# FENITROTHION IN A LAKE ECOSYSTEM

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## ABSTRACT

Fenitrothion was applied as an emulsion in water to a small lake at the rate of 420 g active ingredient per hectare. Peak residues of 21.6 μg/ℓ were present in surface waters one hour after treatment, but rapidly dispersed throughout the lake, with complete mixing within the epilimnion after 12 hours and maximum penetration into the hypolimnion (2.14 μg/ℓ) after 24 hours. All fish species in the lake rapidly accumulated fenitrothion residues with each species accumulating distinctly different residue levels. The highest residue found in each species was 1.01 μg/g in white suckers, *Catastomus commersoni* (Lacépède), 0.76 μg/g in fallfish, *Semotilus corporalis* (Mitchill), 0.44 μg/g in brown bullheads, *Ictalurus nebulosus* (Lesueur), and 0.34 μg/g in smallmouth bass, *Micropterus dolomieu* Lacépède. Rapid loss of accumulated residues was seen in all species except white suckers.

The fenitrothion application had little effect on populations of fish food organisms or on the diet of native fish species, with the possible exception of cladoceran populations and their contribution to the diets of planktivorous fish species.

Static bioassays in the laboratory gave 24 to 96 hour LC50 values between 1.2 and 5.4 mg/ℓ fenitrothion for seven species representing five families. Sensitivity to fenitrothion followed family lines with Salmonidae (trout) the most susceptible family and Ictaluridae (catfish) and Cyprinidae (minnows) the least sensitive.

The results of the field and laboratory studies carried out indicate that fenitrothion applied at dosages registered for forest insect control does not appear to present a serious hazard to native fish populations in lakes exposed to aerial applications.

# RÉSUMÉ

L'eau d'un petit lac a été traitée avec une émulsion de fénitrothion à la dose de 420 g d'ingrédient actif par hectare. Les résidus étaient en concentration maximale (21.6 µg/ℓ) dans les eaux superficielles une heure après le traitement mais se sont dispersés rapidement dans tout le lac, atteignant le mélange total dans l'épilimnion après 12 heures et une pénétration maximale dans l'hypolimnion (2.14 µg/ℓ) après 24 heures. Ils se sont rapidement accumulés dans toutes les espèces de poisson du lac à des concentrations variant selon l'espèce. La plus forte teneur trouvée chez chaque espèce a été 1.01 µg/g chez le catostome noir, *Catastomus commersoni* (Lacépède); 0.76 µg/g chez l'ouitouche, *Semotilus corporalis* (Mitchill); 0.44 g/g chez la barbotte brune, *Ictalurus nebulosus* (Lesueur); et 0.34 µg/g chez l'achigan à petite bouche, *Micropterus dolomieu* (Lacépède). Toutefois les résidus ont disparu rapidement chez toutes les espèces sauf le catostome noir.

L'épandage du fénitrothion a eu peu d'effets sur les populations servant de nourriture aux poissons ou sur le régime alimentaire des espèces de poissons indigènes, sauf peut-être dans les cas des populations de cladocères et de leur contribution à l'alimentation des espèces de poissons planctivores.

La $CL_{50}$ mesurée en laboratoire en conditions statiques après une période de 24 à 96 heures a varié entre 1.2 et 5.4 mg/ℓ de fénitrothion pour sept espèces représentant cinq familles. La sensibilité des espèces suivait des tendances familiales, les Salmonidae (truites) étant les plus sensibles, et les Ictaluridae (barbottes et barbues) et les Cyprinidae (cyprins), les moins.

Les résultats des études sur le terrain et en laboratoire indiquent que les épandages aériens de fénitrothion sur les lacs aux doses employées dans la lutte contre les insectes des forêts, ne semblent pas représenter un danger grave pour les populations de poissons indigènes.

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# I. INTRODUCTION

## A. The History of Forest Pest Control Practices in Canada

Large scale forest spraying to control forest pests has been carried out in Canada since 1952, when spruce budworm, *Choristoneura fumiferana* (Clem.) control programs were initiated in New Brunswick. From the earliest days of aerial forest spraying, concern has been expressed about the effects of these programs upon aquatic fauna living in streams, rivers and lakes within the treated areas. A great number of experimental and monitoring programs have been conducted to study the effects of the applied insecticides on fish and aquatic invertebrates (recently reviewed by Kingsbury, 1975). The nature and focus of these studies have shifted as the application procedures and insecticides used in pest control programs have changed.

Early large scale forest spraying in Canada was carried out using Boeing Stearman aircraft and applying the chlorinated (aryl) hydrocarbon insecticide 1,1,1-trichloro-2,2-bis (*p*-chlorophenyl) ethane (DDT). These small biplanes had a carrying capacity of only 568 litres (150 U.S. gallons) of formulated insecticide per load. Increased size and scope of control operations led to the introduction in 1956 of Grumman Avenger (TBM) aircraft which could treat much larger blocks of forest with their 3180 litre (840 U.S. gallon) maximum capacity. The aircraft maintained their swath track positioning by marking systems (balloons, flags, smoke, etc.) established on the ground and in later years by the use of "pointer" aircraft flying above the spray plane (Randall, 1972). These guidance systems lacked precision but made it possible to avoid directly introducing insecticides into lakes and large rivers. Unsprayed boundary areas could be maintained around the edges of the lakes and rivers and the pilot could shut off spray when crossing major streams visible from the air (Crouter and Vernon, 1959). For these reasons, undesirable insecticide effects were limited to the fish and aquatic invertebrates living in forest streams, and aquatic monitoring studies were confined to these ecosystems and their fauna.

The use of DDT in forest insect control programs was known to have adverse effects on the fish and invertebrate life of forest streams (Crouter and Vernon 1959, Kerswill 1967). This led to the introduction of organophosphate insecticides, which had been found to be considerably less toxic to fish. In 1968, the use of DDT in operational control programs against forest insects was discontinued. Since 1968, the principle insecticide applied to Canadian forests has been the organophosphate fenitrothion (O,O-dimethyl O-(4-nitro-m-tolyl) phosphorothioate).

In 1967 a spruce budworm infestation broke out in Quebec and rapidly spread to encompass millions of acres by 1969. In order to economically control the damage threatened by this outbreak, four-engined spray aircraft were developed capable of applying 15,140 litre (4000 U.S. gallon) loads and utilizing inertial guidance systems. Calibration trials showed that these aircraft could deposit spray formulation over a 914 m (3000 ft.) swath width, with measurable deposit occurring as far as 2.2 km (1.4 miles) downwind of the aircraft's flight path (Randall and Zylstra, 1972). In 1972, Douglas DC-7B aircraft flying at 370 km/h (230 mph) along parallel swath tracks 914 m (3000 ft.) apart were used to spray budworm infested forests in Quebec. Since then, large multi-engine aircraft of several types have been used to apply insecticides to millions of acres of forest in Quebec and New Brunswick. The necessity of flying these aircraft over the forest at high speed along straight lines and the great width of their deposit swath make it impossible to avoid introducing insecticide directly into small lakes present in the treated areas. This has opened up a new area of concern over possible effects of forest spraying on aquatic fauna.

B. Insecticides in Lakes

Few studies have been carried out on the effects of insecticides in lakes, as they have never before been directly applied to lakes in such a widescale manner. Most of the studies which have been carried out have been aimed at studying the persistence, distribution and long term effects of chlorinated hydrocarbon insecticide residues accumulating in lakes (e.g. Hunt and Bischoff 1960, Hunt and Keith 1963, Hickey *et al* 1966, Hannon *et al* 1970). Only a few studies have reported the acute effects of insecticides applied directly to lakes. Shane (1948) reported the upset of the biological balance in a reservoir caused by toxic effects of aerially applied DDT on zooplankton. Murphy and Chandler (1948) and Lindquist and Roth (1950) reported the effects on plankton, littoral fauna and fish of 1,1-dichloro-2, 2 bis (*p*-chlorophenyl) ethane (TDE) applied directly to lakes to control gnat larvae, *Chaoborus astictopus* Dyar and Shannon.

There are a few reports of fish mortality in Canadian lakes attributed to forest pest control operations. Mortality among salmonid and cyprinid fish in lakes was observed following DDT spraying in New Brunswick in 1952, 1953 and 1954 (Kerswill and Edwards, 1967). Crouter and Vernon (1959) reported some trout mortality in lakes resulting from DDT spraying against western black-headed budworm, *Acleris gloverana* (Wals.), on Northern Vancouver Island in 1957. Aside from these early incidents, there was little indication of forest pest control operations having direct effects on lake fauna until the inception of spraying with four-engined aircraft. In 1973, brook trout, *Salvelinus fontinalis* (Mitchill), mortality in a small Quebec lake was attributed to fenitrothion spraying from large aircraft

(Kingsbury, 1973). This incident and other reports of fish mortality within fenitrothion treated areas pointed out the need to study the effects of this insecticide on the ecology of the fish population of small lakes.

C. Fenitrothion in Aquatic Systems

Fenitrothion and other organophosphorus insecticides inhibit cholinesterase activity within animal nervous systems, preventing the hydrolysis of acetylcholine at the postsynaptic membrane (Fest and Schmidt, 1973). This prevents the return of the synapse to its resting state following nerve transmission, with the result that nervous function is seriously impaired. Details of the manufacture, use, toxicology and chemistry of fenitrothion have been compiled by Krehm (1973) and the National Research Council Associate Committee on Scientific Criteria for Environmental Quality (1975). The structure of fenitrothion and some of its metabolites mentioned in the text are illustrated in Fig. 1.

a. Toxic effects on fish

Most toxicological studies of fenitrothion with fish have used salmonid fish as test species. Twenty-four hour LC50's (concentrations lethal to 50% of the test organisms exposed to the toxicant for 24 hours) have been determined to be 7.4 mg/ℓ for young Atlantic salmon, *Salmo salar* L., (Wildish *et al* 1971) and 4.0 mg/ℓ for rainbow trout, *Salmo gairdneri* Rich., (Klaverkamp *et al* 1975). Bull (1971) found the 96 hr. LC50 of fenitrothion to be 1.3 mg/ℓ for juvenile coho salmon, *Oncorhynchus kisutch* Walbaum, while the corresponding value for Atlantic salmon parr was reported as 1.0 mg/ℓ (Hatfield and Anderson, 1972). No values have been published for the toxicity of fenitrothion to other families of fish, but Macek and McAllister (1970) reported that for fenitrothion the relative susceptiblity of an ictalurid or cyprinid to a centrarchid is 2:1 or less. They concluded that for phosphorothioate organophosphorus insecticides in general, there is

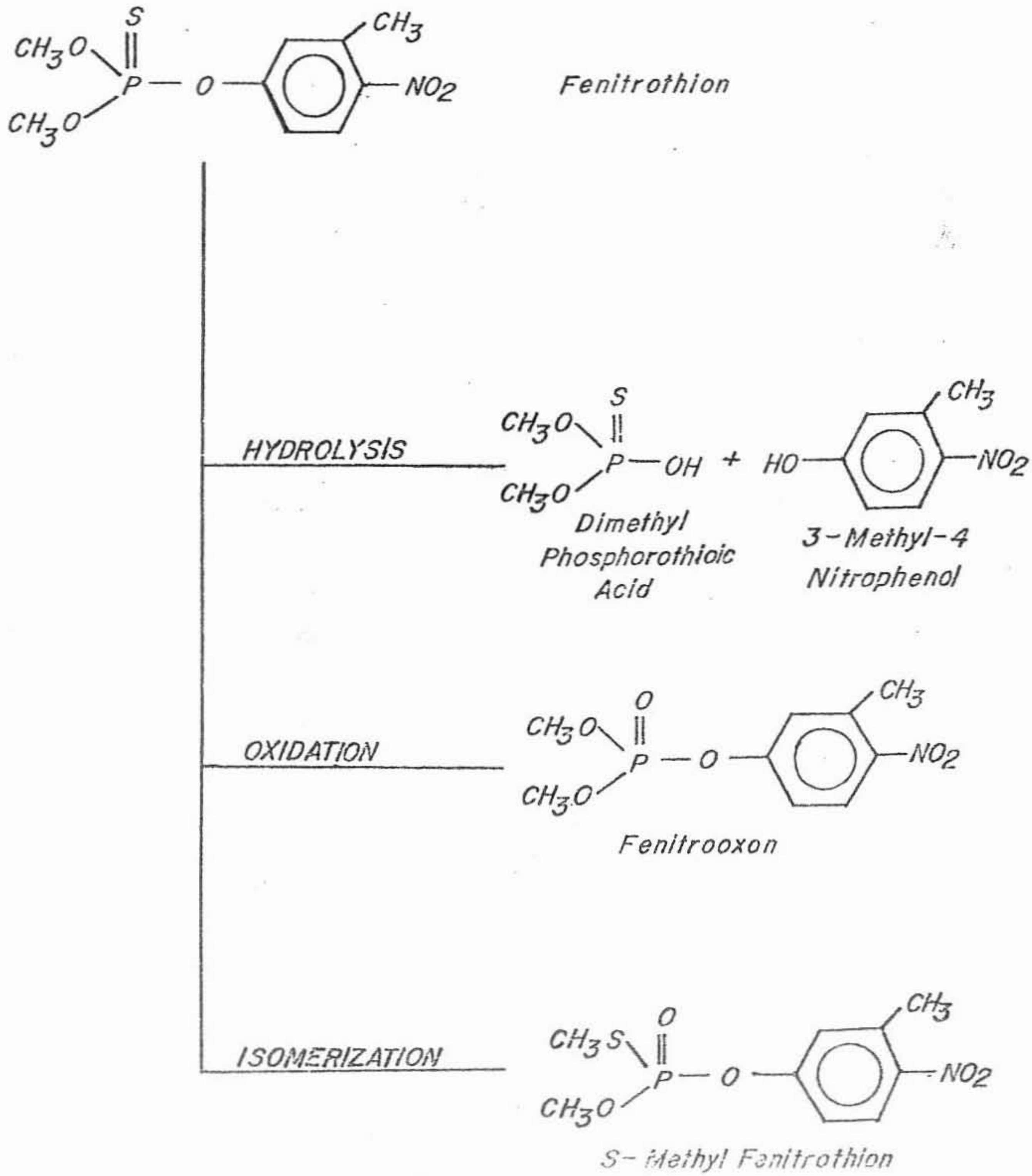



Fig. 1. Chemical structure of fenitrothion and some of its metabolites (after National Research Council Associate Committee on Scientific Criteria for Environmental Quality, 1975).

little difference in the relative susceptibilities of different fish families. S-methyl fenitrothion, a major impurity in technical fenitrothion, was reported by Zitko and Cunningham (1975) to be approximately equally toxic to juvenile Atlantic salmon as fenitrothion.

Aerial application of fenitrothion at rates between 0.21 and 0.56 kg/ha have repeatedly been found to cause little or no direct mortality among caged or wild fish populations in streams (Kingsbury, 1975). Aerial spraying with fenitrothion in New Brunswick did not cause any significant change in acetylcholinesterase activity in salmon and trout, but did lower it in suckers from a treated stream (Zitko *et al* 1970). Caged rainbow trout exposed to aerially applied fenitrothion in Manitoba accumulated whole body residues as high as 1.84 µg/g without exhibiting effects on brain acetylcholinesterase activity or serum chemistry (Lockhart *et al* 1973). Hatfield and Riche (1970) reported whole body residues up to 0.77 µg/g in caged and wild salmon and brook trout from water systems in Newfoundland exposed to fenitrothion spraying. Inhibition of brain cholinesterase activity by direct exposure to fenitrothion in the laboratory has been studied with Atlantic salmon, brook trout and rainbow trout (Zitko *et al* 1970, Lockart *et al* 1973, Klaverkamp *et al* 1975). Brook trout in th laboratory fed food containing 10 mg fenitrothion/kg showed no depression of brain acetylcholinesterase activity, but a dose of 10 mg/g did depress activity of this enzyme (Wildish and Lister 1973, Wildish 1974).

b. Effects on fish behavior

The effects of sublethal exposure to fenitrothion on the behavior of salmonid fish has been studied widely. Twenty-four hour exposure of Atlantic salmon parr to 1 mg/ℓ fenitrothion completely inhibited learning (Hatfield and Johansen 1972) and increased vulnerability to predation by large brook trout (Hatfield and Anderson 1972); neither ability was affected by 24 hour exposure to 0.1 mg/ℓ fenitrothion. Symons (1973) found that 15-16 hour exposure to 1 mg/ℓ caused a 50% decrease in the number of Atlantic salmon holding territories, with a lesser reduction (20%) following similar exposure to 0.1 mg/ℓ fenitrothion. Peterson (1976) found no singificant effect on temperature selection when juvenile Atlantic salmon were exposed to fenitrothion at 1 mg/ℓ for 24 hours. Bull and McInerney (1974) found that juvenile coho salmon suffered physiological impairment reducing most behaviors when exposed to 0.48 or 0.75 mg/ℓ fenitrothion, while at lower exposure levels (0.10 and 0.23 mg/ℓ) comfort movements increased and social behaviors and feeding decreased from normal levels. Critical swimming velocities of brook trout following exposure to 0.15, 0.5 and 1.5 mg/ℓ fenitrothion were found to be 100, 83 and 70% of the performance of control fish (Peterson 1974). Wildish and Lister (1973) found that feeding brook trout with food containing 10 mg fenitrothion/g reversed the hierarchical pattern among groups of fish as determined by food partitioning.

There is some evidence that fish avoid fenitrothion present in water or food material. Scherer (1975) found that goldfish, *Carassius auratus* (L.), avoided water containing as little as 10 µg/ℓ fenitrothion, with a larger avoidance response to higher test concentrations. Symons (1973) found that Atlantic salmon would not voluntarily eat mealworms (*Tenebrio* sp) if they had been injected with pure fenitrothion and often regurgitated such worms 8 to 12 hours after being force fed them. Brook trout were found to have a threshold for tolerance of fenitrothion in the stomach of 376 mg fenitrothion per kg of wet fish weight, above which levels regurgitation occurred (Wildish and Lister 1973).

c. Effects on fish food organisms

Some toxicological studies have been conducted with fenitrothion on various freshwater invertebrates. These have yielded the following 24 hour LC50's for the organisms listed: 0.5 to 5.0 μg/ℓ for different species of mosquito larvae; 2.0 μg/ℓ for the stonefly nymph *Acroneuria* sp.; 32 μg/ℓ for small crayfish, *Orconectes limosus*; 50 μg/ℓ for the cladoceran, *Daphnia pulex*; 66 μg/ℓ for the dragonfly nymph, *Ophiogomphus* sp.; greater than 100 μg/ℓ for the amphipod, *Gammarus locustris* and large crayfish, *O. limosus*; 186 μg/ℓ for the alderfly larva, *Nigronia serricornis*; 610 μg/ℓ for the caddisfly larva, *Pycnosyche* sp.; 40.4 mg/ℓ for the cranefly larvae, *Eriocera spinosa*, and greater than 50 mg/ℓ for the snail, *Symnaea elodos* (Wildish and Phillips 1972, Flannagan 1973, McLeese 1976). Rorke *et al* (1974) reported LD 50 values (dosage of insecticide lethal to 50% of the test organisms) of 175 μg/ℓ for fenitrothion and 140 μg/ℓ for fenitro-oxon applied directly to the foot of estivating snails, *Helix aspersa*.

Many studies have been conducted to determine the effects of fenitrothion on bottom fauna populations in streams (e.g. Flannagan 1973, Peterson and Zitko 1974, Eidt 1975, review in Kingsbury 1975). These studies have generally shown that aerial applications of fenitrothion cause increases in the drift of aquatic insects but do not seriously deplete the standing crop of benthos. Some attempts have been made to determine if the reductions in biomass of fish food caused by fenitrothion spraying are reflected in reduced fish growth. MacDonald and Penney (1968) found no difference between growth of salmon parr sampled from fenitrothion treated and control streams as measured by calculation of average condition factors. Symons and Harding (1974) found that the average early summer increase in biomass of fish and salamanders in three fenitrothion sprayed streams was less than the average increase in two unsprayed streams. They reported this decrease in biomass to be about one-quarter the effect found in a stream where fish food was almost completely eliminated by the addition of levels of fenitrothion not lethal to fish.

Very few determinations have been made on the quantities of fenitrothion accumulated by fish food organisms. Wildish and Lister (1973) quote levels of fenitrothion in aquatic insects from treated areas ranging from 0.15 to 3.19 μg/g. Their studies show this to be 3,000 times less than the levels of fenitrothion which must be fed to brook trout in the laboratory to produce behavioral changes. They conclude that it is unlikely that ingestion of insects killed by operational spray dosages of fenitrothion can cause direct lethal or sublethal effects in salmonids. Crayfish, *Orconectes virilis* (Hagen), caged in a fenitrothion treated stream accumulated whole body residues up to 1.37 μg/g without suffering mortality or behavioral changes (Leonhard, 1974).

d. Persistence and fate in aquatic ecosystems.

The hydrolysis of fenitrothion and the subsequent formation of 3-methyl-4-nitrophenol has been shown to proceed very slowly under environmenal conditions (Zitko and Cunningham, 1974). Despite this, fenitrothion has been found to disappear rapidly from natural waters, indicating that processes other than hydrolysis are important in its degradation. Zitko and Cunningham (1974) found a half-life of 30 to 50 hours for fenitrothion in river water and attributed this rapid disappearance to microbiological processes. Lockhart *et al* (1973) found that fenitrothion in a Pyrex® flask exposed to sunlight disappeared far more quickly (half time of less than a day) than in an aluminum foil covered flask and concluded that photodecomposition was probably an important mechanism of fenitrothion disappearance.

anhydrous sodium sulfate. The separatory funnel was rinsed with 10 mℓ of toluene and then the sodium sulfate was rinsed with an additional 40 mℓ. The toluene portion was collected in a brown glass bottle, sealed and stored in a dry ice chest for transportation back to the laboratory. There it was flash-evaporated to a small volume, transferred to a graduated centrifuge tube and adjusted to a volume of 10 mℓ for GLC analysis without further cleanup.

GLC analysis was carried out with a Hewlett-Packard model 7610A gas chromatograph (GC) fitted with a flame photometric detector. Operating parameters of the GC are given in Table 3. This method allows for identification of the parent compound, fenitrothion, and two of its metabolites, fenitrooxon and S-methyl fenitrothion. Gas chromatographs were standardized with freshly prepared solutions of analytical grade samples obtained from the Sumitomo Chemical Company, Japan.

3. Fenitrothion extraction and analysis - Animal Tissue.

Prior to treatment of Lac Tassel, native smallmouth bass, *Micropterus dolomieu* Lacépède, white suckers, *Catastomus commersoni* (Lacépède), fallfish, *Semotilus corporalis* (Mitchill) and brown bullheads, *Ictalurus nebulosus* (Lesueur) were trap netted and held in cages along the shoreline. Freshwater clams (*Eulamellibranchia:Unionidae*) were also collected and held at the same site. Following treatment of the lake, individual fish of each species available were taken from the cages at intervals, killed, wrapped in aluminum foil and frozen on dry ice. Dead fish from the cages were also removed and kept for analysis, as were "wild" fish found dead or distressed in the lake. When no caged fish were left, "wild" fish for GLC analysis were trapped or angled from the lake wherever possible. Clams were sampled for GLC analysis by removing five live individuals from the cage, removing them from their

Table 3

Operating parameters of Hewlett-Packard 7610A gas chromatograph

| | |
|---|---|
| Detector | FPD (P-mode) |
| Column: | |
| Length | 1.83 m |
| Inside diameter | 4 mm |
| Support | Chromosorb W, AW-DMCS |
| Mesh | 80/100 |
| Temperature: | |
| Injection port | 240°C |
| Oven | 195°C |
| Detector | 175°C |
| Gas flow: | |
| Nitrogen (carrier) | 1.30 ml/s |
| Air | 2.50 ml/s |
| Oxygen | 0.83 ml/s |
| Hydrogen | 0.33 ml/s |
| Attenuation | 32 |
| Range | $10^3$ |
| Chart speed | 0.21 mm/s |
| Retention time | 4.4 min. (fenitrothion) |

shells, wrapping them together in aluminum foil and freezing them on dry ice. On one occasion (32 hours after treatment), a sample of clams was collected at a depth of 2 m and sealed there in a plastic bag to compare their accumulated residue level with clams from the surface cage sampled at the same time. Fish and clams sampled for residue analysis are summarized in Table 4.

Individual fish and pooled clams were weighed and fenitrothion and its metabolites extracted from them in 200 mℓ of pesticide grade ethyl acetate in a Sorvall-Omni-Mixer (5 min. at speed 6). The extract was filtered through a sharkskin filter paper and washed with an additional 25 mℓ of ethyl acetate. An aliquot of the extract was taken proportional to the extract from 5 g of animal tissue. After being passed through a plug (50 g) of anhydrous sodium sulfate into a 500 mℓ round-bottomed flask, this extract was flash-evaporated to 5 mℓ. The residue was dissolved in 25 mℓ of acetonitrile and partitioned twice with 25 mℓ of hexane. The hexane phase was discarded and the acetonitrile phase flash-evaporated to approximately 2 mℓ. The residue was transferred quatitatively to a column containing 2.5 g of an activated charcoal-Celite 545 mixture (6:4 w/w ratio) between two 5 g layers of anhydrous sodium sulfate, then eluted with 100 mℓ of 25% benzene in ethyl acetate. The eluate was then flash-evaporated to 2 mℓ for GLC analysis. Gas chromatograph operating conditions were the same as those used in analysis of residues in water.

Samples of fish tissue, water, sediment, soil and balsam fir foliage were collected at Lac Tassel on 18 May 1976, to analyze for persistent fenitrothion residues. The extraction, cleanup and analysis of residues in sediment, soil and foliage were similar to those of Yule and Duffy (1972).

Table 4

Fish and clams collected for GLC analysis from Lac Tassel

| | Time relative to treatment | Caged Live | Caged Dead | "Wild" |
|---|---|---|---|---|
| Smallmouth bass | 15 min. | | | X (Distressed)* |
| | 6 hr. | X | | |
| | 12 hr. | X | | |
| | 26.5 hr. | X | X | |
| | 36 hr. | X | X | |
| | 50 hr. | X | X | |
| | 75 hr. | X | X | |
| | 5 days | X | | X (T) |
| | 8 days | X | | X (A) |
| Fallfish | 6 hr. | X | | |
| | 12 hr. | X | | |
| | 26.5 hr. | X | | |
| | 30 hr. | | | X (Dead)* |
| | 36 hr. | X | | |
| | 50 hr. | X | X | X (T) |
| | 75 hr. | | X | X (T) |
| White suckers | 6 hr. | X | | |
| | 12 hr. | | X | |
| | 50 hr. | | | X (T) |
| | 75 hr. | | | X (T) |
| | 5 days | | | X (T) |
| | 1 year | | | X (T) |
| Brown bullheads | 6 hr. | X | X | |
| | 12 hr | X | X | |
| | 26.5 hr. | | X | |
| | 51 hr. | | | X (T) |
| Freshwater clams | 26.5 hr. | X | | |
| | 32 hr. | X | | X (Collected from 2 m) |
| | 36 hr. | X | | |
| | 50 hr. | X | | |
| | 75 hr. | X | | |
| | 5 days | X | | |
| | 8 days | X | | |

* - distressed and dead wild fish were found on surface of the lake.

