THE RESIDUAL EFFECT OF TEMEPHOS (ABATE 4-E) ON NONTARGET COMMUNITIES

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ABSTRACT. The impact of mosquito control on nontarget organisms using Abate 4-E was investigated in terms of immediate mortality and residual activity. Three 10 year old, man-made ponds having similar community structures and population densities were studied. The residual activity, determined by bioassays with 4th instar *Aedes communis*, was significantly longer in a relatively cooler pond. Populations of copepods and Cladocera took longer to return to control densities in that same pond. The role played by the physicochemical characteristics of the pond water as well as the intrinsic susceptibility and recovery capacity of the populations considered are discussed.

INTRODUCTION

Chemical control of mosquito larvae implies voluntary introduction of insecticides into an aquatic ecosystem. Understanding of the resulting impact should precede control operations. The bulk of the literature is essentially concerned with the efficacy aspect of control; the other aspect, impact on nontarget organisms, is much less extensively covered. The usual approach to assess impact consists of determination of species abundance after insecticide application. The resulting data represents a momentary picture which does not consider the dynamics involved. Difficulties related to the intrinsic high variability of communities found in mosquito habitats are largely responsible for this situation. Artificial, polyethylene-lined, pools have been used to overcome the situation. This altered habitat, while easing comparison, does not necessarily compare well with the natural habitats in terms of communities dynamics (Hurlbert et al. 1972) and residual activity of the insecticide (Hughes et al. 1980).

In southern Québec, the spring emergence of *Aedes* spp. mosquitoes is an important component of the nuisance due to biting flies (Maire et al. 1976). These species belong mainly to the subgenus *Ochlerotatus* which dominates the temperate zone of North America (Ross 1964). Since they are univoltine, they overwinter in the egg stage (Kardatzke 1977). Their life cycle is adapted to the temporary pools formed by the spring thaw in poorly drained forest. From an ecological point of view, the characteristics of this habitat are unique and distinguish it from permanent water bodies. The community of species colonizing this habitat reflect this uniqueness (Wiggins et al. 1980). This habitat and the communities it supports has not been well investigated in terms of mosquito control studies.

This paper studies the impact of temephos (Abate 4-E®), an organophosphorous insecticide, on nontarget organisms. The time of recovery of these populations is discussed in relation to the susceptibility and life cycle of the species sampled and to the residual activity of the chemical.

MATERIAL AND METHODS

We selected 3 man-made ponds, more than 10 years old, located in the Trois-Rivières area, Québec (46° 18′ N, 72° 37′ W). These ponds were in a red maple forest, a habitat characteristic of the St. Lawrence Valley and the Great Lakes area (Danks 1979). They had the following advantages: 1) deeper than their natural counterparts, allowing a longer sampling season in case of a dry spring; 2) regular, rectangular shape, allowing an accurate evaluation of water volume; 3) narrow enough to allow sampling without having to step or walk in the water. These characteristics made them ideally suitable for a quantitative impact study. The substratum at the bottom of these ponds was composed of red maple and ash leaves and hemlock needles in various proportions.

Organisms were sampled with a 1 liter dipper. Three samples of 5 liters were collected following predetermined transects in each pond. The material was filtered on a 100 μm sieve before fixation in 5% formaldehyde solution. The following physicochemical characteristics of the water were measured at each sampling time: actual, minimal and maximal temperature; dissolved oxygen (Winkler's method, A.P.H.A. 1975); conductivity (Myron L SD meter, model EP); pH (measured with a Fisher Accumet 230A, on a water sample brought back to the laboratory); and water depth, measured at a reference point. Sampling began on May 4, 1982; the ponds were sampled 3 times prior to insecticide

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application. During the 2 weeks following treatment, samples were taken at 3 or 4 day intervals and later on a weekly basis. The following summer, we sampled the ponds 5 times. In order to collect data corresponding to the pretreatment and immediate posttreatment period of the previous year, the sampling schedule was determined according to the development of the mosquito larvae.

Ponds 2 and 3 were treated on May 14, 1982; when fourth instar larvae began to appear. Pond 1 was kept as a control. The insecticide used was Abate 4-E, emulsifiable concentrate at 43.8% AI (active ingredient). The ponds were treated at a nominal concentration of 30 μg/liter AI. The insecticide was first diluted in 10 liters of water and then sprayed at the surface of the ponds with a manual compressed air sprayer. The amount of insecticide was determined from the volume of water in the ponds as measured the day prior to treatment. This concentration corresponded to an application rate of 130 and 530 g/ha AI for ponds 2 and 3, respectively.

