THE MEASUREMENT OF UPSTREAM MIGRATION IN A LABORATORY STREAM AS AN INDEX OF POTENTIAL SIDE-EFFECTS OF TEMEPHOS AND CHLORPYRIFOS ON *GAMMARUS FASCIATUS* (AMPHIPODA, CRUSTACEA)

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ABSTRACT. This paper describes a simple inexpensive laboratory stream which is used to detect possible side-effects of pesticides on stream invertebrates. *Gammarus fasciatus*, an important crustacean in river food-chains, tends to migrate up-current which makes it subject to possible drift effects. Data are presented on the effects of 24 hr. LD_{50} levels of temephos (Abate®) and chlorpyrifos (Dursban®) on the capacity of this organism to migrate upstream.

INTRODUCTION. A number of workers have studied the phenomenon of drift of invertebrates in streams (Waters 1972). Drift occurs when stream organisms are carried downstream by the current. Maintenance of position against a current is clearly a major problem with which such organisms must cope effectively in order to exist in the habitat. Drift may occur as a consequence of foraging activities or of dispersion due to high population densities, in that the more active creature is more likely to be caught up and swept away. Several workers (Waters 1965, Hughes 1970, Muller 1963) have shown that a tendency to migrate upstream exists in stream species of the amphipod, *Gammarus* and have studied the conditions under which it occurs. "Catastrophic," as opposed to normal drift, may occur when excess current velocity during spring floods sweeps away large proportions of a population or when, as a consequence of pesticide applications, a large portion of a population is debilitated or killed and swept away (see e.g. Hoffman and Merkel 1948, Coutant 1964).

Evaluation of pesticide side-effects in such cases have been attempted in the field by catching and censusing the drifted organisms and sometimes studying rates of repopulation. Drift data in the field, however, are crude and probably reflect only the more dramatic events on a short term basis, with the consequence that nasty surprises may show up in the longer term. Small, specially created streams have been used to study drift in the field but such strategy is not available to those of us working in the more crowded areas of our nation. We, therefore, have set up a very simple artificial stream wherein the effects of pesticides on the behavior of stream invertebrates can be observed with the objective that such data can be used to predict some of the consequences of field applications. The plans are modified from Hughes (1969).

METHODS. A surplus army steam-table, stainless steel, of a dimension of 38 in. x 77 in. was converted with plexi-glass sheets and PVC piping into a system as shown in fig. 1. Flow was created by hooking an old washing machine motor, geared down, and hooked up to an old variable transformer, to a paddle-wheel device. Everything but the tank surface itself was lined with polyethlene sheeting of four mil thickness, and all joints were sealed with a mixture of 2 parts of beeswax to 1 of common petroleum jelly. Thus partition and pipe surfaces could be renewed simply by disposing of the plastic sheeting while the stainless steel tank surface was scrubbed with steel wool and detergent. This clean-up is quite time-consuming and so most pesticide treatments were not made in the stream, but rather in a finger bowl. Organisms were routinely subjected to the pesticide for 24 hours and then tested. Pesticides used were temephos (Abate®) and chlorpyrifos (Dursban®), diluted to a 1% stock in acetone and then diluted further in tap water as needed.

Tests for toxicity or behavioral effects of acetone at doses used, polyethylene sheeting, beeswax-petroleum jelly and tapwater showed that these factors did not significantly affect the organisms.

The organism selected for this study was *Gammarus fasciatus*, a small amphipod crustacean. Amphipods are widely distributed in fresh and salt waters and seem to be important food for various fishes; for instance, Ball (1961) reported that *Gammarus pulex* formed 24% of the food (by volume) of the brown trout, *Salmo trutta*. *G. fasciatus* was collected from the Sudbury River where it inter-