T - captured in a trap net.

A - caught angling with lures.

c. Biological sampling

1. Zooplankton

Zooplankton populations in the study lakes were sampled with a Schindler-Patalas plankton trap (Schindler, 1969). The trap was lowered to the desired depth and a 12ℓ water sample taken and strained through a 154 mesh to the cm straining net to capture the zooplankton present in this volume of water. On each sampling date samples were taken from the shoreline and from the surface, 4 m and 8 m at a buoy anchored at a deep station in each lake. All zooplankton samples were preserved with formaldehyde and later counted and identified in the laboratory by placing them in a grided dish under a dissecting microscope.

2. Bottom fauna and insect emergence

Bottom fauna populations were sampled with an Ekman grab which took 232 $cm^2$ bottom samples. Ten samples were taken from Lac Tassel on each sampling date while five were collected from Lac Herman. Samples were taken from the same portion of shoreline on each occasion and from a relatively narrow range of depths (1 to 3 m). All bottom samples were preserved with formaldehyde in the field in their entirety and organisms later separated from substrate in the laboratory with the aid of a "bubbler" (Kingsbury and Beveridge, 1977). Benthic organisms were then counted and identified to order or family.

Aquatic insects emerging as adults from the surface of the study lakes were sampled with submerged emergence traps (Flannagan and Lawler, 1972) suspended from styrofoam floats. Ten traps were set along the shoreline of Lac Tassel while five were used in Lac Herman. Adult insects which had emerged into the traps were removed daily, counted and identified to order.

3. Fish

The native fish populations of the study lakes were sampled periodically by leaving gill nets set in the lakes overnight. Gangs of gill nets with 30 m sections of various mesh size (1.3 to 5.1 $cm^2$) were run from points of attachment along the shoreline in the late afternoon and left until the following morning. Fish caught in the net were removed and preserved whole with formaldehyde. An incision was made into the abdominal cavity of each fish to facilitate penetration of the preservative and stop digestive processes within the stomach and intestine.

Preserved gill net catches were returned to the laboratory where a representative sample of twenty fish of each species was selected for measuring, weighing sexing and analysis of stomach contents. It was not always possible to capture twenty fish of each species for each sample and on some occasions bass and fallfish samples from gill nets were supplemented with fish caught angling with lures in order to increase the sample size. After recording the total length, fork length, preserved weight and sex of each fish, the stomach and intestine was removed and preserved until a later date when the contents of the digestive tract were removed, their volume recorded and their composition determined under a dissecting microscope. The contents of only the stomach were analyzed for fish with distinct stomachs (smallmouth bass, brook trout, brown bullhead) but the contents of the entire digestive tract was analyzed for fish without a distinct stomach (white sucker, fallfish). In measuring the volume of the digestive tract contents the amount of non-food material present (ingested substrate, parasites, etc.) was estimated and the measured volume corrected accordingly so as to only represent actual volume of food items. No measurements were taken of the volume of food present in white sucker digestive tracts because of the large proportion of non-food material present in most individual digestive tracts.

Some direct observations on native fish populations and smallmouth bass reproduction were made in Lac Tassel with the aid of scuba and snorkeling equipment.

B. Toxicity of Fenitrothion to Different Fish Species

Static bioassays were conducted in the laboratory to determine the toxicity of fenitrothion to a number of fish species native to small Quebec lakes. Groups of small fish suitable for this kind of testing were collected from a number of locations close to Ottawa, Ontario (Table 5). Pumpkinseeds, *Lepomis gibbosus* (Linnaeus), largemouth bass, *Micropterus salmoide* (Lacépède), golden shiners, *Notemigonus crysoleucas* (Mitchill), white suckers and brown bullheads were collected from ponds, creeks and rivers with a seine net. Smallmouth bass fry just off the nest were collected at Lac Tassel with a hand net. Brook trout were obtained from the Quebec Service de Pisciculture hatchery at Lac de Écorces, Quebec. All groups of fish were held in the laboratory at 19°C for a period of not less than a week before being used in bioassays.

Bioassays were carried out in 48.5 x 38.0 x 20.0 cm polycarbonate animal cages (Maryland Plastics, Inc.) in a temperature controlled room held at 19 ± 1°C. Twenty litres of water were added to each test container and left overnight before adding the toxicant and test fish. The depth of water in each tank was 12 cm with a surface area of 0.176 $m^2$. Fenitrothion was added to the tanks as an emulsion in water made up with Arotex and Atlox used in the same proportions as in the formulation applied to Lac Tassel. Each fish species was first tested in a logrithmic series of fenitrothion

Table 5

Fish used in fenitrothion toxicity studies

| Family | Species | Collection site and date | Mean length (mm) | Mean weight (g) | Number used per test tank |
|---|---|---|---|---|---|
| Salmonidae | *Salvelinus fontinalis* (brook trout) | Lac-des-Écorces hatchery, Jan. 1976 | 115.2 | 13.4 | 5 |
| Cyprinidae | *Notemigonus crysoleucas* (golden shiner) | Larose Forest, Aug. 1975 | 68.5 | 2.5 | 10 |
| Catastomidae | *Catostomus commersoni* (white sucker) | Green Creek, Nov. 1975 | 77.5 | 4.2 | 5 |
| Ictaluridae | *Ictalurus nebulosus* (brown bullhead) | Larose Forest, Aug. 1975 | 87.9 | 7.0 | 5 |
| Centrarchidae | *Lepomis gibbosus* (pumpkinseed) | Larose Forest, Aug. 1975 | 34.8 | 0.4 | 10 |
| | *Micropterus dolomieu* (smallmouth bass) | Lac Tassel, June 1976 | 7.0 | 0.02 | 20 |
| | *Micropterus salmoides* (largemouth bass) | Ottawa River, July 1976 | 53.2 | 1.8 | 10 |

concentrations (1.0, 2.2, 4.7 and 10 mg/ℓ) with additional intermediate concentrations used where more data were necessary. A control group of fish were exposed to a mixture of Arotex and Atlox equal to the amount present in the highest test concentration. After the toxicant had been added and stirred into the test tanks, from five to twenty test fish were placed in each tank in random fahsion. Two tanks of five brook trout, white suckers and brown bullhead were tested at each concentration, while single tanks containing ten individuals were used for pumpkinseeds, large-mouth bass and golden shiners. Twenty smallmouth bass were tested in a single tank at each fenitrothion concentration. The fish were not fed and the water was not aerated during the duration of the bioassays. Fish mortality and symptoms of poisoning were recorded 0.5, 1, 3, 6, 12, 24, 36 and 48 hours after the tests were started and at 24 hour intervals beyond this time. All dead fish were removed from the tanks at the times mortality was being recorded. All tests were run for 96 hours and some were extended beyond this time where mortality was still occurring at the low test concentrations of fenitrothion.

# III RESULTS

## A. Field Studies

### a. Water chemistry and weather data

Both Lac Herman and Lac Tassel showed an extensive degree of thermal stratification by the third week of May in 1975 (Figs. 5 and 6). Lac Herman had quite low dissolved oxygen levels in its bottom waters throughout the spring and early summer (Table 6), indicating that the lake waters did not undergo complete mixing between the ice going out and the onset of thermal stratification. By August Lac Herman's bottom waters showed severe oxygen depletion. Dissolved oxygen levels in Lac Tassel's bottom waters decreased to a lesser extent over the summer (Table 7). Both lakes underwent complete turnover and oxygen replenishment in May of 1976.

Weather data around the treatment date are presented in Table 8. Moderate to heavy rainfall fell 64 and 94 hours after treatment of the lake. Weather conditions at the time the lake was treated were highly conducive to a heavy deposit of emitted spray products. The low air temperature (2.2°C) and high relative humidity (100%) minimized loss by evaporation, while the complete absence of wind restricted off-target drift.

### b. Distribution and persistence of fenitrothion residues in Lac. Tassel.

#### 1. Deposit

Measurement by GLC analysis and computerized spot counting show a relatively high and evenly distributed deposit of emitted spray products onto the surface of Lac Tassel (Table 9). The somewhat lower and more

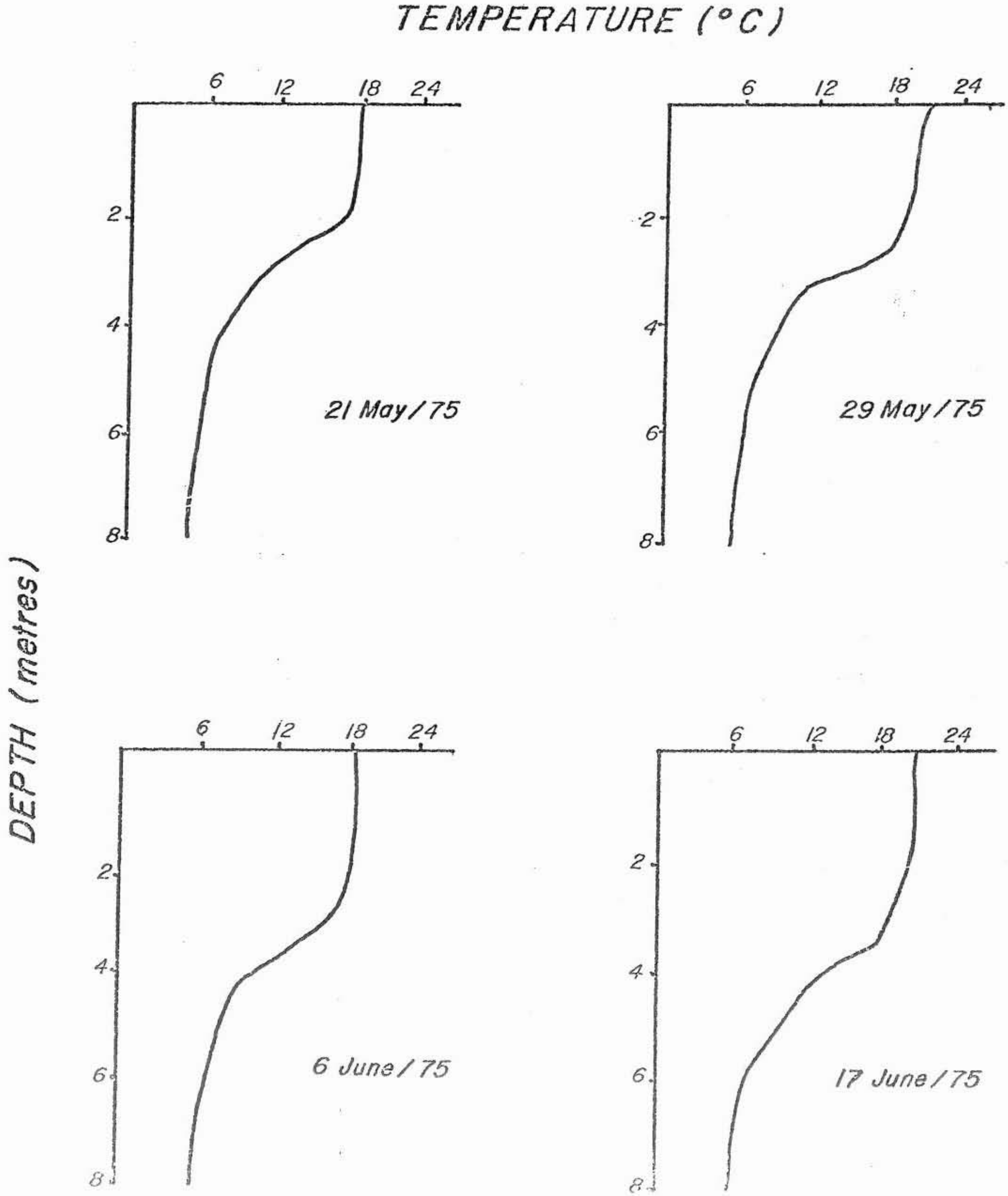



Fig. 5. Temperature profiles in Lac Herman, Quebec, May 1975 to May 1976.

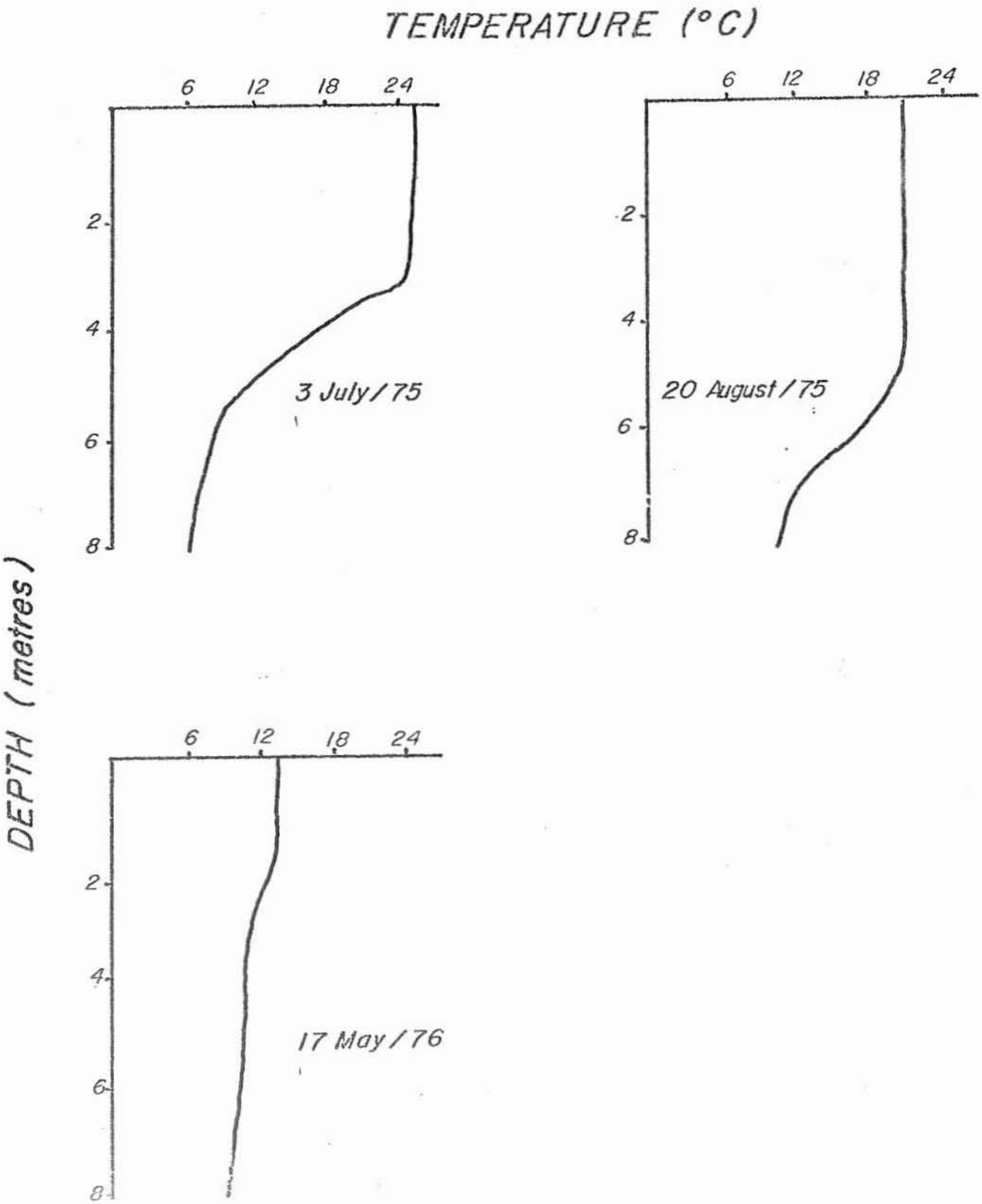

TEMPERATURE (°C)
DEPTH (metres)
6
12
18
24
2
4
6
8
3 July/75
20 August/75
17 May/76

Fig. 5. (Cont'd.)

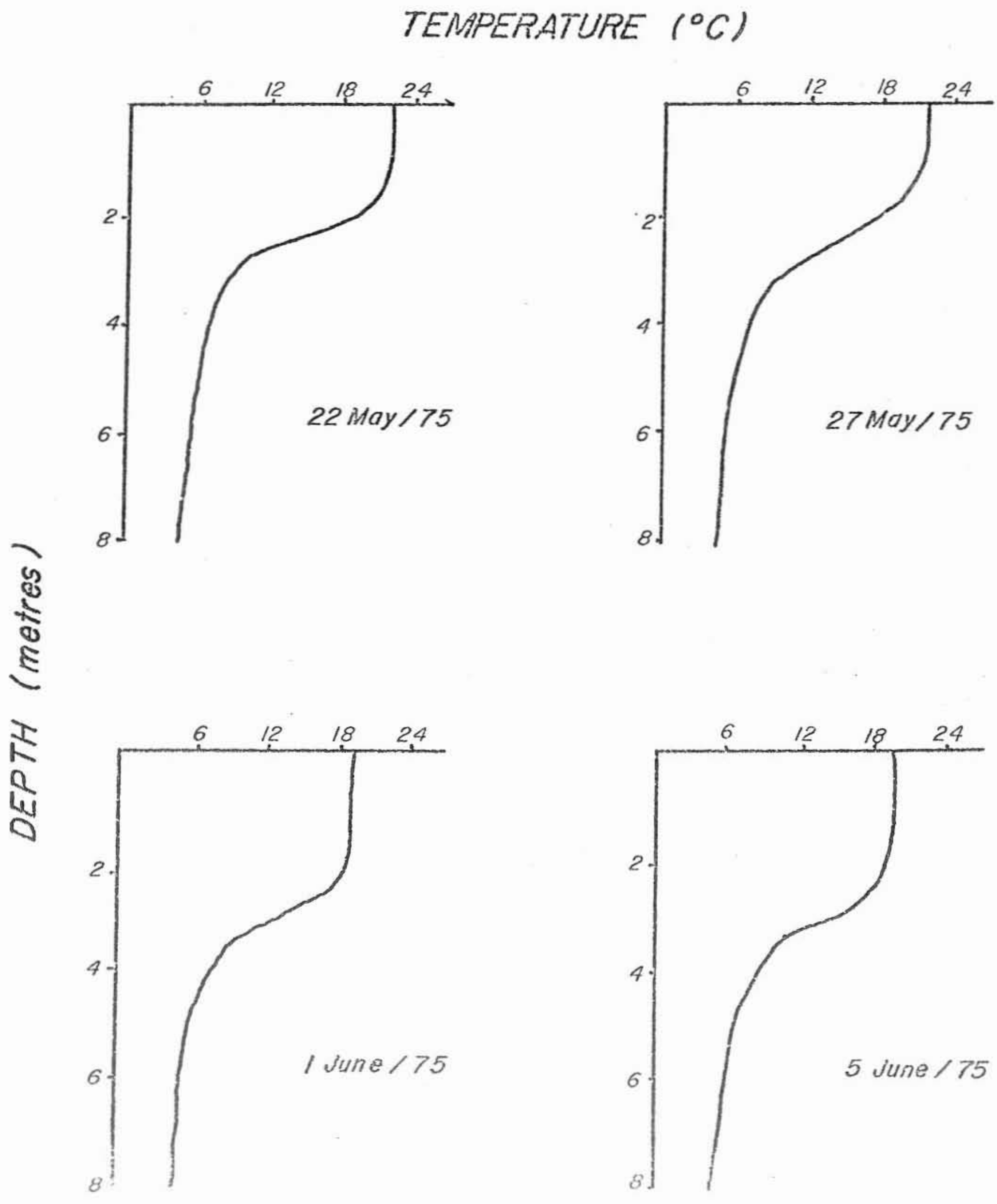



Fig. 6. Temperature profiles in Lac Tassel, Quebec, May 1975 to May 1976.

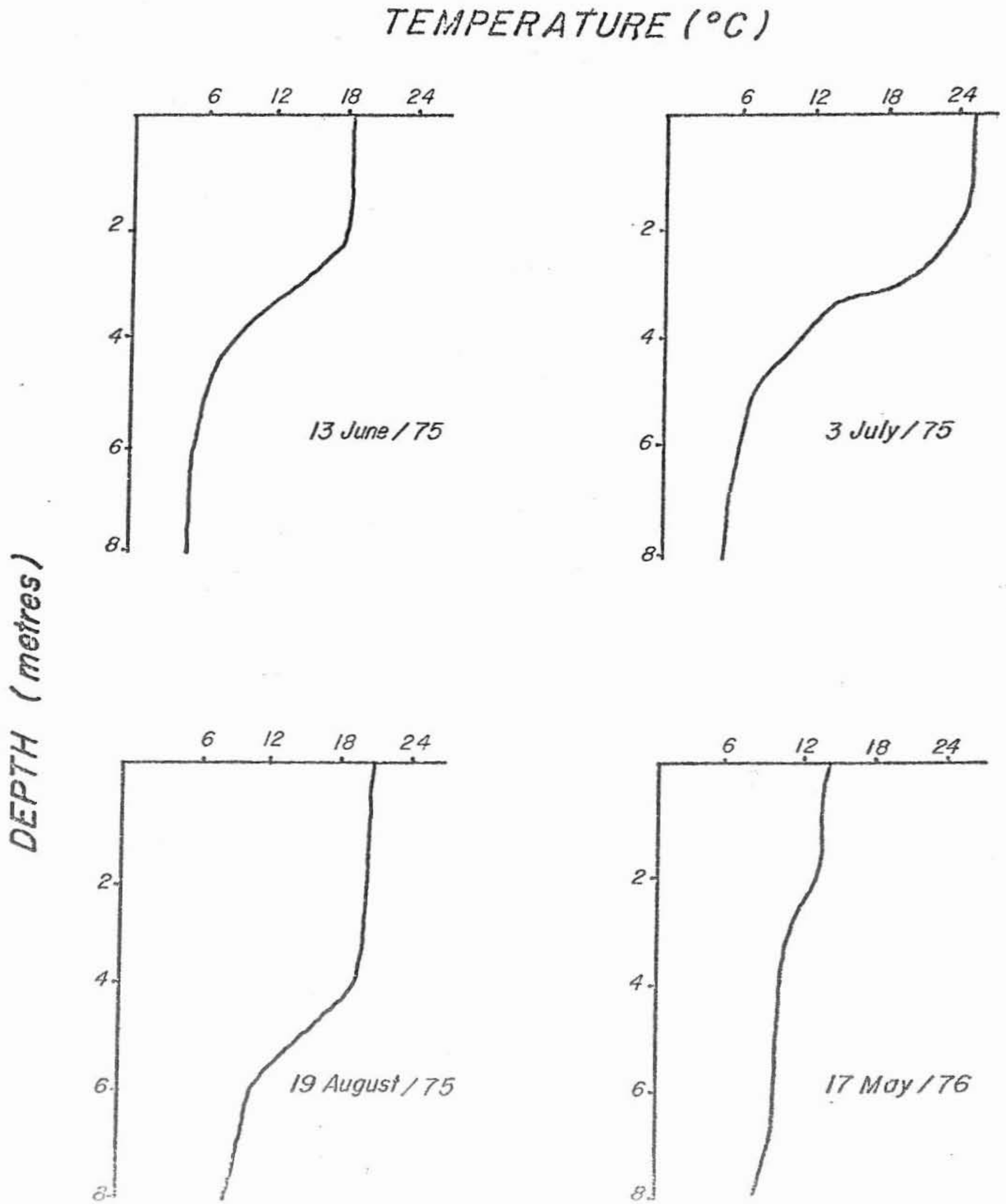

TEMPERATURE (°C)
DEPTH (metres)
6
12
18
24
2
4
6
8
13 June / 75
3 July / 75
19 August / 75
17 May / 76

Fig. 6. (Cont'd.)

Table 6

Water chemistry parameters in Lac Herman, May 1975 to May 1976

| Date | Secchi disc reading metres | Depth metres | Dissolved oxygen mg/ℓ | pH | Alkalinity gpg $CaCO_3$ * | Hardness gpg $CaCO_3$* |
|---|---|---|---|---|---|---|
| 21 May 1975 | 3.50 | Surface | 11 | 6.5 | 2 | 2 |
| | | 4 | 9 | | | |
| | | 8 | 4 | 6.0 | 1 | 1 |
| 29 May 1975 | 3.75 | Surface | 11 | 6.6 | 1 | 1 |
| | | 4 | 11 | | | |
| | | 8 | 6 | 6.0 | 1 | 1 |
| 6 June 1975 | 3.50 | Surface | 9 | 6.4 | 1 | 1 |
| | | 4 | 11 | | | |
| | | 8 | 5 | 6.0 | 1 | 1 |
| 17 June 1975 | 4.00 | Surface | 9 | 6.5 | 1 | 2 |
| | | 4 | 10 | | | |
| | | 8 | 3 | 6.0 | 1 | 2 |
| 3 July 1975 | 4.00 | Surface | 9 | 7.0 | 1 | 2 |
| | | 4 | 7 | | | |
| | | 8 | 6 | 6.0 | 1 | 2 |
| 8 August 1975 | 5.00 | Surface | 8 | 6.8 | 1 | 1 |
| | | 4 | 8 | | | |
| | | 8 | 1 | 6.0 | 1 | 2 |
| 17 May 1975 | 3.50 | Surface | 12 | 6.7 | 1 | 2 |
| | | 4 | 12 | | | |
| | | 8 | 12 | 6.5 | 1 | 2 |

* grains per gallon calcium carbonate.

Table 7

Water chemistry parameters in Lac Tassel

| Date | Secchi disc reading metres | Depth metres | Dissolved oxygen mg/ℓ | pH | Alkalinity gpg $CaCO_3$* | Hardness gpg $CaCO_3$* |
|---|---|---|---|---|---|---|
| 22 May 1975 | 3.50 | Surface | 10 | 6.3 | 1 | 2 |
| | | 4 | 10 | | | |
| | | 8 | 7 | 6.0 | 1 | 2 |
| 27 May 1975 | 3.25 | Surface | 9 | 6.6 | 1 | 1 |
| | | 4 | 10 | | | |
| | | 8 | 9 | 6.0 | 1 | 1 |
| 1 June 1975 | 3.25 | Surface | 10 | 6.5 | 1 | 2 |
| | | 4 | 11 | | | |
| | | 8 | 7 | 6.0 | 1 | 2 |
| 5 June 1975 | 3.50 | Surface | 10 | 6.7 | 1 | 1 |
| | | 4 | 11 | | | |
| | | 8 | 8 | 5.8 | 1 | 1 |
| 13 June 1975 | 3.00 | Surface | 9 | 6.8 | 1 | 1 |
| | | 4 | 9 | | | |
| | | 8 | 7 | 5.5 | 1 | 1 |
| 3 July 1975 | 3.50 | Surface | 8 | 7.0 | 1 | 1 |
| | | 4 | 12 | | | |
| | | 8 | 5 | 6.0 | 1 | 2 |
| 19 August 1975 | 3.00 | Surface | 8 | 6.8 | 1 | 1 |
| | | 4 | 11 | | | |
| | | 8 | 4 | 5.8 | 1 | 1 |
| 17 May 1976 | 2.50 | Surface | 10 | 6.7 | 1 | 2 |
| | | 4 | 10 | | | |
| | | 8 | 10 | 6.7 | 1 | 2 |

* grains per gallon calcium carbonate.

