation of this species was thought to originate from two ricefields a mile from the city. They also conducted flight range experiments with 4,000 marked mosquito adults liberated near the ricefields. Only 10 adults were recaptured. Nine were caught 0.75 mile from the release point and one was recaptured a mile away. Whitehead (1957) conducted further experiments in the area on the flight range of ricefield mosquitoes. These data indicated that if breeding of rice-field mosquitoes is prevented for a distance of 4 miles from a given area, less than 3% of the mosquitoes originating outside will fly into the area. Only about 10% were trapped at a distance of more than 1.7 miles from the nearest field in the study.

Kiker and Breedlove (1941) conducted flight dispersal studies in Tennessee. They showed that Anopheles mosquitoes traveled up to 1.25 miles from the breeding site, but average flight range was 1 mile.

In relation to aquatic arthropods other than mosquito larvae, Fales et al. (1968) eradicated a large population of Chaoborus spp. in a lake treated with Abate(R) at a rate of 0.39 lb/acre. This concentration also proved toxic to nearly all other insects in the lake. Von Windeguth and Patterson (1966) studied the effects of an organophosphorous insecticide on aquatic biota. Field application of 0.25 lb of technical Abate per acre produced no noticeable mortality of Odonata, Chaoborus, Copepoda and Ostracoda. Porter and Gojmerac (1969) stated that Abate at 0.03 lb/acre was toxic to nymphs of Libellulidae and to

Cladocera (Crustacea). It was not toxic to mosquito pupae, Amphipoda, Isopoda, Ostracoda and Copepoda.

Kimball and Perruzzi (1970) applied Flit MLO at the rate of 2-3 gal/acre to breeding sources in an urban community. They concluded that Flit MLO killed both mosquito larvae and pupae when applied at the rate of 2-3 gal/acre and provided control of mosquitoes for a period of up to 14 days in Orange County, Calif. Felton (1944) stated that petroleum oils do not kill mosquito larvae and pupae by suffocation. The volatile components of the oil exert a direct toxic effect on the tissue of the larvae and pupae which result in death.

Mount et al. (1970), using a Leco cold aerosol nozzle connected to a modified Curtis 55,000 cold aerosol generator, showed that technical malathion (95%) was dispersed in droplets averaging 11μ in diameter. The nozzle was operated at 3.5 psi with a flow rate of 2.85 fl oz/min; vehicular speed was 10 mph. The dispensed droplet size corresponds to the optimum of 5-10μ mass median diameter as suggested by Mount (1970). Caged female Aedes taeniorhynchus (Wiedemann) adults were used as the test animal. At distances of 150,300 and 600 ft percentage mortality after 18 hr was 93, 93 and 93 respectively. The LD_{50}'s for malathion and fenthion were 0.025 and 0.072 lb/acre respectively, based on amount of active ingredient used per acre. Taylor and Schoof (1968) tested thermal and non-thermal fogs against adults of Aedes aegypti (Linnaeus), Anopheles albimanus (Wiedemann), Culex quinquefasciatus and Aedes taeniorhynchus. At distances of 150 and 300 ft malathion was found superior to Dursban, naled and Baygon(R). The latter three were metered out at the rate of 2 oz/min/gal, whereas the malathion dose rate was 6 oz/min/gal. Dursban proved most effective at the 2 oz/min/gal level.

Paulini et al. (1962) demonstrated residual activity of fenthion against Culex fatigans (Wiedemann) adults on various types of wood surfaces. Bare wood surfaces produced the best residual activity to the adult mosquitoes when fenthion was applied at 1.1 - 2.3 g/m^2. Residual activity of the chemical lasted from 3 to 6 months.

Lewallen and Wilder (1963) tested insecticides on mosquito larvae in polluted and pure tapwater. Polluted tapwater was created by mixing pure tapwater with manure. C. fatigans larvae were found to be more susceptible to DDT and fenthion in polluted tapwater than in pure tapwater. Malathion was equally toxic to the larvae in the two water conditions. Parathion was more effective in pure tapwater than in polluted tapwater. Using 1% fenthion, Stevens et al. (1963) produced 100 and 99.4% mortality at distances of 80 to 330 ft respectively from the release point. Burton (1964), using the World Health Organization Kit for larval resistance or susceptibility, found fenthion to be the most toxic of the chemicals tested. Diazinon was second, followed by malathion, BHC, dieldrin and DDT. Gahan and Noe (1955) studied control of mosquito larvae in ricefields with water soluble phosphorous insecticides. The study was conducted to determine the effectiveness of water soluble larvicides for control of ricefield mosquitoes. The chemicals used were Bayer L 13/59, Shell OS 2046, DDVP and parathion. All were applied with an automatic applicator to the water before it entered the field. Parathion at 0.1 ppm proved to be highly effective after flowing more than 0.5 mile through a canal and 400 ft into the ricefield. This kill rate was in relation to Psorophora confinnis (Lynch and Arribalzaga). None of the chemicals had residual activity against A. quadrimaculatus and Culex erraticus (Dyar and Knab).

Mulla et al. (1961a) found that parathion produced a high toxicity to C. quinquefasciatus with an LD_{50} of 0.0045 ppm. Mulla (1961b) stated that C. quinquefasciatus larvae were more susceptible to insecticides in the early larval instars than in the latter stages of larval development.

The 48-hr LC_{50} of Abate for stoneflies (Pteronarcys californica) and Amphipods (Gammarus lacustris) was 100 ppb and 1,500 ppb respectively (FWPCA, 1968). The 24-hr LC_{50} of Abate for the Amphipod (G. lacustris) was 960 ppb (Sanders, 1969).

Abate was one of the least toxic of eight chemicals tested against Cyclops spartinus (Ruber, 1963), and Cypronotus incongruens was remarkably insensitive to Abate (Ruber, 1963, 1965a, b).

The LC_{50} of malathion for various arthropods is shown in Table III (Pimentel, 1971).

