PESTIFEROUS MIDGES[1] AND THEIR CONTROL IN A SHALLOW RESIDENTIAL-RECREATIONAL LAKE IN SOUTHERN CALIFORNIA[2]

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ABSTRACT. The chironomid fauna of a shallow recreational lake was studied from April 1977-April 1978. Benthic larval densities were assessed weekly or biweekly by collecting Ekman dredge (15 x 15 cm) samples; prevalence of adults was studied from their weekly accumulations in New Jersey light traps.

Eleven species of midges were collected; *Tanytarsus* [n. sp. 2 and 3 after Sublette (Darby 1962)], *Chironomus decorus* (Johannsen), and *Procladius freemani* Sublette, were quantitatively important. Larvae of *Tanytarsus* spp., were dominant prevailing at 100–2500/0.09 m^2 (= 1 ft^2), and were highest in the spring and summer months when as many as 50 thousand adults/trap/week were collected. The seasonal quantitative composition of adult *Tanytarsus* spp. and *Chironomus* spp. generally correlated with their prevailing larval numbers, but *Procladius* spp. did not follow this pattern.

Two applications of the insect growth regulator diflubenzuron (25% WP) at 0.012 ppm during April-August 1977 gave excellent control of the midges for 2–3 weeks after each treatment.

In laboratory studies, chlorpyrifos was highly toxic to *Tanytarsus* spp. and *C. decorus*, was relatively less toxic to *P. freemani*. Temephos and fenthion were very active against *Tanytarsus* spp., but temephos was ineffective against *P. freemani*. Fenthion showed poor activity against *C. decorus* and *P. freemani*; malathion also was only slightly toxic to *P. freemani*. Some new synthetic pyrethroids, exceptionally toxic to *Tanytarsus* spp. (LC_{90} values 0.023–0.058 ppb), were also highly active against *C. decorus* and *P. freemani*.

Chironomid midges emerge at nuisance levels from man-made residential-recreational lakes of southern California. The problems created by these midges were previously described (Ali 1978, Mulla 1974, Mulla et al. 1971), and studies on chemical control strategies in some of the lakes were reported (Ali and Mulla 1977, Mulla et al. 1975, 1976). These studies show that the midge faunal composition in different lakes as well as the level of the larval susceptibility to various insecticides differ from lake to lake; thus each lake has its own individuality in terms of midge fauna, requiring an independent and specific approach for the development of chemical control methods.

The current studies were initiated in a shallow (1.25 m deep) lake supporting 2–5 times more midge larvae than some other 3–5 m deep lakes in southern California, such as Spring Valley Lake and Silver Lakes in San Bernardino County, and West Lake in Los Angeles and Ventura Counties (Ali and Mulla 1977, Mulla et al. 1976). In the deeper lakes, midge species belonging to Tanypodinae and Chironomini predominate, while in the presently investigated lake, members of Tanytarsini prevailed over Tanypodinae and Chironomini.

To develop chemical control measures, laboratory studies on 4 OP insecticides and 4 new synthetic pyrethroids, and field evaluation of the IGR diflubenzuron were undertaken. The larval population changes in the lake were assessed from April 1977 to April 1978, and during the same time period, the prevalence of

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adults in the lake surroundings was also monitored by using New Jersey light traps.

MATERIALS AND METHODS

STUDY AREA. The study was conducted in Village Grove Lake 250 m elevation, in the City of Corona, Riverside County, California. The lake described earlier (Ali and Mulla 1978a) has a 4 ha surface area and an average depth of 1.25 m.

LARVAL AND ADULT SAMPLING. Between April 1977 and April 1978, benthic larval densities were assessed weekly or biweekly by taking random 10–16 Ekman dredge (15x15 cm) samples from various locations in the lake. Larvae were separated from the bottom substrate materials by the procedures of Mulla et al. (1971). Samples were sorted in the laboratory for larval counting (Ali et al., 1977a) and identified to the generic level (Darby 1962, Mason 1973, Wirth and Stone 1956). The temperature of water at the lake bottom was measured throughout the study period by using a remote recording thermograph (Model 615, P.T.C. Instruments, Los Angeles, Calif.) with its probe resting at a fixed location on the lake bottom; the weekly mean temperatures were derived from the daily maximum and minimum readings. The air temperature data for the area were obtained from the substation of the National Oceanic and Atmospheric Administration at Corona.

