BLACK FLY CONTROL AND ENVIRONMENTAL QUALITY WITH REFERENCE TO CHEMICAL LARVICIDING IN WESTERN CANADA[1]

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The principles and general effects of black fly larviciding in large western Canadian rivers are reviewed and some of the factors affecting the ecological impact of this method of black fly abatement are discussed.

DDT was used sparingly in the Saskatchewan River system, 1948 to 1967 inclusive, and methoxychlor after 1967, to prevent damaging outbreaks of black flies. Populations of aquatic organisms were apparently unaffected in the long term. In 1968 minute concentrations of DDT and metabolites were detected in fish in treated and untreated portions of the Saskatchewan River alike. Residues of methoxychlor were less persistent.

Les principes et les effets généraux du traitement chimique de larves de simulies dans les grandes rivières de l'ouest du Canada sont passés en revue, et certains facteurs qui affectent l'impact écologique de cette méthode de diminution de simulies sont traités.

Dans la rivière Saskatchewan pour empêcher les fléaux de simulies, des quantités minimes de DDT ont été employées de 1948 à 1967 inclusivement et de l'oxychlorure de méthyle après 1967. A la longue, les populations aquatiques n'ont apparemment pas souffert. En 1968 dans des poissons provenant des parties traitées et non-traitées de la rivière ont été décelées des concentrations infimes de DDT et de ses produits métaboliques. Les résidus d'oxychlorure de méthyle ont persisté moins longtemps.

INTRODUCTION

Livestock producers situated near portions of the Saskatchewan and Athabasca Rivers in western Canada are threatened annually by outbreaks of black flies, mainly *Simulium arcticum* Mall. and occasionally *S. luggeri* N. and M. (Fredeen 1969; Fredeen, 1977 (a)). Prior to 1948, the ever present threats of outbreaks prevented farmers in more than 52,000 km^2 (20,000 square miles) of Saskatchewan from fully using livestock in their farming enterprises. Only about 65% of this area is suitable for cultivation and a much smaller percentage (about 20%) is suitable for wheat production (Mitchell, Moss and Clayton 1944). Thus most farms in the outbreak areas are dependent upon livestock for optimum use of land, and stability of these livestock enterprises is greatly affected by outbreaks of black flies.

REVIEW OF BLACK FLY LARVICIDE TREATMENTS IN THE SASKATCHEWAN RIVER SYSTEM

Tests were commenced with DDT as a black fly larvicide in the Saskatchewan River system in 1948 (Arnason *et al.* 1949; Fredeen *et al.* 1953(a) (b)). In most of the years between 1948 and 1967 inclusive, DDT was applied either once or twice to either one or both branches of the Saskatchewan River in Saskatchewan at rates of 0.1 to 0.3 ppm for 15 min (Fredeen *et al.* 1971). A single injection was generally sufficient to eliminate most larvae from at least 185 km (115 miles) of river. Invertebrates and fish remained relatively abundant in the South Saskatchewan River throughout this period despite these treatments but in the North Saskatchewan

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River were periodically reduced due to severely polluted water that entered the province from the west (Reed 1962). Early in 1968 fish were collected from both branches of the Saskatchewan River and analyzed for their chlorinated hydrocarbon content (Fredeen *et al.* 1971). Half of the fish analyzed singly or in pooled samples contained less than 0.01 ppm of either DDT, DDD or DDE in their muscle tissues. The highest concentrations, 0.05, 0.05 and 0.06 ppm respectively, occurred in one pooled sample of goldeye. Fish from an untreated part of the South Saskatchewan River above Gardiner Dam contained similar concentrations of chlorinated hydrocarbons.