The 48-hr EC_{50} (immobilization value at 60°F) of malathion for waterfleas, Simocephalus serrulatus and Daphnia pulex, was 3.5 ppb and 1.8 ppb respectively (Sanders and Cope, 1966).

Crayfish in streams in a malathion-treated (2 lb/acre) watershed were unaffected by the treatment (Peterle and Giles, 1964). Other arthropod numbers decreased greatly but recovered soon after treatment.

The 48-hr EC_{50} (immobilization value at 60°F) of fenthion for waterfleas, Simocephalus serrulatus and Daphnia pulex, was 0.92 ppb and 0.80 ppb respectively (Sanders and Cope, 1966). The LC_{50} values of fenthion for various arthropods are shown in the Table IV (Pimentel, 1971)

Mortality has been observed in dytiscid adults and larvae and in hydrophilid and notonectid adults after application of a surface film of Flit MLO to their normal habitat. Dragonflies, damselflies, mayflies and caddisflies were not affected by Flit MLO (Exxon, 1973). The only significant hazard observed is to certain insect life with biological stages that occur at the air-water interface (Humble, 1972).

Table III. LC_{50} of malathion for various arthropods.

Arthropod Species	Exposure Time (hr)	LC_{50} (ppm)	Source
Amphipod (*Gammarus lacustris*).........	24	0.0038	Sanders, 1969
Stonefly (*Pteronarcella badia*)........	24	0.010	Sanders and Cope, 1966
Stonefly (*Claassenia sabulosa*)........	24	0.013	"
Stonefly (*Pteronarcys californica*)....	24	0.035	"
Hermit crab....................	24	0.118	Eisler, 1969
Grass shrimp...................	24	0.131	"
Sand shrimp....................	24	0.246	"
Waterflea (*Daphnia pulex*)..............	48	0.0018	FWPCA, 1968
Amphipod (*G. lacustris*)...............	48	0.0018	"
Waterflea (*D. pulex*)...........	48	0.002	Cope, 1966
Stonefly (*Simocephalus serrulatus*)....	48	0.003	"
Stonefly (*P. badia*)............	48	0.006	FWPCA, 1968
Mayfly (*Baetis sp.*)............	48	0.006	Cope, 1966
Stonefly (*P. californicus* [sic])......	48	0.020	"
Red crawfish...................	48	20.0	Muncy and Oliver, 1963

Table IV. LC_{50} of fenthion for various arthropods.

Arthropod Species	Exposure Time (hr)	LC_{50} (ppm)	Source
Amphipod (*Gammarus lacustris*).........	24	0.015	Sanders, 1969
Stonefly (*Pteronarcys californica*)....	24	0.130	Sanders and Cope, 1966
Stonefly (*Simocephalus serrulatus*)....	48	0.0031	FWPCA, 1968
Waterflea (*Daphnia pulex*)..............	48	0.004	"
Stonefly (*P. californica*)............	48	0.039	"
Amphipod (*G. lacustris*)...............	48	0.070	"
Stonefly (*P. californica*)............	48	0.130	"

RESULTS AND DISCUSSION

For the past three years the community of Lonoke, Arkansas, has been the site of a mosquito control demonstration. The project was to demonstrate that mosquito numbers could be reduced within the budget of a ricefield community, and was supported jointly by the City of Lonoke, the Lonoke Chamber of Commerce, and a grant from the Office of Water Resources Research. The project was supervised and directed by the Arkansas Agricultural Experiment Station and the Arkansas Cooperative Extension Service. This program is hoped to have altered a rather prevalent negative attitude toward mosquito control; i.e., mosquitoes have always been troublesome, they always will be, and nothing can be done about it.

As in the two previous years, the 1972 Lonoke program consisted of larviciding mosquito breeding sites within a 2-sq-mile area with Lonoke at the center. All ricefields within an additional 2-mile zone were larvicided; however, no other breeding sites were treated. A ULV cold aerosol generator was used against adult mosquitoes as a supplement to larviciding. Finally, aerial sprays were made when mosquito populations could not be controlled by the aforementioned techniques.

Two mosquito species (*Psorophora confinnis* and *Anopheles quadrimaculatus*) collected from New Jersey light traps were of primary concern during the three year study (Fig. 1). *Psorophora confinnis* was most abundant. Peak numbers occurred near June 10 and 20 and July 1. After July 1, *P. confinnis* numbers decreased sharply. *Anopheles quadrimaculatus* gradually increased throughout the season and became the dominant species after August 1. The rise in Anopheles numbers coupled with the decrease in Psorophora numbers served to maintain pestiferous populations of mosquitoes late in the summer. It should be noted that A. quadrimaculatus is not a species which is readily attracted to light traps; however, other observations including landing rate counts and larval surveys indicated that the population trend shown by light traps was correct.

Total numbers of mosquitoes collected from New Jersey light traps in 1970 and 1971 were averaged and compared to total numbers of mosquitoes collected in 1972 (Fig. 2). In 1970 and 1971, populations exceeded 2000/trap for much of June, whereas the maximum in 1972 was 412. These numbers are expressed as logarithms; numerically, a single trap in 1970 captured as many as 38,000 specimens, and in 1971 and 1972 the maximum numbers were 4000 and 1500 respectively. Five aerial sprayings were needed in 1970, one in 1971, and two in 1972. Control was not absolute, but mosquito numbers were reduced substantially.

The scope of the Lonoke project was restricted by financial resources. For more effective control the abatement area should be increased at least twofold. A mosquito abatement district is the ultimate solution. Even though the value of mosquito abatement has been proven, many local authorities remain skeptical and it appears necessary to demonstrate the practicality of mosquito control. The technology for successful mosquito control in Arkansas does exist; however, the best available recommendations at this time are primarily chemically oriented. The approach must become more integrated and additional research is needed for long-range control, because many mosquito abatement problems in Arkansas rice-growing areas are unique to Arkansas.

