Effects of an Organophosphorus Insecticide on the Phytoplankton, Zooplankton, and Insect Populations of Fresh-Water Ponds

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EFFECTS OF AN ORGANOPHOSPHORUS INSECTICIDE ON THE PHYTOPLANKTON, ZOOPLANKTON, AND INSECT POPULATIONS OF FRESH-WATER PONDS[1]

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TABLE OF CONTENTS

ABSTRACT

Dursban, an organophosphorus insecticide, was applied on June 3, June 18, and July 1 to eight shallow (24 cm) experimental ponds near Bakersfield, California. Four ponds were treated at 0.028 kg/ha (= 0.025 lb./acre), four were treated at 0.28 kg/ha, and four were kept as controls. Phytoplankton, zooplankton, and insect populations were sampled on 21 dates between May 20 and August 16. Insect larvae and nymphs were more reduced in numbers than were insect adults, reflecting in part the ability of the latter to emigrate and immigrate. Twenty-four-hour posttreatment samples for the second and third, but not first, treatments showed greater reductions of predaceous (Notonectidae, Dytiscidae, Coenagrionidae, larval Hydrophilidae) than of "herbivorous" (Corixidae, Baetidae, adult Hydrophilidae) insect populations. Predaceous insect populations generally recovered to control-pond levels more slowly than herbivorous insect populations. Five weeks after the last insecticide treatment, predaceous insects averaged only 45% and 9% as abundant in low dose and high dose ponds, respectively, as they were in control ponds ($P < 0.02$); corresponding figures for herbivorous insects were 108% and 206% ($P < 0.10$). Initially, *Cyclops vernalis* and *Moina micrura* were the only crustacean zooplankters present, and both experienced high mortality due to treatments. Recovery in low dose ponds was variable, requiring 1–3 weeks, and in high dose ponds occurred only 3–6 weeks after the final treatment. Populations of *Diaptomus pallidus* seemed unaffected by the lower rate of treatment, but became large only after *Cyclops* populations had been reduced by the insecticide or other factors. *Ceriodaphnia* sp. became abundant in late July or early August in all four control ponds but not in any treated ponds. Herbivorous rotifers, principally in the genera *Brachionus, Polyarthra, Hexarthra, Filinia,* and *Tripleuchlanis,* increased dramatically, often five- to twentyfold, within 1–3 days after *Moina* and *Cyclops* populations were decimated by Dursban, but became abundant in control ponds only during the brief absence of *Moina* in early July. All planktonic rotifers, except *Polyarthra,* were more abundant in treated than in control ponds; all benthic-littoral rotifers (e.g., *Lecane, Monostyle, Tripleuchlanis, Platyias, Lepadella, Testudinella*) were more abundant in control than in treated ponds. The predaceous rotifer *Asplanchna brightwelli* was 35 times more abundant in treated than in control ponds, feeding primarily on herbivorous rotifers, sometimes on *Cyclops, Diaptomus, Moina,* and large algae, and rarely on small mayfly (Baetidae) nymphs and chironomid larvae. *Asplanchna* populations were composed of three morphotypes, ampulliform, cruciform, and campanuliform, the last of which tended to be highly cannibalistic. The "wings" of humps of the cruciform morphotype apparently represent a mechanism for minimizing such cannibalism. The reduction of herbivorous crustaceans by Dursban and the restraint of herbivorous rotifers by *Asplanchna* predation permitted the rapid increase of phytoplankton populations in treated ponds and, even 6 weeks after the last treatment, the phytoplankton was two and 16 times more abundant in low dose

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and high dose ponds, respectively, than in control ponds. Blooms of bluegreen algae (*Anabaena, Anabaenopsis*) developed in three high dose and one low dose pond, and a bloom of the diatom *Synedra* developed in one low dose pond. The long-spined alga *Schroederia setigera* seemed favored by high *Moina* and *Diaptomus* populations and low *Cyclops* populations. The significance of these results for insect-control programs is discussed.