From 24 hours after the treatment, until disappearance of response, bioassays were conducted with mosquito larvae to measure the residual activity of the chemical in the treated ponds. Samples of water from the 3 ponds were collected twice a day, filtered through a 100 μm sieve and brought back to the laboratory where groups of 25 fourth instar *Aedes communis* (De Geer) larvae were exposed for 24 hours. This procedure was carried in quadruplicates using 250 ml of water in 400 ml glass beakers kept in an environmental chamber set at 15°C. The water from pond 1 was used as control. The 24 hour mortality was the endpoint of these bioassays.

RESULTS

Ponds 1 and 3 contained about the same volume of water (Fig. 1), had the same shape and their air-water interface was 13 and 14 m^2 respectively. Both had a maximum depth of 1.2 m. Pond 2 contained 12 m^3, had an air-water interface of 24 m^2 and a maximum depth of 0.45 m. These differences had a direct effect on the thermal regimen of the ponds (Fig. 1). The other physicochemical characteristics were within the same range for all 3 ponds (pH 6–4.5, conductivity 30–40 μmhos cm^{-1}, and dissolved oxygen 10–30% saturation).

The fauna sampled was essentially composed of Diptera larvae and macrozooplankton (copepods, Cladocera and ostracods). The ostracods were present in pond 3 only and were not affected by the treatment (data not presented). The pretreatment sampling shows well established populations in each of the 3 ponds (Fig. 2). The treatment had the forseeable immediate effect on the populations of ponds 2 and 3; the control pond did not show any similar variation. During the 3 weeks following the treatment, the populations gradually recovered to densities (Fig. 2) and diversities (Fig. 3) comparable to the control. At the 3 stations, mosquito populations were initially composed of spring species of *Aedes* i.e., *Ae. communis*, *Ae. canadensis* (Theobald), *Ae. punctor* (Kirby), *Ae. excrucians* (Walker) and *Ae. abserratus* (Felt and Young) in various proportions. All of these were eliminated by the treatment. At pond 1 they were gradually replaced by the genera *Culex* and *Chaoborus*. The same phenological change occurred in the treated ponds, though in an abrupt fashion (Fig. 3). Copepods were less affected. As soon as 3 days after the treatment, copepodites were found in the habitat. Within 2 weeks after the treatment copepod densities were back to control level. Cladocera remained absent from the treated ponds for 2 weeks. Later, their densities remained low in comparison to the control.

Results from the 1983 sampling showed that the control and the 2 treated ponds presented a community and density build-up similar to the season of the treatment (data not presented). This similar evolution was maintained during the period corresponding to the 1982 posttreatment at the control. The gradual change of species observed in the control was also observed in the previously treated ponds.

The residual activity of the insecticide in ponds 2 and 3, in terms of response by the fourth instar larvae of *Aedes communis* is presented in Fig. 4. An analysis of covariance showed that these 2 slopes are statistically different ($P >$ 0.01) (Snedecor and Cochran 1980).

DISCUSSION

The overall effect of any chemical on aquatic communities results from: 1) immediate mortality following application, this being influenced by the selectivity of the chemical; 2) residual activity of the chemical, which will depend on its stability under the prevailing conditions, and; 3) recovery capacity of the populations affected, which depends on the growth rate and the mode of dispersion of the organisms, i.e., active or passive.

Direct comparison of our results with the bulk of the literature dealing with impact of mosquito control operations cannot be done readily, since in most cases, the actual concentration of chemical present in the water is not available. Most of the time, the information is presented in terms of application rate (i.e., quantity of active ingredient or formulation/surface area), without information concerning the depth of the water