Table 8

Meteorolgical data from Lac Tassel, 24 May to 4 June, 1975

| | Temperature ($^{o}$C) | | | Atmospheric pressure (millibars Hg) | | Solar radiation (cal/cm$^2$/day) | Rainfall (cm) |
|---|---|---|---|---|---|---|---|
| | Max. | Min. | Mean | High | Low | | |
| 24 May | 32.2 | 5.0 | 15.6 | 1003 | 1000 | 558 | 0.00 |
| 25 May | 30.0 | 1.1 | 16.0 | 1006 | 1002 | 434 | 0.00 |
| 26 May | 20.6 | 10.0 | 15.8 | 1002 | 990 | 93 | 2.59 |
| 27 May | 22.2 | 5.5 | 13.2 | 996 | 988 | 93 | 1.47 |
| 28 May | 24.4 | 2.2 | 15.6 | 1000 | 992 | 636 | 0.00 |
| 29 May | 27.8 | 0.0 | 12.5 | 1005 | 1000 | 434 | 0.00 |
| 30 May | 15.6 | 5.0 | 12.9 | 1001 | 989 | 78 | 0.65 |
| 31 May | 25.0 | 8.9 | 16.8 | 992 | 987 | 264 | 0.00 |
| 1 June | 18.9 | 5.6 | 12.0 | 997 | 990 | 217 | 1.12 |
| 2 June | 21.7 | 0.6 | 11.0 | 1002 | 997 | 512 | 0.00 |
| 3 June | 26.7 | 0.6 | 14.2 | 999 | 993 | 496 | 0.00 |
| 4 June | 24.4 | - | - | - | - | 542 | - |

Table 9

Deposit of emitted spray products on the surface of Lac Tassel, 28 May, 1976

| Deposit sampler | Method of measuring deposit | | | | | |
|---|---|---|---|---|---|---|
| | GLC analysis | | Computerized spot counting | | Colorimetric analysis | |
| | kg/ha AI deposited* | % deposit | ℓ/ha deposited** | % deposit | ℓ/ha deposited** | % deposit |
| 1 | 0.161 | 38.3 | 0.793 | 54.3 | 0.161 | 10.7 |
| 2 | 0.196 | 46.7 | 0.706 | 48.4 | 0.088 | 6.0 |
| 3 | 0.164 | 39.0 | 0.657 | 45.0 | 0.117 | 8.0 |
| 4 | 0.241 | 57.4 | 0.390 | 26.7 | 0.102 | 7.0 |
| 5 | 0.096 | 22.8 | 0.097 | 6.6 | 0.066 | 4.5 |
| 6 | 0.270 | 64.3 | 0.938 | 64.2 | 0.197 | 13.5 |
| 7 | 0.140 | 33.3 | 0.422 | 28.9 | 0.073 | 5.0 |
| 8 | 0.270 | 64.3 | 0.192 | 13.2 | 0.102 | 7.0 |
| 9 | 0.163 | 38.8 | 0.472 | 32.3 | 0.066 | 4.5 |
| 10 | 0.113 | 26.9 | 0.093 | 6.4 | 0.036 | 2.5 |
| Mean | 0.181 | 43.1 | 0.476 | 32.6 | 0.101 | 6.9 |

* 0.420 kg/ha AI emitted

** 1.460 ℓ/ha emitted

variable results from spot counting may reflect loss of water from descending spray droplets through evaporation. Mean deposit determined by colorimetric analysis is four to five times smaller than measured by the other methods. This is believed to be due to fading of the Rodamine B dye between landing on the aluminum pans and being washed off for analysis, an interval of about 70 days. Results more consistent with the other methods of deposit assessment may have been obtained by washing the dye off the pans in the field with a solvent in which the dye had been shown to be stable. An interesting result of the GLC analysis is that from 5.0 to 37.5% (mean 22.8%) of the active ingredient (AI) measured was present as fenitrooxon. This may be due to catalysis of the oxidation of fenitrothion by the aluminum pans in the presence of solar radiation.

2. Dispersion and distribution in lake waters

Pre-treatment water samples from Lac Tassel contained total residues of 0.16 μg/ℓ fenitrothion and fenitrooxon, with most of this consisting of the oxon. Lac Herman surface waters contained 0.18 μg/ℓ fenitrooxon. Following treatment of Lac Tassel, fenitrothion residues rapidly dispersed throughout the lake waters (Table 10). Peak total residues of 21.6 μg/ℓ were present in the surface waters after one hour and by twelve hours residue levels of about 3 μg/ℓ were found at all depths between the surface and 4 m. Residues in the bottom waters (6 m) peaked at 2.14 μg/ℓ (after twenty-six hours) and beyond this time residues below 2 m generally declined, while residues between the surface and 2 m remained relatively constant for a few days before gradually declining to less than 1 μg/ℓ after two weeks. Residues at the surface along the shoreline were often quite different from residues found in surface waters at the deep station. Fenitrooxon levels generally remained

Table 10

Fenitrothion and fenitrooxon residues* in Lac Tassel, 22 May 1975 to 17 May 1976.

| Time relative to treatment | | Pre-spray | + 1 h | + 6 h | + 12 h | + 26 h | + 36 h | + 50 h | + 75 h | + 5 days | + 8 days | + 14 days | + 1 year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shoreline Station | | | | | | | | | | | | | |
| Surface | Fenitrothion | | 4.63 | 11.33 | 5.67 | 2.87 | 1.47 | N.D. | 2.83 | 2.20 | 0.78 | 0.15 | |
| | Fenitrooxon | | 0.35 | 0.17 | 0.37 | 0.24 | 0.31 | N.D. | 0.05 | 0.08 | 0.13 | 0.09 | |
| | Total | | 4.98 | 11.50 | 6.04 | 3.11 | 1.78 | N.D. | 2.88 | 2.28 | 0.91 | 0.24 | |
| Deep Station | | | | | | | | | | | | | |
| Surface | Fenitrothion | N.D. | 21.33 | 7.67 | 2.63 | 2.90 | 1.47 | 3.50 | 3.90 | 2.77 | 0.23 | 0.57 | T |
| | Fenitrooxon | 0.16 | 0.29 | 0.55 | 0.26 | 0.23 | 0.28 | 0.26 | 0.34 | 0.28 | 0.10 | 0.16 | N.D. |
| | Total | 0.16 | 21.62 | 8.22 | 2.89 | 3.13 | 1.75 | 3.76 | 4.24 | 3.05 | 0.33 | 0.73 | T |
| 1 m | Fenitrothion | | 15.47 | 7.57 | 2.40 | 1.75 | 1.71 | 2.74 | Sample lost | 2.67 | 2.17 | 0.67 | |
| | Fenitrooxon | | 0.18 | 2.63 | 0.23 | 0.26 | 0.32 | 0.28 | | 0.20 | 0.27 | 0.16 | |
| | Total | | 15.65 | 10.20 | 2.63 | 2.01 | 2.03 | 3.02 | | 2.87 | 2.44 | 0.83 | |
| 2 m | Fenitrothion | | 11.80 | 5.67 | 2.86 | 1.67 | 3.88 | 1.63 | 2.93 | 3.07 | 1.83 | 0.69 | |
| | Fenitrooxon | | 0.70 | 0.33 | 0.26 | 0.25 | 0.25 | 0.24 | 0.25 | 0.24 | 0.60 | 0.19 | |
| | Total | | 12.50 | 6.00 | 3.12 | 1.92 | 4.13 | 1.87 | 3.18 | 3.31 | 2.43 | 0.88 | |
| 4 m | Fenitrothion | | 1.25 | 0.40 | 2.13 | 0.83 | 1.50 | 1.13 | 0.45 | 0.17 | 0.08 | 0.12 | 0.02 |
| | Fenitrooxon | | 0.70 | 0.29 | 0.27 | 0.28 | 0.52 | 0.35 | 0.21 | 0.09 | 0.13 | 0.10 | N.D. |
| | Total | | 1.95 | 0.69 | 2.40 | 1.11 | 2.02 | 1.48 | 0.66 | 0.26 | 0.21 | 0.22 | 0.02 |
| 6 m | Fenitrothion | 0.04 | 0.36 | 0.24 | 0.24 | 0.90 | 0.24 | 0.07 | 0.06 | 0.30 | 0.32 | 0.07 | |
| | Fenitrooxon | 0.12 | 0.70 | 0.20 | 0.14 | 1.24 | 0.23 | 0.17 | 0.12 | 0.10 | 0.18 | 0.07 | |
| | Total | 0.16 | 1.06 | 0.44 | 0.38 | 2.14 | 0.47 | 0.24 | 0.18 | 0.40 | 0.50 | 0.14 | |
| 8m | Fenitrothion | | | | | | | | | | | | 0.03 |
| | | | | | | | | | | | | | N.D. |
| | Total | | | | | | | | | | | | 0.03 |

* expressed in μg/ℓ (ppb)    N.D. - not detected    T - Traces (< 0.02 μg/ℓ)

constant around the 0.20 - 0.30 μg/ℓ level but occasionally were found to be up to ten times higher. Water samples did not contain any detectable amounts of S-methyl-fenitrothion.

A year after treatment only trace amounts of fenitrothion were present in Lac Tassel surface waters while bottom waters contained 0.03 μg/g fenitrothion and the insecticide was still present in small amounts in balsam fir foliage (0.08 μg/g) and soil (0.01 μg/g). No fenitrooxon was detected in either aquatic or terrestrial samples.

3. Accumulation and persistence in fish and clams

Fenitrothion residues were found in all fish and clams sampled over the first eight days after treatment of Lac Tassel (Table 11). Distinct differences were apparent in the extent to which live individuals of different species of fish accumulated fenitrothion residues (Fig. 7). White suckers accumulated the highest residues, followed by fallfish, brown bullheads and smallmouth bass. Residues also persisted longer in white suckers. All fish species reached maximum residue levels within about 24 hours of treatment and "wild" fish appeared to accumulate similar residues to caged fish. Dead fish taken from the cages contained residues similar to or lower than those in live fish sampled at the same time. Clams contained relatively small amounts of fenitrothion. Neither fish nor clams contained detectable quantities of S-methyl fenitrothion and fenitrooxon was found only in smallmouth bass sampled within 36 hours of treatment of the lake.

A smallmouth bass found distressed on the surface of the lake 15 minutes after treatment contained more fenitrothion than any other bass sampled, indicating that it was exposed to and rapidly accumulated relatively concentrated insecticide. The fallfish found dead in the lake

Table 11

Fenitrothion residues* in fish and clams from Lac Tassel, 28 May to 5 June, 1975

| Time relative to treatment | +15 min | +6h | +12h | +26.5h | +30h | +32h | +36h | +50h | +75h | +5 days | +8 days |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Smallmouth bass | | | | | | | | | | | |
| Caged - live | | 0.14** | 0.18** | 0.28*** | | | 0.12** | 0.05 | 0.06 | 0.08 | 0.03 |
| Caged - dead | | | | 0.07 | | | 0.08 | 0.07 | 0.07 | | |
| Wild | 0.34 | | | | | | | | | 0.04 | 0.05 |
| Fallfish | | | | | | | | | | | |
| Caged - live | | 0.43 | 0.71 | 0.76 | | | 0.54 | 0.34 | | | |
| Caged - dead | | | | | | | | 0.35 | 0.28 | | |
| Wild | | | | | 0.18 | | | 0.36 | 0.40 | | |
| White suckers | | | | | | | | | | | |
| Caged - live | | 1.01 | | | | | | | | | |
| Caged - dead | | | 0.15 | | | | | | | | |
| Wild | | | | | | | | 0.91 | 0.89 | 0.91 | |
| Brown bullheads | | | | | | | | | | | |
| Caged - live | | 0.28 | 0.44 | | | | | | | | |
| Caged - dead | | 0.11 | 0.24 | 0.41 | | | | | | | |
| Wild | | | | | | | | 0.24 | | | |
| Clams | | | | | | | | | | | |
| Caged - live | | | | 0.06 | | 0.07 | 0.03 | 0.03 | 0.02 | 0.12 | 0.02 |
| Wild | | | | | | 0.02 | | | | | |

* expressed in µg/g (ppm) ** includes 0.02 µg/g fenitrooxon *** includes 0.03 µg/g fenitrooxon

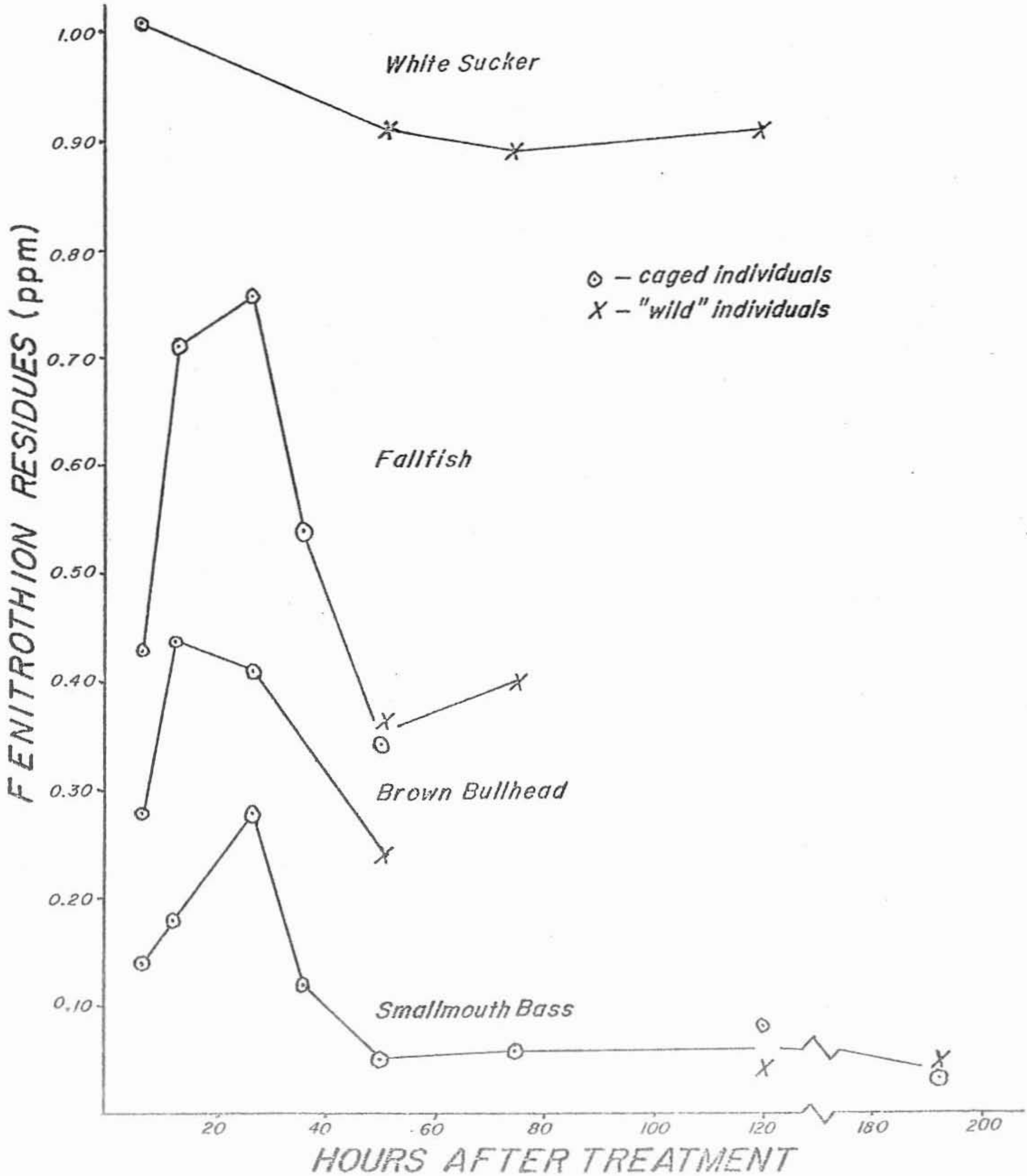



Fig. 7. Fenitrothion residues in live fish from Lac Tassel following aerial spraying of the lake.

had relatively small amounts of insecticide in it. The clams sealed at 2 m contained smaller amounts of fenitrothion than those sampled at the surface at the same time. A year after treatment 0.01 µg/g fenitrothion was found in a ripe female white sucker, but no insecticide was detected in her eggs.

C. Changes in biological populations

1. Zooplankton

Throughout the study period the genera *Daphnia* and *Holopedium* dominated cladoceran catches in zooplankton samples from the deep station in Lac Tassel (Table 12). Cladoceran populations at the deep station in Lac Herman were dominated by the genus *Bosmina* but moderate numbers of *Daphnia, Holopedium* and *Diaphanosoma* also appeared in most samples (Table 13). Both lakes had large, mixed populations of calanoid, cyclopoid and immature copepods present at their deep station. Surface zooplankton catches at the shoreline station in both lakes generally showed similar composition to deep station catches (Tables 14 and 15).

Cladoceran populations at the deep station in Lac Tassel doubled over pre-spray levels by the eighth day after treatment and then fell to low levels until increasing to near pre-spray levels in late summer. In Lac Herman, cladoceran populations increased to very high levels in early summer. Cladoceran populations at the shoreline station of Lac Tassel fell to low levels shortly after treatment while those at the shoreline in Lac Herman showed the same increase until early summer seen at the deep station. Copepod populations at both stations followed similar patterns of relative abundance in the two lakes, although actual numbers of copepods were consistently higher in Lac Herman samples. With

Table 12

Plankton trap catches* at the deep station in Lac Tassel, 22 May 1975 to 17 May 1976

| Number of days before or after treatment | -6 | | | | -1 | | | | +4 | | | | +16 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surf | 4m | 8m | Total | Surf | 4m | 8m | Total | Surf | 4m | 8m | Total | Surf | 4m | 8m | Total |
| Cladocera | | | | | | | | | | | | | | | | |
| Polyphemidae: *Polyphemus* | - | - | - | - | - | - | - | - | 1 | - | - | 1 | - | - | - | - |
| Holopedidae: *Holopedium* | 54 | 30 | - | 84 | 7 | 1 | 20 | 28 | 25 | 15 | 4 | 44 | 27 | 330 | - | 357 |
| Sididae: *Diaphanosoma* | 1 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| Daphnidae: *Daphnia* | 2 | 44 | 1 | 47 | - | 119 | 3 | 122 | - | 25 | 44 | 69 | 3 | 6 | 18 | 27 |
| *Ceriodaphnia* | - | 5 | - | 5 | - | - | - | - | - | - | - | - | - | - | - | - |
| Bosminidae: *Bosmina* | - | - | - | - | - | - | - | - | 1 | - | - | 1 | - | - | - | - |
| Macrothricidae: *Macrothrix* | 46 | - | - | 46 | - | - | 2 | 2 | - | - | - | - | - | - | - | - |
| *Ilyocryptus* | - | - | - | - | - | 7 | - | 7 | - | - | - | - | - | - | - | - |
| Immatures | - | 12 | - | 12 | - | - | - | - | - | - | - | - | - | - | - | - |
| Unknowns | - | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | - |
| Total | 103 | 91 | 1 | 195 | 7 | 128 | 25 | 160 | 27 | 40 | 48 | 115 | 30 | 336 | 18 | 384 |
| Copeopoda | | | | | | | | | | | | | | | | |
| Calanoida | 84 | 53 | 4 | 141 | 10 | 133 | 26 | 169 | - | 173 | 81 | 254 | 81 | 742 | 33 | 856 |
| Cyclopoida | - | 243 | 11 | 254 | - | 24 | 21 | 45 | - | 55 | 34 | 89 | 8 | 34 | 42 | 84 |
| Nauplii | 75 | 75 | 8 | 158 | 17 | 71 | 37 | 125 | 81 | 240 | 37 | 358 | 35 | 246 | 5 | 286 |
| Copepodids | 6 | 6 | - | 12 | - | 36 | 16 | 52 | - | 12 | 5 | 17 | 10 | - | 4 | 14 |
| Total | 165 | 377 | 23 | 565 | 27 | 264 | 100 | 391 | 81 | 480 | 157 | 718 | 134 | 1022 | 84 | 1240 |
| Diptera | | | | | | | | | | | | | | | | |
| Culicidae: *Chaoborus* | - | 1 | - | 1 | - | 1 | - | 1 | - | - | 1 | 1 | - | - | - | - |

* from single 12ℓ Shindler-Patalas plankton trap samples

Table 12 (Cont'd.)

| Number of days before or after treatment | +16 | | | | +36 | | | | +84 | | | | +354 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surf | 4m | 8m | Total | Surf | 4m | 8m | Total | Surf | 4m | 8m | Total | Surf | 4m | 8m | Total |
| Cladocera | | | | | | | | | | | | | | | | |
| Polyphemidae:*Polyphemus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Holopedidae:*Holopedium* | - | 25 | 1 | 26 | 9 | 4 | - | 13 | 14 | 7 | 1 | 22 | 59 | 44 | 3 | 106 |
| Sididae:*Diaphanosoma* | - | - | - | - | - | - | - | - | 8 | 74 | - | 82 | 1 | - | - | 1 |
| Daphnidae:*Daphnia* | - | 5 | 29 | 34 | - | 5 | 2 | 7 | 1 | 5 | 21 | 27 | 37 | 49 | 10 | 96 |
| *Ceriodaphnia* | - | - | - | - | - | - | - | - | - | 12 | - | 12 | - | - | - | - |
| Bosminidae:*Bosmina* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| Macrothricidae:*Macrothrix* | - | - | - | - | - | 2 | - | 2 | - | - | - | - | - | - | - | - |
| *Ilyocryptus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Immatures | - | - | - | - | - | - | - | - | - | - | - | - | - | 23 | - | 23 |
| Unknowns | - | 3 | - | 3 | 1 | - | - | 1 | - | - | 1 | 1 | - | - | - | |
| Total | - | 33 | 30 | 63 | 10 | 11 | 2 | 23 | 23 | 98 | 23 | 144 | 97 | 116 | 14 | 227 |
| Copeopoda | | | | | | | | | | | | | | | | |
| Calanoida | 1 | 85 | 39 | 125 | 2 | 61 | 21 | 84 | 35 | 19 | 7 | 61 | 49 | 34 | 17 | 170 |
| Cyclopoida | 10 | 14 | 39 | 63 | 12 | 11 | 107 | 130 | 32 | 67 | 12 | 111 | 25 | 76 | 25 | 126 |
| Nauplii | 13 | 515 | 7 | 535 | 70 | 36 | 18 | 124 | 23 | 77 | 1 | 101 | 86 | 112 | 32 | 230 |
| Copepodids | - | 19 | 7 | 26 | - | 14 | 8 | 22 | 8 | - | 16 | 24 | 1 | - | - | 1 |
| Total | 24 | 633 | 92 | 749 | 84 | 122 | 154 | 360 | 98 | 163 | 36 | 297 | 231 | 222 | 74 | 527 |
| Diptera | | | | | | | | | | | | | | | | |
| Culicidae:*Chaoborus* | - | - | 3 | 3 | - | - | - | - | 1 | 1 | - | 2 | - | - | - | - |

Table 13

Plankton trap catches* at the deep station in Lac Herman, 21 May 1975 to 17 May 1976

| Number of days before or after treatment | -7 | | | | +1 | | | | +20 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surf | 4m | 8m | Total | Surf | 4m | 8m | Total | Surf | 4m | 8m | Total |
| Cladocera | | | | | | | | | | | | |
| Holopedidae:*Holopedium* | - | 1 | - | 1 | 8 | - | 1 | 9 | 2 | 7 | 3 | 12 |
| Sididae:*Diaphanosoma* | 2 | 1 | - | 3 | 8 | 1 | - | 9 | 2 | 1 | 3 | 6 |
| Daphnidae:*Daphnia* | - | 2 | - | 2 | 2 | 6 | 2 | 10 | 3 | 51 | 9 | 63 |
| Bosminidae:*Bosmina* | 11 | 4 | 4 | 19 | 138 | 316 | 44 | 498 | - | 2 | 2174 | 2176 |
| Immatures | - | - | - | - | - | - | - | - | - | - | - | - |
| Total | 13 | 8 | 4 | 25 | 156 | 323 | 47 | 526 | 7 | 61 | 2189 | 2257 |
| Copepoda | | | | | | | | | | | | |
| Calanoida | 131 | 16 | 7 | 154 | 906 | 950 | 151 | 2007 | 420 | 191 | 498 | 1109 |
| Cyclopoida | 29 | 38 | 13 | 80 | 54 | 192 | 277 | 523 | 38 | 46 | 180 | 264 |
| Nauplii | 301 | 646 | 101 | 1048 | 144 | 208 | 70 | 422 | 3 | 23 | 516 | 542 |
| Copepodids | 25 | 23 | 13 | 61 | - | 18 | - | 18 | - | - | - | - |
| Total | 486 | 723 | 134 | 1343 | 1104 | 1368 | 498 | 2970 | 461 | 260 | 1194 | 1915 |

* from single 12ℓ Shindler-Patalas plankton trap samples.