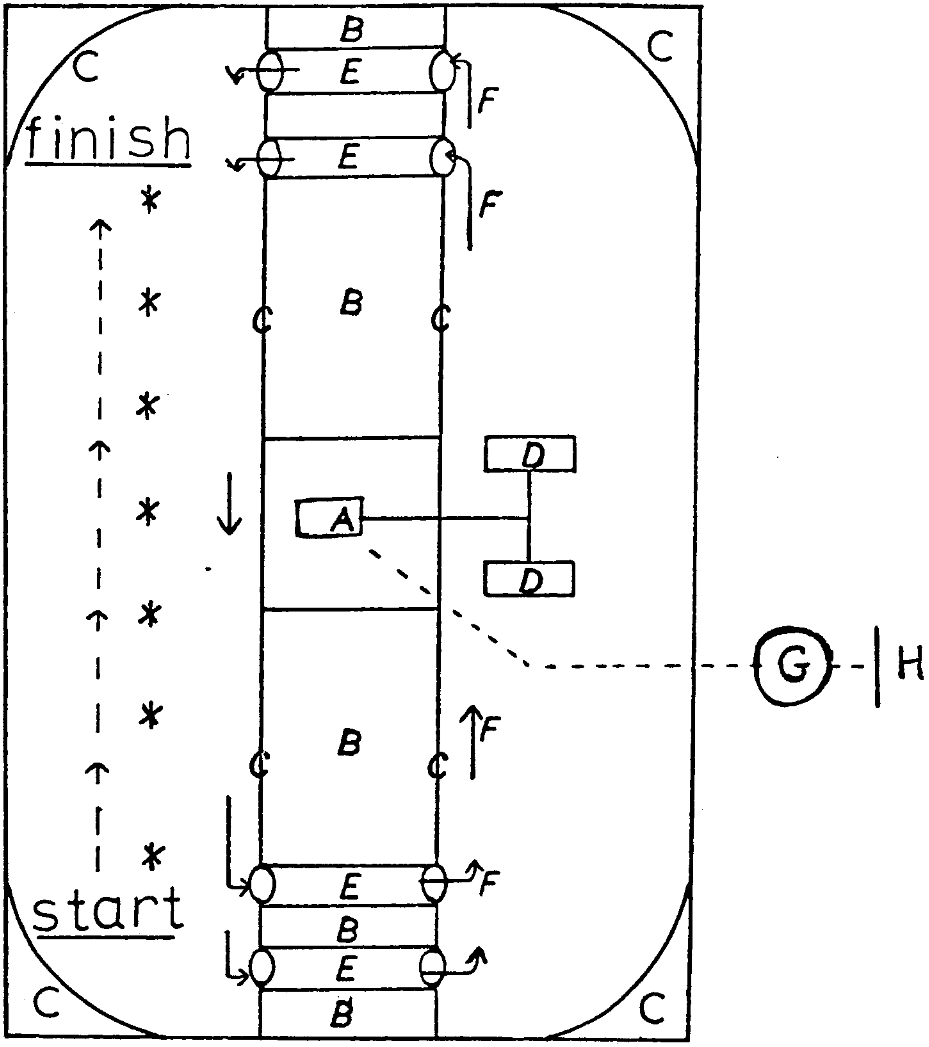

Fig. 1. Schematic overhead view of system. Paddlewheel, D, is driven by motor, A, controlled by variable power transformer, G, powered by standard wall source, H. B are blocked off unused sections and C is plastic covered plexiglass. Direction of water flow is indicated by F and solid arrows. E are PVC pipes connecting the troughs and dashed arrows indicate direction and path of *Gammarus* migration.

sects Route 117 west of Boston. The amphipods were held and tested at 12–15° C and a 12–12 light-dark regime.

Groups of 100 *G. fasciatus* were, after pre-treatment, placed at one end of the stream and observed for 8 min. after which measurements of their progress upstream against the current were made in two ways.

One way is the "finish-line" method, where we count only the number of organisms completing the full run of a course of predetermined length (120 cm). The performance is then computed by:

$$\frac{\dfrac{\text{No. finishing (120 cm)}}{\text{100 ind.}}}{\text{480 sec.}} = \text{Average ind. velocity}$$

This ignores individuals which make only part of the trip. A second method consists of marking the run off into equal segments and, after 8 min., shutting down the stream and placing barriers in it so the amphipods are trapped at several distances along the way. In this way these partial distances covered can also be included in the numerator of the equation by:

$$\frac{\dfrac{N_1D_1 + N_2D_2 + \dots + N_5D_5}{\text{100 ind.}}}{\text{480 sec.}} = \text{Average ind. velocity}$$

where N is the number of organisms trapped in the segment and D is the distance of the midpoint of the given segment from the starting point, N_5 being 120 cm, the finish-line. This "divided" stream method is superior in giving more information, but from a few data comparisons we concluded that while the "divided" method always gives higher rates, the changes in the experimentals vs. the controls are always in the same direction so the conclusions derived from the experiment remain the same. For the present we are using "finish-line" data which can be collected more rapidly without precluding the possibility of going to the other method if, at some later time, that seems more useful.

RESULTS AND DISCUSSION. We addressed ourselves to a number of questions in the course of these studies. First: Can sublethal effects be detected in this system? To answer this, concentrations of pesticide were selected which gave LD_{10} values (or less) over a 24 hr period in the finger bowls. These values were around 2.0 ppm for temephos and 0.01 ppm for chlorpyrifos (but note differences in Thayer and Ruber, succeeding articles).