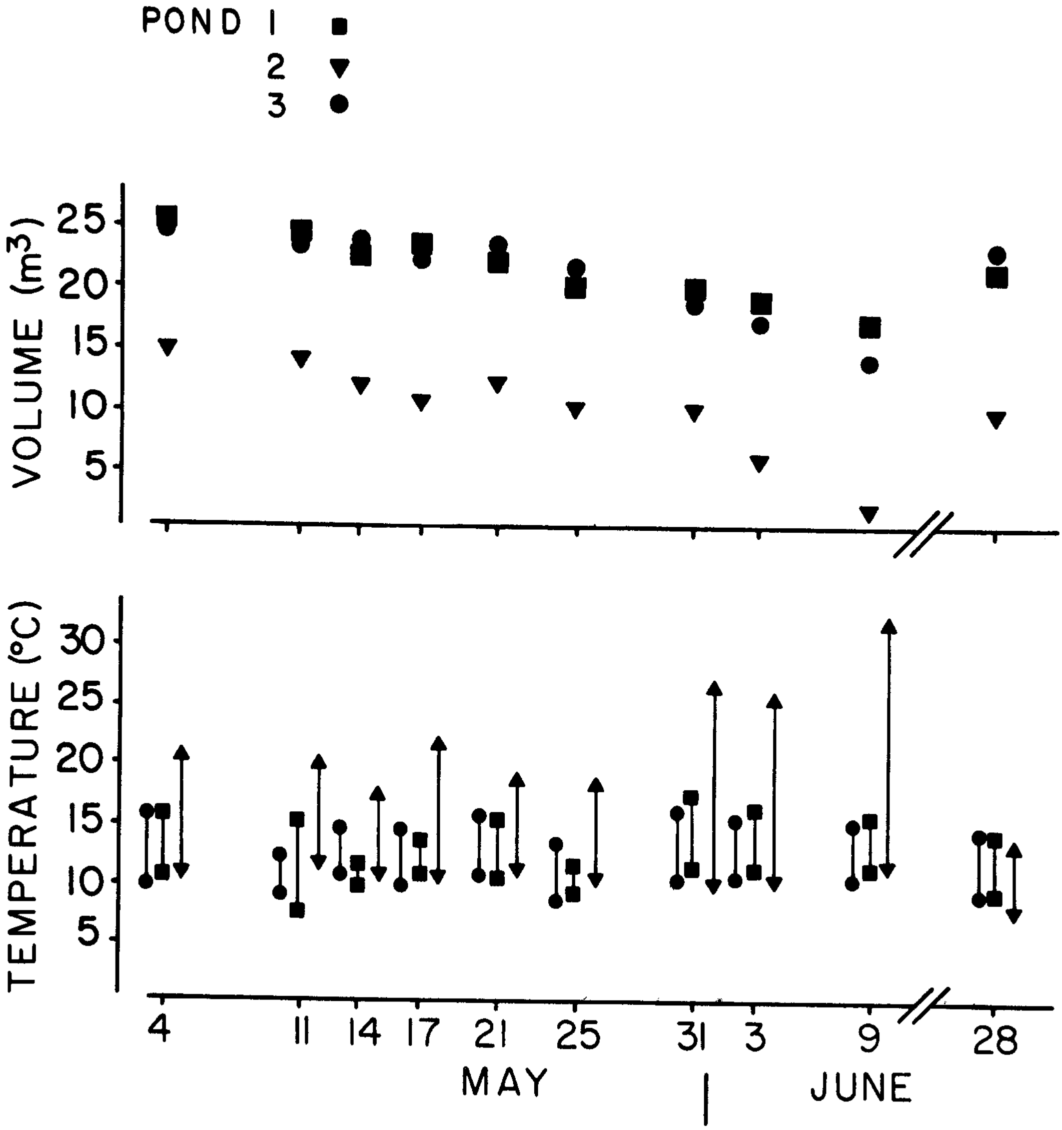

Fig. 1. Variations in water volumes and temperatures for the three studied ponds at Trois-Rivières, P.Q.

body considered. However, the difference of susceptibility between Cladocera and copepods has also been reported by other authors (Hughes et al. 1980, Porter and Gojmerac 1969, Didia et al. 1975, Yasuno et al. 1982). Hughes et al. (1980) aimed at a concentration of 10 ppb in a study conducted in artificial, polyethylene-lined, ponds. In terms of initial kill, their results show the same trend as the present study. However, as stated by these authors, the follow-up is not comparable to the natural habitat. Yasuno et al. (1982) also observed the high susceptibility of Cladocera in eel ponds treated at 100 ppb for chironomid control; copepod nauplii being not affected by the treatment. The ostracods, present at station 3 were not affected by the treatment, an observation also made by Porter and Gojmerac (1969). Pennak (1978) describes the tolerance of ostracods to a wide range of ecological factors; the nature of the tolerance of these organisms to insecticides has not been investigated yet.

