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Effects of two insecticides on the vulnerability of Atlantic salmon parr to trout predation

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Abstract

After exposure for 24 hours to 1.0 ppm of the organophosphate insecticide, Sumithion, Atlantic salmon parr were more vulnerable to predation by large brook trout. The experiments were conducted in large out-of-doors concrete pools in which the salmon had access to a safe haven. Sumithion at 0.1 ppm, and 0.07 ppm DDT, had no noticeable effect. The results, particularly for Sumithion, correlate well with previous laboratory work on the effect of insecticides on the learning ability of salmon.

Introduction

There is now good evidence that fish which survive exposure to insecticides can exhibit changes in their physiology and behaviour (Anderson, 1970). The results have come almost entirely from carefully controlled laboratory experiments in which little attempt has been made to approximate natural conditions in the field.

Some of the above work indicates that insecticides, administered in sublethal doses, can affect the learning ability of fish (Warner *et al.*, 1966; Anderson and Peterson, 1969; Anderson and Prins, 1970; Jackson *et al.*, 1970; Hatfield, 1970). This fact, together with the assumption that learning plays some role in the ability of young fish to escape natural predation, prompted the present investigation. It reports on the effect on the ability of Atlantic salmon (*Salmo salar*, L.) parr, when the latter are exposed to sublethal levels of a chlorinated hydrocarbon insecticide and an organophosphate insecticide, to escape predation by large brook trout (*Salvelinus fontinalis*, Mitchill).

Materials and Methods

The brook trout were two and a half years old and ranged from 30 to 35 cm in length. The Atlantic salmon were yearlings, 10 to 12 cm in length.

The predator-prey experiments were conducted in two circular outdoor concrete ponds with gently sloping bottoms, each pond holding approximately 11,000 litres of water. Water depth in the centre of each pond was about 1 metre. The ponds were protected from direct sunlight by overhead shading.

The insecticides used were Sumithion* and DDT**. All exposures were for 24 hours, in 25 litres of water, one fish per exposure container. Both insecticides were tested at concentrations near the 96 hr LC50 level. For Sumithion this was 1.0 ppm (Sprague, personal communication); for DDT it was 0.07 ppm (Gagnon, 1958). In addition Sumithion was tested at 1/10th its 96 hr LC50 concentration, a level generally accepted as being biologically safe (Mount and Stephan, 1969; Sprague, 1970). Acetone was used

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* This is a trade name; proposed common name, Fenitrothion; chemical formula O,O-DIMETHYL O-(4-NITRO-*m*-TOLYL) PHOSPHOROTHIOATE.

** Technical grade.

as the carrier for DDT. Untreated (control) fish were similarly held in 25 litres of (clean) water for 24 hr. After exposure all fish, treated and controls, were held for 24 hr in clean water before the experiment was begun.

Each pond was provided with a haven for the salmon in the form of a 2.5 x 1.5 x 0.2 metres high galvanized poultry wire box made of 3 x 3 cm mesh through which the salmon could easily pass but the trout could not. Preliminary work seemed to indicate that 20 salmon parr and 10 trout in each pond provided a good predator-prey ratio.

Both ponds were used for each separate experiment (trial). In one pond 10 of the salmon were treated; the other 10 (pelvic fin-clipped) were untreated controls. The other pond contained 20 untreated control salmon. Each trial was replicated six times. In addition six trials were run in which both ponds contained 20 untreated control salmon. A new batch of salmon was used for each trial, but the same 20 trout were used as predators throughout the experimental series.

Each trial ran for 24 hours, starting at 0900 hrs on Monday, Wednesday, and Friday of each week. Each trial began by releasing the salmon beneath the wire mesh haven, and was terminated by netting the survivors at the end of the 24-hour period.

The experiments were conducted during the period mid-May to mid-July, 1970. Water temperature in the ponds gradually increased from 9 C at the beginning and reached a constant temperature of 16 C by mid-June. Temperatures did not fluctuate by more than 1.5° for any one trial. All exposures to insecticides were done at constant temperatures approximating the current out-of-doors pond temperature.