Table 13 (Cont'd)

| Number of days before or after treatment | | +36 | | | | +85 | | | | +354 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Surf | 4m | 8m | Total | Surf | 4m | 8m | Total | Surf | 4m | 8m | Total |
| Cladocera | | | | | | | | | | | | |
| Holopedidae:*Holopedium* | - | - | 5 | 5 | - | - | 6 | 6 | 18 | 9 | 3 | 30 |
| Sididae:*Diaphanosoma* | 9 | 28 | 4 | 41 | - | 5 | - | 5 | 2 | - | - | 2 |
| Daphnidae:*Daphnia* | 3 | 3 | 11 | 17 | - | 102 | 58 | 160 | 7 | 15 | 5 | 27 |
| Bosminidae:*Bosmina* | 2 | - | 104 | 106 | 3 | 8 | 1 | 12 | 3 | 6 | 7 | 16 |
| Immatures | - | - | - | - | - | 6 | 5 | 11 | - | - | - | - |
| Total | 14 | 31 | 124 | 169 | 3 | 121 | 70 | 194 | 30 | 30 | 15 | 75 |
| Copepoda | | | | | | | | | | | | |
| Calanoida | 201 | 250 | 464 | 915 | 225 | 412 | 6 | 643 | 434 | 390 | 118 | 942 |
| Cyclopoida | 7 | 9 | 128 | 144 | 2 | 6 | 13 | 21 | 62 | 111 | 83 | 256 |
| Nauplii | 4 | - | 486 | 490 | 7 | 8 | 551 | 566 | 346 | 294 | 357 | 997 |
| Copepodids | - | 17 | - | 17 | - | - | - | - | - | 57 | 31 | 88 |
| Total | 212 | 276 | 1078 | 1566 | 234 | 426 | 570 | 1230 | 842 | 852 | 589 | 2283 |

Table 14

Surface plankton trap catches* at the shoreline station in Lac Tassel, 22 May 1975 to 17 May 1976

| Number of days before or after treatment | −6 | −1 | +4 | +16 | +36 | +84 | +354 |
|---|---|---|---|---|---|---|---|
| Cladocera | | | | | | | |
| Polyphemidae: *Polyphemus* | – | 10 | – | – | – | 128 | 2 |
| Holopedidae: *Holopedium* | – | 4 | 16 | – | 1 | – | – |
| Sididae: *Diaphanosoma* | – | – | – | – | – | 14 | – |
| Daphnidae: *Daphnia* | – | – | – | – | – | 1 | – |
| Bosminidae: *Bosmina* | 2 | 86 | – | – | – | – | 1 |
| Total | 2 | 100 | 16 | – | 1 | 143 | 3 |
| Copepoda | | | | | | | |
| Calanoida | 90 | 16 | – | 9 | 5 | 30 | 2 |
| Cyclopoida | 2 | 3 | 1 | 5 | 24 | 126 | 5 |
| Nauplii | 115 | 86 | 20 | 11 | 32 | 34 | 17 |
| Copepodis | 14 | – | 1 | 16 | – | – | – |
| Total | 221 | 105 | 22 | 41 | 61 | 190 | 24 |

* from single 12 ℓ Shindler-Patalas plankton trap samples

Table 15

Surface plankton trap catches* at the shoreline station in Lac Herman, 21 May 1975 to 17 May 1976.

| Number of days before or after treatment | -7 | +1 | +20 | +36 | +85 | +354 |
|---|---|---|---|---|---|---|
| Cladocera | | | | | | |
| Polyphemidae:*Polyphemus* | - | - | - | - | 1 | - |
| Holopedidae:*Holopedium* | - | - | - | - | - | 1 |
| Sididae:*Diaphanosoma* | 2 | - | - | 2 | 5 | - |
| Daphnidae:*Daphnia* | - | 1 | 1 | - | 1 | - |
| Bosminidae:*Bosmina* | 11 | 48 | 85 | 4 | 10 | 6 |
| Total | 13 | 49 | 86 | 6 | 17 | 7 |
| Copepoda | | | | | | |
| Calanoida | 116 | 528 | 28 | 7 | 16 | 112 |
| Cyclopoida | 8 | 92 | 24 | 18 | - | 36 |
| Nauplii | 684 | 114 | 41 | 14 | 25 | 276 |
| Copepodids | 37 | 24 | - | - | - | - |
| Total | 845 | 758 | 93 | 39 | 41 | 424 |

* from single 12ℓ Shindler-Patalas plankton trap samples.

the exception of copepods at the shoreline station of Lac Tassel, relative abundance of zooplankters was similar in the springs of 1975 and 1976 at both stations in the two lakes.

2. Bottom fauna and insect emergence

Bottom fauna populations in Lac Tassel and Lac Herman were very similar in numbers and composition prior to treatment (Tables 16 and 17). Total numbers of benthic organisms in Lac Tassel decreased slightly after treatment but were generally very stable over the entire summer. Dragonfly nymphs (Odonata:Anisoptera), marl beetle larvae (Coleoptera:Elmidae) and amphipods (Amphipoda) showed the most substantial reductions in numbers present in Ekman grab samples following treatment. In Lac Herman, benthic populations were stable until mid-June when large numbers of midge larvae (Diptera:Chironomidae) appeared in bottom samples. These fell to very low numbers by August. Dragonfly nymph and amphipod populations were somewhat more stable in Lac Herman than in Lac Tassel. Marl beetle larvae were not found in bottom samples from Lac Herman. Bottom fauna populations in the two lakes in May of 1976 were similar in composition and somewhat higher in numbers than in the spring of 1975.

Insect emergence trap catches in Lac Tassel and Lac Herman around the treatment date followed similar patterns (Fig. 8). Catches consisted primarily of adult midges but a few adult mayflies (Ephemeroptera) were caught in the two lakes two and three days before treatment and 20 adult caddisflies (Trichoptera) were caught emerging from Lac Tassel in the week following treatment. Two caddisflies were caught emerging from

Table 16

Benthic organisms* collected in Ekman grab samples from Lac Tassel, 22 May 1975 to 17 May 1976

| Number of days before or after treatment | -6 | -1 | +4 | +8 | +16 | +36 | +84 | +354 |
|---|---|---|---|---|---|---|---|---|
| Mean depth sampled (m) | 1.48 | 2.08 | 1.95 | 2.08 | 1.78 | 2.03 | 2.00 | 2.05 |
| hemeroptera:Ephemeridae | – | 0.1 ± 0.3 | 0.2 ± 0.4 | – | – | 0.1 ± 0.3 | 0.4 ± 0.5 | 1.5 ± 1.8 |
| :Baetidae | – | 0.1 ± 0.3 | – | – | 0.1 ± 0.3 | – | – | – |
| onata:Gomphidae | 0.3 ± 0.5 | 0.4 ± 1.0 | – | – | – | – | – | 0.2 ± 0.4 |
| :Libellulidae | 0.8 ± 1.1 | – | – | – | 0.2 ± 0.4 | – | – | 0.1 ± 0.3 |
| pidoptera:Pyralidae | – | 0.3 ± 0.5 | – | – | – | – | – | 0.1 ± 0.3 |
| ichoptera:Various families | 0.2 ± 0.4 | 0.7 ± 1.1 | 0.6 ± 0.5 | 0.6 ± 0.7 | 0.5 ± 0.5 | 0.2 ± 0.4 | 0.4 ± 0.5 | 1.1 ± 1.7 |
| galoptera:Sialidae | – | – | 0.1 ± 0.3 | – | – | – | 0.2 ± 0.5 | – |
| leoptera:Elmidae | 1.2 ± 1.3 | 1.5 ± 2.0 | 0.2 ± 0.4 | 0.4 ± 1.0 | 0.3 ± 0.5 | 0.3 ± 1.0 | 0.6 ± 1.3 | – |
| :Psephenidae | 0.1 ± 0.3 | – | – | – | – | – | – | – |
| ptera:Chironomidae | 13.0 ± 9.4 | 11.5 ± 9.4 | 10.9 ± 7.2 | 12.5 ± 4.4 | 10.1 ± 9.5 | 10.3 ± 5.8 | 11.2 ± 6.1 | 18.1 ± 6.8 |
| :Heleidae | 0.7 ± 0.8 | 0.9 ± 1.0 | 0.6 ± 0.8 | 1.4 ± 1.3 | 0.7 ± 1.3 | 0.3 ± 0.5 | 0.6 ± 0.9 | 0.9 ± 1.1 |
| :Tipulidae | – | – | 0.1 ± 0.3 | – | – | – | – | – |
| rbellaria | 0.1 ± 0.3 | – | 0.2 ± 0.6 | – | – | – | – | – |
| igochaeta | 1.4 ± 1.3 | 1.4 ± 1.8 | 0.9 ± 1.0 | 0.9 ± 1.9 | 1.2 ± 1.2 | 3.5 ± 4.4 | 1.6 ± 1.5 | 0.7 ± 1.5 |
| rundinea | – | 0.1 ± 0.3 | – | – | – | – | – | – |
| phipoda | 1.4 ± 2.1 | 0.1 ± 0.3 | 1.5 ± 2.9 | – | 0.1 ± 0.3 | 0.1 ± 0.3 | – | 0.6 ± 0.8 |
| ari | 0.2 ± 0.4 | – | – | – | – | – | – | – |
| stropoda | 0.9 ± 0.9 | 0.4 ± 0.5 | 0.5 ± 1.1 | 0.1 ± 0.3 | 0.2 ± 0.4 | 0.5 ± 1.1 | 0.6 ± 0.9 | 0.4 ± 0.7 |
| lecypoda:Sphaeriidae | 0.1 ± 0.3 | 0.1 ± 0.3 | 0.1 ± 0.3 | 0.2 ± 0.4 | – | – | – | 0.2 ± 0.4 |
| :Unionidae | – | – | 0.1 ± 0.3 | – | – | – | – | – |
| tal | 20.4 ± 10.7 | 17.6 ± 12.0 | 16.0 ± 7.6 | 16.1 ± 6.3 | 13.4 ± 10.5 | 15.3 ± 8.8 | 15.6 ± 7.4 | 24.2 ± 6.9 |

expressed as mean number and standard deviation found in ten 232 $cm^2$ Ekman grab samples

Table 17

Benthic organisms* collected in Ekman grab samples from Lac Herman, 21 May 1975 to 17 May 1976

| Number of days before or after treatment | -7 | +1 | +8 | +20 | +36 | +85 | +354 |
|---|---|---|---|---|---|---|---|
| Mean depth sampled (m) | 1.80 | 1.90 | 1.65 | 1.85 | 2.00 | 1.75 | 1.35 |
| Ephemeroptera:Ephemeridae | 0.2 ± 0.4 | 0.6 ± 0.5 | 0.8 ± 1.3 | - | | - | 0.4 ± 0.5 |
| Odonata:Gomphidae | 0.6 ± 0.9 | 0.4 ± 0.5 | - | 0.8 ± 0.8 | 0.2 ± 0.4 | - | 0.4 ± 0.5 |
| :Libellulidae | 0.2 ± 0.4 | - | - | - | - | - | - |
| Lepidoptera:Pyralidae | - | - | - | 0.2 ± 0.4 | - | 0.4 ± 0.5 | 1.4 ± 1.7 |
| Megaloptera:Sialidae | - | - | - | - | - | 0.4 ± 0.5 | - |
| Trichoptera:Various families | 1.2 ± 0.8 | - | - | 0.2 ± 0.4 | 0.4 ± 0.5 | - | 0.2 ± 0.4 |
| Diptera:Chironomidae | 13.0 ± 5.8 | 11.4 ± 10.6 | 15.4 ± 12.4 | 32.0 ±13.1 | 16.6 ± 10.5 | 2.8 ± 1.6 | 20.6 ± 6.8 |
| :Heleidae | 0.4 ± 0.9 | 2.0 ± 2.5 | 0.6 ± 0.5 | 0.4 ± 0.5 | 0.4 ± 0.5 | - | 1.0 ± 1.7 |
| :Tipulidae | - | - | 0.2 ± 0.4 | - | - | - | - |
| Nematoda | - | - | - | - | - | 0.2 ± 0.4 | - |
| Turbellaria | - | - | 0.2 ± 0.4 | 0.4 ± 0.9 | - | - | - |
| Oligochaeta | 2.6 ± 1.8 | 3.6 ± 2.5 | - | 2.8 ± 2.6 | 5.2 ± 4.1 | 1.0 ± 0.7 | 1.2 ± 1.3 |
| Hirundinea | 0.2 ± 0.4 | - | - | | 0.2 ± 0.4 | 0.4 ± 0.9 | - |
| Amphipoda | 1.6 ± 2.2 | 2.0 ± 1.2 | 0.4 ± 0.9 | 9.2 ± 6.4 | 2.2 ± 2.5 | 5.4 ± 4.9 | 5.2 ± 5.1 |
| Gastropoda | 0.8 ± 0.8 | 0.4 ± 0.5 | 0.6 ± 0.9 | - | - | - | 0.4 ± 0.5 |
| Total | 20.8 ± 7.2 | 20.4 ± 13.7 | 18.2 ± 13.1 | 46.0 ± 9.1 | 25.2 ± 10.9 | 10.6 ± 3.8 | 30.8 ± 11.4 |

* expressed as mean number and standard deviation found in five 232 $cm^2$ Ekman grab samples.

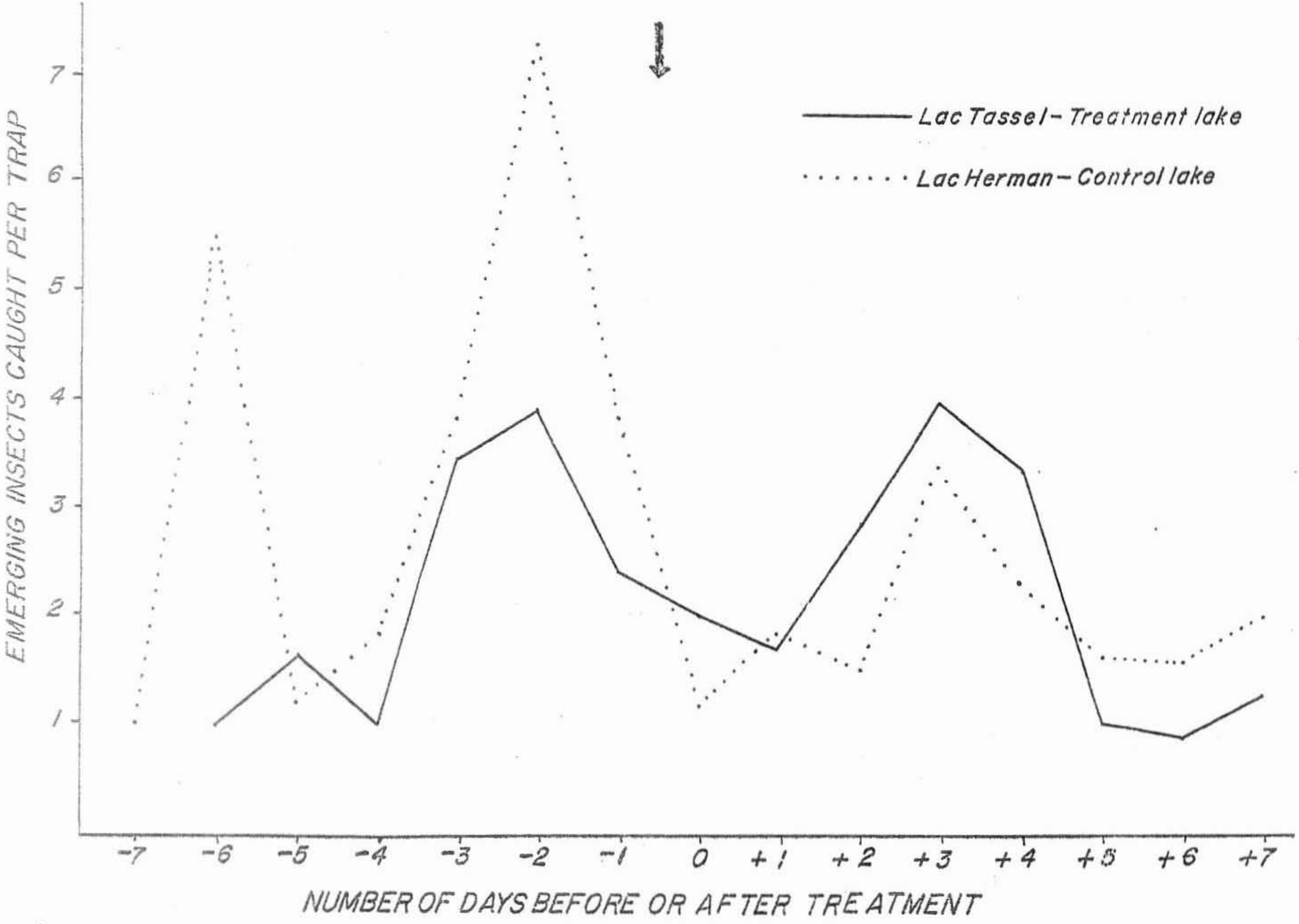


Fig. 8. Insect emergence trap catches in Lac Tassel and Lac Herman, 22 May to 4 June, 1975.

Lac Herman during the same period.

3. Fish diets and condition

Large numbers of fish were obtained for stomach analysis from Lac Tassel and Lac Herman (Appendix, Tables 1 and 2), mostly by gill netting but also by angling and trap netting. White suckers were consistently sampled in large numbers from both lakes. Smallmouth bass, fallfish, brown bullheads and yellow perch, *Perca flavescens* (Mitchill), from Lac Tassel and brook trout and brown bullheads from Lac Herman were captured in less consistent numbers over the study period. Small numbers of common shiners, *Notropis cornutus* (Mitchill), were also captured from Lac Tassel and analyzed for stomach content. A small number of creek chub, *Semotilus atromaculatus* (Mitchill), were caught in a gill net set in Lac Herman on 22 May 1975, but no other individuals of this species were captured on later sampling dates.

White suckers in both lakes fed primarily on aquatic insects and planktonic organisms (Fig. 9, Appendix Tables 4 to 9), with suckers from Lac Herman feeding more extensively on aquatic insects. In both lakes feeding activity was consistent throughout the study period, with no more than 20% of the individual fish in any sample having empty digestive tracts. The diet of white suckers in Lac Tassel was relatively stable over the study period, particularly in terms of the mean numbers of various food items found in their digestive tracts. The most noticeable variation was the decrease in occurrence and percent volume contributed by cladocerans in mid-June, with a subsequent increase of cladocerans in the diet through the rest of the summer. In Lac Herman suckers, cladocerans increased in their occurrence, numbers and contribution to the volume of food up until

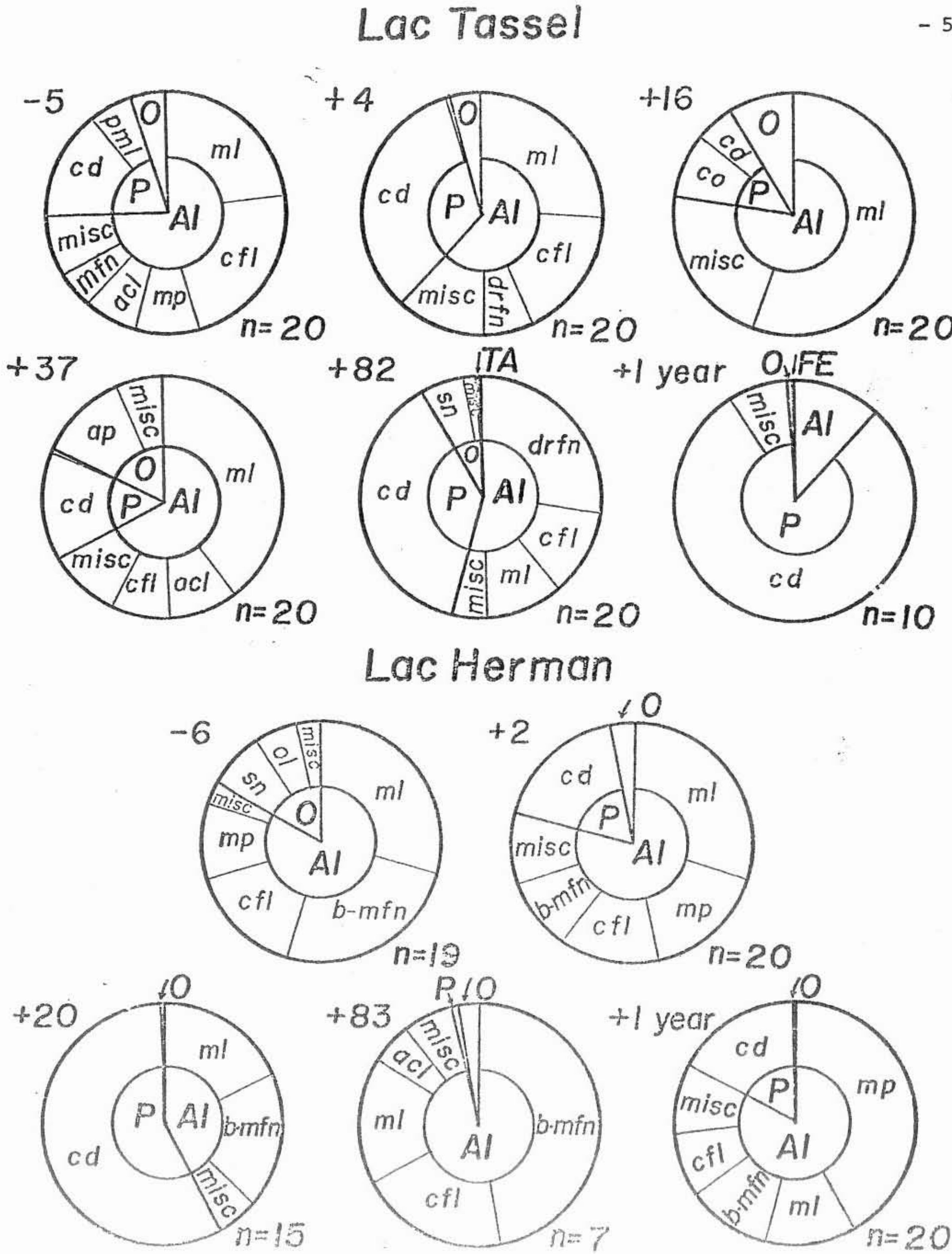
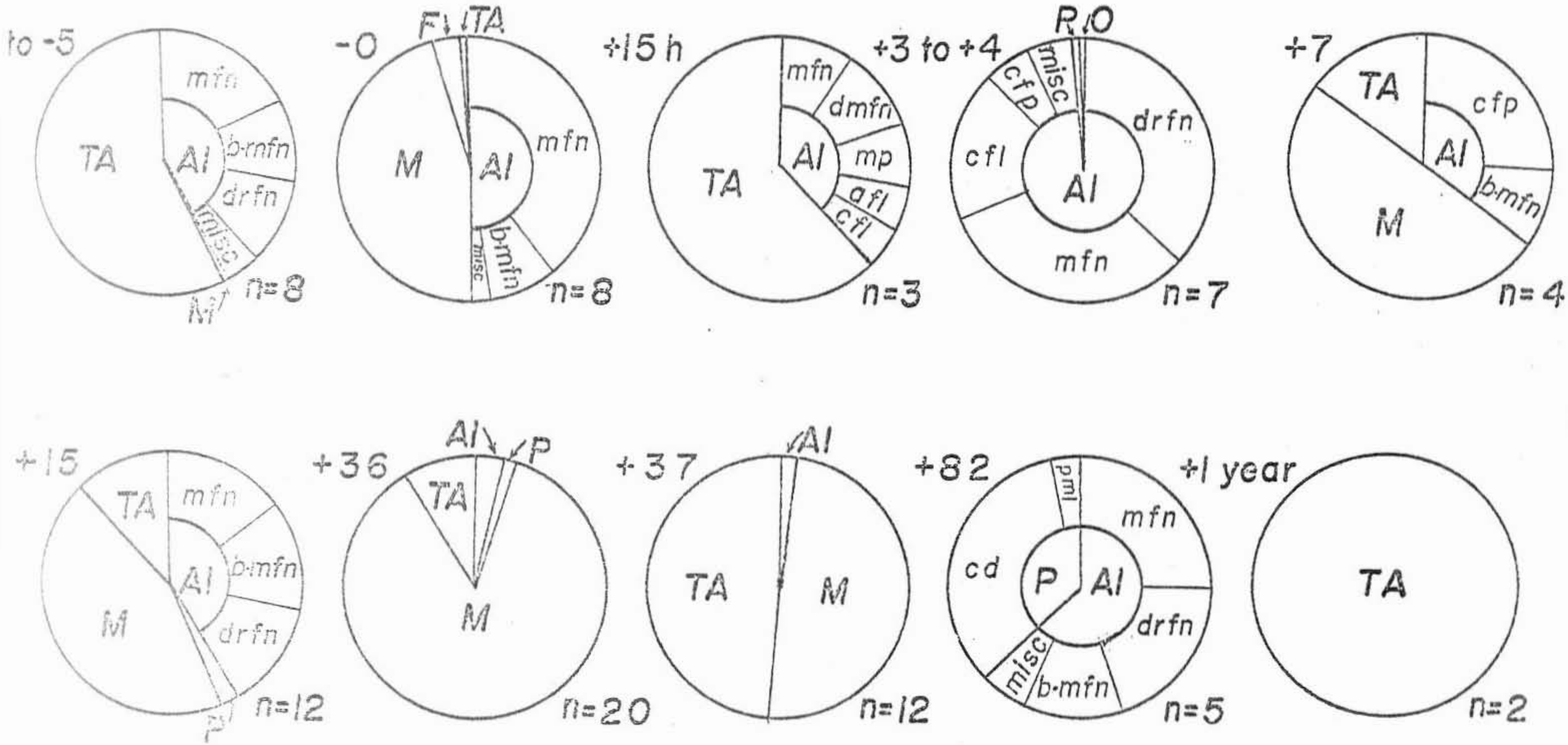



Fig. 9. Contributions of various food items to the diet of white suckers in the study lakes. AI–aquatic insects (acl–aquatic beetle larvae, b-mfn–burrowing mayfly nymphs, cfl–caddisfly larvae, drfn–dragonfly nymphs, mfn–mayfly nymphs, ml–midge larvae, mp–midge pupae, misc.–miscellaneous), P–plantonic organisms (cd–cladocerans, co–copepods, pml–phantom midge larvae), O–other aquatic invertebrates (ap–amphipods, ol–oligochaetes, sn–snails, misc.–miscellaneous), TA – terrestrial arthropods, FE–fish eggs, n = number of fish sampled, –5, +4 etc. – days before or after treatment.

mid-June but were no longer found in sucker stomachs in July. Caddisfly larvae decreased in importance in sucker diets in both lakes in mid-June and became important again later in the summer.

Smallmouth bass in Lac Tassel fed primarily on minnows, large aquatic insects (mayfly and dragonfly nymphs) and flying insects (Fig. 10 Appendix, Tables 10 to 12). On about half the sampling dates, close to 50% of bass stomachs were empty, and the mean volume of stomach contents fluctuated widely over the study period. The composition of the stomach contents also fluctuated widely between the three predominant food groups without showing any distinct pattern in change of diet. Numbers of both flying and aquatic insects in bass stomachs were higher in the first few days following treatment than at any other time. Fallfish in Lac Tassel fed on a varied diet of aquatic insects (mainly caddisfly larvae, dragonfly nymphs and burrowing mayfly nymphs), flying insects, plankton and occasional minnows (Fig. 11, Appendix Tables 13 to 15). A large percentage of the fallfish caught from mid-June through August had empty stomachs and the mean volume of digestive tract contents was generally much lower throughout the summer than in May. Cladocerans were numerous and important in their contribution to the diet of fallfish before treatment, but almost completely absent after treatment. Large numbers of flying insects were found in a single fallfish caught 15 hours after treatment of Lac Tassel, indicating heavy feeding on insect knockdown. Relatively large mean numbers of some aquatic insect groups were found in stomachs a few days after treatment, particularly dragonfly nymphs.