The prevalence of adult midges was investigated by employing 2 NJ light traps. Each trap fitted with a 25 watt bulb and an adjustable time switch was operated from sunset to sunrise. The traps, set ca. 200 m apart in up-wind and down-wind directions, were hung 1½ m above the ground in the patio of lake-front homes. Adult collections from each trap were made at weekly intervals during April 1977-April 1978. In the laboratory, adult midges were identified (Darby 1962) and were counted. Samples containing large numbers (>1000 specimens) were subsampled by weight (Ali et al. 1977b).

DIFLUBENZURON TREATMENTS. On April 26, 1977, diflubenzuron (25% WP) was applied to the entire lake surface at a concn. of ca. 0.012 ppm (or 156 g AI/ha-surface) by means of a 12–l stainless-steel pressurized sprayer. Small amounts of the WP placed in a plastic bucket were mixed with the lake water and transferred to the spray can. More water was added to the can to bring the volume to 12–l; the pressurized liquid was discharged as a jet stream behind the prop wash of a motor boat (Mulla et al. 1971). The can was filled 3 times with the mixture of WP and lake water for making 7 swaths. The treatment was repeated on August 24, 1977. Midge larval density in the lake mud and one night's emergence of adults were assessed prior to and at weekly intervals after each treatment. For larval population assessments, 12 random dredges were collected, while emergence was estimated by using submerged emergence traps (Mulla et al. 1974). A total of 12 traps was randomly placed in the lake and left overnight on each sampling occasion.

LABORATORY STUDIES. In the laboratory, chlorpyrifos, temephos, fenthion, malathion, and the following 4 synthetic pyrethroids were tested during March-August, 1977, against field-collected 4th-instars of the predominant midges:

FMC-45498 or decamethrin (NRDC-161): (-)-(Cyano)-3-phenoxybenzyl-(+)*cis*-3-(2,2-dibromovinyl)-2,2-dimethyl-cyclopropane-1-carboxylate.

FMC-45497 (NRDC-160): (±)*cis* and chloro analog of FMC-45498.

FMC-35171 (NRDC-148): 3-Phenoxybenzyl (±)-*cis*-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate

SD-43775: α-Cyano-3-phenoxybenzyl 4-chloro-α-(1-methylethyl)-phenylacetate.

The bioassay procedures employed during this study were the same as described by Mulla and Khasawinah (1969). Average percent larval mortality against different log concentrations was noted after 24 hr. Resulting data were subjected to log-probit regression analysis by using a Compucorp 145 E computor to obtain the LC_{50} and LC_{90} values.

RESULTS AND DISCUSSION

MIDGE FAUNA. Larvae of the genera, *Tanytarsus* spp., *Chironomus* spp., *Procladius* spp., *Cryptochironomus* sp., *Dicrotendipes* sp., *Tanypus* sp., and *Cricotopus* sp. were collected. Since there are no larval keys to species, adult midges from the light trap and emergence trap collections were periodically processed for microscopic examination of the male genitalia (Borror et al. 1976) and species identification. On several occasions, field-collected larvae were also reared in the laboratory for the same purpose. Adults of the following species were taken during the period of study: *Tanytarsus* n. sp. 2 and 3 after Sublette (Darby 1962), *Chironomus decorus* Johannsen, *Chironomus frommeri* Atchley and Martin, *Dicrotendipes californicus* (Johannsen), *Cryptochironomus fulvus* (Johannsen), *Procladius freemani* Sublette, *Procladius sublettei* Roback, *Procladius culiciformis* (L.), *Tanypus grodhausi* Sublette, and *Cricotopus sylvestris* (Fabr.).

LARVAL MIDGE POPULATIONS. Larval trends of the most common genera, *Tanytarsus* spp., *Procladius* spp., and *Chironomus* spp., and the air and water temperature changes from April 1977 to

