Literature Cited

Bidlingmayer, W.L. 1961. Field activity studies of adult *Culicoides furens*. Ann. Entomol. Soc. Amer 54: 149–156.

Davies, J.B. 1964. Research and the sand fly problem in Jamaica. Bull. Sci. Res. Co. Jamaica. 5: 33–39.

Davies, J.B. 1966a: An evaluation of the emergence or box trap for estimating sand fly (*Culicoides* spp) populations. Mosquito News 26: 69–72.

Davies, J.B. 1966 b: Report on the pilot scheme to determine the feasibility of controlling sand flies and mosquitoes by the impoundment method. Report to Ministry of Health, Jamaica 16 pp.

Davies, J.E. and Giglioli, M.E.C. 1977. The breeding sites and seasonal occurrence of *Culicoides furens* (Poey) in Grand Cayman, with notes on the breeding sites of *C. insignis* Lutz. (Diptera: Ceratopogonidae). Mosquito News, 37: 414–423.

Linley, J.R. 1966. Field and laboratory observations on the behavior of the immature stages of *Culicoides furens* (Poey) (Diptera: Ceratopogonidae). J. Med. Entomol. 2:385–391.

Linley, J.R. 1969. Studies on the larval development in *Culicoides furens* (Poey) (Diptera: Ceratopogonidae). I. Establishment of a standard rearing technique. Ann. Entomol. Soc. Amer 62: 702–711.

Myers, J.G. 1932. Report on the sandfly (*Culicoides*) investigations in the Bahamas. Bahamas Govt. Pub. Nassau 18 pp.

Rogers, A.J. 1962. Effects of impounding and filling on the production of sand flies (*Culicoides*) in Florida salt marshes. J. Econ. Entomol. 55: 521–527.

Williams, R.W. 1962. Observations on the bionomics of *Culicoides furens* (Poey) on St. John, U.S. Virgin Islands (Diptera: Ceratopogonidae). Mosquito News 22: 155–157.

RESPONSE OF *CULEX* SPP. LARVAE AND THEIR NATURAL INSECT PREDATORS TO TWO INOCULATION RATES WITH *DUGESIA DOROTOCEPHALA* (WOODWORTH) IN SHALLOW PONDS

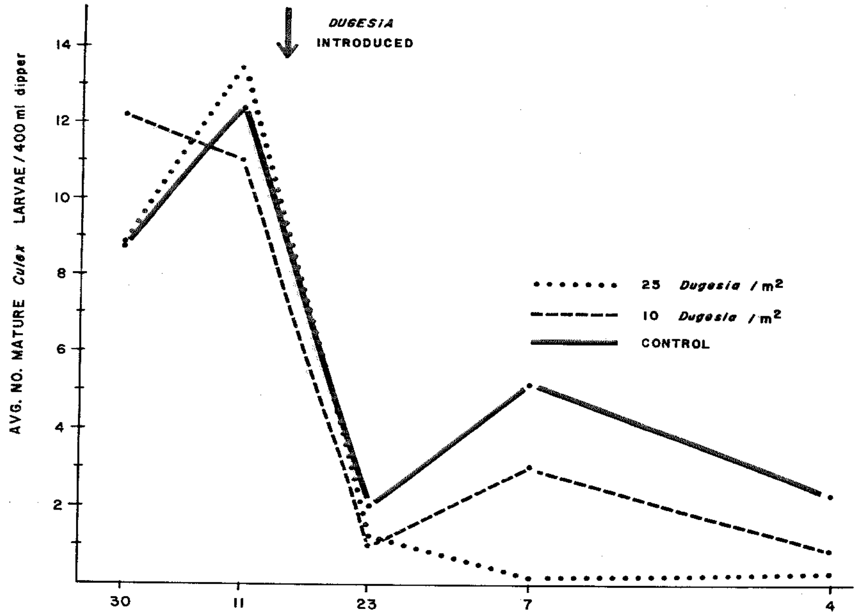
E. F. LEGNER

Division of Biological Control, University of California, Riverside 92521

ABSTRACT. Population densities of mature *Culex* spp. larvae were reduced proportional to numbers of the planarian, *Dugesia dorotocephala* (Woodworth) inoculated in experimental earthen pond ecosystems; whereas the abundance of natural insect predators in these ponds was unaffected. Planaria densities also increased proportional to initial inoculation numbers. A single inoculation at the highest rate, 25 planaria/m² of water surface, on July 15, 1975, resulted in a sustained suppression of *Culex* spp. below 0.25 mature larvae/400 ml-dipper sample for 51 days.