Hydrolysis and photolysis are the most important route of degradation of organophosphorous insecticides in water (Tinsley 1979, McEwen and Stephenson 1979). Temperature and pH directly affect the rate of these reactions (Tinsley 1979, Korte 1978). The relatively warmer conditions prevailing in pond 2, and the proportionally larger air-water interface, which

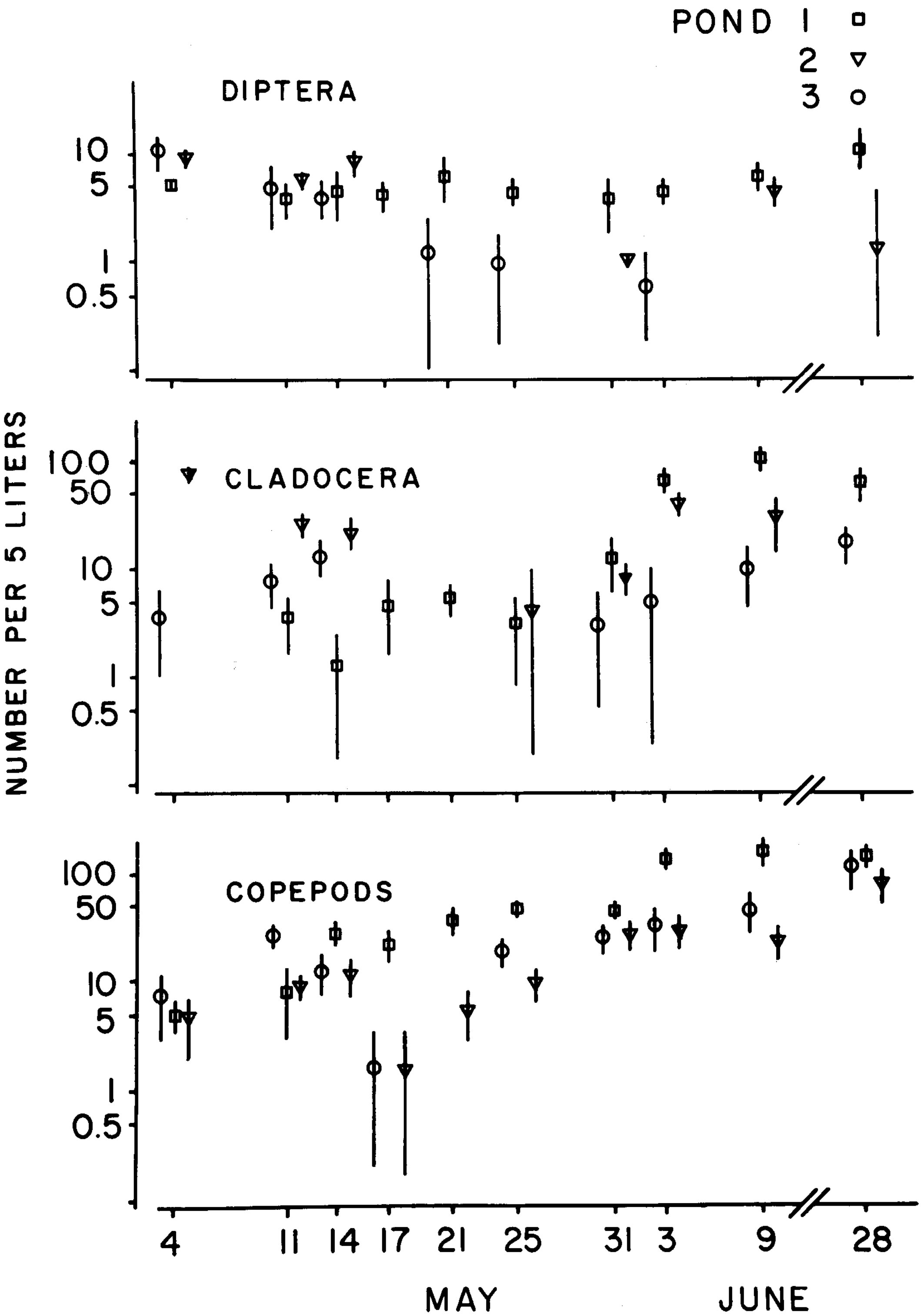

Fig. 2. Variations in densities of organisms sampled in the three studied ponds. Treatment was done at ponds 2 and 3 just after the May 14, 1982 sampling. The average and standard deviation of three samples per pond is presented.