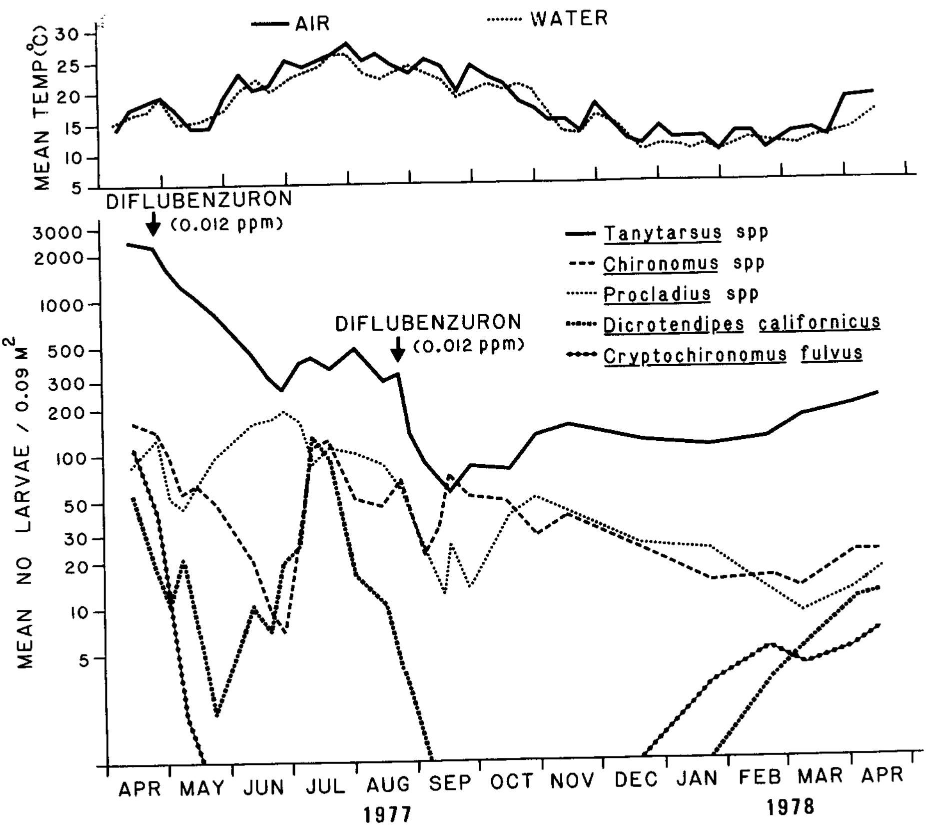

Figure 1. Population trends of chironomid midge larvae in Village Grove Lake. Air and water temperatures represent the weekly means derived from the daily maximum and minimum readings. Arrows indicate time of diflubenzuron applications.

April 1978 are shown in Fig. 1. The larval densities, predominated by *Tanytarsus* spp., were very high (>2500 larvae/01.09 m^2) in April 1977 but gradually declined considerably in the subsequent months, fluctuating between 150–500/01.09 m^2 from August 1977 to April 1978. *Tanytarsus* spp. formed 71% of the total midge larvae collected in the 13 months' study period with monthly composition ranging from 54–89%; *Procladius* spp. comprised 14% of the total larvae, followed by *Chironomus* spp. (12%), *D. californicus* (2%) and *C. fulvus* (1%). Monthly compositions of *Procladius* spp. and *Chironomus* spp. varied between 3–32% and 2–33%, respectively. *D. californicus* was absent from the lake from early September to mid-December, and *C. fulvus* from mid-May until mid-December (Fig. 1).

The larval decline in April-May and August-September (Fig. 1) primarily resulted from the IGR treatments; however, the general declining trend of larvae was probably due to a progressive weed growth (mostly *Chara*) in the lake. In April-May 1977, only 5–10% of the lake bottom was covered with weeds, increasing to 40–60% in June-July and higher in later months. The weeds persisted in the lake until after the termination of the studies in April 1978.

ADULT MIDGE POPULATIONS. In the light trap collections, *Tanytarsus* spp., *Chironomus* spp., and *Procladius* spp., in that order were quantitatively important (Fig. 2). *Tanytarsus* spp. [mostly n. sp. 3 after Sublette (Darby 1962)] predominated throughout the year forming 85% of the total adults; their monthly composition ranged between 68–95%. They attained several peaks of abundance during April-December when as many as 50 thousand/trap/week were collected. The sharp declines in May and August-September (Fig. 2) resulted from the diflubenzuron treatments.

Adults of *Chironomus* spp., present throughout the observation period constituted 10% of the total adults collected in the 13 months, and 4–24% of the monthly totals. During April to mid-September among *Chironomus* only *C. decorus* was presented in the area; *C. frommeri* appearing in late September persisted until February. The pattern of monthly changes of *Chironomus* spp. populations in the traps was similar to that of *Tanytarsus* spp., having maxima (up to 6000/trap/week) between April-December and minima from January-March (Fig. 2). *Procladius* spp., comprising mostly of *P. freemani* throughout the study period, formed 3.6% of the total midges with monthly distribution ranging from 0–7% and their total numbers never exceeding 300/trap/week. No adult specimen of *Procladius* occurred in the January collections. The other species, represented primarily by *D. californicus* and *C. fulvus* prevailed from April-October forming only 1.4% of the total adults collected during this study.

