RECOVERY OF STREAM BENTHOS AND ITS UTILIZATION BY NATIVE FISH FOLLOWING HIGH DOSAGE PERMETHRIN APPLICATIONS

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ABSTRACT

Bottom fauna and native fish populations were sampled during four consecutive years following high dosage experimental permethrin applications to coldwater streams in the Gaspe Peninsula, Quebec. Stream benthos density and diversity returned to normal levels within one year of a 35.0 g AI/ha permethrin application, but remained suppressed for up to 16 months in a stream treated with 70.0 g AI/ha permethrin. The feeding activity of native fish in the two treated streams reflected the availability of food organisms. As the abundance and diversity of benthic invertebrates increased, the selection of various fish food organisms by both brook trout, **Salvelinus fontinalis,** and slimy sculpins, **Cottus cognatus,** showed comparable increases. Pesticide-induced changes in diet composition did not appear to adversely affect the condition of brook trout and no significant differences ($p < 0.05$) were found in ovary production of female trout in the treated and control streams 16 months after the permethrin applications.

RÉSUMÉ

Nous avons cueilli des échantillons de faune benthique et de poissons indigènes pendant quatre années consécutives, après l'épandage expérimental de fortes doses de perméthrine au-dessus de cours d'eau froids en Gaspésie. La densité et la diversité du benthos fluviatile sont revenues à la normale moins d'un an après l'épandage de 35 g de perméthrine (matière active) à l'hectare, mais elles sont restées diminuées jusqu'à 16 mois dans un cours d'eau exposé à 70 g/ha. Dans les deux cours d'eau d'eau traités, l'alimentation des poissons indigènes a reflété la disponibilité des organismes leur servant de nourriture. À mesure que l'abondance et la diversité des invertébrés benthiques augmentaient, la disponibilité des divers organismes servant de nourriture à l'omble de fontaine **(Salvelinus fontinalis)** et au chabot visqueux **(Cottus cognatus)** augmentait. Les changements du régime alimentaire provoqués par le pesticide n'ont pas semblé nuire à l'omble, et il n'y a eu aucune différence significative de la production ovarienne chez l'omble femelle dans le cours d'eau traité et dans le témoin soixante mois après l'épandage de perméthrine.

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INTRODUCTION

The synthetic pyrethroid permethrin has been identified and tested as a potential material for use in forest pest control programs. The Forest Pest Management Institute has conducted several field trials to assess the environmental hazards of this compound to aquatic ecosystems. Experimental and semi-operational applications of permethrin to streams at dosages ranging from 8.8 to 70.0 g AI/ha have demonstrated major disturbances of benthic invertebrates and, to a lesser extent, consequential changes in the feeding activity of indigenous fish. Despite drastic post-spray reductions of bottom fauna, recovery of benthic invertebrates in the affected streams has been rapid. In streams treated with single applications of 8.8 and 17.5 g AI/ha (Kingsbury and Kreutzweiser 1980 a, b) and double applications of 17.5 g AI/ha permethrin (Kingsbury and Kreutzweiser 1979) repopulation of invertebrates was evident within the year of application. One year post-spray sampling in streams treated with single and double 17.5 g AI/ha permethrin applications revealed bottom fauna populations and feeding activity of resident fish at levels similar to or greater than those found prior to the applications (Kingsbury and Kreutzweiser 1982, and Kreutzweiser, 1982a).

In the 1977 field program of the Forest Pest Management Institute, experimental permethrin applications at higher dosages (35.0 and 70.0 g AI/ha) to streams produced reductions in benthos and feeding activity of indigenous fish measurable beyond the year of application (Kingsbury and Kreutzweiser 1980 b). In order to determine the extent and duration of the pesticide impact and to document the rate of subsequent recovery, sampling of the stream benthos and native fish in these streams was continued through parts of the 1978 to 1981 field seasons. This report contains a summary of the data collected over that period and discusses the patterns of recovery demonstrated by benthos and fish within these two streams.