In 1968 tests were commenced with methoxychlor as a black fly larvicide in the Saskatchewan River system and by the end of 1972 14 treatments with dosages ranging from 0.143 to 0.443 ppm for 15 min (Fredeen 1974) were completed. Three of the tests were performed in exceptionally low river volumes when a reservoir on the South Saskatchewan River was being filled but all other tests were performed at normal volumes. Fish, including caged rainbow trout yearlings, were not visibly affected. Larvae of Simuliidae, Chironomidae, Plecoptera and Ephemeroptera collected from the annually-treated areas with the aid of artificial substrates were more abundant in 1972 than in 1969; larvae of Trichoptera were less abundant in one treated area in 1972 but more abundant in another (Fredeen 1974). On one occasion populations of these orders declined suddenly and for undetermined reasons in an untreated section of the river.

A single 7.5-min treatment of the North Saskatchewan River with 0.6 ppm of methoxychlor in 1973 resulted in removal of 96% of larval instars 1 and 2 of *S. arcticum* and 66% of older instars at a distance of 161 km downstream from the point of injection of the methoxychlor, and larger percentages at lesser distances (Fredeen 1975). Immatures of Plecoptera were similarly affected but those of Chironomidae, Ephemeroptera and Trichoptera were less affected. Within two to four weeks populations of these non-target organisms had recovered in most sampling sites as far as the 161-km site but populations of *S. arcticum* larvae did not recover during the entire 10-week post-treatment study because this species has only one major generation each summer.

RATIONALE OF BLACK FLY LARVICIDING

Since black fly larvae are restricted to flowing water and larvae develop synchronously in the Saskatchewan River in spring time, exact sources of outbreaks generally can be pinpointed in place and time. Thus larviciding offers the most reliable and economical means of management, at least in the plains areas where large rivers are few and far between. This is not true for mountainous areas if the larvae of target species inhabit networks of small streams.

Dependable and economic management schemes have not yet been developed to cope with adult black flies that emerge from these large rivers in the plains areas of Saskatchewan and Alberta and have spread into adjacent farmlands. Thus, for the time being at least, we have to depend upon the judicious use of chemical larvicides. Data from our larvicide tests have indicated at least four general reasons why the ecological impact of treatments need not be great if the proper chemicals and dosages are used in restricted times and places:

1. Black fly larvae are relatively more susceptible to DDT and methoxychlor than are the larvae of all other aquatic taxa except perhaps Plecoptera. Most black fly larvae are very efficient but indiscriminate filter feeders. The larvae of *S. arcticum* collect and ingest very large amounts of silt in order to obtain the small proportions of food particles carried in the water. In studying the selective effects of DDT larvicide in the river 25 years ago we found that the DDT was rapidly adsorbed onto silt particles in the water (Fredeen *et al.* 1953(a); Fredeen 1962) and

more recently that the fate of methoxychlor was similar (Fredeen *et al.* 1975). Thus non-particulate formulations of either of these chemicals applied to silty water were naturally converted into particulate larvicides which acted in a selective way as stomach poisons for filter feeders. Non-filter feeding larvae belonging to other dipterous families and to non-dipterous orders except perhaps Plecoptera were less affected by these larvicides.

We reported that the adsorption of these chemicals onto silt particles also presumably aided in their long-distance transport downriver, with high mortalities of black fly larvae observed 100 or more miles (160 km) downstream from single injection points (Fredeen *et.al.* 1953(b); Fredeen 1975).

Particulate formulations *per se* have been tested in clear streams (Noel-Buxton 1956; Kershaw *et al.* 1968) but so far have not proven practical.

Obviously, DDT is not needed as a larvicide. Methoxychlor performs equally well and neither it nor its known metabolites pose lasting threats to the environment (Kapoor *et al.* 1970; Fredeen *et al.* 1975; Fredeen 1975). However, the search for new larvicides must be continued, and adsorbability onto suspended solids should be included in the tests.

2. Larvae of economic species of black fly larvae attach themselves to surfaces of rocks, where they are directly exposed to flowing water that is carrying the larvicide. Larvae of most other taxa are domiciled in relatively less exposed niches. Many Trichoptera and chironomid larvae are enclosed in cases while most Plecoptera and Ephemeroptera larvae are secluded under rocks. Larvae of many species, but especially those of Chironomidae and Odonata, comprising the bulk of the biomass in the Saskatchewan River, burrow deeply into the river bed. None of these are as directly exposed as are simuliid larvae to the treated slug of water that passes their stations. Larvae in a sand bed of the river were shown to be entirely unaffected in one test (Fredeen 1974).