During the Lonoke study, 588 samples of aquatic fauna were analyzed from the 1970 collections; 277 and 427 were analyzed respectively from 1971 and 1972 collections. The numbers and identity of the species found are shown in Table V. A comparison of the average numbers by years and section is shown in Table VI. During the course of the investigation, reduction in numbers could be detected after treatment but recovery was also apparent. Another factor to be borne in mind is that when winged adults emerged, migration out of the aquatic habitat resulted. Comparison with control samples indicates considerable reduction in overall aquatic fauna in all sections. The fact that the highest percentage reduction occurred in mosquito larvae attests to the effectiveness of the chemicals for mosquito control.

Fig. 1. Comparison of numbers of *Psorophora confinnis* and *Anopheles quadrimaculatus* mosquitoes collected in light traps.

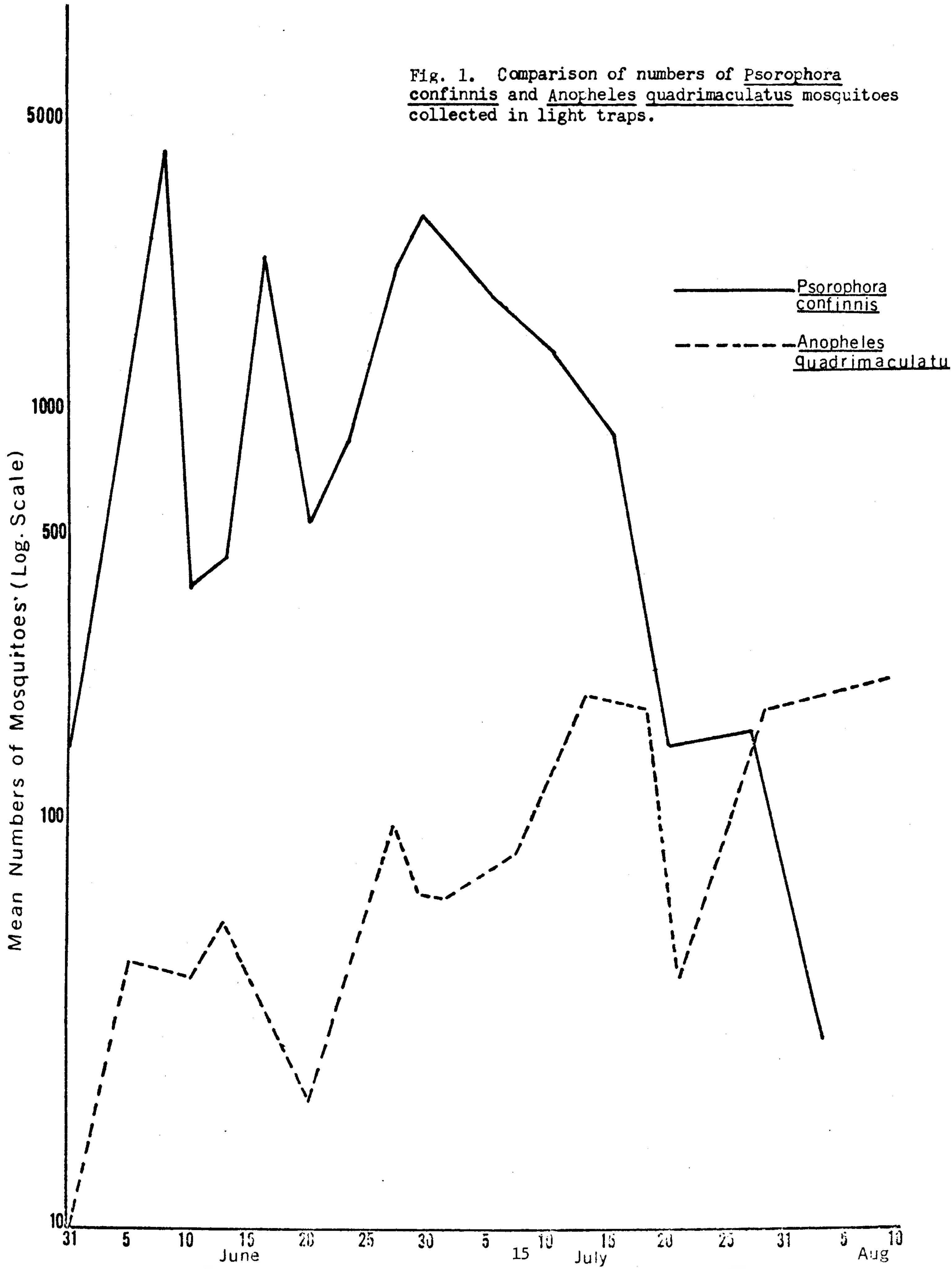

Fig. 2. Comparison of total numbers of mosquitoes collected/light trap.