Introduction

The influx of pesticides into fresh-water environments is increasing throughout the world with uncertain long-term effects on aquatic ecosystems and with frequently severe damage to vertebrate wildlife in particular. In the United States, 1968 production of synthetic organic pesticides was 1.2 billion pounds, an increase of 14% over the preceding year; and, in this same year, United States' exports of these pesticides increased by 23% (Fowler, Mahan, and Shepard 1970). Insecticides compose slightly more than one-half of this production and are applied to 5% of the total area of the 48 states at an average annual rate of approximately 4.5 kg/ha (President's Science Advisory Committee 1963, Frear 1968, Fowler et al. 1970). Some insecticide is applied directly to aquatic environments to temporarily reduce populations of mosquitoes, blackflies, and chaoborid and chironomid midges. Larger amounts enter aquatic systems in runoff water from agricultural land, or as a result of discharge of industrial wastes into streams and rivers by pesticide manufacturers and formulators (Nicholson 1967), or by the settling out of airborne, insecticide-contaminated dust (Risebrough et al. 1968). Whatever the mode of transport and introduction, these insecticides have a multiplicity of undesirable effects (see reviews by Bauer 1961, Rudd 1964, Cope 1965, Stickel 1967, Johnson 1968).

Among the least studied effects of insecticides are those on the population dynamics of aquatic plants and animals. Rarely have experiments assessed the influence of an insecticide on competitive, plant-herbivore, or prey-predator interactions of aquatic populations. The present study documents such influences as they were demonstrated by phytoplankton and invertebrate populations of small fresh-water ponds treated with the insecticide Dursban. This study was stimulated primarily by earlier observations (Hurlbert et al. 1970) of large unexplained increases in populations of the copepod *Diaptomus pallidus* and the predaceous rotifer *Asplanchna brightwelli* after treatment of ponds with this insecticide.

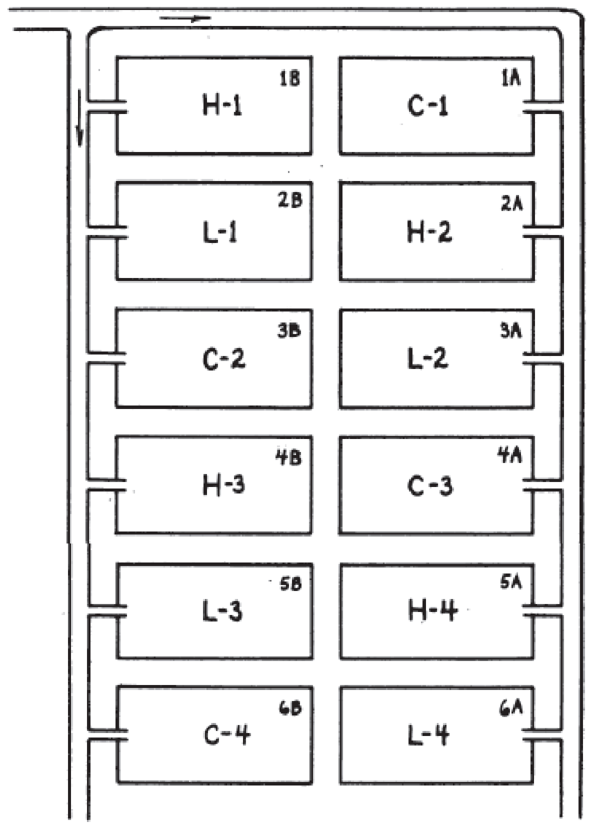

FIG. 1. Arrangement of experimental ponds. C = control pond, L = low dose pond (0.028 kg/ha), H = high dose pond (0.28 kg/ha). Numbers in upper right hand corners are those used in Hurlbert et al. (1970). Arrows show direction of water flow through ditches to the valved inlet pipes of the ponds.

Methods and Materials

Insecticide

Dursban (0,0-diethyl 0-3,5,6,-trichloro-2 pyridyl phosphorothioate) is an organophosphorus insecticide developed by Dow Chemical Company. It is presently registered for use against mosquitoes at 0.05 lb./acre (= 0.56 kg/ha) and has been tested at 0.1–0.2 lb./acre for control of chironomid midges. Dursban constituted about 2½% of the approximately 320,000 lb. of insecticide applied for mosquito control in California in 1969 (California Mosquito Control Association 1970). Much of its value as an insecticide stems from its stability; it is more resistant to hydrolysis and oxidation (Dow Chemical Company 1967) and to microbial degradation (Hirakoso 1968) than are most organophosphorus insecticides. It is not subject to food-chain magnification, however, as it is rapidly degraded enzymatically in animal tissues.

Ponds and treatments

The experimental ponds, located 15 miles south of Bakersfield, Kern County, California, and consisting of shallow, unlined excavations measuring 8 m by 17 m, were maintained at a depth of about