Results

The trout caught salmon by charging the school and then continuously chasing one individual until caught, or most often by singling an individual out from the group and forcing it against the side of the pond, where it was easily eaten. Salmon escaped predation by outswimming or outmanoeuvring the trout, including retreating to the wide-mesh haven, and occasionally by suddenly becoming immobile, a response which seemed to make them "invisible" to the trout.

Skill in the use by the salmon of the wire-mesh haven seemed to increase with time. After 12-15 hours a stable predator-prey relationship appeared to be established since few additional salmon were caught.

In Figure 1 A is shown the predation mortality in the two ponds (each vertical bar represents a pond) for the six trials when all of the 20 salmon in each of the two ponds were untreated. On the average 60% of the salmon were eaten from each pond. There is no significant difference between the ponds.

The remaining histograms compare, for each trial, the number of salmon eaten in the pond containing only control fish (right-hand vertical bar for each trial) with the number of salmon eaten in the pond in which 10 of the 20 salmon were treated. (Treated fish denoted by solid black part of bar; extended open part of bar denotes untreated fish).

The results for 1.0 ppm Sumithion (1 B) are the most interesting. On the average (for both ponds taken together) 67.1% of the salmon were eaten. In every trial more were eaten in the pond containing the treated fish than in the pond containing only the control fish; furthermore, in the former pond 95% of the treated fish were eaten as compared to only 58% for the untreated ones. The predation pressure on the treated fish might actually have been greater than indicated since in four of the trials all of the treated fish had been eaten by the end of the 24-hour period, but in none of the trials were all of the control fish eaten. Unfortunately it was not possible to record the exact time-course of predation, because the control fish could not easily be distinguished from the treated fish during the experiment. It seems likely, however, that the treated salmon parr might have been shown to be even more vulnerable to predation if more than 10 treated fish had been used. Statistical analyses, employing a normal approximation test for binomial proportions (Brownlee, 1960), show that the greater predation of trout on 1.0 ppm Sumithion-treated salmon is significant.

Analyses of the data for 0.1 ppm Sumithion and .07 DDT-treated fish confirm the impression, given by inspection of Figures 1 C and 1 D, that these treatments had no effect on predation rates.

Discussion

The Sumithion results above correlate well with previous laboratory work. The treatment of salmon parr with 1.0 ppm Sumithion inhibits learning ability in a shuttle-box conditioning apparatus; 0.01 ppm Sumithion has no noticeable effect on learning (Hatfield, 1970).

The results for DDT are somewhat more equivocal. The first paper on the effect of DDT on learning (Anderson and Peterson, 1969) indicated that learning (in trout) was inhibited by exposure to sublethal DDT. However, it was subsequently shown that by modifying the apparatus and training procedure, salmon and trout could be trained in a shuttle-box apparatus (Jackson, et al., 1970). Hatfield, using the very same apparatus, and the same techniques, as used and described by Jackson, et al., established as reported above that Sumithion-treated salmon parr did show severe learning impairment. Furthermore, Hatfield not only confirmed that DDT treatment did not inhibit learning in his fish, but stated that his data suggested that the DDT-treated salmon might even have learned faster than his control fish. However, our results (Figure 1 D) do not suggest that DDT-treated fish were any better able to escape predation than untreated fish. (In the ponds containing the treated and control fish together, 39 DDT-treated and 38 control fish were eaten.)

Sumithion, because of its relative non-toxicity to fish, has replaced DDT as the insecticide used in the massive annual aerial spraying program to control the spruce budworm in the Province of New Brunswick. Fish mortalities have certainly not been a conspicuous feature of the present spray program. However, the results presented here indicate that the lack of mortality does not necessarily mean that there has been no effect.