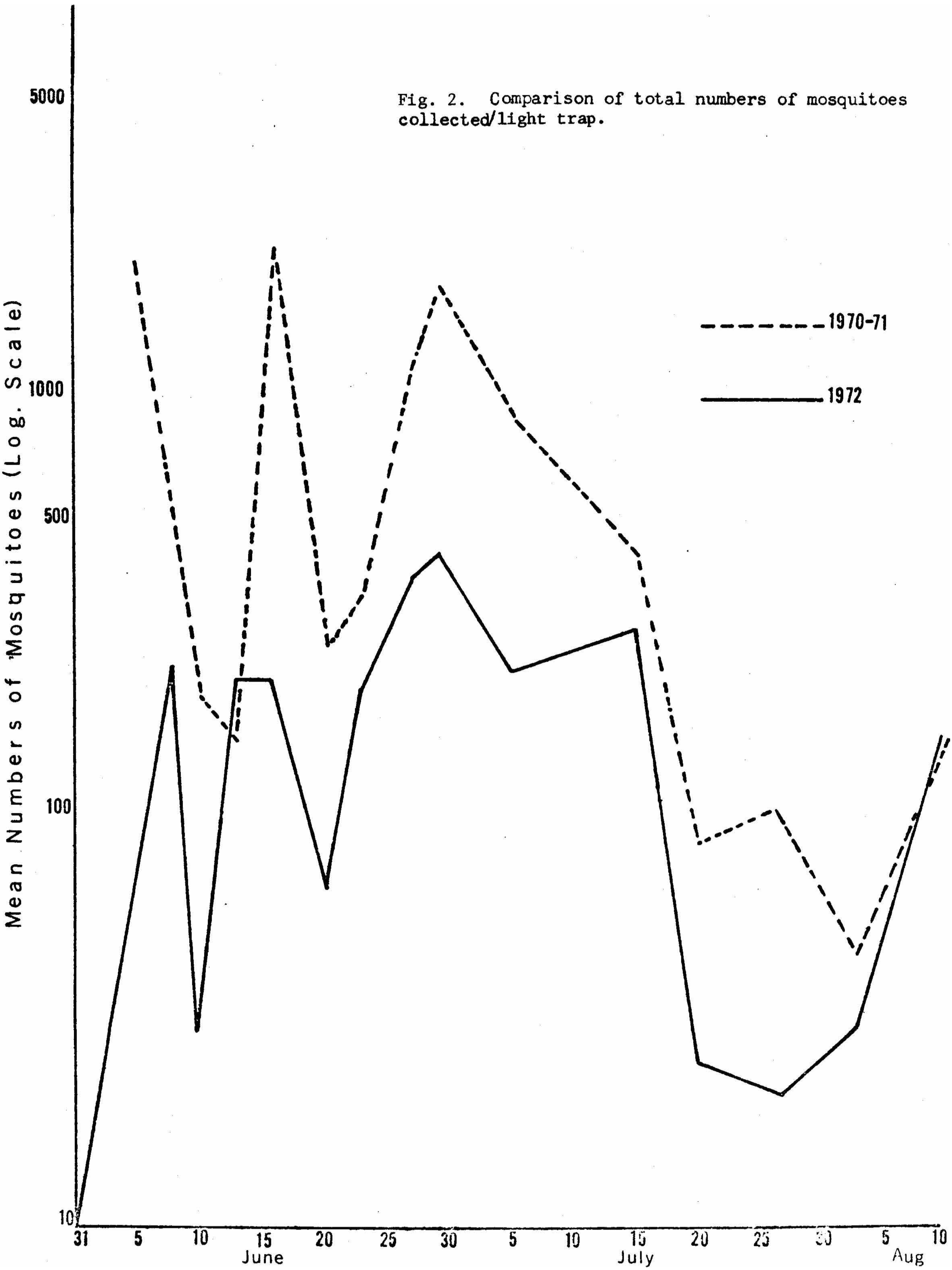

Table V. Numbers and identities of species found in water samples, Lonoke, Arkansas.

Specimens	1970						1971						1972					
	Total	Control	NE	SE	NW	SW	Total	Control	NE	SE	NW	SW	Total	Control	NE	SE	NW	SW
Gastropoda	2091	107	451	1028	125	380	29	12	---	1	12	4	2109	315	515	538	498	243
Arachnida	41	---	---	---	---	---	1844	523	231	506	344	240	59	---	5	19	16	19
Araneida	29	3	8	10	4	4	39	8	7	3	9	12	30	6	1	12	7	4
Acarina	12	3	2	4	1	2	4	0	1	---	---	3	37	2	4	7	9	15
Crustacea	553 (555)						610						3340	---	24	145	590	2581
Ostracoda	256	112	6	60	71	7	189	102	31	7	42	7	359	107	3	31	47	171
Malocostraca	67 (69)	---	---	---	---	---	63	---	---	---	---	---	5	---	1	---	---	4
Decapoda	10	---	1	---	9	---	12	2	1	9	---	---	7	1	1	2	---	3
Isopoda	13	10	1	---	---	2	34	5	9	2	10	8	8	7	---	---	---	1
Isopoda (non-aquatic)	2	---	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Amphipoda	44	5	---	6	32	1	17	8	1	2	---	6	---	---	---	---	---	---
Branchiopoda	36	---	---	---	---	---	51	---	---	---	---	---	3027	---	20	112	489	2406
Cladocera	32	---	---	---	---	---	24	---	---	---	---	---	3027	---	20	112	489	2406
Daphnidae	25	---	---	---	---	---	1	---	---	---	---	---	3012	---	20	98	488	2406
Moina brachiata	23	5	2	---	8	8	1	1	---	---	---	---	3015	3	20	98	488	2406
Ceriodaphnia spp.	2	---	---	---	1	1	---	---	---	---	---	---	---	---	---	---	---	---
Diaptomidae	1	---	---	---	---	---	23	---	---	---	---	---	15	---	---	14	1	---
Diaptomus spp.	1	---	---	1	---	---	23	2	---	---	19	2	16	1	---	14	1	---
Immature stages	6	1	---	---	---	5	---	---	---	---	---	---	---	---	---	---	---	---
Conchostraca	4	---	---	---	---	4	88	27	---	18	26	17	14	14	---	---	---	---

Table V. (continued)