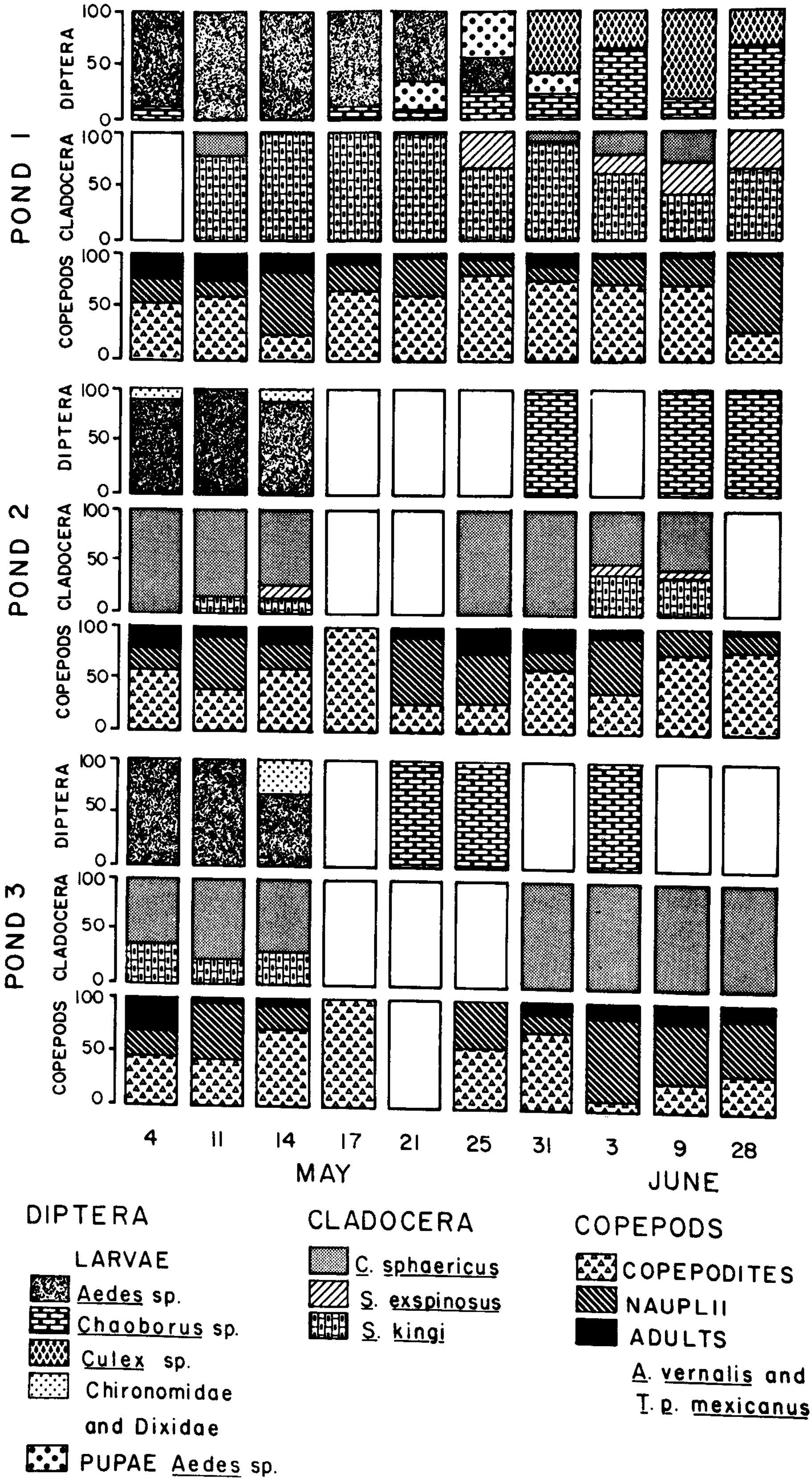

Fig. 3. Relative densities of organisms sampled in the three studied ponds. Cases when no organisms were sampled are presented as empty boxes. Treatment was done at ponds 2 and 3 just after the May 14, 1982 sampling.