Fig. 2 shows that the higher air and water temperatures from April-November induced a greater emergence than during December-March. The seasonal quantitative composition of adults of *Tanytarsus* spp. and *Chironomus* spp. generally correlated with their prevailing larval numbers but *Procladius* spp. did not follow this pattern. Larvae of *Procladius* spp. usually formed a greater proportion of the total larvae than their adults in the light trap collections. Adult *Procladius* spp. probably are not attracted to lights as readily as are *Tanytarsus* spp. and *Chironomus* spp.

DIFLUBENZURON TREATMENTS. The April application resulted in excellent control of midges for 2–3 weeks; the IGR was highly effective on all midge species, completely inhibiting adult emergence of *Tanytarsus* n. sp. 2 and 3 after Sublette (Darby 1962), *C. decorus, P. freemani,* and *C. fulvus* during the first week after the treatment (Fig. 3). Their emergence, however, returned to >70 total adults/trap/night in the 3rd week posttreatment with *Tanytarsus* spp. dominating throughout the evaluation period. The high degree of control given by the treatment was also reflected by the reduced numbers of adults occurring in light traps in the 1–6 weeks period of posttreatment (Fig. 2). The IGR simultaneously caused some larval mortality (Fig. 1).

The 2nd treatment was also highly effective for a somewhat longer period causing almost complete inhibition of emergence of all midge adults for 3 weeks following the application. Adults of *Tanytarsus* spp., *C. decorus*, and *P. freemani* reappeared in small numbers during the 3rd and 4th week after application, but their emergence remained below the pretreatment levels for at least 5 weeks posttreatment (Fig. 3). The prolonged low level of posttreatment emergence of adults may have been due to the change