Specimens	1970						1971						1972					
	Total	Control	NE	SE	NW	SW	Total	Control	NE	SE	NW	SW	Total	Control	NE	SE	NW	SW
Copopeda	194	---	---	---	---	---	307	---	---	---	---	---	163	---	---	---	---	---
Eucopepoda	194	---	---	---	---	---	307	---	---	---	---	---	---	---	---	---	---	---
Calanoida	9	2	---	3	4	---	12	2	---	3	7	---	---	---	---	---	---	---
Harpacticoida	15	---	---	---	---	---	3	---	---	---	---	---	---	---	---	---	---	---
Ergasilidae	15	---	---	---	---	---	3	---	---	---	---	---	---	---	---	---	---	---
Ergasilus	15	11	1	2	---	1	3	1	---	---	1	1	---	---	---	---	---	---
Cyclopoida	170	---	---	---	---	---	72	---	---	---	---	---	54	---	---	---	54	---
Cyclopidae	170	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cyclops	169	54	5	21	55	34	72	25	11	5	8	23	94	40	---	---	54	---
Immature stages	1	---	---	---	---	1	110	39	41	4	26	---	20	20	---	---	---	---
Insecta	1156(1268)	---	---	---	---	---	2380	---	---	---	---	---	2524	---	228	328	564	1404
Psocoptera	---	---	---	---	---	---	---	---	---	---	---	---	1	---	1	---	---	---
Collembola	6	---	---	---	---	---	129	---	---	---	---	---	22	---	2	15	3	2
Entomobryidae	4	---	2	1	---	1	66	21	13	32	---	---	22	11	2	6	2	1
Sminthuridae	2	1	---	---	---	1	63	25	14	---	24	1	23	13	---	9	1	---
Ephemeroptera	75	---	---	---	---	---	361	---	---	---	---	---	763	---	6	54	34	669
Baetidae	74	---	---	---	---	---	361	---	---	---	---	---	763	---	6	54	34	669
Cloeon	74	37	5	3	9	20	361	116	18	7	24	196	840	77	6	54	34	669
Immature stages	1	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---
Odonata	29	---	---	---	---	---	112	---	---	---	---	---	201	---	12	22	87	80

Table V. (continued)

Specimens	1970 Total	Control	NE	SE	NW	SW	1971 Total	Control	NE	SE	NW	SW	1972 Total	Control	NE	SE	NW	SW
Libellulidae	4	---	---	---	---	---	3	---	---	---	---	---	42	---	3	3	---	36
Sympetrum	1	---	---	1	---	---	3	---	---	---	---	3	39	---	---	3	---	36
Other	3	---	---	3	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Aeshnidae	1	---	---	---	---	---	1	---	---	---	---	---	2	---	---	---	---	2
Aeshna	1	---	---	---	---	---	1	---	---	---	---	1	2	---	---	---	---	2
Coenagrionidae	21	---	---	---	---	---	102	---	---	---	---	---	---	---	---	---	---	---
Enallagma	17	9	5	---	1	2	76	37	9	5	3	22	---	---	---	---	---	---
Neonura	1	---	---	---	---	1	12	2	---	---	---	10	---	---	---	---	---	---
Ischnura	3	---	2	---	---	1	14	8	1	---	---	5	---	---	---	---	---	---
Lestidae	2	---	---	---	---	---	4	---	---	---	---	---	127	---	8	19	76	29
Lestes	2	---	---	2	---	---	4	---	1	1	---	2	127	---	8	19	76	29
Gomphidae	1	---	---	---	---	---	2	---	---	---	---	---	16	---	1	---	11	4
Gomphus	1	1	---	---	---	---	2	---	---	---	1	1	17	1	1	---	11	4
Orthoptera	3	---	---	---	---	---	1	---	---	---	---	---	4	---	1	2	1	---
Blattidae	1	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Tettigoniidae	2	1	1	---	---	---	1	---	1	---	---	---	4	1	---	2	1	---
Plecoptera	1	---	1	---	---	---	2	---	---	---	2	---	---	---	---	---	---	---
Dermaptera	2	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Hemiptera	39 (44)	---	---	---	---	---	47	---	---	---	---	---	60	---	2	21	11	26
Corixidae	31	1	4	8	4	14	4	1	1	---	2	---	54	1	2	19	7	25
Veliidae	1	1	---	---	---	---	7	3	---	2	---	2	4	2	---	2	---	---

Table V. (Continued)

Specimens	1970						1971						1972					
	Total	Control	NE	SE	NW	SW	Total	Control	NE	SE	NW	SW	Total	Control	NE	SE	NW	SW
Notonectidae	1	---	---	---	---	---	33	---	---	---	---	---	5	---	---	---	4	1
Buenoa	1	---	---	---	---	---	33	7	5	5	10	6	9	4	---	---	4	1
Belostomatidae	3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Lethocerus	---	---	---	---	---	---	3	---	1	---	---	2	---	---	---	---	---	---
Haliplidae	1	---	---	---	---	---	4	---	---	---	---	---	14	---	4	1	---	9
Peltodytes	1	1	---	---	---	---	4	---	---	---	2	2	14	---	4	1	---	9
Nitidulidae	1	---	1	---	---	---	8	1	3	---	4	---	1	1	---	---	---	---
Noteridae	6	---	---	---	---	---	1	1	---	---	---	---	---	---	---	---	---	---
Hydrocanthus	6	5	---	---	1	---	1	---	---	---	1	---	---	---	---	---	---	---
Curculionidae	29	---	---	---	---	---	28	---	---	---	---	---	28	---	3	8	8	9
Lissorhoptrus	29	6	4	2	4	13	28	9	5	1	5	8	35	8	2	8	8	9
Hydraenidae	1	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---
Hydraena	1	---	---	---	1	---	1	---	1	---	---	---	---	---	---	---	---	---
Cantharidae	1	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Scarabaeidae	5	1	---	2	1	1	4	1	1	1	1	---	2	1	---	1	---	---
Carabidae	3	1	---	1	1	---	13	---	2	1	10	---	22	1	---	1	16	4
Staphylinidae	1	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---
Other (non-aquatic)	3	1	2	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---
Homoptera	---	---	---	---	---	---	33	7	2	7	5	11	110	4	33	9	51	13
Neuroptera	---	---	---	---	---	---	16	---	---	---	---	---	2	---	---	---	---	2
Corydalidae	---	---	---	---	---	---	15	---	---	---	---	---	2	---	---	---	---	2

Table V. (continued)