SITE DESCRIPTION

The two treatment streams and the control are cold water streams flowing north from the Chic-Choc mountains of the Gaspe Peninsula, Quebec into the St. Lawrence River near Ste. Anne des Monts. Ruisseau Landry, site of the 70 g AI/ha application, is a headwater tributary of Riviere du Cap Chat located approximately 15 km west of Ste. Anne des Monts, while Ruisseau du Petit Capucin, treated with a 35.0 g AI/ha application, flows direcly into the St. Lawrence River about 10 km further west. Ruisseau de la Grande Tourelle, the untreated control stream, drains into the St. Lawrence River about 8 km east of Ste. Anne des Monts (Fig. 1).

The descriptive features of each of the three streams were similar with an approximate width of 2 to 5 m, depths from 10 to 70 cm, a fast current with numerous riffles and few pools, and a bottom type comprised of small to large rocks with a few gravel sections. Instream cover was abundant, consisting of fallen logs, instream boulders, and undercut banks. Speckled alder, **Alnus rugosa,** lined the banks of all three streams and provided as much as 80% canopy in some areas. The adjacent forested land contained spruce, **Picea** spp., balsam fir, **Abies balsamea,** white birch, **Betula papyrifera,** and trembling aspen, **Populus tremuloides.**

Two sampling stations were established within the treated sections of each of the two treatment streams, with one located near the extreme headwater area and the other further downstream below the confluence with an untreated tributary (Fig. 1). The control stream was sampled at a single station.

METHODS

Since the recovery assessment was incorporated into the sampling regimes of four consecutive field programs, some changes in the collection and analysis of the samples occurred. In an attempt to provide comparative data, the information has been presented in a format used in the initial evaluation process, regardless of