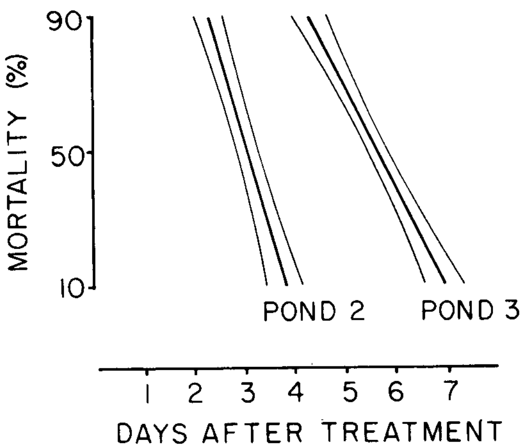

Fig. 4. Probit regression lines, with 95% confidence limits, of the residual activity of Abate 4-E applied in two mosquito breeding ponds.

increases volatilization and photolysis, may explain the difference in residual activity between the 2 treated ponds. The slight differences in pH between the 2 treated ponds is not believed to have played a significant role in the process.

The literature dealing with the residual activity of temephos is not very abundant. Hughes et al. (1980) present results concerning the persistence of temephos applied at 10 ppb. The chemical was only detectable at 10% of the initial application (as measured by gas chromatography) after 1.05 days, this at a temperature ranging between 15.6 and 19°C and a pH of 7.6. Dixon and Brust (1971) measured residual activity of temephos using bioassays with mosquito larvae. The initial amount of chemical applied was expressed in terms of application rate on their artificial ponds but the concentration in water can be estimated at about 20 ppb. Their results showed a 100% mortality of the larvae during the first 7 days following treatment and no mortality after 12 days. Unfortunately no measurement was done between day 7 and 12. Physicochemical characteristics were not reported. Didia et al. (1975) studied the residual activity of temephos in aquaria located in a forested area. They quantified residual activity by *in situ* bioassays with groups of selected organisms (Cladocera, copepods and various insect larvae including *Culex pipiens* Linn.). At 13.5 ppb, they observed 100% mortality of Cladocera for the first 3 days; the mortality falling to 30% on the 4th day. At 27 ppb, 100% mortality was observed for 7 days. No information is presented concerning the physicochemical characteristics of the water. Back et al. (1983) followed the activity of granular temephos in a pond from northern Québec after aerial application. The comparison of their results with ours is difficult since the actual initial concentration and the pond temperature were not presented. Using a bioassay procedure comparable to the one followed for this study, their results show a residual activity of 5 days on *Aedes canadensis.*

The longer residual activity at pond 3 may explain the delayed reappearance of the most sensitive organisms, compared to pond 2. The recovery capacity of the affected populations will largely depend on their life cycle. Wiggins et al. (1980) developed a classification of aquatic animals inhabiting temporary pools. Their classification is based on ecological and evolutionary strategies developed to avoid the extreme conditions prevailing in this habitat. The Crustacea are considered as overwintering residents, spending the winter in a resistant stage and only capable of passive dispersion. These resistant stages may be responsible for the return of these organisms in the habitat after the treatment. The absence of these resistant stages in a new artificial pond contributes to the unsuitability of artificial ponds for recovery studies. In the case of mosquitoes, the species targeted by the treatment are univoltine; therefore their return in the habitat was unexpected.

The absence of *Culex territans* in ponds 2 and 3 cannot be explained by the data gathered for this study. However, considering: 1) the relatively late appearance of this genus in the control pond, and 2) the return of highly sensitive organisms, such as Cladocera, in the treated ponds, it is unlikely that the colonization of the treated ponds this opportunistic genus had been affected by the treatment.

The absence of *Culex territans* in ponds 2 and 3 cannot be explained by the data gathered for this study. However, it is considered unlikely that the colonization of the treated ponds by this opportunistic genus had been affected by the treatment. This interpretation is based on: 1) the relatively late appearance of this genus in the control pond, and 2) the return of highly sensitive organisms, such as Cladocera, in the treated ponds.

CONCLUSIONS

The results of this study demonstrate that temephos does not persist in the treated water and that effective control can be achieved with short term impact. The residual activity of temephos is, on one hand dependent on environmental factors while, on the other hand regulates the recolonization of the habitat by the affected organisms. The ponds used for this study combined the repeatability of artificial ponds with the realism of natural water bodies.

The interpretation of the impact was carried out using information concerning the susceptibility and life histories of the organisms involved, as well as physicochemical characteristics of the water. This approach allowed us to present a tentative explanation concerning the difference between the 2 treated ponds in terms of residual activity and time of recovery for the affected populations.

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