The ability of the planarian, *Dugesia dorotocephala*, to suppress natural populations of *Culex* spp. mosquitoes has been demonstrated (Legner and Yu 1975, Legner et al. 1975, Medved and Legner 1974, Yu and Legner 1975). However, the response of mosquito populations to different planaria inoculation rates and the effects such inoculations have on non-target beneficial insect predators was not determined. This study investigated these effects.

MATERIALS AND METHODS. Studies were performed in 12, 4 x 7-m, 0.36-m deep, earthen ponds at the University of California, Riverside. Ponds were filled on June 23, 1975, to a center depth of ca. 0.36 m, which was maintained during the study.



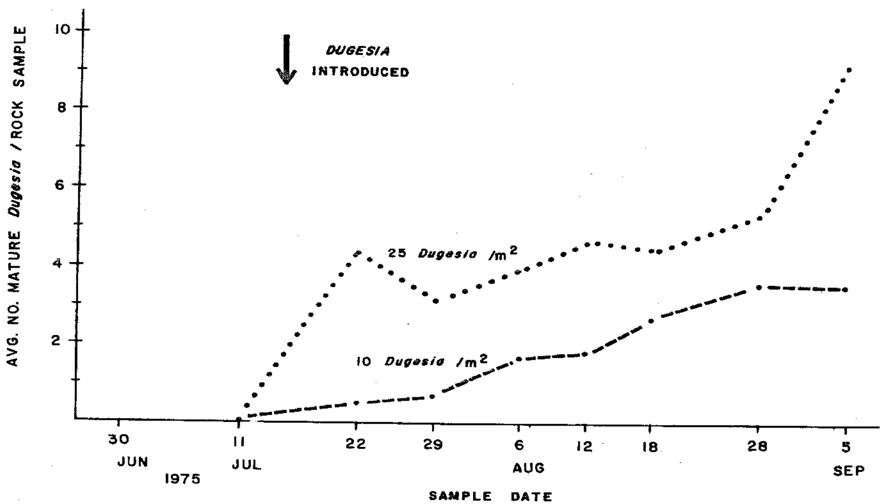


Fig. 1. Average density of mature *Culex* spp. larvae (top) and *Dugesia dorotocephala* (bottom) sampled from 4 x 7 m earthen ponds (0.36 m deep) at Riverside, California, 1975.

Each pond was fertilized once with 2 liters of chick starter mash immediately after flooding.

Mature *Dugesia dorotocephala* (16 mm long) were introduced at rates of 10 and 25 / m^2 of water surface in each of 4 replicated ponds on July 15, 1975, 3 weeks after flooding when mosquito larval densities exceeded 10 last instars / 400-ml dipper. Four control replicates were untreated. The experimental design was completely random.

Mosquito larval densities were estimated following planaria inoculation by means of 8 dips with a 400-ml dipper taken at random from each replicate every sample period. Only final instars were counted. All larvae captured were returned to the ponds.

Estimates of *D. dorotocephala* density were made using four 200-cm^3 round granite rocks placed separately in each of 4 corners of a pond (Yu and Legner 1975). Planaria that attached to the rocks were counted in the field and the planaria and rocks immediately replaced.

Insect predators were sampled with a water column sampler (Legner et al. 1975) consisting of a plexiglass cylinder plunged into the water at random so as to embed its base in ca. 4 cm of benthic mud and removing the captured insect fauna within by suction into a wash bottle. The bottle was removed from the cylinder and backflushed through a 12.6 mesh/cm nylon screen to isolate the insects. The screen was stored in a plastic bag for later counting. Ten samples were taken from each pond on a given sample day.