Specimens	1970 Total	Control	NE	SE	NW	SW	1971 Total	Control	NE	SE	NW	SW	1972 Total	Control	NE	SE	NW	SW
Corydalus	---	---	---	---	---	---	15	14	1	---	---	---	9	7	---	---	---	2
Sialidae	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---
Sialus	---	---	---	---	---	---	1	---	1	---	---	---	---	---	---	---	---	---
Coleoptera	---	---	---	---	---	---	361	---	---	---	---	---	310	---	32	45	76	157
Hydrophilidae	---	---	---	---	---	---	92	---	---	---	---	---	49	---	7	9	13	20
Hydrophilus	---	---	---	---	---	---	13	9	1	---	3	---	53	5	6	9	13	20
Berosus	---	---	---	---	---	---	8	---	1	---	1	6	---	---	---	---	---	---
Tropisternus	---	---	---	---	---	---	26	3	10	3	4	6	---	---	---	---	---	---
Helophorus	---	---	---	---	---	---	20	3	1	5	8	3	---	---	---	---	---	---
Paracymus	---	---	---	---	---	---	20	1	9	---	---	10	---	---	---	---	---	---
Hydrochus	---	---	---	---	---	---	5	---	2	---	2	1	---	---	---	---	---	---
Neohydrophiluscastus	-	---	---	---	---	---	9	---	3	---	6	---	---	---	---	---	---	---
Gyrinidae	---	---	---	---	---	---	8	---	8	---	---	---	---	---	---	---	---	---
Helodidae	---	---	---	---	---	---	3	---	---	---	1	2	5	---	1	2	1	1
Dytiscidae	---	---	---	---	---	---	199	---	---	---	---	---	123	---	8	13	38	64
Dytiscus	---	---	---	---	---	---	10	5	2	---	1	2	125	3	7	13	38	64
Desmopachria	---	---	---	---	---	---	18	5	1	9	3	---	---	---	---	---	---	---
Bidessus	---	---	---	---	---	---	2	---	2	---	---	---	---	---	---	---	---	---
Laccophilus	---	---	---	---	---	---	6	---	3	2	1	---	---	---	---	---	---	---
Hydrovatus	---	---	---	---	---	---	86	25	7	---	3	51	---	---	---	---	---	---
Acilus	---	---	---	---	---	---	76	17	17	11	23	8	---	---	---	---	---	---

Table V. (continued)

Specimens	1970						1971						1972					
	Total	Control	NE	SE	NW	SW	Total	Control	NE	SE	NW	SW	Total	Control	NE	SE	NW	SW
Suphiseltus	---	---	---	---	---	---	1	---	---	---	1	---	---	---	---	---	---	---
Lepidoptera	4	1	2	---	1	---	4	---	---	3	---	1	2	1	---	1	---	---
Diptera	608(635)	---	---	---	---	---	1315	---	---	---	---	---	1007	---	125	147	294	441
Chironomidae	72	---	---	---	---	---	131	---	---	---	---	---	489	---	68	72	256	93
Pupae	1	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Pentaneura	27	6	1	5	7	8	63	22	1	30	1	9	15	14	---	---	---	1
Tendipes	25	14	---	3	4	4	68	8	54	5	---	1	499	11	68	72	256	92
Unidentified	19	1	3	2	---	13	---	---	---	---	---	---	---	---	---	---	---	---
Sciomyzidae	1	1	---	---	---	---	2	---	---	2	---	---	40	1	7	5	16	11
Culicidae	480	366	17	24	31	42	1085	---	---	---	---	---	372	183	12	38	40	199
Culicidae pupae	12	3	---	---	8	1	12	---	9	3	---	---	7	2	2	2	---	1
Psorophora confinnis	432	350	10	23	28	21	598	306	88	24	17	163	720	328	29	9	39	315
Aedes vexans	19	10	2	---	6	1	429	313	14	36	27	39	204	162	16	26	---	---
A. quadrimaculatus	6	1	1	1	2	1	7	2	---	3	2	---	3	2	1	---	---	---
Culex salinarius	2	---	---	---	2	---	4	---	---	3	---	1	3	---	3	---	---	---
C. territans	1	1	---	---	---	---	2	1	1	---	---	---	2	1	---	---	---	1
C. quinquefasciatus	3	1	2	---	---	---	26	5	3	17	1	---	5	3	1	---	---	1
Chaoborus	1	---	1	---	---	---	8	2	1	1	3	1	20	1	15	1	1	2
Unidentified larva	4	---	1	---	3	---	---	---	---	---	---	---	---	---	---	---	---	---
Mycetophillidae	1	---	---	---	---	1	4	---	1	1	2	1	---	---	---	---	---	---
Ceratopogonidae	6	---	---	---	---	---	21	---	---	---	---	---	20	---	---	---	7	13

Table V. (continued)

Specimens	1970						1971						1972					
	Total	Control	NE	SE	NW	SW	Total	Control	NE	SE	NW	SW	Total	Control	NE	SE	NW	SW
Culicoides	6	1	1	---	2	2	21	---	6	15	---	---	---	---	---	---	---	---
Sciaridae	1	---	---	---	---	1	5	1	3	---	1	---	28	---	---	8	1	19
Simulidae	3	---	2	---	---	1	5	1	3	---	1	---	2	1	---	---	---	1
Tabanidae	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	1	---
Otitidae	1	1	---	---	---	---	2	---	---	2	---	---	1	1	---	---	---	---
Ephydridae	3	---	---	---	1	2	1	---	1	---	---	---	---	---	---	---	---	---
Stratiomyidae	4	---	---	---	---	---	1	---	---	---	---	---	3	---	---	---	1	2
Eulalia	4	3	---	---	---	1	1	---	---	1	---	---	5	2	---	---	1	2
Tipulidae	1	---	---	---	---	---	55	---	---	---	---	---	10	---	---	3	4	3
Tipula	1	---	1	---	---	---	55	7	4	22	16	6	14	4	---	3	4	3
Cecidomyiidae	1	---	---	1	---	---	5	1	3	---	---	1	2	1	---	---	1	---
Other dipterous larva	57	1	2	5	45	4	---	---	---	---	---	---	---	---	---	---	---	---
Other dipterous adults	4	---	1	2	1	---	---	---	---	---	---	---	---	---	---	---	---	---
Hymenoptera	22	---	7	4	3	8	62	13	21	5	3	20	57	7	14	14	8	14
Annelida	1	---	---	---	1	---	24	3	---	4	---	17	16	2	1	6	---	7
Nematode	4	1	---	1	---	2	38	7	1	13	12	5	63	4	13	38	8	---
Anura	48	---	13	32	1	2	120	16	16	29	20	39	---	---	---	---	---	---
Osteichthyes	3	2	1	---	---	---	86	21	11	9	27	18	---	---	---	---	---	---
	Total number of samples: 588						Total number of samples: 277						Total number of samples: 427					

Table VI. Comparison of average numbers of aquatic arthropods by years and sections, Lonoke, Arkansas.