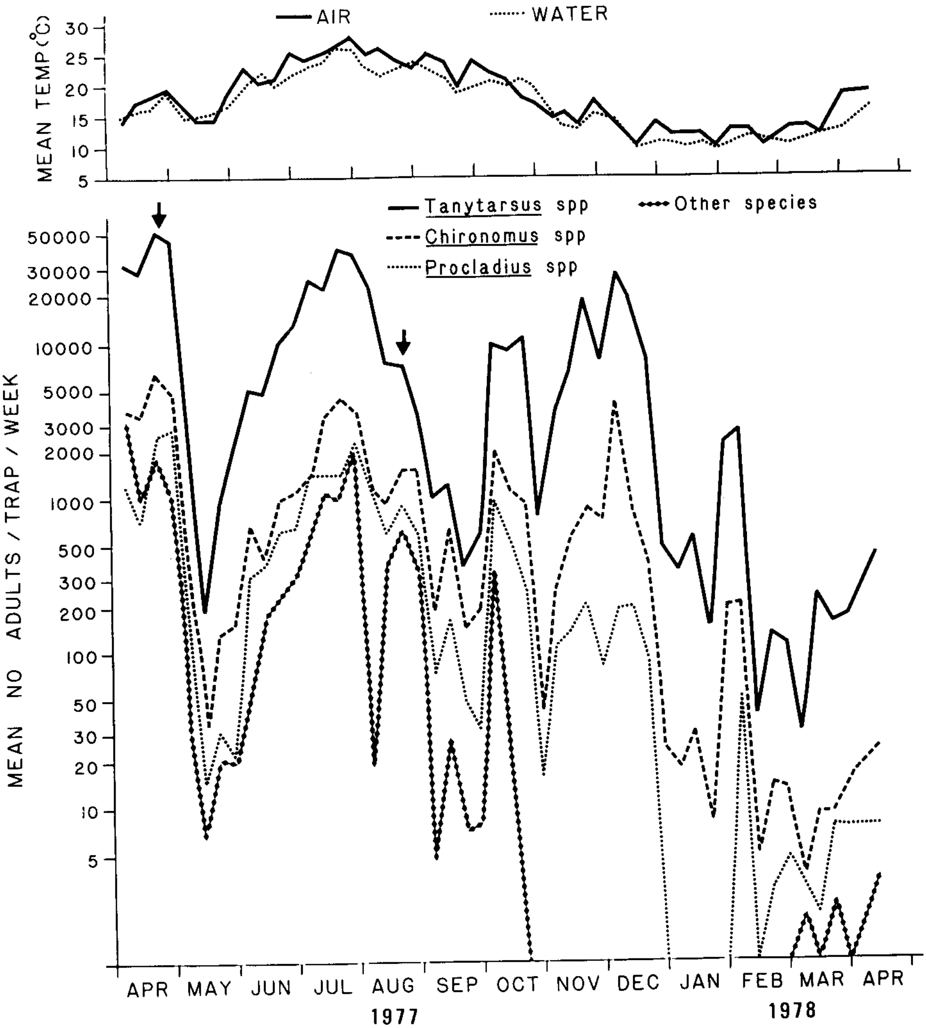

Figure 2. Abundance trends of adult chironomids in the vacinity of Village Grove Lake as sampled by New Jersey Light trap. Air and water temperatures represent the weekly means derived from the daily maximum and minimum readings. Arrows indicate time of diflubenzuron applications to the lake.

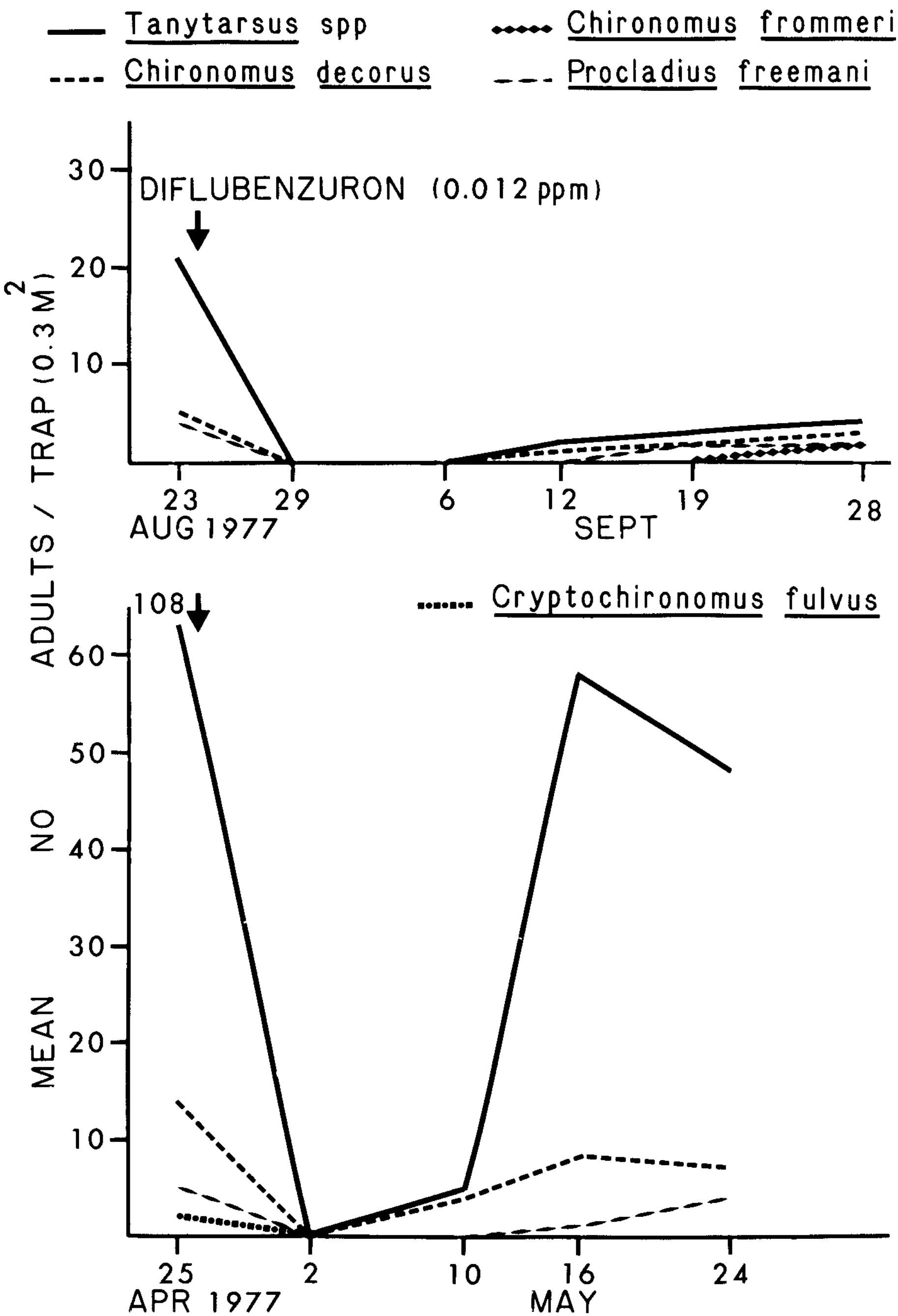

Figure 3. Emergence of adult chironomids per night/trap (covering 0.3 m² area of lake bottom) from Village Grove Lake treated with diflubenzuron. Arrows indicate time of lake treatment.