Data were converted to $\sqrt{X+0.5}$ before being analyzed for statistical differences with Duncan's New Multiple Range Test (Steel and Torrie 1960).

RESULTS AND DISCUSSION. Three species, *Culex peus* Speiser, *Cx. tarsalis* Coquillett, and *Cx. pipiens quinquefasciatus* Say were present during the experimental period, with the first 2 species predominating in ca. equal numbers. Densities of mature larvae of these 3 species precipitously increased then declined in treatment and control ponds during the first 3 weeks after flooding, but then remained significantly depressed (Duncan's 0.05 level) at densities proportional to planaria inoculation rates through Sept. 5 (Figure 1). The density of *D. dorotocephala* also increased significantly and proportional to inoculation rates, but this predator was absent in the controls (Duncan's 0.05 level, Figure 1). The correlation coefficient for the average number of planaria obtained in pond samples

Table 1. Insect predators sampled from 4 x 7 m earthen ponds during June 30–Sept. 5 at Riverside, California, 1975.

Family and Species	Stages Observed[a]
Coleoptera	
Dytiscidae	
Laccophilus terminalis Sharp	A, L
Rhantus gutticollis (Say)	A,
Hydroporus Clairville	L
Hydrophilidae	
Berosus punctatissimus LeConte	A, L
Tropisternus lateralis (Fab)	A, L
Laccobius californicus d'Orchymont	L
Odonata	
Anisoptera	
Libellulidae	
Libellula pulchella Drury	N
Pantala hymenaea (Say)	N
Zygoptera	
Coenagrionidae	
Anomalagrion hastatum Selys	N
Ischnura perparva Selys	N
Hemiptera	
Corixidae	
Corisella sp.	N
Hesperocorixa laevigata (Uhler)	N

[a] A=adult, L=larva, N=naiad or nymph.

compared to the numbers inoculated was highly significant (r = 0.695, 12 df, 0.01 level).

None of the insect predator species was significantly affected in density by planaria treatment throughout the study period. Predatory species present are shown in Table 1, and their combined average density in controls diagrammed in Figure 2, the values in the treatments being very close and not differing significantly at either planaria inoculation rate. These predators are thought to have been largely responsible for the initial decline of mosquito larvae during the first 3 weeks after flooding and for subsequently maintaining larval densities below 5/400-ml sample in the controls as judged by previously reported research (Legner et al. 1974). By comparison, coincident studies in the same area and period which measured the effects of *Gambusia affinis-affinis* (Baird and Girard) on insect predators showed that the presence of this fish in experimental ponds caused significant reductions of many key species (Walters 1976).

The relationship between the number of *D. dorotocephala* applied per m² of water surface and the average density of mature *Culex* spp. larvae (Figure 3) apparently was lineal (0.05 signif.), with higher variability existing among samples in the controls than at either of the 2 planaria inoculation rates.

The use of *D. dorotocephala* for direct mosquito suppression as an alternative to insecticides is desirable because natural predator densities appeared unaffected and a single application resulted in a prolonged and increased suppression of mosquito larvae as the planarians reproduced in the environment to which they had been introduced. Although the species is widespread in North America (Kenk 1972, McConnell 1967), some strains are highly cannibalistic and might be unsuitable for mass rearing. The production of adequate numbers of the noncannibalistic strain in south California for practical mosquito