Fig. 2 shows that for chlorpyrifos, in a test where the LD_{10} was 0.01 ppm, inhibition of upstream migration relative to control values was detectable at this concentration and at the lower stream flow rate, detectable even at 0.001 ppm. The higher rate of flow suppressed upstream migration so much even in the untreated gammarids that no chlorpyrifos treatment lower than .01 ppm yielded statistically different results from the controls. Flow rates used in these various experiments were 9 and 15 cm/sec. Within each set of tests the lower flow rate always yielded higher migration rates. Temephos with an LD_{10} of 2.0 ppm suppressed migration significantly, and with an LD_{10} of 1.5 ppm at 15 cm/sec, and down to 0.5 ppm at 9 cm/sec. Below these concentrations there appeared to be some suppression as well, but it was not statistically significant as can be seen in fig. 3. Response to temephos in this range of concentration is complex as will be seen from the following paper (Thayer and Ruber).

A second question was, which is the more desirable compound to be used considering possible side-effects to *G. fasciatus*, temephos or chlorpyrifos? As cited above, LD_{10} values for chlorpyrifos were always at least one order of magnitude lower than those for temephos. Similarly, migration was inhibited by chlorpyrifos at concentrations at least 10 times lower than those for temephos. Since both compounds are active against mosquitoes at similar doses we would suggest that temephos is preferable. As far as the responses we recorded—mortality and migration—

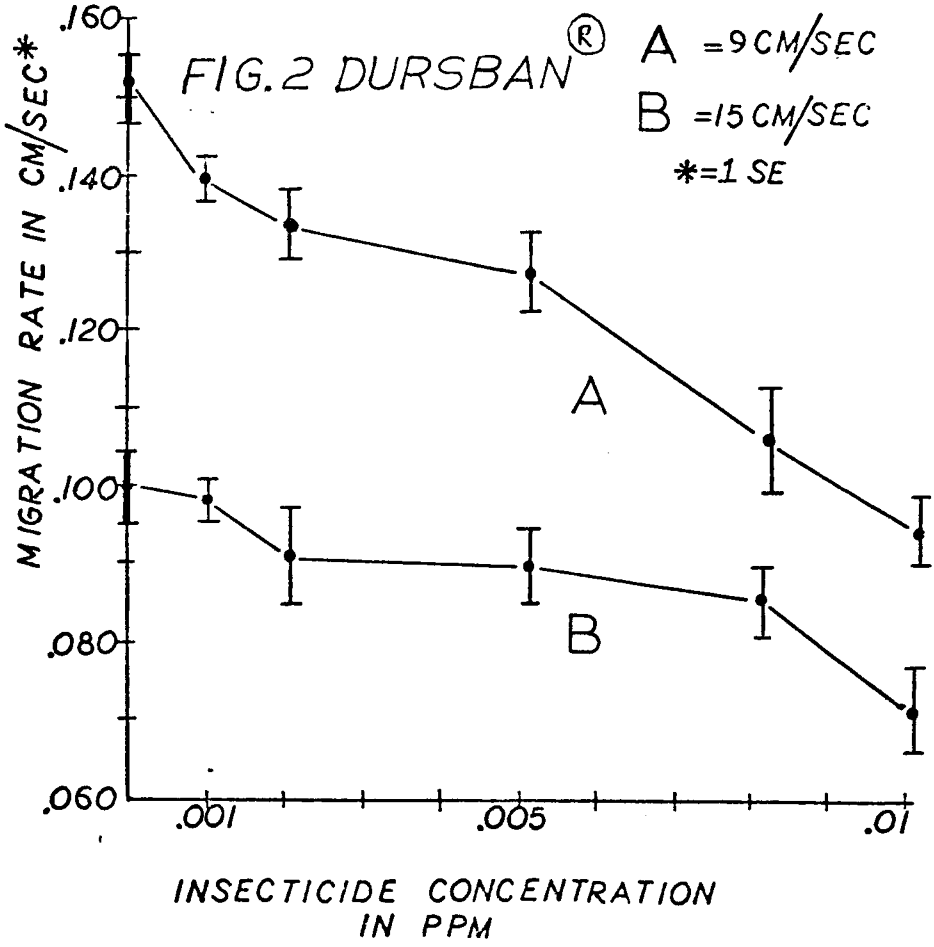

Fig. 2. Suppression of rates of upstream migration of *G. fasciatus* by chlorpyrifos at two stream flow rates. Dots placed directly on the ordinate are untreated control values. Bars enclose one standard error of the mean.

doses achieving concentrations of 0.1 ppm temephos or lower should do this species no harm. Abate® granular has been used in the swampy flood areas of the Sudbury River as an agent against spring woodland mosquitoes. Dursban® has been used on small areas purely on an experimental basis. It has been impossible for us to obtain reliable field samples which would serve to evaluate side-effects. This is because of the complexity of the habitat which makes replicable sampling very difficult indeed. These facts determined the insecticides used and provided the impetus for this work.