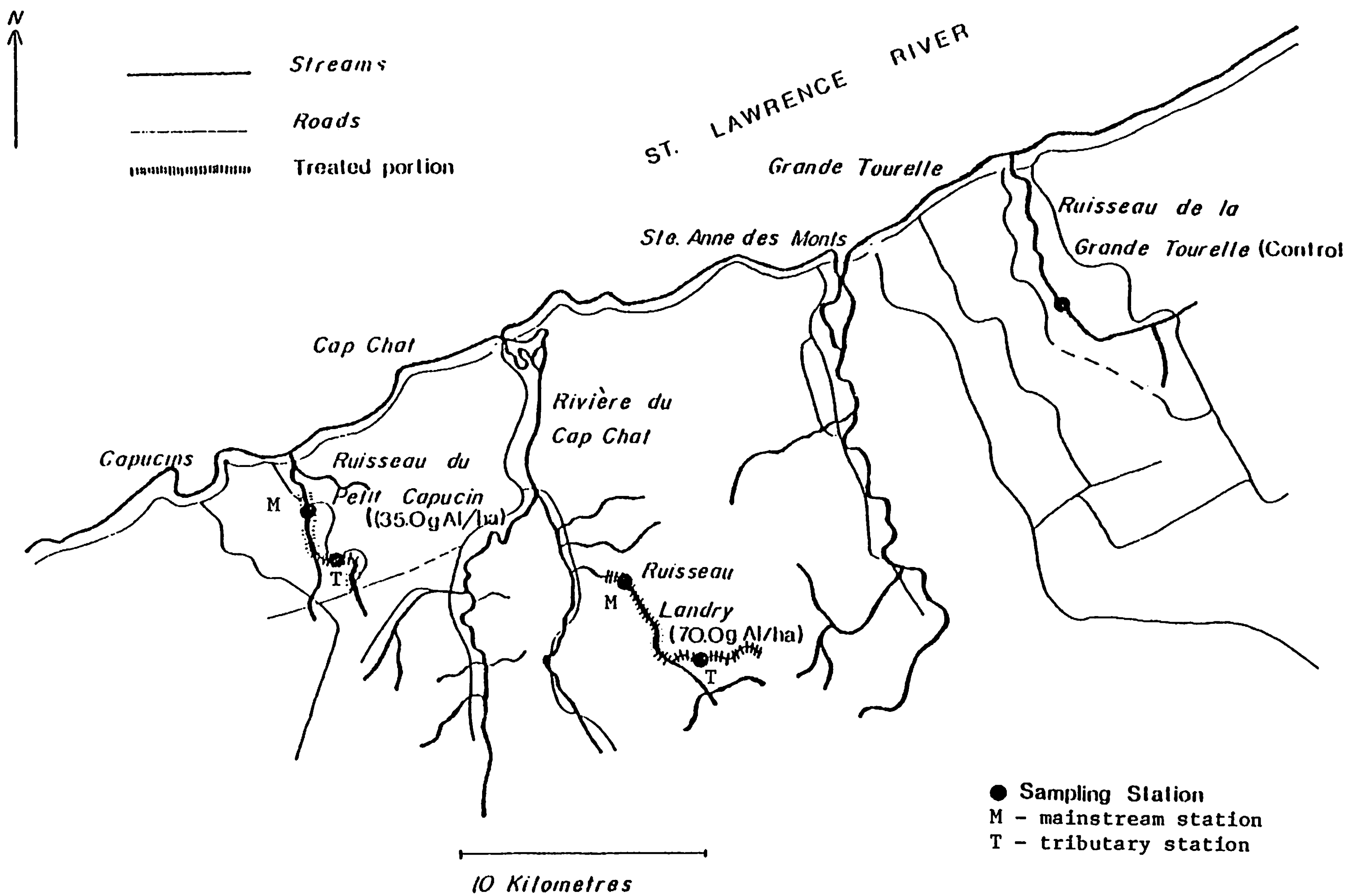

Figure 1. Treatment and control streams, Ste-Anne-des monts, Gaspé-Ouest County, Quebec.

the subsequent changes made within that process. For example, in the more recent programs the identification of collected organisms has been done at a lower taxonomic level, but since the earlier benthic samples were processed mainly to Order, and in some cases to Family, the data from the pre-spray and the four post-spray years have been compiled at the higher taxonomic level. The actual operation and sampling methods have been altered to a lesser extent and are summarized below.

Insecticide Formulation and Application

Ruisseau Landry was treated with 70.0 g AI/ha permethrin* at 0557 hours on 16 June 1977, while a 35.0 g AI/ha permethrin** application was made to Ruisseau du Petit Capucin at 0458 hours on 20 June, 1977. For both applications the permethrin was mixed with 0.5% Automate 'B' dye and No. 2 fuel oil diluent.

The pesticide was delivered at an emission rate of 4.68 L/ha from an AU 3000 Micronair atomizer system mounted on a Cessna 185 aircraft flying a single 50 m wide swath up the stream following changes in stream direction as closely as possible. The spray swath was initiated on the mainstream portion of the treatment stream and continued up a tributary for an overall swath length of 5 km (Ruisseau du Petit Capucin) to 8 km (Ruisseau Landry).

Biological Sampling

The methods used for assessing the immediate and short term impact of the permethrin applications have been reported previously (Kingsbury and Kreutzweiser 1980b). The recovery of benthic invertebrates was determined by sampling bottom fauna populations with a 0.093 m^2 Surber net (Surber 1936). The collected organisms were hand sorted, preserved in 70% methanol and later counted, identified, and presented as mean number and standard deviation of four samples. Invertebrates collected from four randomly selected rocks (approximately 15 cm in diameter) at each station were used to supplement the bottom fauna population assessment. The benthic organisms from rocks were sorted and enumerated in the manner described for stream Surber sampling. Diversity indices of the benthos sampled with Surber nets at each station were calculated using the formula presented by Shannon and Weaver (1963):

$$D = - \sum \left(\frac{ni}{N} \right) \text{Log} \left(\frac{ni}{N} \right)$$

where ni =no. of individuals in each taxonomic group represented in the sample
N =total no. of individuals in sample

Indigenous populations of brook trout, ***Salvelinus fontinalis***, in each stream and slimy sculpins, ***Cottus cognatus***, in Ruisseau Landry were sampled with an electro-shocker and dip net for measurement, sexing, and diet analysis. Total length, fork length, weight, and sex were determined for each of a sample of approximately 10 fish using a measuring board, an Ohaus 1600 gram capacity balance, and dissecting tools. The stomach from each fish was extracted and preserved in 10% formalin to be opened later and analyzed for content and volume. Condition coefficients (K) of the collected brook trout were calculated using the following formula (Carlander 1969):

$$K = \frac{10^5 \times \text{weight (g)}}{\text{total length (mm)}^3}$$

In October, 1978, 16 months after the permethrin applications, samples of brook trout were collected from each study stream in order to investigate possible differences in gonad weight resulting from different food item availability in the three streams. When the fish were dissected it was found that the testes of male fish from all streams were too small for establishing any kind of length-gonad weight

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*permethrin - 50% oil concentrate, 500 g AI/L (Formulation No. JF5751, Chipman Inc.