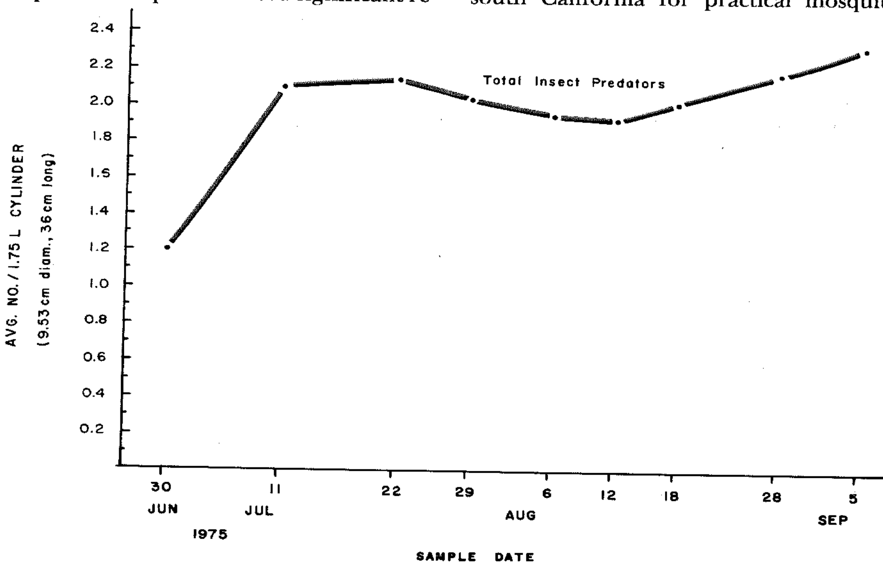


Fig. 2. Average density of all insect predators sampled from 4 x 7 m earthen ponds (0.36 m deep) at Riverside, California, 1975.

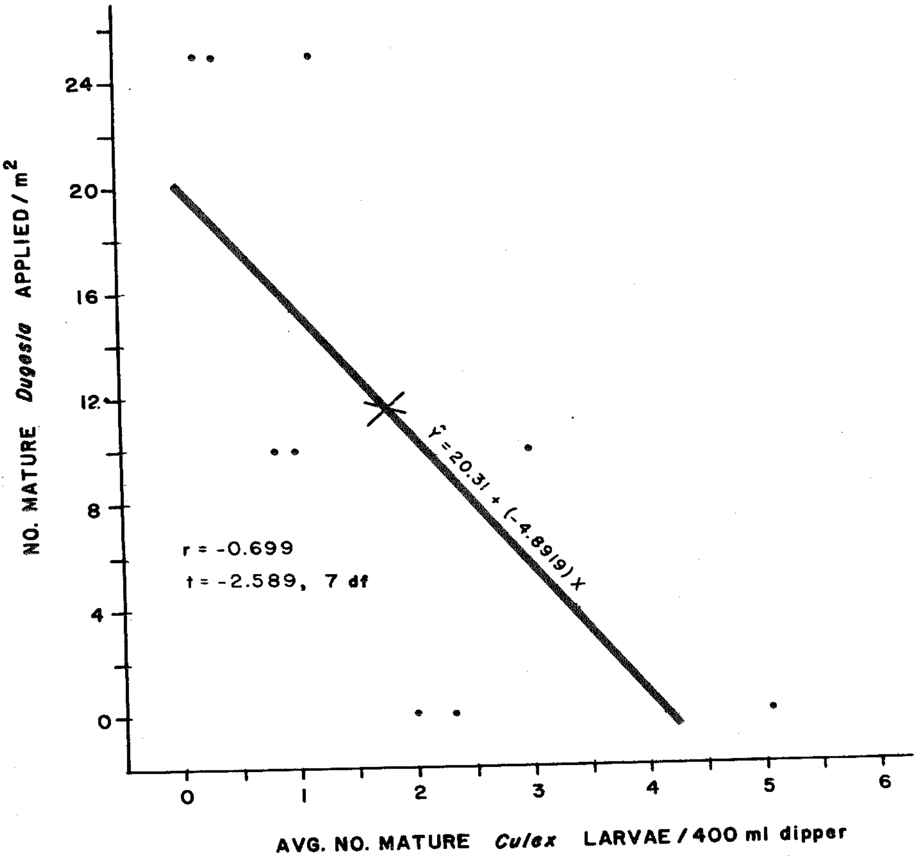


Fig. 3. Relationship between number of *Dugesia dorotocephala* applied per m² of water surface and the average density of *Culex* spp. mature larvae sampled from 4 x 7 m earthen ponds (0.36 m deep) at Riverside, California, 1975.

abatement is possible if cultures are stockpiled during winter months (Legner et al. 1976) and rapid mass production of *D. dorotocephala* can be obtained through carefully controlled culture with filtration, optimum temperature and dissolved oxygen, and food (Legner et al. 1976, Tsai and Legner 1977). Progeny require ca. 1 month to reach maturity. Further improvements in mass production and harvesting can be expected to facilitate the use of planaria in mosquito abatement.