Brook trout in Lac Herman fed on a varied diet of aquatic insects, minnows, flying insects and plankton (Fig. 12, Appendix Tables 16 to 18).




. 10. Contributions of various food items to the diet of smallmouth bass in Lac Tassel. AI-aquatic insects (afl-alderfly larvae, b-mfn-burrowing mayfly nymphs, cfl-caddisfly larvae, cfp-caddisfly pupae, dmfn-damselfly nymphs, drfn-dragonfly nymphs, mfn-mayfly nymphs, mp-midge pupae, misc.-miscellaneous), P-planktonic organisms (cd-cladocerans, pml-phantom midge larvae), M-minnows, F-frogs, TA-terrestrial arthropods, n = number of fish sampled, -8, +3 etc. - days before or after treatment.

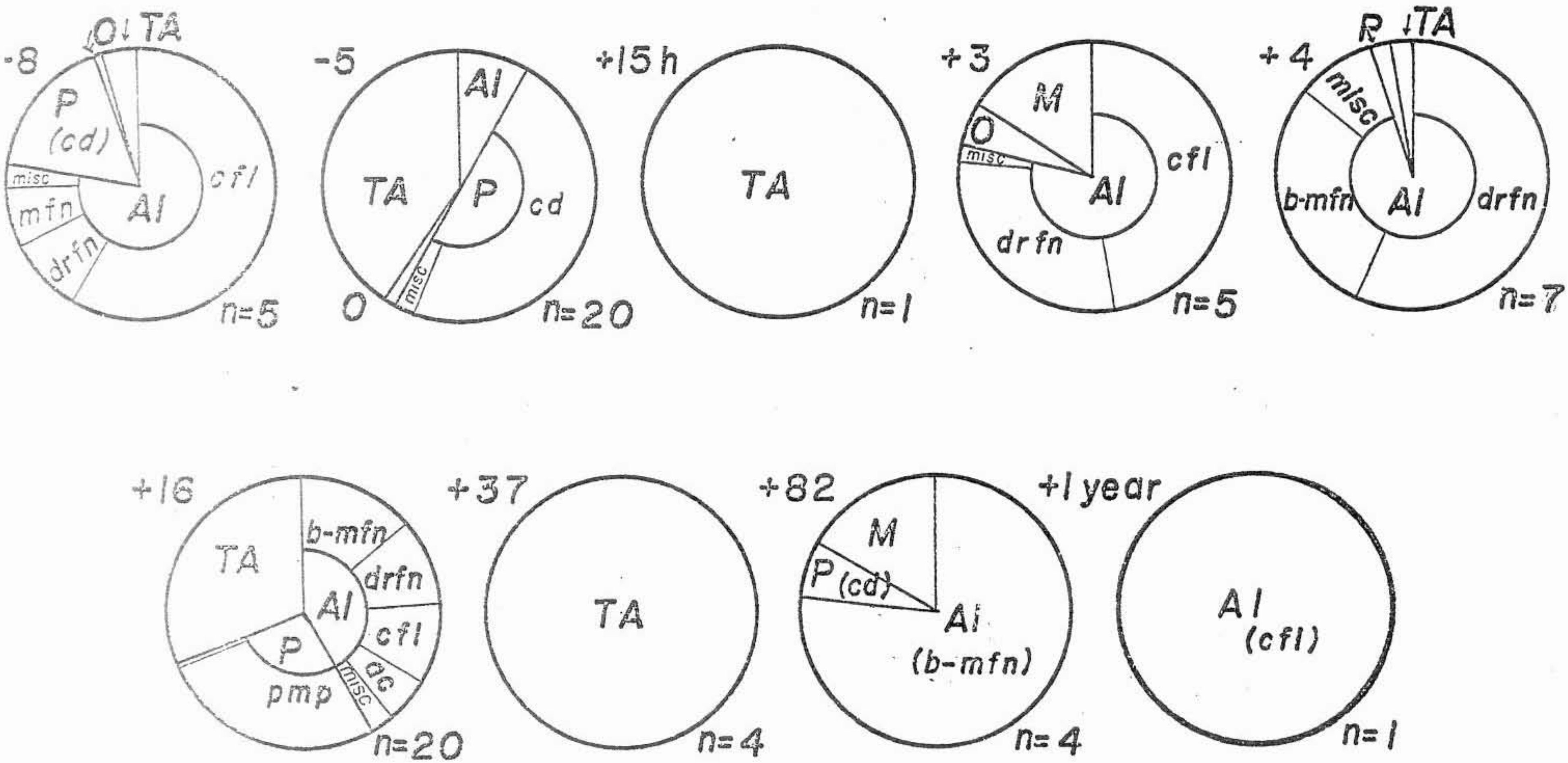



Fig. 11. Contributions of various food items to the diet of fallfish in Lac Tassel. AI-aquatic insects (ac-aquatic beetles, b-mfn-burrowing mayfly nymphs, cfl-caddisfly larvae, drfn-dragonfly nymphs, mfn-mayfly nymphs, misc.-miscellaneous), P-planktonic organisms (cd-cladocerans, pmp-phantom midge pupae, misc.-miscellaneous), O-other aquatic invertebrates, M-minnows, TA-terrestrial arthropods, n = number of fish sampled, -8, +3 etc. - days before or after treatment.

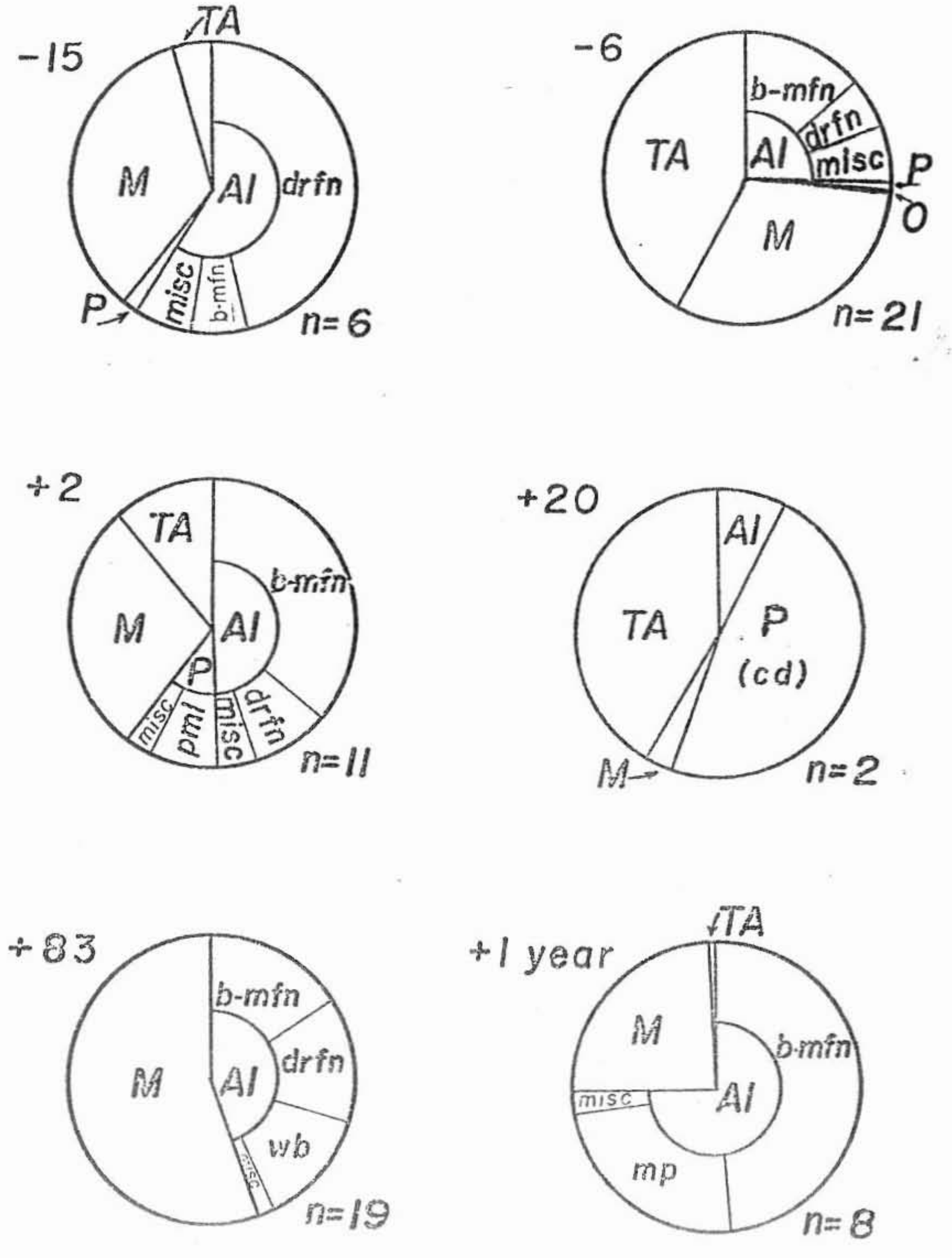



Fig. 12. Contributions of various food items to the diet of brook trout in Lac Herman. AI-aquatic insects (b-mfn-burrowing mayfly nymphs, drfn-dragonfly nymphs, mp-midge pupae, wb-water boatmen, misc.-miscellaneous), P-planktonic organisms (pml-phantom midge larvae, misc.-miscellaneous), O-other aquatic invertebrates, M-minnows, TA-terrestrial arthropods, n = number of fish sampled, -15, +2 etc. - number of days before or after treatment.

Feeding activity among brook trout slowly declined throughout the summer as seen by changes in the occurrence of empty stomach contents. The contribution of cladocerans to the diet of brook trout increased in late May, peaked in mid-June and fell to nil in August. Aside from this, brook trout fed on a fairly steady diet of minnows and aquatic insects with occasional large input of flying insects.

Brown bullheads in Lac Tassel and Lac Herman fed on similar diets predominated by a large variety of aquatic insects with some input of other aquatic invertebrates, particularly amphipods (Fig. 13, Appendix, Tables 19 to 24). Caddisfly larvae and pupae did not occur in bullhead stomachs in either lake during mid to late summer, but other aquatic insect groups and amphipods were generally present in varying numbers throughout the study period. Some bullheads in Lac Tassel fed on blackfly larvae and fish eggs from the inlet stream in mid-May of 1975.

The diet of yellow perch in Lac Tassel consisted primarily of planktonic organisms (both cladocerans and phantom midge larvae and pupae), aquatic insects and minnows, principally smallmouth bass fry (Fig. 14, Appendix, Tables 25 to 27). Cladocerans fell off greatly in occurrence and contribution to the volume of food in perch stomachs following treatment and then gradually regained importance throughout the summer. Phantom midge larvae and pupae were particularly important in perch diets during the periods when cladocerans were not occurring in the stomachs. Smallmouth bass fry were quite extensively fed on by perch in mid-June. The drop in the importance of cladocerans in the diets of fish in Lac Tassel after treatment was also seen in the small number of common shiners sampled for analysis of their digestive tract contents (Appendix, Table 28). Following treatment shiners fed primarily

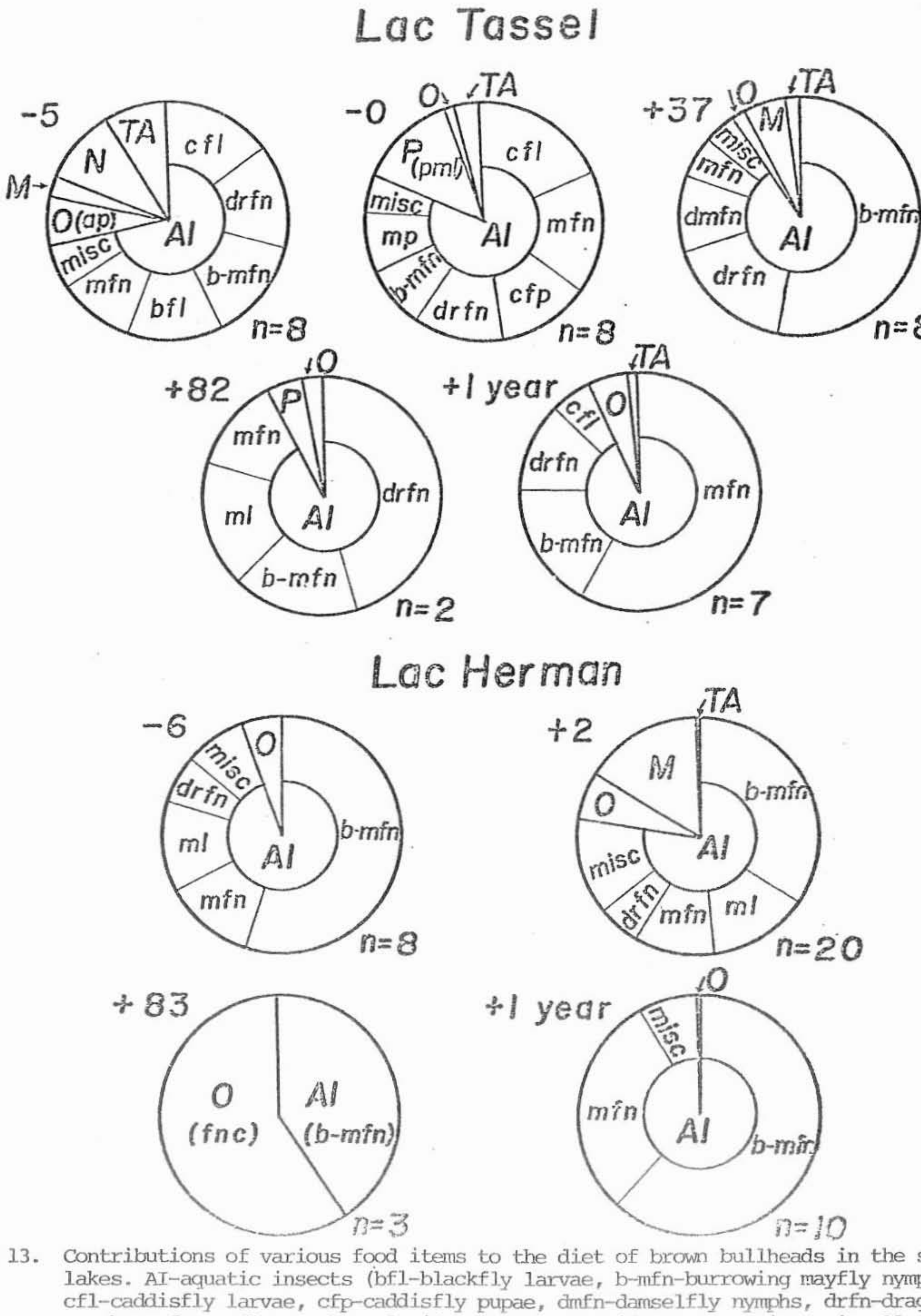



Fig. 13. Contributions of various food items to the diet of brown bullheads in the study lakes. AI-aquatic insects (bfl-blackfly larvae, b-mfn-burrowing mayfly nymphs, cfl-caddisfly larvae, cfp-caddisfly pupae, dmfn-damselfly nymphs, drfn-dragonfly nymphs, mfn-mayfly nymphs, ml-midge larvae, mp-midge pupae, misc.-miscellaneous), P-planktonic organisms (pml-phantom midge larvae), O-other aquatic invertebrates (ap-amphipods, fnc-fingernail clams), M-minnows, N-newts, TA-terrestrial arthropods, n = number of fish sampled, -5, +37 etc. days before or after treatment.

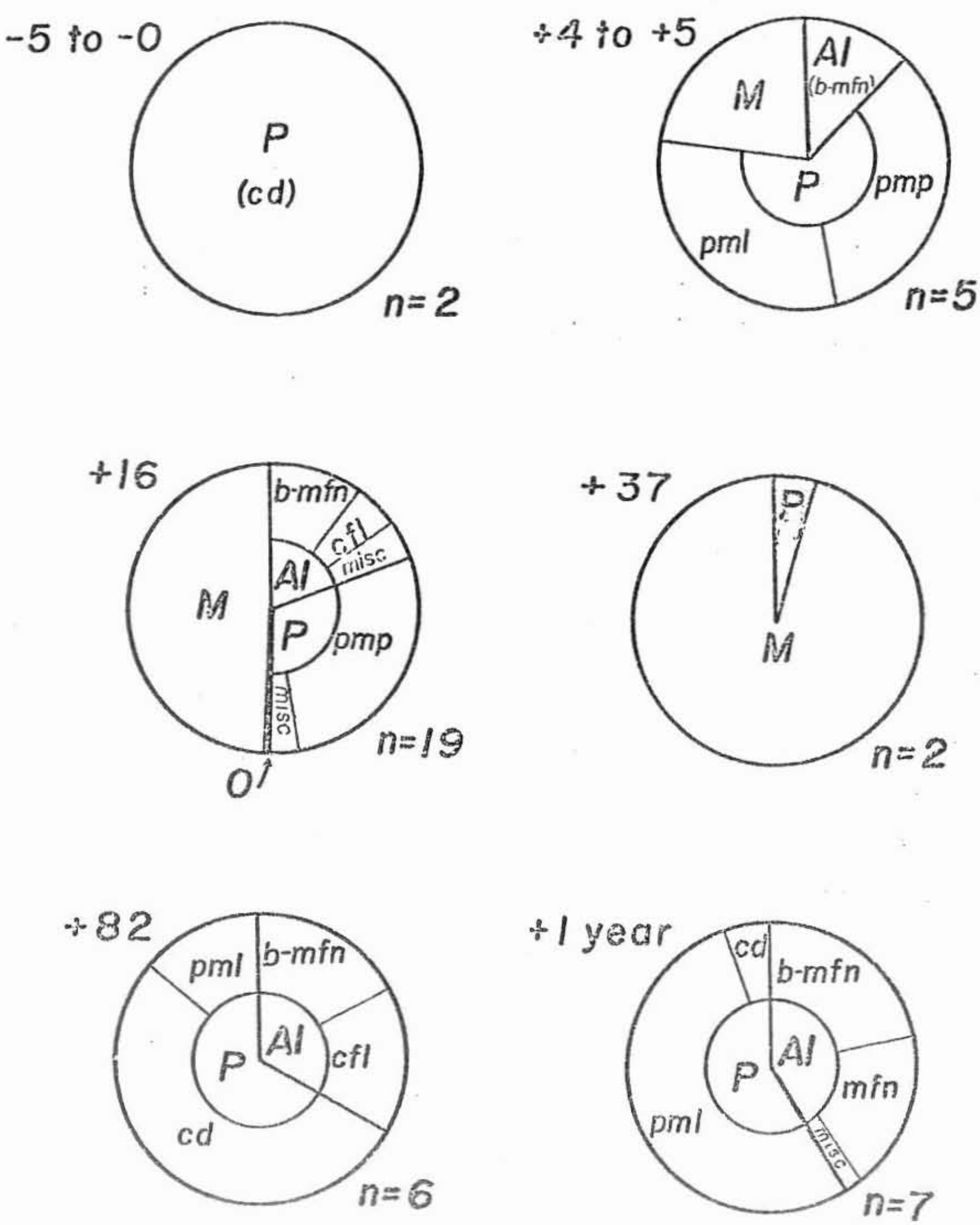



Fig. 14. Contribution of various food items to the diet of yellow perch in Lac Tassel. AI-aquatic insects (b-mfn-burrowing mayfly nymphs, cfl-caddisfly larvae, mfn-mayfly nymphs, misc.-miscellaneous), P-planktonic organisms (cd-cladocerans, pml-phantom midge larvae, pmp-phantom midge pupae, misc.-miscellaneous), O-other aquatic invertebrates, M-minnows, n = number of fish sampled, - 5, +4 etc. - days before or after treatment.

on phantom midge larvae and pupae.

Mean condition coefficients ($K = \frac{10^5 \text{ x weight in grams}}{(\text{length in mm})^3}$) were calculated for three different size classes of white suckers from Lac Tassel and Lac Herman (Table 18). For both lakes, general trends in changes in relative condition were apparent which applied to suckers of all size classes. Condition coefficients decreased to various extents (3.7 to 14.7%) during the last week of May in both lakes. Suckers in Lac Tassel continued to lose condition over the first two weeks of June, except for small suckers in which condtion increased slightly (3.1%). During this same period, all sizes of suckers in Lac Herman increased in condition by relatively large extents (8.4 to 21.5%). Suckers in both lakes increased in condition between mid-June and August with similar gains being recorded for similar sized groups of fish. The net change in condition coefficients over the summer was almost identical for large suckers in the two lakes (an increase of about 9%). Medium-sized suckers in Lac Tassel showed a net decrease of 2.1% whereas the same group had a net increase of 3.8% in the untreated lake. Small suckers in Lac Tassel showed a net decrease in condition over the summer of 4.4%. No comparable calculation can be made for small suckers in Lac Herman because of their absence from the early May sample, but this group showed strong gains in condition between late May and August.

Fallfish in Lac Tassel showed a similar trend in changes in condition as seen in suckers, up until July (Table 19). Their condition coefficients decreased in late May and the first half of June but then increased strongly by early July. Between July and August they lost condition again. Insufficient or incomplete samples of other fish species prevented any meaningful evaluation of changes in their condition.

Table 18

Condition coefficients (K) of different size classes* of white suckers from Lac Tassel and Lac Herman,

May 1975 to May 1976

Lac Tassel

| | | 23 May 1975 | 1 June 1975 | 13 June 1975 |
|---|---|---|---|---|
| >250 mm | K value | 1.111 ± 0.069 (10) | 1.070 ± 0.075 (18) | 1.039 ± 0.049 (13) |
| | % change | - | -3.7% | -2.9% |
| 200 mm to 250 mm | K value | 1.164 ± 0.081 (26) | 1.081 ± 0.068 (28) | 1.014 ± 0.074 (14) |
| | % change | - | -7.1% | -6.2% |
| <250 mm | K value | 1.207 ± 0.088 (13) | 1.043 ± 0.067 (8) | 1.075 ± 0.044 (8) |
| | % change | - | -13.6% | +3.1% |

| | | 4 July 1975 | 19 Aug.1975 | 18 May 1976 |
|---|---|---|---|---|
| >250 mm | K value | 1.089 ± 0.059 (5) | 1.210 ± 0.132 (7) | 1.182 ± 0.106 (7) |
| | % change | +4.8% | +11.1% | -2.3% |
| 200 mm to 250 mm | K value | 1.090 ± 0.041 (5) | 1.140 ± 0.056 (10) | 1.147 ± 0.075 (4) |
| | % change | +7.5% | +4.6% | +0.6% |
| <250 mm | K value | 1.139 ± 0.070 (10) | 1.154 ± 0.069 (4) | 1.090 ± 0.071 (9) |
| | % change | +6.0% | +1.3% | -5.5% |

* Total length

Number of fish in each sample is given in parenthesis.

Table 18 (Cont'd)

Lac Herman

| | | 22 May 1975 | 30 May 1975 | 17 June 1975 |
|---|---|---|---|---|
| >250 mm | K value | 1.170 ± 0.035 (4) | 0.998 ± 0.105 (3) | 1.108 (1) |
| | % change | - | -14.7% | +11.0% |
| 200 mm to 250 mm | K value | 1.144 ± 0.096 (15) | 1.065 ± 0.076 (17) | 1.154 ± 0.040 (3) |
| | % change | - | -6.9% | +8.4% |
| <250 mm | K value | - | 0.971 ± 0.233 (22) | 1.180 ± 0.082 (11) |
| | % change | - | - | +21.5% |

| | | 20 Aug. 1975 | 17 May 1976 |
|---|---|---|---|
| >250 mm | K value | 1.277 (1) | 1.260 ± 0.006 (3) |
| | % change | +15.3% | -1.3% |
| 200 mm to 250 mm | K value | 1.188 ± 0.037 (2) | 1.021 ± 0.122 (16) |
| | % change | +2.9% | -14.0% |
| <250 mm | K value | 1.257 ± 0.009 (4) | 1.029 ± 0.117 (6) |
| | % change | +6.5% | -18.1% |

Number of fish in each sample is given in parenthesis.

Table 19

Condition coefficients of fallfish from Lac Tassel,
23 May to 19 August 1975

| Date | Number of fish in sample | Condition coefficient (% Change) |
|---|---|---|
| 23 May | 42 | 1.083 ± 0.074 |
| 1 June | 7 | 1.035 ± 0.036 (-4.4%) |
| 13 June | 20 | 1.003 ± 0.075 (-3.1%) |
| 4 July | 3 | 1.285 ± 0.088 (+28.1%) |
| 19 August | 4 | 1.165 ± 0.119 (-9.3%) |

4. Observations on fish and aquatic invertebrates

Considerable mortality occurred among the fish caged at the surface of Lac Tassel to study residue accumulation and persistence. All the white suckers (29) and bullheads (11) held in cages died within 24 hours of treatment of the lake, except for those sampled live for residue analysis over this period. Ten suckers and one bullhead had died in cages over two days before treatment. Thirteen of twenty-one caged bass died over an eight day period after treatment with four bass dying in four days of caging prior to fenitrothion application. Fallfish survival in cages was good until two days after treatment when the last five caged individuals all died.

No indications of mortality or abnormal behavior were observed among native fish populations during scuba dives 30 hours and two weeks after treatment. Three bass nests containing fry in various stages of development appeared unaffected 30 hours after spray application, and the behavior of their guarding males was normal. Large numbers of free swimming fry were observed in the vicinity of these nests two weeks later.

The only observation made of aquatic invertebrate mortality in Lac Tassel was the finding, 30 hours after treatment, of a number of dead small dragonfly nymphs in shallow (1m and less) areas along portions of the lake's shoreline. One apparently healthy large dragonfly nymph was seen at the same time. At this and other times normal appearance and behavior was noted among planarians, water mites, freshwater clams, mayfly nymphs, beetle larvae and darters. Cast off mayfly nymph exuvia were observed in some numbers on the bottom 30 hours after treatment, and adult mayfly activity at the surface of the lake at dusk of this day was very noticeable.

B. Laboratory Bioassays.

The static bioassays with fish were run for periods up to 336 hours (2 weeks) or until significant mortality began to occur among control groups. Ten percent mortality or less occurred among low dosage groups of golden shiners, white suckers and brown bullheads over 336 hours, indicating that the incipient LC50 value (concentration lethal to 50 percent of the individuals on long exposure (Sprague, 1969)) for these groups was higher than the lowest dosages tested (> 1 mg/ℓ). Mortality among the lowest dosage groups of pumpkinseeds had reached 60 percent after 336 hours while no mortality had occurred in the control groups, indicating that the incipient LC50 value for pumpkinseeds is less than 1 mg/ℓ. Substantial mortality occurred between 96 and 336 hours in the control groups of brook trout and basses, making it impossible to draw conclusions as to whether the incipient LC50 value was approached.