Northeast section

Date		1970	1971	1972
May	19	———	7.75	———
	25	———	———	2.75**
	30	———	———	4.33**
June	2	0.62	———	———
	4	———	———	———
	5	———	———	———
	6	2.25	———	10.67*
	7	———	———	———
	8	———	29.16	———
	9	0.66	———	7.33*
	10	7.50	2.00	———
	11	———	———	———
	12	2.25	———	———
	13	———	———	2.60*
	15	———	———	———
	16	11.00	———	8.00*
	17	———	26.66*	———
	18	———	———	———
	19	———	———	———
	20	1.00	———	12.17*
	21	———	———	———
	22	0.83	———	———
	23	———	11.81**	9.00*
	24	———	2.33*	———
	25	3.25	———	———
	26	———	———	———
	27	———	———	6.17*
	28	———	———	———
	30	———	———	10.71**
July	1	———	5.00**	———
	5	———	———	8.33**
	6	———	———	———
	7	———	7.33**	6.17*

Date		1970	1971	1972
July	8	———	———	———
	9	———	———	———
	10	2.00	———	———
	11	———	———	4.25*
	12	———	3.00*	———
	13	———	———	19.40*
	14	1.00	———	———
	15	———	———	———
	16	0.50	———	———
	17	———	———	———
	18	———	———	6.33*
	20	———	———	———
	21	———	1.00**	———
	22	———	———	———
	23	———	1.75*	———
	25	———	———	3.50*
	27	1.50	———	———
	28	0.50	———	6.33**
	29	———	2.14*	———
	30	———	———	———
August	2	———	———	9.20**
	4	———	1.50**	———
	5	———	———	———
	6	2.33	1.66*	———
	8	———	———	11.67*
	9	———	———	———
	10	1.33	16.25*	———
	11	———	———	———
	12	0.66	———	———
	13	1.00	———	———
	14	———	———	———
	17	———	———	———
	18	———	3.00*	———
	26	1.25	———	———

* Post-treatment.
** Pre-treatment.

Table VI. (continued)

Southeast section

Date		1970	1971	1972
May	19	—	10.60	—
	25	—	—	14.00**
	30	—	—	49.50**
June	2	1.43	—	—
	4	—	—	—
	5	1.50	—	—
	6	4.00	—	5.67*
	7	—	13.16	—
	8	5.75	4.00*	—
	9	—	—	6.33*
	10	10.50	—	—
	11	—	—	—
	12	3.33	—	—
	13	—	—	8.33*
	15	—	—	—
	16	3.75	—	18.80*
	17	0.50	6.66*	—
	18	—	—	—
	19	1.00	—	—
	20	0.50	1.00*	16.74*
	21	—	—	—
	22	0.14	—	—
	23	1.25	1.00**	6.33*
	24	—	4.00*	—
	25	—	—	—
	26	0.75	—	—
	27	—	—	1.40*
	28	—	3.33*	—
	30	—	—	5.00*
July	1	—	—	—
	5	—	—	1.50**
	6	5.00	6.66**	—
	7	1.00	3.00**	2.17*
July	8	—	2.50	—
	9	—	—	—
	10	1.00	—	—
	11	—	—	1.75*
	12	—	—	—
	13	—	—	20.40*
	14	1.00	—	—
	15	—	—	—
	16	0.50	—	—
	17	—	—	—
	18	—	—	3.67*
	20	1.33	—	—
	21	—	5.00*	—
	22	1.50	—	—
	23	0.50	2.83*	—
	25	—	—	4.80*
	27	—	0.66*	—
	28	13.50	—	43.50**
	29	0.50	—	—
	30	0.66	2.00*	—
August	2	—	3.00*	20.00*
	4	—	1.00	—
	5	—	—	—
	6	—	—	—
	8	—	—	14.00*
	9	—	—	—
	10	4.00	1.16**	—
	11	—	2.40*	—
	12	—	—	—
	13	3.33	—	—
	14	0.50	—	—
	17	1.00	—	—
	18	—	—	—
	26	4.00	—	—

* Post-treatment.
** Pre-treatment.

Table VI. (continued)

Northwest section

Date	1970	1971	1972
May 19	-----	20.16	-----
25	-----	-----	3.67**
30	-----	-----	5.24**
June 2	2.80	-----	-----
4	3.00	-----	-----
5	-----	-----	-----
6	1.50	-----	8.40*
7	-----	-----	-----
8	3.00	1.00	-----
9	9.20	-----	21.60*
10	3.50	9.40	-----
11	-----	-----	-----
12	1.00	-----	-----
13	-----	-----	5.67*
15	-----	-----	-----
16	9.00	-----	35.50*
17	1.00	-----	-----
18	-----	-----	-----
19	9.00	-----	-----
20	1.00	-----	3.20*
21	-----	-----**	-----
22	5.00	-----	-----
23	2.66	-----	2.50*
24	1.66	8.60*	-----
25	0.33	-----	-----
26	1.00	-----	-----
27	-----	-----	4.00*
28	-----	-----	-----
30	6.50	-----	5.60**
July 1	55.00	-----	-----
5	-----	-----	3.33**
6	-----	-----	-----
7	1.50	-----	106.60*
July 8	0.20	3.00*	-----
9	-----	2.33*	-----
10	-----	-----	-----
11	-----	-----	9.80*
12	-----	-----	-----
13	5.00	-----	104.80*
14	8.00	-----	-----
15	-----	-----	-----
16	0.66	-----	-----
17	-----	-----	-----
18	-----	-----	8.50*
20	0.50	-----	-----
21	0.50	2.00**	-----
22	0.50	-----	-----
23	1.00	1.60*	-----
25	-----	-----	1.33*
27	4.00	-----	-----
28	-----	-----	7.50*
29	4.00	23.33**	-----
30	2.50	5.50*	-----
August 2	-----	1.00*	7.40**
4	2.00	5.00	-----
5	2.33	-----	-----
6	0.50	0.75**	-----
8	-----	-----	9.50*
9	-----	-----	-----
10	4.00	12.80*	-----
11	-----	-----	-----
12	-----	-----	-----
13	-----	-----	-----
14	-----	-----	-----
17	-----	-----	-----
18	-----	-----	-----
26	3.00	-----	-----