ACKNOWLEDGMENTS. Appreciation is expressed to R. A. Medved and L. L. Janka for technical assistance. This study was aided by a special appropriation for mosquito research authorized by the California State Legislature during 1975.

References Cited

Kenk, R. 1972. Freshwater planarians (Turbellaria) of North America. Biota of freshwater ecosystems identification Manual No. 1. Smithsonian Institution, Washington, D.C. 81 pp.

Legner, E. F. and H. S. Yu. 1975. Larvicidal effects on mosquitoes of substances secreted by the planarian *Dugesia dorotocephala* (Woodworth). Proc. Calif. Mosq. Contr. Assoc. 43:128–31.

Legner, E. F., R. D. Sjogren and I. M. Hall. 1974. The biological control of medically important arthropods. Critical Reviews in Environ. Control 4(1):85–113.

Legner, E. F., R. A. Medved and R. D. Sjogren. 1975. Quantitative water column sampler for insects in shallow aquatic habitats. Proc. Calif. Mosq. Contr. Assoc. 43:110–15.

Legner, E. F., T. C. Tsai, and R. A. Medved. 1976. Environmental stimulants to asexual reproduction in the planarian, *Dugesia dorotocephala* (Woodworth). Entomophaga 21:415–23.

Legner, E. F., H. S. Yu, R. A. Medved and M. E. Badgley, 1975. Mosquito and chironomid midge control by planaria. Calif. Agric. 29(11):3–6.

McConnell, J. V. 1967. On the procuring and the care of planarians. *In*: A Manual of Psychological Experimentation on Planarians, (J. V. McConnell, ed.). Planarian Press, Ann Arbor, Mich. 128 pp.

Medved, R. A. and E. F. Legner. 1974. Feeding and reproduction of the planarian *Dugesia dorotocephala* (Woodworth), in the presence of *Culex peus* Speiser. Environ. Entomol. 3:637–41.

Steel, G. D. and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Co., Inc., New York. 481 pp.

Tsai, S. C. and E. F. Legner. 1977. Exponential growth in culture of the planarian mosquito predator *Dugesia dorotocephala* (Woodworth). Mosquito News 37 (this number).

Walters, L. L. 1976. Comparative effects of the desert pupfish, *Cyprinodon macularius* Baird & Girard, and the mosquitofish, *Gambusia affinis-affinis* (Baird & Girard) on pond ecosystems; and mass rearing feasibility of *C. macularius*. M. S. Thesis, Univ. of California, Riverside. 249 pp.

Yu, H. S. and E. F. Legner. 1975. Regulation of aquatic Diptera by planaria. Entomophaga 21:3–12.

INHERITANCE OF A NEW MUTANT, PLUM EYE, IN THE MOSQUITO *AEDES TOGOI*

TAKEO TADANO

Department of Medical Zoology, St. Marianna University, School of Medicine, Sugao, Kawasaki City, Kanagawa, Japan

ABSTRACT. A new recessive mutant, plum eye (*pm*), of the mosquito *Aedes* (*Finlaya*) *togoi* expresses dark brown eyes prominently in pupae, though difficulty is encountered in detection of this phenotype in larvae and adults. This allele has been located in the same linkage group as yellow larva (*y*) and curved wing (*c*), which have been tentatively assigned to linkage group 3. The gene sequence and the map units among them were: *c*— (17–18 units)—*y*—(40–41 units)—*pm*. There was positive interference between the two segments, the coincidence coefficient being 0.542–0.636 in the females and 0.685–0.743 in the males.

Six genetic markers thus far known for *Aedes* (*Finlaya*) *togoi* (Theobald), a vector of various species of filariae, have been tentatively assigned to the expected three linkage groups (Tadano, in preparation), since the haploid chromosome number in this mosquito is three (Suzuki 1939; Sinoto and Suzuki 1943; Rai 1963; Kanda 1968); two of these mutants, yellow larva (*y*) and curved wing (*c*), have been placed in linkage group 3, and 16–20 map units exist between the two alleles.