The time-response results of the bioassays were fitted to a probit plane equation involving the two independent variables log time (t) and log dose (x) to yield an equation,

$$\text{Response (in probits)} = A + Bt + Cx.$$

The equation was estimated by a maximum likelihood procedure based on the method of Fletcher and Powell (1963), taking into account the number of subjects per dose level and the observed number of subjects responding at 3, 6, 12, 24, 36, 48, 72 and 96 hours at each dose level.

LC50 values for 24, 48, 72 and 96 hours for each fish species, as calculated from the probit plane equations derived, are presented in Table 20. The range of LC50's for the species tested was quite small, with the most suceptible species (brook trout) only about two and a half times as sensitive as the least sensitive species (brown bullhead and golden shiner). Smallmouth bass fry and yearling largemouth bass were very close in their susceptibility to fenitrothion. They were both about one and a half times as sensitive as pumpkinseeds, the other centrarchid species tested.

Table 20

LC50's of fenitrothion (mg/ℓ) to various fish species determined from static bioassays

| | 24h | 48h | 72h | 96h |
|---|---|---|---|---|
| Brook trout | 2.2 | 1.6 | 1.4 | 1.2 |
| Golden shiner | 4.9 | 3.9 | 3.3 | 3.0 |
| White sucker | 3.6 | 2.7 | 2.2 | 2.0 |
| Brown bullhead | 5.4 | 3.7 | 2.9 | 2.5 |
| Pumpkinseed | 4.9 | 3.4 | 2.8 | 2.4 |
| Smallmouth bass (fry) | 2.9 | 1.9 | 1.4 | 1.2 |
| Largemouth bass | 3.2 | 2.2 | 1.7 | 1.5 |

# IV. DISCUSSION

## A. Deposit and Dynamics of Fenitrothion in Lake Waters and Fauna

The measured deposit of spray products onto the surface of Lac Tassel accounts for less than half of the emitted dosage. Although deposits of this percentage of emitted material are considered good in forest stands, they seem low for the large flat surface presented by the lake, particularly in light of the excellent weather conditions at the time of treatment. The factor probably responsible for this apparent discrepancy was the difference in temperature between the lake's surface waters (about 20°C) and the air above it (2.2°C). This resulted in rising currents of moist air heated by the warmth of the lake interfering with deposit of spray products.

Spray products reaching the lake's surface rapidly dispersed throughout the epilimnion (surface to 2m) within the first hour. Penetration through the thermocline was somewhat slower but still occurred rapidly, with complete dispersion of fenitrothion through the top 4 metres of the lake occurring within 12 hours. Relatively small amounts of fenitrothion reached the deeper portions of the lake, probably because of the relatively slow rate of mixing between the epilimnion and hypolimnion and within the hypolimnion itself (Hutchinson, 1957). These patterns of disperion of insecticide residues are of great significance in terms of the effects the insecticide has on lake fauna. The rapid dilution of initially high concentrations at the surface would limit the probability and length of exposure of any organism to these relatively high and potentially hazardous concentrations. On the other hand, complete mixing of residues within the epilimnion exposes a greater number and variety of organisms to the insecticide than if it remained concentrated at the surface. This is probably of greatest significance to benthic organisms confined to the littoral zone. Zooplankton and fish would still not be exposed to these levels of insecticide if their normal habitat were the deep portions of the lake or if they were able to detect and avoid fenitrothion in shallower waters by retreating below the themocline. The rather low (10 μg/ℓ) threshold value at which goldfish detected and avoided fenitrothion in the laboratory (Scherer, 1975) suggests that it may be feasible that some native fish species could partially avoid exposure to the insecticide in this way.

Once fenitrothion residues had reached their maximum dispersion with the lake waters, they persisted at close to these levels for various periods, with different rates of disappearance at different depths. The major factors affecting the disappearance were breakdown to metabolites, continued dispersion within the lake and addition of residues washed into the lake by rainfall and runoff. Residues declined fastest below the hypolimnion, probably due to the combined effects of breakdown, slow dispersion throughout the hypolimnion and adsorption into bottom sediments. Persistence at the surface was somewhat erratic, probably due to horizontal movement of residues across the surface by wind and waves (suggested by differences in residues found at the surface deep and shoreline stations), and input of residues from rainfall and runoff 64 and 94 hours after treatment. Faster rates of breakdown by photodecomposition by sunlight (Lockhart *et al*, 1973) presumably occurred at the surface than in deeper waters. Fenitrothion residues appear to be most stable and persist longest in the epilimnetic waters just above the themocline. This suggests that the greatest hazard posed by the fenitrothion residues would be to bottom fauna and fish confined to the epilimnion.

Conflicting results with respect to long term persistence of fenitrothion residues in water were found between pre-spray water samples from both study lakes and water samples from Lac Tassel collected a year after treatment. Both lakes contained residues between 0.16 and 0.18 μg/ℓ of mostly fenitrooxon when sampled prior to treatment in 1975, even though the last time fenitrothion spraying took place in their vicinity appears to be during the 1974 Quebec spruce budworm control program. In 1976, Lac Tassel waters contained only trace to 0.03 μg/ℓ fenitrothion with no detectable quantities of fenitrooxon being found. These residues were highest in the deeper waters, even though the lake was only slightly stratified. The variation from year to year may be due to differing water chemistry parameters in the lakes over the winters of 1975-75 and 1975-76. Early spring samples suggest that oxygen depletion may have been more severe in the study lakes in the winter of 1974-75 than 1975-76.

The fenitrothion residues accumulated by caged and wild fish in Lac Tassel are similar to those found in caged and wild fish in streams within fenitrothion treated areas in Manitoba (Lockhart *et al*, 1973), Newfoundland (Hatfield and Riche, 1970) and Maine (Marancik, 1976). They demonstrate the rapid accumulation by fish of residues many times higher than in surrounding water. Similar accumulation of fenitrothion residues by anuran larvae has been demonstrated in forest ponds (Lyons *et al*, 1976). The relative level of residues accumulated is distinctly different for different species of fish, and this seems to be true for both fish of different species caged in the same location and fish moving freely in the lakes. This suggests that the accumulation of fenitrothion residues by different species of fish is more dependent on differences in metabolic rate or tissue composition than on differences in habitat preference. Bottom feeding species such as white suckers and brown bullheads accumulated as much fenitrothion as smallmouth bass and fallfish, which fed on the surface to a much greater extent. Since all the fish in the lake appeared to be feeding in the epilimnion of the lake at the time of treatment, they probably were all exposed to similar concentrations of fenitrothion. The only exception noted was the smallmouth bass exposed to and affected by concentrated residues at the surface within minutes of treatment. The hazard of exposure of surface feeding species of fish to this type of concentrated residue is increased by the presence of distressed flying and terrestrial insects knocked down onto the surface.

The significance of the fenitrothion levels accumulated in fish is difficult to determine. Since no distress or mortality was noted among "wild" fish, with the exception already noted, these fenitrothion levels do not appear to constitute a serious hazard to fish survival. Mortality among caged fish suggests that those levels of fenitrothion do constitute a significant stress factor which can lead to mortality when combined with caging and high temperature stress. Salmonids accumulating residue levels close to those found in this study have not suffered effects on brain acetylcholinesterase activity or serum chemistry (Lockhart *et al*, 1973). The rapid disappearance of residues from all fish species with the possible exception of white suckers suggests that long term effects are unlikely to be found.

Freshwater clams accumulate relatively small residue levels depsite their filter-feeding existence. This is notably different from the dramatic accumulation of the persistent organochlorine insecticides which has been found in bivalve molluscs (Butler, 1969).

B. Effects of Fenitrothion on Populations of Fish Food Organisms in Lakes

Even the highest fenitrothion residues found in Lac Tassel after treatment were below reported 24 hour LC50 values for all but the most sensitive aquatic invertebrates (McLeese, 1976). Residues of these levels have, however, been shown to cause considerable disturbance among benthic invertebrates in streams (Eidt, 1975). Lakes generally constitute more stable ecosystems than streams as they are far less subject to extreme short term physical, chemical and temperature fluctuations, and this might moderate both impact on and recovery of invertebrate populations.

Comparison between changes in cladoceran populations in the treated and control lake suggest that some short term depression of cladoceran populations related to the fenitrothion treatment occurred in Lac Tassel. The differences may, however, simply reflect natural differences in the cladoceran faunas of the two lakes as the increases in cladoceran numbers in Lac Herman at the time when populations were depressed in Lac Tassel was almost entirely due to increases in *Bosmina*, a genus never represented by more than a single individual in plankton catches from the deep station at Lac Tassel. *Bosmina* were present in large numbers at the shoreline station of Lac Tassel before treatment but disappeared completely after treatment, suggesting that the differences could also be due to a selective effect on this genus of cladoceran.

Changes in abundance of the larger genera *Daphnia* and *Holopedium* in the two lakes showed no apparent differences attributable to fenitrothion treatment. Copepod populations in Lacs Tassel and Herman followed similar patterns of abundance, showing that they were not affected by the fenitrothion treatment.

The relative stability of total benthic organisms sampled per Ekman grab sample from Lac Tassel over the study period shows that the insecticide treatment did not greatly affect benthic organisms in general. Comparison with populations in the control lake suggest that dragonfly nymphs, amphipods and possibly marl beetle larvae were selectively affected, with some indications that recovery of these groups was quite slow. Unfortunately, Ekman grab samples do not provide a very suitable method of measuring populations of larger, widely scattered or highly mobile benthic invertebrates as the numbers sampled per unit area are very low while the standard deviation among groups of samples are often as high as 200 to 300 percent for groups of benthic organisms present at low densities. Some method of visual counts along a grid system or even population assessment using a mark-recapture system such as used for measuring crayfish populations in lakes (Emery, 1975) might be more suitable for measuring impact on important large fish food items such as dragonfly nymphs.

No effects on emerging insect populations were apparent from emergence trap collections from the study lakes. Toxicology studies have demonstrated that pupal stages of insects are much less susceptible to insecticide poisoning than larval stages, due to their quiescent, non-feeding habit, so effects on emerging insects would not be expected.

C. Effects of Fenitrothion on the Diet and Condition of Fish in Lakes

Severe effects of the chlorinated hydrocarbon insecticide DDT on fish food organisms in New Brunswick streams in the 1950's, resulted in dramatic changes in the food consumed by young Atlantic salmon (Keenleyside, 1967). Reductions of the aquatic insect populations on which salmon had been feeding resulted in a change in diet towards midge larvae recolonizing the streams and snails, worms and fish, previously unimportant as salmon food items. This kind of change in the diet of fish can adversely affect their condition and growth through insufficient food being available, less nutritional value being represented in the sources of food turned to, or more energy being expended in procuring the new food items.

There were few indications that the fenitrothion treatment caused significant changes in the diets of fish in Lac Tassel. The contribution of cladocerans to the diets of white suckers, fallfish and yellow perch did appear to decline during the period when cladoceran populations were depressed in the lake. Aquatic insects consistently made up a large proportion of the stomach contents of white suckers and brown bullheads over the summer following treatment, and none of the major aquatic insect food items were consistently absent following the treatment. The insecticide application had a short lasting effect of increasing the availability of terrestrial arthropods to surface feeding smallmouth bass and fallfish, but their utilization of this food supply was simply opportunistic feeding and not a lasting deviation from their normal diet. There is some indication that the fenitrothion treatment made some of the larger aquatic insects susceptible to fish predation for a short period by increasing their movements in response to the irritating effects of the insecticide. This has often been seen in streams where insect drift increases after an insecticide application and fish feed on the disturbed insects in the drift.

MacDonald and Penney (1968) found that salmon parr populations in a fenitrothion treated and an untreated stream showed similar increases in their average condition factor over an eight week period. In this study white suckers over 250 mm in total length in the two lakes had a similar net change in mean condition coefficient over the summer, while smaller white suckers appeared to increase in condition to a greater extent in the untreated lake. No definitive conclusions can be made on the effects of the fenitrothion treatment on fish condition because of small sample sizes and large standard deviations within samples. The limited observations made on nesting smallmouth bass indicated that reproduction of this species occurred successfully and the newly hatched fry survived the period of greatest fenitrothion residues in their environment.

D. Toxicity of Fenitrothion to Different Fish Species

Bioassays with different fish species have shown that there is a tendency for sensitivity to a pesticide to follow family lines (Walker *et al*, 1964). Macek and McAllister (1970) tested twelve species of fish against nine insecticides and found that susceptibility was generally similar within systematic groups, with Salmonidae being the most susceptible of the families tested and Ictaluridae and Cyprinidae being the least susceptible. Identical results were found in the fenitrothion bioassays conducted, even though different species were used than in the Macek and McAllister study. The salmonid (brook trout) was the most sensitive species while the ictalurid (brown bullhead) and cyprinid (golden shiner) were the least sensitive. The two species of *Micropterus* tested were found to be very similar in their response to fenitrothion, even though individuals of very different size were tested. This suggests that the closer the systematic relationship, the closer the susceptiblity to fenitrothion.

The toxicity of fenitrothion to cyprinids and ictalurids as compared to the three centrarchids tested fall within the range of 1:1 to 2:1 found by Macek and McAllister. They related the low range of susceptibilities of different fish families to phosphorothioate insecticides in general to the structure of the organophosphorus molecule which is released during phosphorylation of cholinesterase. All organophosphorus insecticides such as fenitrothion having a substituted phenyl moiety as a leaving group appear to exhibit a small range of toxicities to different fish species.

## V. GENERAL DISCUSSION AND CONCLUSIONS

Fenitrothion applied at dosages registered for forest insect control does not appear to present a serious hazard to native fish populations in lakes exposed to aerial applications. Insecticide deposit on lakes from early morning or late evening applications is limited by air currents rising from the surface of the lake, provided that surface waters are warmer than air temperatures. Concentrations of fenitrothion in lake waters are unlikely to exceed suggested 'safe levels' of 0.1 to 0.05 of the incipient LC50 (Sprague, 1971). Maximum fenitrothion concentrations measured in lake waters from the application of twice the normal dosage applied in forest pest control operations were 21.6 µg/ℓ, while incipient LC50 values for most fish species appear to be close to or greater than 1 mg/ℓ.

Individual fish may suffer acute or sublethal effects if they come into contact with concentrated fenitrothion residues at the lake's surface shortly after they enter the lake. This hazard may be increased if the insecticide is carried in a solvent oil which holds it in a surface film or if fish are drawn to the surface to feed on knocked down flying insects. Fenitrothion applied as an emulsion in water rapidly disperses throughout lake waters and fish frequenting different habitats within the lake are all exposed to it and rapidly accumulate residues many times higher than found in water. Fenitrothion applied as an oil formulation would probably remain concentrated near the surface and would be expected to be accumulated to a greater extent by fish feeding in shallow water or at the surface than by bottom feeding species.

The application of 420g fenitrothion/ha to Lac Tassel had little effect on populations of fish food organisms or the diet of native fish species, with the possible exception of numbers of cladocerans and their contribution to the diets of white suckers, fallfish and yellow perch. The impact of severe reductions of zooplankton populations by insecticides in lakes would be most serious in terms of reduced survival and growth of juvenile fish totally dependent on these tiny organisms as the only suitable food source available.

Many aspects of insecticides in lakes require further study to broaden our understanding of possible effects and permit sound decision making concerning their use. Some suggested areas for focusing future investigations are implications of the type of formulation used on the fate and biological effects of insecticides, the role of lake sediments in the storage and persistence of insecticides, effects on large, shallow dwelling invertebrate fish food organisms such as dragonfly nymphs and crayfish, effects on the juvenile life stages of fish species reproducing in the early spring and long term persistence of insecticides in lake ecosystems.

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APPENDIX

Diets of fish in Lac Tassel and Lac Herman

May 1975 to May 1976

Table 1

Fish sampled for stomach content analysis from Lac Tassel

White suckers

| | | | |
|---|---|---|---|
| Date | May 23 (-5) | June 1 (+4) | June 13 (+16) |
| Number of fish sampled | 20 | 20 | 20 |
| Capture method | Gill Net | Gill Net | Gill Net |
| Mean total length (mm) | 238.6 | 258.1 | 241.6 |
| Mean fork length (mm) | 220.8 | 239.6 | 227.0 |
| Mean preserved weight (g) | 157.9 | 201.3 | 150.0 |
| Sex ratio (males:females) | 17:3 | 15:5 | 14:6 |

| | | | |
|---|---|---|---|
| Date | July 4 (+37) | Aug. 19 (+82) | 18 May 1976 (+1 year) |
| Number of fish sampled | 20 | 20 | 20 |
| Capture method | Gill Net | Gill Net | Gill Net |
| Mean total length (mm) | 221.9 | 239.4 | 264.3 |
| Mean fork length (mm) | 207.6 | 225.3 | 246.8 |
| Mean preserved weight (g) | 138.7 | 175.2 | 221.8 |
| Sex ratio (males:females) | 18:2 | 14:6 | 7:3 |

Smallmouth bass

| | | | |
|---|---|---|---|
| Date | May 20-23 (-8 to -5) | May 28 (+0) | May 28 (+15 hours) |
| Number of fish sampled | 8 | 8 | 3 |
| Capture method | Angling | Trap Net | Angling |
| Mean total length (mm) | 269.2 | 244.5 | 344.6 |
| Mean fork length (mm) | 256.6 | 233.5 | 317.3 |
| Sex ratio (males:females:immatures | 5:3:0 | 1:5:2 | 2:1 |

Table 1 (Cont'd.)

Smallmouth bass (Cont'd.)

| Date | May 31-June 1 (+3 to +4) | June 4 (+7) | June 12 (+15) | July 3 (+36) |
|---|---|---|---|---|
| Number of fish sampled | 7 | 4 | 12 | 20 |
| Capture method | Angling | Angling | Angling (9) Gill Net (3) | Angling |
| Mean total length (mm) | 205.0 | 176.5 | 231.6 | 284.4 |
| Mean fork length (mm) | 196.8 | 168.0 | 220.6 | 270.8 |
| Sex ratio (males:females:immatures) | 4:2:1 | 0:1:3 | 7:5:0 | 17:3:0 |

| Date | July 4 (+37) | Aug. 19 (+82) | 18-30 May, 1976 (+1 year) |
|---|---|---|---|
| Number of fish sampled | 12 | 5 | 2 |
| Capture method | Gill Net (7) Trap Net (5) | Gill Net | Angling (1) Gill Net (1) |
| Mean total length (mm) | 208.7 | 160.8 | 247.5 |
| Mean fork length (mm) | 200.5 | 153.2 | 241.0 |
| Sex ratio (males:females:immatures) | 12:0:0 | 4:0:1 | 2:0:0 |

Brown bullheads

| Date | May 23 (-5) | May 28 (-0) | July 4 (+37) | Aug. 19 (+82) | 18 May, 1976 (+1 yea |
|---|---|---|---|---|---|
| Number of fish sampled | 8 | 8 | 8 | 2 | 7 |
| Capture method | Gill Net | Trap Net | Gill Net (5) Trap Net (3) | Gill Net | Gill Net |
| Mean total length (mm) | 205.6 | 190.1 | 186.6 | 159.5 | 205.6 |
| Mean preserved weight (g) | 129.1 | 108.8 | 94.7 | 51.8 | 131.6 |
| Sex ratio (males:females:immatures) | 4:4:0 | 3:3:2 | 5:3:0 | 1:1:0 | 3:4:0 |

Table 1 (Cont'd.)

Yellow Perch

| | | | |
|---|---|---|---|
| Date | May 23-28 (-5 to -0) | June 1-2 (+4 to +5) | June 13 (+16) |
| Number of fish sampled | 2 | 5 | 19 |
| Capture method | Gill Net (1) Trap Net (1) | Gill Net (4) Trap Net (1) | Gill Net |
| Mean total length (mm) | 217.5 | 180.8 | 208.9 |
| Mean fork length (mm) | 208.0 | 173.2 | 199.8 |
| Mean weight (g) | 110.8 | 62.2 | 101.9 |
| Date | July 4 (+37) | Aug. 19 (+82) | 18 May, 1976 (+1 year) |
| Number of fish sampled | 2 | 6 | 7 |
| Capture method | Gill Net | Gill Net | Gill Net |
| Mean total length (mm) | 230.0 | 195.2 | 143.3 |
| Mean fork length (mm) | 221.0 | 187.5 | 138.1 |
| Mean weight (g) | 124.5 | 80.3 | 42.3 |

Common Shiners

| | | | |
|---|---|---|---|
| Date | May 23 (-5) | May 30 (+2) | June 13 (+16) |
| Number of fish sampled | 2 | 1 | 2 |
| Capture method | Gill Net | Trap Net | Gill Net |
| Mean total length (mm) | 162.5 | 198.0 | 160.5 |
| Mean fork length (mm) | 148.0 | 183.0 | 147.5 |
| Mean weight (g) | 63.0 | 130.5 | 61.5 |
| Sex ratio (males:females) | 2:0 | 1:0 | 1:1 |

Table 1 (Cont'd.)

Fallfish

| | | | |
|---|---|---|---|
| Date | May 20 (-8) | May 23 (-5) | May 28 (+15 hours) |
| Number of fish sampled | 5 | 20 | 1 |
| Capture method | Angling | Gill Net | Angling |
| Mean total length (mm) | 261.8 | 231.1 | 268.0 |
| Mean fork length (mm) | 238.6 | 208.4 | 246.0 |
| Mean preserved weight (g) | - | 136.2 | - |
| Sex ratio (males:females) | 2:3 | 8:12 | 1:0 |
| Date | May 31 (+3) | June 1 (+4) | June 13 (+16) |
| Number of fish sampled | 5 | 7 | 20 |
| Capture method | Angling | Gill Net | Gill Net |
| Mean total length (mm) | 233.6 | 227.9 | 215.5 |
| Mean fork length (mm) | 210.6 | 205.7 | 196.3 |
| Mean preserved weight (g) | - | 125.6 | 105.5 |
| Sex ratio (males:females) | 5:0 | 4:3 | 13:7 |
| Date | July 4 (+37) | Aug. 19 (+82) | 18 May 1976 (+1 year) |
| Number of fish sampled | 4 | 4 | 1 |
| Capture method | Angling (1) Gill Net (3) | Gill Net | Gill Net |
| Mean total length (mm) | 261.8 | 252.5 | 260.0 |
| Mean fork length (mm) | 239.3 | 231.8 | 240.0 |
| Mean preserved weight (g) | 184.5 | 185.6 | 238.0 |
| Sex ratio (males:females) | 4:0 | 1:3 | 0:1 |

Table 2

Fish sampled for stomach content analysis from Lac Herman

White Suckers

| | | | |
|---|---|---|---|
| Date | May 22 (-6) | May 30 (+2) | June 17 (+20) |
| Number of fish sampled | 19 | 20 | 15 |
| Colletion method | Gill Net | Gill Net | Gill Net |
| Mean total length (mm) | 248.5 | 221.0 | 193.4 |
| Mean fork length (mm) | 230.3 | 206.9 | 181.1 |
| Mean preserved weight (g) | 184.2 | 122.9 | 90.9 |
| Sex ratio (males:females) | 7:12 | 13:7 | 7:8 |

| | | |
|---|---|---|
| Date | Aug. 20 (+83) | 17 May, 1976 (+1 year) |
| Number of fish sampled | 7 | 20 |
| Colletion method | Gill Net | Gill Net |
| Mean total length (mm) | 206.1 | 235.8 |
| Mean fork length (mm) | 192.4 | 219.4 |
| Mean preserved weight (g) | 116.3 | 154.0 |
| Sex ratio (males:females) | 2:5 | 6:14 |

Brook Trout

| | | | |
|---|---|---|---|
| Date | May 13 (-15) | May 22 (-6) | May 30 (+2) |
| Number of fish sampled | 6 | 21 | 11 |
| Collection method | Angling | Gill Net | Gill Net |
| Mean total length (mm) | 312.8 | 276.6 | 267.0 |
| Mean fork length (mm) | 299.8 | 263.8 | 254.8 |
| Sex ratio (males:females:immatures) | 1:5:0 | 10:10:1 | 4:7:0 |

Table 2 (Cont'd.)

Brook Trout (Cont'd.)

| | | | |
|---|---|---|---|
| Date | June 17 (+20) | Aug. 20 (+83) | 17 May, 1976 (+1 year) |
| Number of fish sampled | 2 | 19 | 8 |
| Collection method | Gill Net | Gill Net | Gill Net |
| Mean total length (mm) | 213.5 | 228.6 | 330.0 |
| Mean fork length (mm) | 206.0 | 217.8 | 317.6 |
| Sex ratio (males:females:immatures) | 1:1:0 | 14:5:0 | 2:4:2 |

Brown bullheads

| | | | | |
|---|---|---|---|---|
| Date | May 22 (-6) | May 30 (+2) | Aug. 20 (+83) | 17 May 1976 (+1 year) |
| Number of fish sampled | 8 | 20 | 3 | 10 |
| Collection method | Gill Net | Gill Net | Gill Net | Gill Net |
| Mean total length (mm) | 125.0 | 135.4 | 144.3 | 156.6 |
| Mean preserved weight (g) | 30.7 | 35.5 | 36.8 | 48.8 |
| Sex ratio (males:females:immatures) | 1:3:4 | 14:6:0 | 3:0:0 | 5:5:5 |

Table 3

Food items found in fish stomachs from Lac Tassel and Lac Herman

| Food group | Common Name | Comments |
|---|---|---|
| Aquatic insects | Alderfly larvae | Megaloptera:Sialidae (*Sialis sp.*) |
| | Backswimmers | Hemiptera:Notonectidae |
| | Beetles | Coleoptera:various families |
| | Beetle larvae | Coleoptera:primarily Elmidae |
| | Blackfly larvae | Diptera:Simuliidae (from streams entering lakes) |
| | Burrowing mayfly nymphs | Ephemeroptera:Ephemeridae |
| | Caddisfly larvae | Trichoptera-various families |
| | Caddisfly pupae | " " " |
| | Caterpillars | Lepidoptera:Pyralidae |
| | Damselfly nymphs | Odonata:Zygoptera |
| | Dragonfly nymphs | Odonata:Gomphidae and Libellulidae |
| | Fishfly larvae | Megaloptera:Corydalidae |
| | Mayfly nymphs | Ephemeroptera:Baetidae and Heptageniidae |
| | Midge larvae | Diptera:Chironomidae and some Heleidae (Culicoides sp.) |
| | Midge pupae | " " |
| | Spongilla-fly larvae | Neuroptera:Sisyridae |
| | Water boatmen | Hemiptera:Corixidae |
| | Water striders | Hemiptera:Gerridae |
| Planktonic organisms | Cladocerans | Crustacea-Cladocera |
| | Copepods | Crustacea-Copepoda |
| | Ostracods | Crustacea-Ostracoda |
| | Phantom midge larvae | Insecta-Diptera:Culicidae (*Chaoborus sp.*) |
| | Phantom midge pupae | " " " " |

Table 3 (Cont'd.)

| Food group | Common name | Comments |
|---|---|---|
| Other aquatic invertebrates | Amphipods | Crustacea-Amphipoda |
| | Fingernail clams | Pelecypoda-Sphaeriidae |
| | Isopods | Crustacea-Isopoda |
| | Leeches | Hirudinea |
| | Oligochaetes | Oligochaeta |
| | Snails | Gastropoda |
| | Water mites | Arachnida-Hydracarina |
| Fish eggs | | Probably white sucker eggs |
| Minnows | | Includes small white suckers and perch as well as cyprinids |
| Frogs | | Probably green frogs. _Rana clamitans_ |
| Newts | | Spotted newts. _Triturus viridescens_ |
| Terrestrial arthropods | Beetles | Coleoptera:various families |
| | Dragonflies | Odonata:Anisoptera |
| | Flying ants | Hymenoptera:Formicidae |
| | Midges | Diptera:various families |
| | Spiders | Arachnida |
| | Unidentified flying insects | Include Diptera, Trichoptera, Ephemeroptera etc. |
| | Unidentified terrestrial insects | Include Hemiptera, larval Lepidoptera etc. |

Notes on appendix Tables 4 to 28.