**permethrin - 300 g AI/L (FX5031), Shell Canada Ltd.

relationship. Twenty-eight female trout from the control stream, 18 from the 35.0 g Al/ha permethrin application stream and 37 from the 70.0 g Al/ha application stream had ovaries large enough (> 0.01 g) for use in determining length-gonad weight relationships for sexually mature and maturing female trout from each stream.

RESULTS

Benthic Invertebrates

Both the 70.0 g and 35.0 g Al/ha permethrin applications resulted in drastic reductions in bottom fauna populations within the treated sections of the streams. Kingsbury and Kreutzweiser (1980b) reported severe depletion of benthos in the two treated streams three days after the applications. Ephemeroptera nymphs, and to a lesser extent Trichoptera larvae, demonstrated the largest reductions in the lower dosage stream, while all invertebrates were virtually eliminated from the higher dosage stream. Recovery of benthic organisms, with the exception of Ephemeroptera nymphs, was apparent by the end of the season (4 October 1977) in the 35.0 g Al/ha treatment stream, but was not measurable in the 70.0 g Al/ha stream except among chironomid larvae.

Bottom fauna sampling in the lower dosage stream approximately one year post-spray (3 June 1978) demonstrated a resurgence of Ephemeroptera nymphs and total numbers of invertebrates approaching or exceeding pre-spray levels. Numbers of benthic invertebrates collected in subsequent samples followed patterns similar to those demonstrated in the control (Appendix Tables A-1 to A-6). The diversity of bottom fauna in the 35.0 g Al/ha treatment stream, also closely followed that of the control (Fig. 2).

One-year post-spray sampling of benthos in the 70.0 g Al/ha treatment stream indicated both greatly reduced numbers (Appendix Tables A-7 to A-10) and a low diversity (Fig. 3, Appendix Table A-11) of invertebrates persisting from effects of the treatment. Population levels were 22 to 96% lower than the pre-spray averages and consisted primarily of Chironomidae larvae. Bottom fauna sampling later in the season of the second year (30 July 1978) demonstrated a continued depression of benthic populations, except for a major increase in chironomids. By 27 October 1978 a resurgence of bottom fauna density and diversity was clearly evident with representation of most of the major taxa found in the pre-spray samples. Although the numbers of aquatic invertebrates had substantially increased, most of the organisms, especially ephemeropterans and plecopterans, were of a uniformly small size range. Subsequent sampling in 1979, 1980 and 1981 revealed a variety of benthic invertebrates similar in density and composition to the patterns of bottom fauna samples collected in the control (Appendix Tables A-7 to A-10).

Fish

Appendix Table A-12 contains a summary of the types, dates and morphometric data of the fish collected from each station during the period of recovery assessment.

The permethrin applications to the two treated streams resulted in a change in food organism selection by brook trout and slimy sculpins from a variety of aquatic insects to a virtually complete dependence on terrestrial arthropods and non-insect aquatic invertebrates (Kingsbury and Kreutzweiser 1980b). By the end of the year of application (4 October 1977) brook trout in the 35 g Al/ha treatment stream had returned to a more normal food organism selection including a substantial proportion of aquatic insects, but with a noticeable absence of Ephemeroptera and Plecoptera nymphs. The diet of brook trout in the 70.0 g Al/ha treatment stream continued to consist almost entirely of terrestrial arthropods for the remainder of the sampling season. Slimy sculpins (present only in the 70.0 g Al/ha stream) relied primarily on Diptera larvae and non-insect aquatic organisms as alternate food sources up to and including the 4 October 1977 sample date.