in the nature of the habitat (weed growth), the small larval populations prevailing during this period and the seasonal declining of air and water temperatures. The effect of treatment on the adult emergence and subsequent prevalence in the lake surroundings was further obvious from the smaller number of adults taken in the light trap catches (Fig. 2).

LABORATORY BIOASSAYS. Table 1 summarizes the activity of the OP insecticides and the new synthetic pyrethroids against field-collected 4th-instars of the midge larvae. Susceptibility of the different groups to the test insecticides varied considerably. Chlorpyrifos, highly toxic to *C. decorus* and *Tanytarsus* spp., was relatively less toxic to *P. freemani*. Temephos and fenthion were very active against *Tanytarsus* spp., but the former insecticide was practically ineffective against *P. freemani*. Fenthion performed poorly against *C. decorus* and *P. freemani*; malathion also was slightly toxic to the latter species. *Tanytarsus* spp. and *C. decorus* were moderately susceptible to malathion.

The synthetic pyrethroids were exceptionally toxic to *Tanytarsus* spp.; all 4 compounds showed similar level of activity against this group with LC_{90} values ranging between 0.025-0.058 ppb (Table 1). FMC-45498 and its analog FMC-45497 were also extremely active against *C. decorus* and *P. freemani*, the former was slightly more active against *C. decorus*, while the latter showed better activity against *P. freemani*. FMC-35171 was also highly active against both the species. SD-43775, showing moderate activity against *C. decorus*, was relatively less effective against *P. freemani*. Overall, FMC-45497 and FMC-45498 showed several times better activity than FMC-35171 and SD-43775; the former 2 pyrethroids were 80–280 times more active against *Tanytarsus* spp., 2–12 times against *C. decorus*, and 50- >300 times against *P. freemani*, than the 2 most active OP insecticides, chlorpyrifos and temephos.

It is evident from these studies that the IGR diflubenzuron and the OP insecticides, chlorpyrifos, temephos, and malathion are highly effective against the problem species of midges, offering a good potential for their control. Temephos, however, is ineffective against *Procladius* spp. in this lake as well as in some other midge habitats in southern California (Ali and Mulla 1976, 1977, Mulla et al. 1975). The synthetic pyrethroids (especially FMC-45497 and FMC-45498) are extremely toxic to midges in Village Grove Lake, and in Silver Lakes (Ali and Mulla 1978b), providing additional highly effective larvicides for future use against nuisance midges in southern California and elsewhere.

Table 1. Laboratory evaluation of Op insecticides and synthetic pyrethroids against 4th-instars[1] of chironomid midges (Mar.-Aug., 1977).

	24 h lethal concn (ppb)					
	Tanytarsus[2] spp.		*Chironomus decorus* (Joh.)		*Procladius*[3] spp.	
Chemical	LC_{50}	LC_{90}	LC_{50}	LC_{90}	LC_{50}	LC_{90}
Chlorpyrifos	0.7	3.1	0.6	1.4	6.0	18.0
Temephos	2.6	7.2	2.1	6.2	>5000	—
Fenthion	2.7	8.8	96.0	480.0	150.0	500.0
Malathion	7.4	39.0	7.8	20.0	100.0	460.0
FMC-45497	0.0096	0.026	0.19	0.5	0.09	0.36
FMC-45498	0.016	0.04	0.23	0.76	0.029	.11
FMC-35171	0.029	0.058	1.5	5.0	1.1	3.5
SD-43775	0.022	0.052	4.2	17.0	15.0	47.0

[1] Field populations from Village Grove Lake, Corona, Riverside Co., CA.
[2] Mixture of *Tanytarsus* n. sp. 2 and 3 after Sublette (Darby 1962) with n. sp. 3 dominating.
[3] Mostly *Procadius freemani* Sublette.

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