Mean volume of stomach contents - Mean of all fish in sample including those with empty stomachs

Mean percent of the volume contributed by various food items - only fish with some food in their stomach are included in calculating these values. The % contribution to volume of each food item in an individual fish's stomach is determined for all fish in the sample with some food in their stomach. For each food item, the % contributions to volume for each fish stomach in which that food item occurs are then summed and the total is taken as a percentage of the possible total contribution (the number of fish with food in their stomachs X 100%). This means that a midge larva contributing 100% of the volume of the stomach contents of one fish ends up with the same value as a 5 cm minnow contributing 100% of the volume of another fish's stomach contents.

Mean numbers of various food items in stomachs in which they occurred - Only fish with the food item in question in their stomachs are included in taking the mean

| | | |
|---|---|---|
| Example | Fish 1 | Six snails (0.2 ml) One minnow (0.6 ml) |
| | Fish 2 | Four snails (0.1 ml) |
| | Fish 3 | Empty |

Mean volume of stomach contents: $\frac{0.8 + 0.1}{3} = 0.3$ ml

Mean percent of the volume contributed by:

Snails $\frac{25\% + 100\%}{2 \times 100\%} = 62.5\%$

Minnows $\frac{80\%}{2 \times 100\%} = 37.5\%$

Mean numbers in stomachs in which they occur:

Snails $\frac{6 + 4}{2} = 5$

Minnows $\frac{1}{1} = 1$

Table 4

Percent occurrence of various food items in white sucker digestive tracts from Lac Tassel, 23 May, 1975 to 18 May, 1976

| Number of days before or after treatment | -5 | +4 | +16 | +37 | +82 | +1 year |
|---|---|---|---|---|---|---|
| No food present | 10 | 0 | 20 | 5 | 5 | 0 |
| Aquatic insects | | | | | | |
| Alderfly larvae | 10 | 5 | 10 | 0 | 5 | 0 |
| Beetles | 25 | 5 | 5 | 30 | 5 | 0 |
| Beetle larvae | 55 | 15 | 20 | 35 | 15 | 10 |
| Burrowing mayfly nymphs | 10 | 15 | 10 | 5 | 5 | 20 |
| Caddisfly larvae | 75 | 65 | 25 | 40 | 50 | 20 |
| Caddisfly pupae | 0 | 5 | 0 | 0 | 0 | 0 |
| Damselfly nymphs | 0 | 0 | 0 | 0 | 15 | 10 |
| Dragonfly nymphs | 20 | 30 | 10 | 5 | 65 | 0 |
| Mayfly nymphs | 20 | 35 | 10 | 25 | 5 | 10 |
| Midge larvae | 85 | 90 | 80 | 85 | 65 | 20 |
| Midge pupae | 55 | 30 | 35 | 10 | 15 | 0 |
| Unidentifiable | 0 | 0 | 0 | 0 | 0 | 10 |
| Planktonic organisms | | | | | | |
| Cladocerans | 25 | 55 | 5 | 35 | 95 | 100 |
| Copepods | 0 | 0 | 25 | 5 | 0 | 10 |
| Ostracods | 0 | 0 | 5 | 0 | 0 | 0 |
| Phantom midge larvae | 20 | 10 | 5 | 0 | 0 | 10 |
| Other aquatic invertebrates | | | | | | |
| Amphipods | 30 | 0 | 10 | 50 | 30 | 10 |
| Fingernail clams | 0 | 10 | 0 | 0 | 0 | 0 |
| Snails | 20 | 15 | 25 | 35 | 40 | 0 |
| Water mites | 5 | 25 | 15 | 25 | 5 | 0 |
| Fish eggs | 0 | 0 | 0 | 0 | 0 | 10 |
| Flying insects | 0 | 0 | 0 | 0 | 5 | 0 |

Table 5

Mean percent of the volume of white sucker digestive tract contents contributed by various food items, Lac Tassel, 23 May, 1975 to 18 May, 1976

| Number of days before or after treatment | -5 | +4 | +16 | +37 | +82 | +1 year |
|---|---|---|---|---|---|---|
| Aquatic insects | | | | | | |
| Alderfly larvae | 0.6 | 0.2 | 1.9 | 0.0 | 0.5 | 0.0 |
| Beetles | 3.4 | 0.8 | 0.6 | 4.7 | 0.3 | 0.0 |
| Beetle larvae | 6.6 | 1.5 | 4.1 | 8.9 | 1.6 | 0.5 |
| Burrowing mayfly nymphs | 0.8 | 2.8 | 2.2 | 0.5 | 0.3 | 4.2 |
| Caddisfly larvae | 21.9 | 17.0 | 3.8 | 7.9 | 11.8 | 1.0 |
| Caddisfly pupae | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| Damselfly nymphs | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 0.3 |
| Dragonfly nymphs | 4.2 | 6.5 | 4.1 | 1.0 | 27.1 | 0.0 |
| Mayfly nymphs | 5.0 | 4.2 | 1.2 | 3.9 | 0.3 | 0.5 |
| Midge larvae | 22.5 | 26.2 | 55.9 | 38.7 | 10.3 | 4.9 |
| Midge pupae | 8.6 | 2.2 | 4.1 | 0.8 | 0.5 | 0.3 |
| Unidentifiable | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 |
| Plantonic organisms | | | | | | |
| Cladocerans | 14.7 | 32.8 | 5.9 | 14.7 | 37.9 | 78.4 |
| Copepods | 0.0 | 0.0 | 7.8 | 0.3 | 0.0 | 3.9 |
| Ostracods | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 |
| Phantom midge larvae | 5.6 | 0.5 | 0.0 | 0.0 | 0.0 | 4.7 |
| Other aquatic invertebrates | | | | | | |
| Amphipods | 3.6 | 0.0 | 2.8 | 11.8 | 2.1 | 0.2 |
| Fingernail clams | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| Snails | 1.2 | 1.8 | 4.4 | 4.5 | 5.0 | 0.5 |
| Water mites | 0.3 | 2.2 | 1.2 | 2.1 | 0.5 | 0.0 |
| Fish eggs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 |
| Flying insects | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 |

Table 6

Mean numbers of various food items in white sucker digestive tracts in which they occurred,

Lac Tassel, 23 May, 1976 to 18 May, 1977

| Number of days before or after treatment | -5 | +4 | +16 | +37 | +82 | +1 year |
|---|---|---|---|---|---|---|
| Aquatic insects | | | | | | |
| Alderfly larvae | 1 | 1 | 1½ | - | 3 | - |
| Beetles | 4 | 5 | 6 | 2 | 4 | - |
| Beetle larvae | 4 | 2 | 5 | 6 | 9 | 10 |
| Burrowing mayfly nymphs | 1 | 2 | 1½ | 2 | 2 | 1 |
| Caddisfly larvae | 6 | 9 | 1 | 3 | ∿12 | 4 |
| Caddisfly pupae | - | 4 | - | - | - | - |
| Damselfly nymphs | - | - | - | - | 1 | 2 |
| Dragonfly nymphs | 3 | 3 | 1 | 3 | 5 | 6 |
| Mayfly nymphs | 4 | 1½ | 1 | 1 | 1 | - |
| Midge larvae | ∿30 | ∿29 | ∿30 | ∿28 | ∿30 | ∿17 |
| Midge pupae | 5 | 1 | 1 | 1½ | 1 | - |
| Unidentifiable | | - | - | - | - | 1 |
| Planktonic organisms | | | | | | |
| Cladocerans | 100's | ∿1000 | 1000's | 100's | ∿1000 | ∿1000 |
| Copepods | - | - | 100's | ∿100 | - | ∿1000 |
| Ostracods | - | - | 50 | - | - | - |
| Phantom midge larvae | ∿20 | 1 | 1 | - | - | ∿300 |
| Other aquatic invertebrates | | | | | | |
| Amphipods | ∿6 | - | 4 | 16 | 10 | 5 |
| Fingernail clams | - | 1½ | - | - | - | - |
| Snails | 1½ | 3 | 5 | 4 | 11 | - |
| Water mites | 2 | 2 | 1 | 1 | 1 | - |
| Fish eggs | - | - | - | - | - | 10 |
| Flying insects | - | - | - | - | 3 | - |

Table 7

Percent occurrence of various food items in white sucker digestive tracts from Lac Herman, 22 May, 1975 to 17 May, 1976

| Number of days before or after treatment of Lac Tassel | -6 | +2 | +20 | +83 | +1 year |
|---|---|---|---|---|---|
| No food present | 0 | 20 | 7 | 14 | 15 |
| Aquatic insects | | | | | |
| Alderfly larvae | 16 | 0 | 0 | 14 | 0 |
| Beetles | 0 | 5 | 0 | 0 | 0 |
| Beetle larvae | 0 | 5 | 0 | 14 | 5 |
| Burrowing mayfly nymphs | 58 | 30 | 33 | 43 | 30 |
| Caddisfly larvae | 42 | 30 | 13 | 43 | 10 |
| Caddisfly pupae | 0 | 5 | 0 | 0 | 0 |
| Dameslfly nymphs | 0 | 5 | 0 | 0 | 5 |
| Dragonfly nymphs | 10 | 15 | 7 | 0 | 5 |
| Mayfly nymphs | 0 | 5 | 7 | 14 | 10 |
| Midge larvae | 90 | 70 | 53 | 71 | 50 |
| Midge pupae | 16 | 30 | 27 | 14 | 55 |
| Water boatmen | 5 | 0 | 0 | 0 | 0 |
| Planktonic organisms | | | | | |
| Cladocerans | 5 | 20 | 64 | 0 | 25 |
| Phantom midge larvae | 0 | 5 | 0 | 0 | 5 |
| Phantom midge pupae | 0 | 0 | 0 | 14 | 0 |
| Other aquatic invertebrates | | | | | |
| Amphipods | 5 | 0 | 0 | 0 | 5 |
| Fingernail clams | 0 | 0 | 7 | 29 | 0 |
| Oligochaetes | 10 | 0 | 0 | 0 | 0 |
| Snails | 32 | 0 | 0 | 0 | 0 |
| Water mites | 5 | 5 | 0 | 0 | 0 |

Table 8

Mean percent of the volume of white sucker digestive tract contents contributed by various food items, Lac Herman, 22 May, 1975 to 17 May, 1976.

| Number of days before or after treatment of Lac Tassel | -6 | +2 | +20 | +83 | +1 year |
|---|---|---|---|---|---|
| Aquatic insects | | | | | |
| Alderfly larvae | 0.6 | 0.0 | 0.0 | 2.5 | 0.0 |
| Beetles | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 |
| Beetle larvae | 0.0 | 0.3 | 0.0 | 5.0 | 0.3 |
| Burrowing mayfly nymphs | 25.5 | 9.4 | 17.5 | 46.7 | 11.5 |
| Caddisfly larvae | 16.0 | 13.1 | 3.2 | 20.8 | 7.9 |
| Caddisfly pupae | 0.0 | 1.2 | 0.0 | 0.0 | 0.0 |
| Damselfly nymphs | 0.0 | 2.5 | 0.0 | 0.0 | 0.3 |
| Dragonfly nymphs | 1.3 | 4.1 | 1.1 | 0.0 | 2.0 |
| Mayfly nymphs | 0.0 | 1.6 | 0.7 | 0.8 | 4.1 |
| Midge larvae | 28.7 | 29.4 | 17.8 | 16.7 | 12.4 |
| Midge pupae | 10.8 | 17.5 | 1.8 | 4.2 | 42.0 |
| Water boatmen | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Planktonic organisms | | | | | |
| Cladocerans | <0.1 | 17.2 | 57.5 | 0.0 | 15.9 |
| Phantom midge larvae | 0.0 | 0.3 | 0.0 | 0.0 | 0.6 |
| Phantom midge pupae | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 |
| Other aquatic invertebrates | | | | | |
| Amphipods | 0.5 | 0.0 | 0.0 | 0.0 | 0.3 |
| Fingernail clams | 0.0 | 0.0 | 0.4 | 2.5 | 0.0 |
| Oligochaetes | 5.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| Snails | 8.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| Water mites | 2.1 | 3.1 | 0.0 | 0.0 | 0.0 |

Table 9

Mean numbers of various food items in white sucker digestive tracts inchich they occurred, Lac Herman, 22 May, 1975 to 17 May, 1976

| Number of days before or after treatment of Lac Tassel | -6 | +2 | +20 | +83 | +1 year |
|---|---|---|---|---|---|
| Aquatic insects | | | | | |
| Alderfly larvae | 1 | - | - | 2 | - |
| Beetles | - | 1 | - | - | - |
| Beetle larvae | - | 2 | - | 7 | 1 |
| Burrowing mayfly nymphs | 5 | 3 | 4 | ∿18 | 3 |
| Caddisfly larvae | 9 | 3 | 7 | 6 | 7 |
| Caddisfly pupae | - | 3 | - | - | - |
| Damselfly nymphs | - | 4 | - | - | 1 |
| Dragonfly nymphs | 1 | 2 | 2 | - | 3 |
| Mayfly nymphs | - | 10 | 1 | 1 | 6 |
| Midge larvae | ∿40 | ∿25 | ∿45 | 9 | ∿17 |
| Midge pupae | ∿40 | ∿20 | 1 | 4 | ∿20 |
| Water boatmen | 1 | - | - | - | - |
| Plankton organisms | | | | | |
| Cladocerans | 1 | 100's | 1000's | - | 100's |
| Phantom midge larvae | - | 10 | - | - | 1 |
| Phantom midge pupae | - | - | - | 1 | - |
| Other aquatic invertebrates | | | | | |
| Amphipods | 1 | - | - | - | 6 |
| Fingernail clams | - | - | 2 | 2½ | - |
| Oligochaetes | 1½ | - | - | - | - |
| Snails | 14 | - | - | - | - |
| Water mites | 2 | 2 | - | - | - |

Table 10

Percent occurrence of various food items in smallmouth bass stomachs from Lac Tassel

20 May, 1975 to 30 May, 1976

| Number of days before or after treatment | -8 to -5 | -0 | +15 hours | +3 to +4 | +7 | +15 | +36 | +37 | +82 | +1 year |
|---|---|---|---|---|---|---|---|---|---|---|
| No food present | 12 | 25 | 33 | 0 | 50 | 17 | 55 | 50 | 0 | 50 |
| Aquatic insects | | | | | | | | | | |
| Alderfly larvae | 12 | 0 | 33 | 0 | 0 | 0 | 0 | 0 | 20 | 0 |
| Beetles | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 |
| Beetle larvae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 |
| Burrowing mayfly nymphs | 12 | 12 | 0 | 14 | 25 | 33 | 10 | 8 | 40 | 0 |
| Caddisfly larvae | 12 | 0 | 33 | 86 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caddisfly pupae | 0 | 0 | 0 | 14 | 25 | 0 | 0 | 0 | 0 | 0 |
| Damselfly nymphs | 0 | 0 | 33 | 29 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dragonfly nymphs | 12 | 0 | 0 | 71 | 0 | 25 | 0 | 0 | 20 | 0 |
| Mayfly nymphs | 38 | 38 | 67 | 71 | 0 | 33 | 0 | 0 | 40 | 0 |
| Midge larvae | 0 | 12 | 0 | 43 | 0 | 8 | 0 | 0 | 0 | 0 |
| Midge pupae | 0 | 0 | 67 | 14 | 0 | 0 | 0 | 0 | 0 | 0 |
| Planktonic organisms | | | | | | | | | | |
| Cladocerans | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 0 |
| Phantom midge larvae | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 20 | 0 |
| Phantom midge pupae | 0 | 0 | 0 | 0 | 0 | 8 | 5 | 0 | 0 | 0 |
| Other aquatic invertebrates | | | | | | | | | | |
| Snails | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 |
| Water mites | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 0 |
| Minnows | 12 | 38 | 0 | 0 | 25 | 42 | 40 | 33 | 0 | 0 |
| Frogs | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Terrestrial and flying insects | | | | | | | | | | |
| Beetles | 0 | 12 | 33 | 0 | 0 | 8 | 0 | 0 | 0 | 0 |
| Dragonflies | 0 | 0 | 0 | 0 | 0 | 8 | 5 | 17 | 0 | 0 |
| Midges | 0 | 0 | 0 | 0 | 25 | 8 | 0 | 0 | 0 | 0 |
| Unidentified flying insects | 12 | 0 | 67 | 0 | 0 | 17 | 5 | 17 | 0 | 50 |
| Unidentified terrestrial insects | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 11

Mean percent of the volume of smallmouth bass stomach contents contributed by various food items, Lac Tassel, 20 May, 1975 to 30 May, 1976

| Number of days before or after treatment | -8 to -5 | -0 | +15 hours | +3 to +4 | +7 | +15 | +36 | +37 | +83 | +1 year |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean volume of stomach contents (ml) | 0.30 | 2.40 | 0.80 | 0.44 | 0.10 | 0.65 | 1.03 | 0.51 | 0.26 | 0.10 |
| Aquatic insects | | | | | | | | | | |
| Alderfly larvae | 2.9 | 0.0 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 |
| Beetles | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 |
| Beetle larvae | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.0 |
| Burrowing mayfly nymphs | 10.0 | 8.3 | 0.0 | 1.4 | 10.0 | 13.5 | 3.3 | 0.0 | 12.0 | 0.0 |
| Caddisfly larvae | 0.7 | 0.0 | 5.0 | 18.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Caddisfly pupae | 0.0 | 0.0 | 0.0 | 5.7 | 25.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Damselfly nymphs | 0.0 | 0.0 | 10.0 | 4.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Dragonfly nymphs | 10.0 | 0.0 | 0.0 | 36.4 | 0.0 | 11.8 | 0.0 | 0.8 | 20.0 | 0.0 |
| Mayfly nymphs | 18.6 | 40.0 | 10.0 | 31.4 | 0.0 | 14.8 | 0.0 | 0.0 | 24.0 | 0.0 |
| Midge larvae | 0.0 | 1.7 | 0.0 | 0.7 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Midge pupae | 0.0 | 0.0 | 7.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Planktonic organisms | | | | | | | | | | |
| Cladocerans | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.0 | 0.0 |
| Phantom midge larvae | 0.0 | 0.0 | 0.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.0 |
| Phantom midge pupae | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 1.1 | 0.0 | 0.0 | 0.0 |
| Other aquatic invertebrates | | | | | | | | | | |
| Snails | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| Water mites | 0.0 | 0.0 | 0.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Minnows | 0.7 | 45.8 | 0.0 | 0.0 | 50.0 | 44.5 | 86.7 | 49.2 | 0.0 | 0.0 |
| Frogs | 0.0 | 3.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Terrestrial and flying insects | | | | | | | | | | |
| Beetles | 0.0 | 0.8 | 2.5 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Dragonflies | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.0 | 5.6 | 33.3 | 0.0 | 0.0 |
| Midges | 0.0 | 0.0 | 0.0 | 0.0 | 15.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| Unidentified flying insects | 14.3 | 0.0 | 60.0 | 0.0 | 0.0 | 4.5 | 3.3 | 15.8 | 0.0 | 100.0 |
| Unidentified terrestrial insects | 42.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Table 12

Mean numbers of various food items in smallmouth bass stomachs in which they occurred,
Lac Tassel, 20 May, 1975 to 30 May, 1976

| Number of days before or after treatment | -8 to -5 | -0 | +15 hours | +3 to +4 | +7 | +15 | +36 | +37 | +83 | +1 year |
|---|---|---|---|---|---|---|---|---|---|---|
| Aquatic insects | | | | | | | | | | |
| Alderfly larvae | 1 | - | 1 | - | - | - | - | - | 1 | - |
| Beetles | - | - | - | - | - | - | - | 1 | - | - |
| Beetle larvae | - | - | - | - | - | - | - | - | 1 | - |
| Burrowing mayfly nymphs | 1 | 1 | - | 1 | 1 | 2 | 1 | - | 1 | - |
| Caddisfly larvae | 2 | - | 3 | 6 | - | - | - | - | - | - |
| Caddisfly pupae | - | - | - | 1 | 1 | - | - | - | - | - |
| Damselfly nymphs | - | - | 3 | 1½ | - | - | - | - | - | - |
| Dragonfly nymphs | 1 | - | - | 3 | - | 1 | - | 1 | 2 | - |
| Mayfly nymphs | 2 | 1 | 2 | 4 | - | 1 | - | - | 2½ | - |
| Midge larvae | - | 1 | - | 2 | - | 2 | - | - | - | - |
| Midge pupae | - | - | 2 | 1 | - | - | - | - | - | - |
| Planktonic organisms | | | | | | | | | | |
| Cladocerans | - | - | - | - | - | - | - | - | ∿100 | - |
| Phantom midge larvae | - | - | - | 4 | - | - | - | - | 7 | - |
| Phantom midge pupae | - | - | - | - | - | 1 | 5 | - | - | - |
| Other aquatic invertebrates | | | | | | | | | | |
| Snails | - | - | - | - | - | 1 | - | - | - | - |
| Water mites | - | - | - | 100's | - | - | - | - | - | - |
| Minnows | 1 | 1 | - | - | 1 | 3 | 2 | 6 | - | - |
| Frogs | - | 1 | - | - | - | - | - | - | - | - |
| Terrestrial and flying insects | | | | | | | | | | |
| Beetles | - | 1 | 1 | - | - | 1 | - | - | - | - |
| Dragonflies | - | - | - | - | - | 1 | 1 | 1 | - | - |
| Midges | - | - | - | - | 2 | 1 | - | - | - | - |
| Unidentified flying insects | 1 | - | 12 | - | - | 2 | 2 | 3 | - | 1 |
| Unidentified terrestrial insects | 1 | - | - | - | - | - | - | - | - | - |

Table 13

Percent occurrence of various food items in fallfish digestive tracts form Lac Tassel,

20 May, 1975 to 18 May, 1976

| Number of days before or after treatment | -8 | -5 | +15 hours | +3 | +4 | +16 | +37 | +82 | +1 year |
|---|---|---|---|---|---|---|---|---|---|
| No food present | 0 | 5 | 0 | 0 | 43 | 40 | 50 | 25 | 0 |
| Aquatic insects | | | | | | | | | |
| Alderfly larvae | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Beetles | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 |
| Burrowing mayfly nymphs | 0 | 0 | 0 | 0 | 43 | 20 | 0 | 75 | 0 |
| Caddisfly larvae | 80 | 5 | 0 | 80 | 79 | 15 | 0 | 0 | 100 |
| Damselfly nymphs | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dragonfly nymphs | 40 | 5 | 0 | 40 | 43 | 10 | 0 | 0 | 0 |
| Mayfly nymphs | 20 | 10 | 0 | 20 | 14 | 5 | 0 | 0 | 0 |
| Midge larvae | 20 | 10 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| Midge pupae | 0 | 0 | 0 | 0 | 14 | 10 | 0 | 0 | 0 |
| Unidentifiable remains | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Planktonic Organisms | | | | | | | | | |
| Cladocerans | 20 | 55 | 0 | 0 | 14 | 0 | 0 | 25 | 0 |
| Phantom midge larvae | 0 | 10 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| Phantom midge pupae | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 |
| Other aquatic invertebrates | | | | | | | | | |
| Snails | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water mites | 20 | 0 | 0 | 40 | 0 | 0 | 0 | 0 | 0 |
| Minnows | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 25 | 0 |
| Terrestrial arthropods | | | | | | | | | |
| Beetles | 0 | 20 | 100 | 0 | 0 | 10 | 0 | 0 | 0 |
| Flying ants | 20 | 35 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| Midges | 20 | 0 | 100 | 0 | 0 | 5 | 0 | 0 | 0 |
| Spiders | 20 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| Unidentified flying insects | 0 | 45 | 100 | 0 | 14 | 30 | 50 | 0 | 0 |
| Unidentified terrestrial insects | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 14

Mean percent of the volume of fallfish digestive tract contents contributed by various food items, Lac Tassel, 20 May, 1975 to 18 May, 1976

| Number of days before or after treatment | -8 | -5 | +15 hours | +3 | +4 | +16 | +37 | +82 | +1 year |
|---|---|---|---|---|---|---|---|---|---|
| Mean volume of digestive tract contents (ml) | 2.58 | 1.50 | 3.50 | 0.60 | 0.80 | 0.80 | 1.95 | 0.30 | 0.20 |
| Aquatic insects | | | | | | | | | |
| Alderfly larvae | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Beetles | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 5.4 | 0.0 | 0.0 | 0.0 |
| Burrowing mayfly nymphs | 0.0 | 0.0 | 0.0 | 0.0 | 28.8 | 14.2 | 0.0 | 76.7 | 0.0 |
| Caddisfly larvae | 58.0 | 0.3 | 0.0 | 48.0 | 3.8 | 7.0 | 0.0 | 0.0 | 100.0 |
| Damselfly nymphs | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Dragonfly nymphs | 9.0 | 4.2 | 0.0 | 29.0 | 57.5 | 10.0 | 0.0 | 0.0 | 0.0 |
| Mayfly nymphs | 7.0 | 2.1 | 0.0 | 2.0 | 1.3 | 0.8 | 0.0 | 0.0 | 0.0 |
| Midge larvae | 0.5 | <0.1 | 0.0 | 0.0 | 0.0 | <0.1 | 0.0 | 0.0 | 0.0 |
| Midge pupae | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 4.4 | 0.0 | 0.0 | 0.0 |
| Unidentifiable remains | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Planktonic organisms | | | | | | | | | |
| Cladocerans | 18.0 | 48.9 | 0.0 | 0.0 | 2.5 | 0.0 | 0.0 | 6.7 | 0.0 |
| Phantom midge larvae | 0.0 | 1.3 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 |
| Phantom midge pupae | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 27.0 | 0.0 | 0.0 | 0.0 |
| Other aquatic invertebrates | | | | | | | | | |
| Snails | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Water mites | 0.5 | 0.0 | 0.0 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Minnows | 0.0 | 0.0 | 0.0 | 16.0 | 0.0 | 0.0 | 0.0 | 16.6 | 0.0 |
| Terrestrial arthropods | | | | | | | | | |
| Beetles | 0.0 | 4.2 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Flying ants | 1.5 | 14.5 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 |
| Midges | 0.5 | 0.0 | 3.0 | 0.0 | 0.0 | 2.5 | 0.0 | 0.0 | 0.0 |
| Spiders | 2.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Unidentified flying insects | 0.0 | 22.1 | 85.0 | 0.0 | 2.5 | 28.0 | 100 | 0.0 | 0.0 |
| Unidentified terrestrial insects | 0.0 | 0.0 | 8.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Table 15