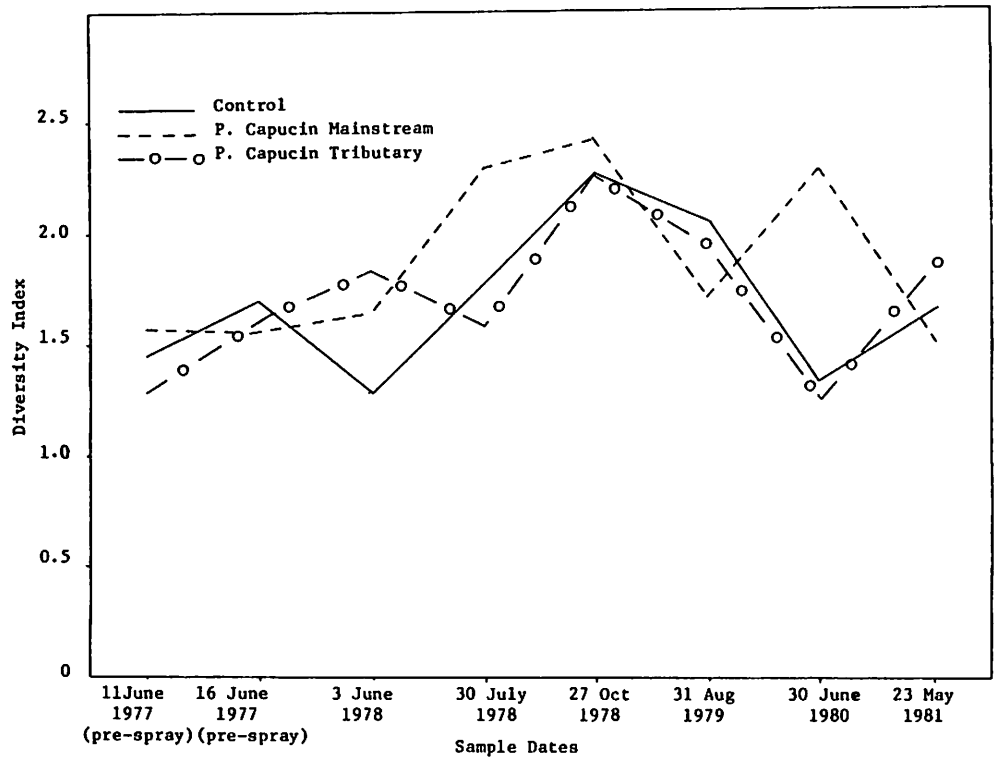


Figure 2. Diversity indices of benthic invertebrates collected in Surber samples from control and 35.0 g AI/ha treatment streams, Gaspé-Ouest County, Quebec.