3. Rapid recolonization is another reason why impact on non-target invertebrates is relatively light. Evidence for this was obtained when populations of aquatic larvae attached to artificial substrates in a 161-km section of the Saskatchewan River were reduced by a larvicide treatment in 1973. In all four sites examined in the treated portion of the river, population densities of chironomid larvae larger than 1 mm long equalled or surpassed the pretreatment densities within one to three weeks, ephemeropterans within one to four weeks, trichopterans one to seven weeks, plecopterans four to five weeks and simuliids in two to 10 weeks. Populations of larvae smaller than 1 mm long were generally restored more rapidly. These recolonization processes included continued hatching of eggs, migrations of larvae from the protected niches described above, and especially immigration of larvae drifting downstream from the 1500 km or so of untreated river. Waters (1972), states that larvae of many taxa in a river drift on a regular, daily basis. Thus, rapid repopulation of a treated section is to be expected provided a significant upstream section of the river is left untreated.

4. A slug of larvicide-treated water is of short duration, generally only 15 min long at the point of injection of the river. Generally there is no need to follow up with a second treatment, on the Saskatchewan River system at least, because the target species of black fly, *S. arcticum*, produces only one large, relatively synchronized generation of larvae in a season. I observed second peaks in late summer but generally these do not produce outbreaks of economic importance in Saskatchewan. On the other hand many prominent non-target species of invertebrates are at least bivoltine and thus capable of relatively rapid regeneration. Unfortunately *S. luggeri*, which has recently appeared in the Saskatchewan River system, is also multivoltine (Fredeen, 1977(a)).

Potentially, the fauna in a large river is in greater danger from the constant, massive input of effluents from large cities and industrial plants (Reed 1962). The constant addition of chemical and biological pollutants, including pesticides, every hour of every year can permanently suppress river fauna for hundreds of miles. Pollution control should begin first with these large persistent sources, and the effects of black fly larvicide treatments should be reviewed in this larger context.

CONTINUING NEEDS

In conclusion I have four general suggestions to make regarding continued development of black fly management programs based on larviciding:

1. Present-day larvicides, well characterized by years of laboratory and field tests in diverse sites around the world, by long-term impact studies, and by data about residues including metabolites, should not be too hastily discarded in favor of an unproven chemical. Many years of research are required before sufficient data are available to allow objective decisions to be made regarding the potential of a new chemical as a black fly larvicide. Thus laboratory and field tests of new chemicals, new formulations, and of new management methods (including methods other than larviciding) should be continued at every opportunity in anticipation of future needs.
2. We are handicapped by a scarcity of data from chemical screening tests in flowing water and thus are tempted to extrapolate treatment effect data from still-water tests. Is it possible to even roughly estimate from data derived from 24, 48 or 96 hr exposures, the L.C.50s one might anticipate from 15 or 30 min exposures? In the past some regulatory decisions seem to have been based upon such data.
3. Methods and equipment for assessing the potential impact of various black fly larvicides in flowing water in the laboratory and in the field continue to be developed and improved. Perhaps the time soon will come when complete standardization of screening methods is possible. Use of drift nets and especially management of captured fauna in such a way as to be able to estimate vitality must be standardized. Also, artificial substrates now offer means of collecting quantitative samples of many species of larvae, even from large, stony rivers (Fredeen 1977(b)). Drift and recolonization of aquatic invertebrates in these large rivers require intensive investigation.
4. Finally, every new black fly problem should be considered a unique situation that requires new research and unique management. Precise data on locations and dates of occurrences of immature populations of the target species are required. Chemical impact and residue studies should be well planned. Even in an established program each new year should be considered a new situation. That is, blind dependency upon an established program should be avoided because precise needs, conditions, and methods are constantly changing. If this attitude is accepted, pollution and non-target effects can be made minimum and effectiveness made maximum.

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