Mean numbers of various food items in fallfish digestive tracts in which they occurred, Lac Tassel, 20 May, 1975 to 18 May, 1976.

| Number of days before or after treatment | -8 | -5 | +15 hours | +3 | +4 | +16 | +37 | +82 | +1 year |
|---|---|---|---|---|---|---|---|---|---|
| Aquatic insects | | | | | | | | | |
| Alderfly larvae | - | 1 | - | - | - | - | - | - | - |
| Beetles | - | - | - | - | 2 | - | - | - | - |
| Burrowing mayfly nymphs | - | - | - | - | 4 | 2 | - | 2 | - |
| Caddisfly larvae | 17 | 1 | - | 6 | 3 | 3 | - | - | 2 |
| Damselfly nymphs | 1 | - | - | - | - | - | - | - | - |
| Dragonfly nymphs | 1 | 2 | - | 8 | 7 | 3 | - | - | - |
| Mayfly nymphs | 3 | 1½ | - | 1 | 1 | 1 | - | - | - |
| Midge larvae | 1 | 1 | - | - | - | 1 | - | - | - |
| Midge pupae | - | - | - | - | 5 | 3 | - | - | - |
| Planktonic organisms | | | | | | | | | |
| Cladocerans | 1000's | 1000's | - | - | ∿20 | - | - | 100's | - |
| Phantom midge larvae | - | ∿15 | - | - | - | 1 | - | - | - |
| Phantom midge pupae | - | - | - | - | - | ∿55 | - | - | - |
| Other aquatic invertebrates | | | | | | | | | |
| Snails | - | 5 | - | - | - | - | - | - | - |
| Water mites | 1 | - | - | 2 | - | - | - | - | - |
| Minnows | - | - | - | 1 | - | - | - | 1 | - |
| Terrestrial arthropods | | | | | | | | | |
| Beetles | - | 3 | 3 | - | - | 2 | - | - | - |
| Flying ants | 1 | ∿8 | - | - | - | 4 | - | - | - |
| Midges | 1 | - | ∿15 | - | - | 5 | - | - | - |
| Spiders | 1 | - | 1 | - | - | - | - | - | - |
| Unidentified flying insects | - | ∿35 | ∿75 | - | 2 | ∿15 | ∿20 | - | - |
| Unidentified terrestrial insects | - | - | ∿15 | - | - | - | - | - | - |

Table 16

Percent occurrence of various food items in brook trout stomachs from Lac Herman

13 May, 1975 to 17 May, 1976

| Number of days before or after treatment of Lac Tassel | -15 | -6 | +2 | +20 | +83 | +1 year |
|---|---|---|---|---|---|---|
| No food present | 0 | 10 | 0 | 0 | 63 | 0 |
| Aquatic insects | | | | | | |
| Alderfly larvae | 0 | 14 | 0 | 0 | 0 | 25 |
| Backswimmers | 0 | 5 | 0 | 0 | 0 | 0 |
| Burrowing mayfly nymphs | 17 | 29 | 54 | 50 | 5 | 75 |
| Caddisfly larvae | 17 | 5 | 0 | 0 | 0 | 0 |
| Damselfly nymphs | 17 | 0 | 0 | 0 | 0 | 0 |
| Dragonfly nymphs | 83 | 14 | 9 | 0 | 5 | 0 |
| Fishfly larvae | 0 | 0 | 0 | 0 | 0 | 12 |
| Mayfly nymphs | 17 | 5 | 0 | 0 | 0 | 0 |
| Midge larvae | 0 | 10 | 45 | 0 | 0 | 0 |
| Midge pupae | 67 | 24 | 18 | 50 | 0 | 25 |
| Water boatmen | 17 | 14 | 0 | 0 | 5 | 0 |
| Water striders | 0 | 0 | 0 | 0 | 5 | 0 |
| Planktonic organisms | | | | | | |
| Cladocerans | 16 | 5 | 18 | 50 | 0 | 0 |
| Phantom midge larvae | 0 | 10 | 27 | 0 | 0 | 0 |
| Other aquatic invertebrates | | | | | | |
| Amphipods | 17 | 5 | 0 | 0 | 0 | 0 |
| Snails | 0 | 5 | 0 | 0 | 0 | 0 |
| Minnows | 67 | 38 | 45 | 50 | 21 | 38 |
| Terrestrial arthropods | | | | | | |
| Beetles | 33 | 52 | 18 | 0 | 0 | 12 |
| Flying ants | 0 | 63 | 0 | 0 | 0 | 0 |
| Spiders | 0 | 0 | 9 | 0 | 0 | 0 |
| Unidentified flying insects | 0 | 0 | 9 | 50 | 0 | 0 |
| Unidentified terrestrial insects | 17 | 5 | 9 | 0 | 0 | 0 |

Table 17

Mean percent of the volume of brook trout stomach contents contributed by various food items, Lac Herman,

13 May, 1975 to 17 May, 1976

| Number of days before or after treatment of Lac Tassel | -15 | -6 | +2 | +20 | +83 | +1 year |
|---|---|---|---|---|---|---|
| Mean volume of stomach contents (ml) | 1.70 | 1.46 | 1.52 | 1.15 | 0.19 | 6.05 |
| Aquatic insects | | | | | | |
| Alderfly larvae | 0.0 | 1.8 | 0.0 | 0.0 | 0.0 | 0.9 |
| Backswimmers | 0.0 | 2.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| Burrowing mayfly nymphs | 5.8 | 13.9 | 35.9 | 7.5 | 14.3 | 49.1 |
| Caddisfly larvae | 3.3 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| Damselfly nymphs | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Dragonfly nymphs | 45.8 | 5.5 | 9.1 | 0.0 | 14.3 | 0.0 |
| Fishfly larvae | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 |
| Mayfly nymphs | 0.8 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| Midge larvae | 0.0 | 0.3 | 2.1 | 0.0 | 0.0 | 0.0 |
| Midge pupae | 1.7 | 0.6 | 1.8 | <0.1 | 0.0 | 24.4 |
| Water boatmen | 0.4 | 0.2 | 0.0 | 0.0 | 14.3 | 0.0 |
| Water strider | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 | 0.0 |
| Planktonic organisms | | | | | | |
| Cladocerans | 1.7 | 0.2 | 3.1 | 47.5 | 0.0 | 0.0 |
| Phantom midge larvae | 0.0 | 0.5 | 8.4 | 0.0 | 0.0 | 0.0 |
| Other aquatic invertebrates | | | | | | |
| Amphipods | <0.1 | <0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Snails | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Minnows | 35.0 | 31.2 | 28.2 | 2.5 | 55.7 | 24.4 |
| Terrestrial arthropods | | | | | | |
| Beetles | 3.8 | 13.4 | 8.2 | 0.0 | 0.0 | 0.6 |
| Flying ants | 0.0 | 28.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| Spiders | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 |
| Unidentified flying insects | 0.0 | 0.0 | 0.9 | 42.5 | 0.0 | 0.0 |
| Unidentified terrestrial insects | 0.8 | 0.1 | 1.8 | 0.0 | 0.0 | 0.0 |

Table 18

Mean numbers of various food items in brook trout stomachs in which they occurred, Lac Herman, 13 May, 1975 to 17 May, 1976

| Number of days before or after treatment of Lac Tassel | −15 | −6 | +2 | +20 | +83 | +1 year |
|---|---|---|---|---|---|---|
| Aquatic insects | | | | | | |
| Alderfly larvae | – | 1 | – | – | – | 2½ |
| Backswimmers | – | 1 | – | – | – | – |
| Burrowing mayfly nymphs | 2 | 3 | 6 | 1 | 1 | 20 |
| Caddisfly larvae | 1 | 1 | – | – | – | – |
| Damselfly nymphs | 1 | – | – | – | – | – |
| Dragonfly nymphs | 2 | 2 | 1 | – | 1 | – |
| Fishfly larvae | – | – | – | – | – | 1 |
| Mayfly nymphs | 1 | 3 | – | – | – | – |
| Midge larvae | – | $\sim$20 | 3 | – | – | – |
| Midge pupae | 2 | 3 | 2 | 1 | – | 45 |
| Water boatmen | 2 | 1 | – | – | 1 | – |
| Water striders | – | – | – | – | 2 | – |
| Plantonic organisms | | | | | | |
| Cladocerans | $\sim$50 | $\sim$100 | $\sim$100 | 1000's | – | – |
| Phantom midge larvae | – | $\sim$35 | $\sim$50 | – | – | – |
| Other aquatic invertebrates | | | | | | |
| Amphipods | 1 | 1 | – | – | – | – |
| Snails | – | 1 | – | – | – | – |
| Minnows | 1 | 3 | 2 | 1 | 5 | 6 |
| Terrestrial arthropods | | | | | | |
| Beetles | 1 | 5 | 1½ | – | – | 1 |
| Flying ants | – | $\sim$10 | – | – | – | – |
| Spiders | – | – | 1 | – | – | – |
| Unidentified flying insects | – | – | 2 | 6 | – | – |
| Unidentified terrestrial insects | 1 | 1 | 2 | – | – | – |

Table 19

Percent occurrence of various food items in brown bullhead stomachs from Lac Tassel,

23 May, 1975 to 18 May, 1976

| Number of days before or after treatment | -5 | -0 | +37 | +82 | +1 year |
|---|---|---|---|---|---|
| No food present | 25 | 25 | 12 | 0 | 14 |
| Aquatic insects | | | | | |
| Alderfly larvae | 12 | 0 | 0 | 0 | 14 |
| Beetle larvae | 12 | 0 | 0 | 0 | 14 |
| Blackfly larvae | 38 | 0 | 0 | 0 | 0 |
| Burrowing mayfly nymphs | 62 | 62 | 0 | 0 | 43 |
| Caddisfly pupae | 0 | 50 | 0 | 0 | 0 |
| Caterpillars | 12 | 0 | 0 | 0 | 0 |
| Damselfly nymphs | 12 | 12 | 12 | 0 | 0 |
| Dragonfly nymphs | 62 | 38 | 38 | 100 | 28 |
| Mayfly nymphs | 62 | 62 | 25 | 50 | 86 |
| Midge larvae | 50 | 62 | 12 | 100 | 28 |
| Midge pupae | 12 | 25 | 38 | 0 | 0 |
| Spongilla fly larvae | 0 | 12 | 0 | 0 | 0 |
| Plantonic organisms | | | | | |
| Cladocerans | 0 | 0 | 0 | 100 | 0 |
| Planton midge larvae | 0 | 62 | 0 | 0 | 0 |
| Other aquatic invertebrates | | | | | |
| Amphipods | 62 | 25 | 12 | 50 | 43 |
| Leeches | 0 | 0 | 0 | 0 | 28 |
| Minnows | 0 | 0 | 25 | 0 | 0 |
| Fish eggs | 12 | 0 | 0 | 0 | 0 |
| Newts | 12 | 0 | 0 | 0 | 0 |
| Terrestrial arthropods | | | | | |
| Spiders | 0 | 12 | 0 | 0 | 0 |
| Unidentified terrestrial insects | 25 | 12 | 12 | 0 | 14 |

Table 20

Mean percent of the volume of brown bullhead stomach contents contributed by various food items, Lac Tassel, 23 May, 1975 to 18 May, 1976

| Number of days before or after treatment | -5 | -0 | +37 | +82 | +1 year |
|---|---|---|---|---|---|
| Mean volume of stomach contents (ml) | 1.53 | 0.61 | 0.42 | 0.10 | 1.57 |
| Aquatic insects | | | | | |
| Alderfly larvae | 0.2 | 0.0 | 0.0 | 0.0 | 0.4 |
| Beetle larvae | 0.3 | 0.0 | 0.0 | 0.0 | 0.4 |
| Blackfly larvae | 12.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| Burrowing mayfly nymphs | 13.7 | 8.3 | 53.6 | 17.5 | 17.1 |
| Caddisfly larvae | 14.5 | 18.3 | 0.0 | 0.0 | 5.0 |
| Caddisfly pupae | 0.0 | 12.5 | 0.0 | 0.0 | 0.0 |
| Caterpillars | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| Damselfly nymphs | 0.5 | 1.2 | 10.0 | 0.0 | 0.0 |
| Dragonfly nymphs | 14.2 | 11.7 | 16.4 | 45.0 | 11.7 |
| Mayfly nymphs | 10.8 | 16.7 | 5.7 | 12.5 | 58.3 |
| Midge larvae | 4.2 | 3.2 | 0.7 | 17.5 | 0.9 |
| Midge pupae | 0.3 | 8.3 | 3.6 | 0.0 | 0.0 |
| Spongilla fly larvae | 0.0 | 1.2 | 0.0 | 0.0 | 0.0 |
| Planktonic organisms | | | | | |
| Cladocerans | 0.0 | 0.0 | 0.0 | 5.0 | 0.0 |
| Phantom midge larvae | 0.0 | 13.7 | 0.0 | 0.0 | 0.0 |
| Other aquatic invertebrates | | | | | |
| Amphipods | 6.5 | 1.5 | 1.4 | 2.5 | 2.1 |
| Leeches | 0.0 | 0.0 | 0.0 | 0.0 | 3.3 |
| Minnows | 0.0 | 0.0 | 6.4 | 0.0 | 0.0 |
| Fish eggs | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| Newts | 10.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| Terrestrial arthropods | | | | | |
| Spiders | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 |
| Unidentified terrestrial insects | 8.3 | 2.5 | 2.1 | 0.0 | 0.8 |

Table 21

Mean numbers of various food items in brown bullhead stomachs in which they occurred, Lac Tassel, 23 May, 1975 to 18 May, 1976

| Number of days before or after treatment | -5 | -0 | +37 | +82 | +1 year |
|---|---|---|---|---|---|
| Aquatic insects | | | | | |
| Alderfly larvae | 1 | - | - | - | 1 |
| Beetle larvae | 1 | - | - | - | 1 |
| Blackfly larvae | ∿300 | - | - | - | - |
| Burrowing mayfly nymphs | 2 | 2 | 2 | 1 | 4 |
| Caddisfly larvae | 4 | 2 | - | - | 2 |
| Caddisfly pupae | - | 2 | - | - | - |
| Caterpillars | 2 | - | - | - | - |
| Damselfly nymphs | 1 | 1 | 3 | - | - |
| Dragonfly nymphs | 1 | 2 | 1 | 2 | 2 |
| Mayfly nymphs | 4 | 3 | 2 | 1 | 17 |
| Midge larvae | 9 | 3 | 1 | 5 | 2 |
| Midge pupae | 5 | 4 | 2 | - | - |
| Spongilla fly larvae | - | 1 | - | - | - |
| Planktonic organism | | | | | |
| Cladocerans | - | - | - | ∿20 | - |
| Phantom midge larvae | - | 3 | - | - | - |
| Other aquatic invertebrates | | | | | |
| Amphipods | 3 | 2 | 5 | 1 | 3 |
| Leeches | - | - | - | - | 1 |
| Minnows | - | - | 1 | - | - |
| Fish eggs | ∿30 | - | - | - | - |
| Newts | 3 | - | - | - | - |
| Terrestrial arthropods | | | | | |
| Spiders | - | 1 | - | - | - |
| Unidentified terrestrial insects | 1 | 1 | 1 | - | 1 |

Table 22

Percent occurrence of various food items in brown bullhead stomachs from Lac Herman, 22 May, 1975 to 17 May, 1976

| Number of days before or after treatment of Lac Tassel | -6 | +2 | +83 | +1 year |
|---|---|---|---|---|
| No food present | 0 | 15 | 33 | 10 |
| Aquatic insects | | | | |
| Alderfly larvae | 0 | 15 | 0 | 30 |
| Beetle larvae | 25 | 5 | 0 | 0 |
| Burrowing mayfly nymphs | 62 | 45 | 33 | 70 |
| Caddisfly larvae | 25 | 15 | 0 | 30 |
| Caddisfly pupae | 0 | 10 | 0 | 0 |
| Damselfly nymphs | 12 | 15 | 0 | 0 |
| Dragonfly nymphs | 12 | 10 | 0 | 10 |
| Mayfly nymphs | 62 | 30 | 0 | 60 |
| Midge larvae | 62 | 45 | 0 | 20 |
| Midge pupae | 0 | 20 | 0 | 10 |
| Other aquatic invertebrates | | | | |
| Amphipods | 12 | 30 | 0 | 10 |
| Fingernail clams | 0 | 5 | 67 | 0 |
| Isopods | 0 | 5 | 0 | 0 |
| Minnows | 0 | 15 | 0 | 0 |
| Flying insects | 0 | 5 | 0 | 0 |

Table 23

Mean percent of the volume of brown bullhead stomach contents contributed by various food items,

Lac Herman, 22 May, 1975 to 17 May, 1976

| Number of days before or after treatment of Lac Tassel | -6 | +2 | +83 | +1 year |
|---|---|---|---|---|
| Mean volume of stomach contents (ml) | 0.18 | 0.68 | 0.03 | 0.62 |
| Aquatic insects | | | | |
| Alderfly larvae | 0.0 | 2.9 | 0.0 | 1.2 |
| Beetle larvae | 2.5 | 0.6 | 0.0 | 0.0 |
| Burrowing mayfly nymphs | 55.0 | 34.4 | 40.0 | 63.3 |
| Caddisfly larvae | 3.8 | 2.4 | 0.0 | 2.6 |
| Caddisfly pupae | 0.0 | 1.2 | 0.0 | 0.0 |
| Damselfly nymphs | 1.9 | 4.7 | 0.0 | 0.0 |
| Dragonfly nymphs | 6.2 | 5.9 | 0.0 | 1.7 |
| Mayfly nymphs | 12.8 | 10.6 | 0.0 | 29.2 |
| Midge larvae | 12.8 | 13.9 | 0.0 | 1.1 |
| Midge pupae | 0.0 | 1.2 | 0.0 | 0.3 |
| Other aquatic invertebrates | | | | |
| Amphipods | 5.0 | 3.5 | 0.0 | 0.6 |
| Fingernail clams | 0.0 | 0.9 | 60.0 | 0.0 |
| Isopods | 0.0 | 1.8 | 0.0 | 0.0 |
| Minnows | 0.0 | 15.9 | 0.0 | 0.0 |
| Flying insects | 0.0 | 0.3 | 0.0 | 0.0 |

Table 24

Mean numbers of various food items in brown bullhead stomachs in which they occurred, Lac Herman,

22 May, 1975 to 17 May, 1976

| Number of days before or after treatment of Lac Tassel | -6 | +2 | +83 | +1 year |
|---|---|---|---|---|
| Aquatic insects | | | | |
| Alderfly larvae | - | 1 | - | 1 |
| Beetle larvae | 2 | 1 | - | - |
| Burrowing mayfly nymphs | 2 | 3 | 1 | 7 |
| Caddisfly larvae | 2 | 2 | - | 1 |
| Caddisfly pupae | - | 1 | - | - |
| Damselfly nymphs | 1 | 1 | - | - |
| Dragonfly nymphs | 1 | 1 | - | 1 |
| Mayfly nymphs | 2 | 4 | - | 2 |
| Midge larvae | 6 | 3 | - | 1 |
| Midge pupae | - | 2 | - | 1 |
| Other aquatic invertebrates | | | | |
| Amphipods | 3 | 2 | - | 1 |
| Fingernail clams | - | 15 | - | - |
| Isopods | - | 1 | 1 | - |
| Minnows | - | 2 | - | - |
| Flying insects | - | 1 | - | - |

Table 25

Percent occurrence of various food items in yellow perch stomachs from Lac Tassel, 23 May, 1975 to 18 May, 1976

| Number of days before or after treatment | -5 to -0 | +4 to +5 | +16 | +37 | +82 | +1 year |
|---|---|---|---|---|---|---|
| No food present | 50 | 20 | 10 | 50 | 50 | 29 |
| Aquatic insects | | | | | | |
| Burrowing mayfly nymphs | 0 | 20 | 16 | 0 | 17 | 29 |
| Caddisfly larvae | 0 | 0 | 5 | 0 | 17 | 0 |
| Dragonfly nymphs | 0 | 0 | 5 | 0 | 0 | 0 |
| Mayfly nymphs | 0 | 0 | 0 | 0 | 0 | 29 |
| Midge larvae | 0 | 20 | 10 | 0 | 0 | 14 |
| Midge pupae | 0 | 0 | 5 | 0 | 0 | 14 |
| Plantonic organisms | | | | | | |
| Cladocerans | 50 | 0 | 16 | 50 | 50 | 29 |
| Phantom midge larvae | 0 | 80 | 21 | 0 | 17 | 43 |
| Phantom midge pupae | 0 | 80 | 79 | 0 | 0 | 0 |
| Other aquatic invertebrates | | | | | | |
| Amphipods | 0 | 0 | 5 | 0 | 0 | 0 |
| Minnows | | | | | | |
| Smallmouth bass fry | 0 | 0 | 63 | 50 | 0 | 0 |
| Unidentified minnows | 0 | 20 | 0 | 0 | 0 | 0 |

Table 26

Mean percent of the volume of yellow perch stomach contents contributed by various food items
Lac Tassel, 23 May, 1975 to 18 May, 1976

| Number of days before or after treatment | -5 to -0 | +4 to +5 | +16 | +37 | +82 | +1 year |
|---|---|---|---|---|---|---|
| Mean volume of stomach contents (ml) | 0.05 | 0.24 | 0.54 | 0.10 | 0.05 | 0.96 |
| Aquatic insects | | | | | | |
| Burrowing mayfly nymphs | 0.0 | 12.5 | 11.2 | 0.0 | 16.7 | 21.0 |
| Caddisfly larvae | 0.0 | 0.0 | 5.3 | 0.0 | 13.3 | 0.0 |
| Dragonfly nymphs | 0.0 | 0.0 | 2.9 | 0.0 | 0.0 | 0.0 |
| Mayfly nymphs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 18.0 |
| Midge larvae | 0.0 | 0.2 | 0.3 | 0.0 | 0.0 | 1.0 |
| Midge pupae | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 1.0 |
| Plantonic organism | | | | | | |
| Cladocerans | 100.0 | 0.0 | 0.7 | 5.0 | 56.7 | 5.0 |
| Phantom midge larvae | 0.0 | 30.4 | 1.9 | 0.0 | 13.3 | 54.0 |
| Phantom midge pupae | 0.0 | 34.4 | 27.8 | 0.0 | 0.0 | 0.0 |
| Other aquatic invertebrates | | | | | | |
| Amphipods | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 |
| Minnows | | | | | | |
| Smallmouth bass fry | 0.0 | 0.0 | 49.1 | 95.0 | 0.0 | 0.0 |
| Unidentified minnows | 0.0 | 22.5 | 0.0 | 0.0 | 0.0 | 0.0 |

Table 27

Mean numbers of various food items in yellow perch stomachs in which they occurred, Lac Tassel,

23 May, 1975 to 18 May, 1976

| Number of days before or after treatment | -5 to -0 | +4 to +5 | +16 | +37 | +82 | +1 year |
|---|---|---|---|---|---|---|
| Aquatic insects | | | | | | |
| Burrowing mayfly nymphs | - | 3 | 1 | - | 2 | 1 |
| Caddisfly larvae | - | - | 5 | - | 4 | - |
| Dragonfly nymphs | - | - | 1 | - | - | - |
| Mayfly nymphs | - | - | - | - | - | $3\frac{1}{2}$ |
| Midge larvae | - | 1 | 2 | - | - | 1 |
| Midge pupae | - | - | 1 | - | - | 7 |
| Planktonic organisms | | | | | | |
| Cladocerans | $\sim$20 | - | $\sim$20 | $\sim$20 | $\sim$35 | $\sim$250 |
| Phantom midge larvae | - | 6 | $\sim$17 | - | 4 | $\sim$230 |
| Phantom midge pupae | - | $\sim$14 | $\sim$37 | - | - | - |
| Other aquatic invertebrates | | | | | | |
| Amphipods | - | - | 1 | - | - | - |
| Minnows | | | | | | |
| Smallmouth bass fry | - | - | 8 | 1 | - | - |
| Unidentified minnows | - | 1 | - | - | - | - |

Table 28

Food items found in common shiner digestive tracts from Lac Tassel, 23 May to 13 June, 1975.

| | | | |
|---|---|---|---|
| Number of days before or after treatment | -5 | +2 | +16 |
| **Percent occurrence of:** | | | |
| Burrowing mayfly nymphs | 0 | 0 | 50 |
| Cladocerans | 100 | 100 | 0 |
| Phantom midge larvae | 50 | 100 | 0 |
| Phantom midge pupae | 0 | 100 | 100 |
| Unidentified flying insects | 0 | 0 | 100 |
| Unidentified terrestrial insects | 50 | 0 | 0 |
| Mean volume of digestive tract contents (ml) | 0.90 | 1.00 | 0.25 |
| **Mean percent volume contributed by:** | | | |
| Burrowing mayfly nymphs | 0.0 | 0.0 | 5.0 |
| Cladocerans | 60.0 | 5.0 | 0.0 |
| Phantom midge larvae | 37.5 | 45.0 | 0.0 |
| Phantom midge pupae | 0.0 | 45.0 | 65.0 |
| Unidentified flying insects | 0.0 | 0.0 | 30.0 |
| Unidentified terrestrial insects | 2.5 | 0.0 | 0.0 |
| **Mean numbers per digestive tract presented in of:** | | | |
| Burrowing mayfly nymphs | - | - | 1 |
| Cladocerans | $\sim$100 | $\sim$20 | - |
| Phantom midge larvae | $\sim$40 | $\sim$40 | - |
| Phantom midge pupae | - | $\sim$30 | $\sim$10 |
| Unidentified flying insects | - | - | 3½ |
| Unidentified terrestrial insects | 2 | - | - |