SUMMARY AND CONCLUSIONS. With an inexpensive stream apparatus such as described, the involvement of pesticides in inducing catastrophic drift of stream invertebrates like *G. fasciatus* may be predictable. What may be more important, the more subtle effects on the capacity to

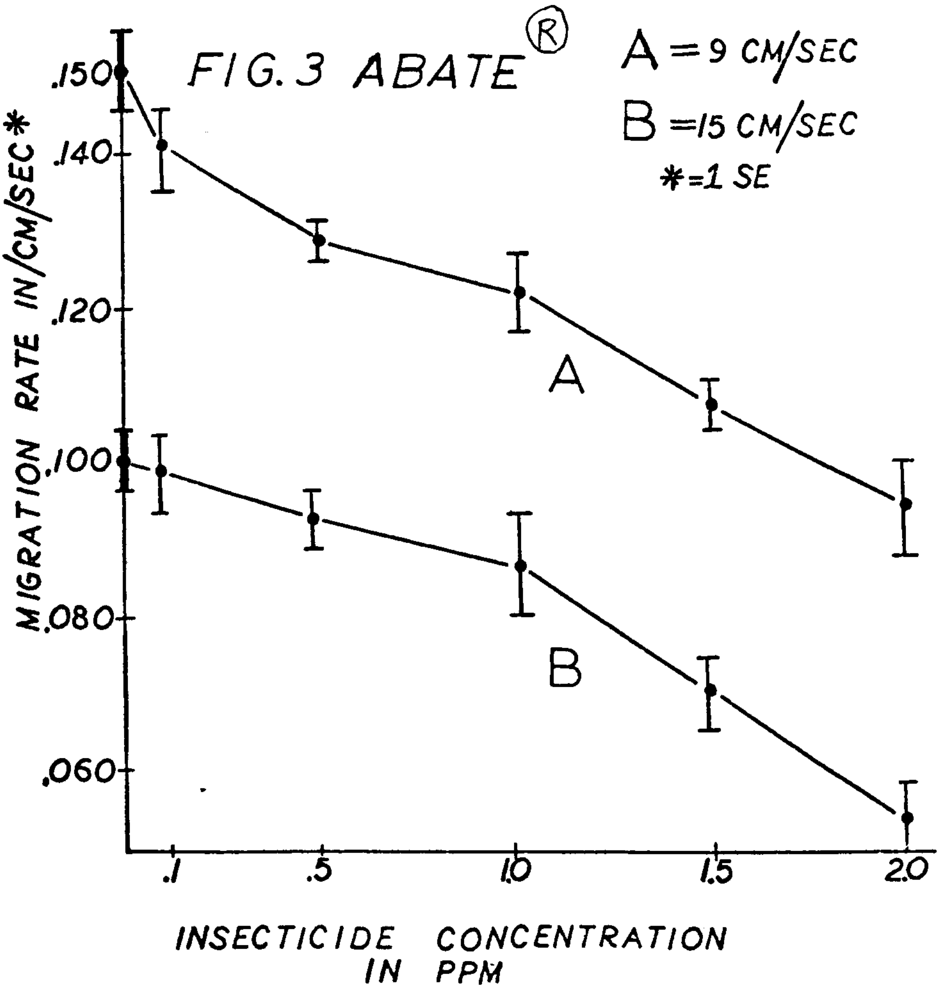

Fig. 3. Suppression of rates of upstream migration of *G. fasciatus* by temephos at two stream flow rates. Dots placed directly on the ordinate are untreated control values. Bars enclose one standard error of the mean.

migrate upstream may also be predictable.

While not everyone can get a cheap surplus army steam-table, a similar and in some respects more desirable structure can be built from wood quite as cheaply and lined with replaceable plastic sheeting. Old electric motors and transformers seem to be readily available in university workshops, flea-markets and other places found readily by graduate students, particularly those inclined toward ecological work.

This study was mainly designed to determine the feasibility of this approach, therefore, certain facets of the treatment were unrealistic such as, for example, the initial treatment of the organisms in a finger bowl for 24 hours. Such matters can and should, of course, be adjusted to reflect the field situation as closely as possible. Despite these limitations in our study some practical inferences may be drawn from our study as follows.

At concentrations of temephos and chlorpyrifos below the 24 hr LD_{10} levels, it was possible to demonstrate inhibition of upstream migration of *G. fasciatus*. Chlorpyrifos was inhibitory at concentrations of one-tenth or lower than those for temephos. Temephos is judged by the criteria used in this study more desirable than chlorpyrifos. Temephos at less than 0.1 ppm will probably not be directly harmful to *G. fasciatus*.

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