* Post-treatment.
** Pre-treatment.

Table VI. (continued)

Southwest section

Date	1970	1971	1972
May 19	-----	10.66	-----
25	-----	-----	9.00**
30	-----	-----	5.25**
June 2	2.44	-----	-----
4	3.66	-----	-----
5	4.00	-----	-----
6	1.50	-----	51.50*
7	-----	-----	-----
8	5.00	8.33*	-----
9	3.75	-----	65.00*
10	-----	-----	-----
11	-----	-----	-----
12	2.00	-----	-----
13	-----	-----	323.50*
15	-----	-----	-----
16	2.33	-----	14.17*
17	-----	-----	-----
18	-----	5.00*	-----
19	1.00	-----	-----
20	-----	-----	5.00*
21	-----	-----	-----
22	2.50	-----	-----
23	-----	-----	4.00*
24	10.50	2.33*	-----
25	2.00	-----	-----
26	0.75	-----	-----
27	-----	-----	52.43*
28	-----	-----	-----
30	-----	-----	8.40**
July 1	-----	16.66*	-----
5	-----	-----	9.00*
6	-----	-----	-----
7	5.00	-----	10.17*

Date	1970	1971	1972
July 8	1.50	1.50*	-----
9	-----	1.83*	-----
10	3.33	-----	-----
11	-----	-----	3.40*
12	-----	-----	-----
13	4.00	-----	14.67*
14	1.00	-----	-----
15	-----	-----	-----
16	2.00	-----	-----
17	0.66	47.00**	-----
18	-----	-----	7.50*
20	-----	-----	-----
21	4.00	-----	-----
22	1.00	-----	-----
23	1.00	2.25*	-----
25	-----	-----	3.00*
27	2.00	43.33**	-----
28	0.50	27.40*	31.80*
29	8.50	22.00	-----
30	-----	-----	-----
August 2	-----	-----	18.17*
4	6.00	2.33*	-----
5	5.66	-----	-----
6	3.00	-----	-----
8	-----	-----	12.83*
9	-----	1.00**	-----
10	5.20	32.66*	-----
11	-----	1.00*	-----
12	-----	-----	-----
13	-----	-----	-----
14	0.50	-----	-----
17	2.33	-----	-----
18	-----	0.66*	-----
26	3.66	-----	-----

* Post-treatment.
** Pre-treatment.

Table VI. (continued)

Control

Date		1970	1971	1972
May	19	-----	14.66	14.66
	25	-----	-----	-----
	30	-----	-----	-----
June	2	-----	-----	-----
	4	24.66	-----	24.66
	5	38.14	-----	38.14
	6	3.00	-----	3.00
	7	-----	24.00	24.00
	8	-----	6.00	6.00
	9	11.00	-----	11.00
	10	-----	28.75	28.75
	11	-----	-----	-----
	12	2.25	-----	2.25
	13	-----	-----	-----
	15	-----	32.50	32.50
	16	6.60	-----	6.60
	17	3.50	25.50	14.50
	18	-----	20.00	20.00
	19	-----	-----	-----
	20	-----	11.00	11.00
	21	-----	11.00	11.00
	22	-----	-----	-----
	23	-----	31.50	31.50
	24	-----	28.00	28.00
	25	-----	5.00	5.00
	26	-----	-----	-----
	27	-----	-----	-----
	28	-----	13.50	13.50
	30	-----	-----	-----
July	1	-----	14.66	14.66
	5	-----	-----	-----
	6	30.00	8.50	19.25
	7	-----	22.55	22.55
July	8	2.50	34.50	18.50
	9	-----	11.00	11.00
	10	42.00	-----	42.00
	11	-----	-----	-----
	12	-----	15.00	15.00
	13	-----	-----	-----
	14	1.00	-----	1.00
	15	2.00	-----	2.00
	16	3.50	-----	3.50
	17	-----	14.50	14.50
	18	-----	-----	-----
	20	6.00	-----	6.00
	21	4.00	21.50	12.75
	22	-----	-----	-----
	23	36.00	37.00	36.50
	25	-----	-----	-----
	27	3.00	17.00	10.00
	28	-----	8.50	8.50
	29	2.00	15.00	8.50
	30	8.66	27.00	17.83
August	2	-----	32.00	32.00
	4	8.00	10.00	9.00
	5	0.50	-----	0.50
	6	-----	25.33	25.33
	8	-----	-----	-----
	9	-----	6.50	6.50
	10	1.00	11.00	6.00
	11	-----	29.50	29.50
	12	-----	-----	-----
	13	-----	-----	-----
	14	-----	-----	-----
	17	1.00	-----	1.00
	18	-----	12.50	12.50
	26	1.33	-----	1.33

CONCLUSION

The data collected demonstrate that community mosquito control, with presently available chemicals, can be achieved in the rice-producing area of Arkansas. Such a program requires that someone be responsible for having the necessary work carried out when and where it is needed. The data also demonstrate that mosquito control chemicals, used as recommended, did not create a biological desert although a reduction in numbers of aquatic arthropods did occur after treatment. Abate and Flit MLO were the least damaging to non-target organisms.

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