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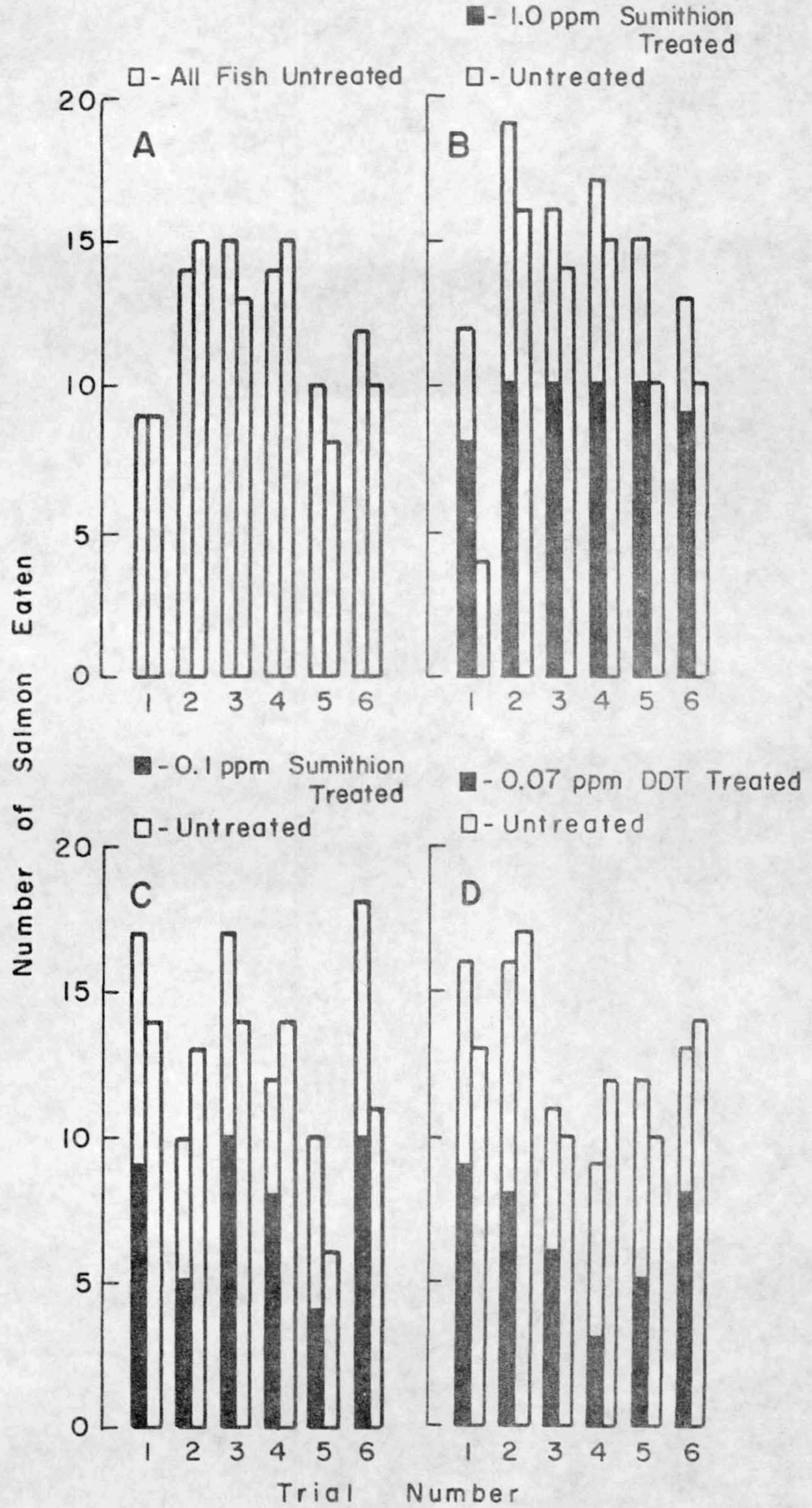

Figure 1. Predation mortality expressed as the number of salmon parr eaten in each of the two ponds used for each trial. Ten trout and 20 salmon per pond. A - Control salmon only in each of the ponds. B, C. and D - Treatment with 1.0 ppm Sumithion, 0.1 ppm Sumithion, and 0.07 ppm DDT respectively. For each trial the right-hand bar represents the pond containing only control salmon. In the adjacent bar, the lower (solid) part represents the treated salmon; the upper (open) part represents the control fish. In the ponds containing treated fish, 10 were treated, 10 were controls.