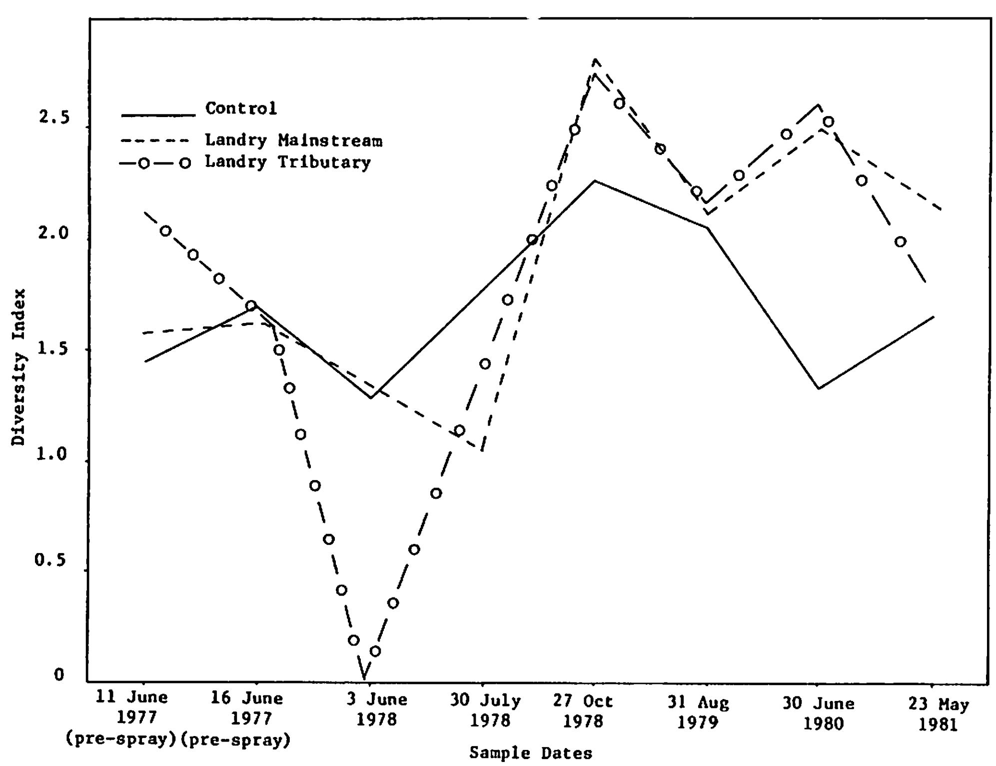


Figure 3. Diversity indices of benthic invertebrates collected in Surber samples from control and 70.0 g AI/ha treatment streams, Gaspé-Ouest county, Quebec.

In the spring following the year of the permethrin applications (3 June 1978) brook trout in the 35.0 g AI/ha treatment stream had resumed feeding on a variety of aquatic insects and to a lesser extent on terrestrial arthropods. Ephemeropterans, trichopterans, and plecopterans comprised 32 to 36, 12 to 18, and 5 to 6%, respectively, of the volume of food organisms consumed at the two sample stations while chironomid larvae contributed approximately 14 to 20%. Stomach content analysis of brook trout collected throughout 1978 and on subsequent sample dates in 1979, 1980 and 1981, indicated normal feeding activity similar to the patterns of food organism selection by brook trout in the control stream (Appendix Tables A-13 to A-16).

A dependence on alternate food sources by brook trout in the 70.0 g AI/ha treatment stream was still evident one year after the application, (Figures 4 and 5, and Table 1). Stomachs of brook trout collected from the two stations on 3 June 1978 contained 44 to 61% Diptera larvae and 19 to 47% terrestrial arthropods with a notable absence of Ephemenoptera nymphs and only minor representation of Plecoptera and Trichoptera. These three taxa contributed 62% of the volume of food organisms consumed by brook trout in the control during the same period. By 30 July 1978 aquatic insects, other than Diptera larvae, were still virtually absent from the stomach contents of brook trout in the 70.0 g AI/ha treatment stream. Sampling at the end of the one year post-spray season (27 October 1978) indicated an increased utilization of various aquatic invertebrates, with the exception of Ephemeroptera nymphs. Although they comprised 23% of the food intake by brook trout in the control, ephemeropterans represented only 1 to 8% of the food organisms selected by the trout in the treated stream. By the end of the following year and in the 1980 and 1981 early season collections, the feeding patterns of brook trout in the 70.0 g AI/ha treatment stream and the control were similar (Appendix Tables A-16 to 18).

Mean volumes of stomach contents of brook trout from both treated and control streams varied greatly throughout the sampling regime (Table 2). The volumes of food organisms consumed by trout in both treated streams approached or exceeded those in the control during the one year post-spray season (1978) but were substantially lower in the fall of 1979. The two subsequent sampling dates (spring of 1980 and 1981) demonstrated food consumption of brook trout in the treated streams at or above the level of food intake by the control trout.

Sculpins in the 70.0 g AI/ha stream fed almost exclusively on Diptera and Trichoptera larvae during the one year post-spray sampling periods of 3 June and 30 July, 1978, whereas Ephemeroptera and to a lesser extent Plecoptera had also contributed significantly to sculpin diets prior to the permethrin application. Ephemeroptera and Plecoptera nymphs had again become important components of the diet by the end of the season (27 October 1978), and although ephemeropterans continued to comprise a major portion of the food organisms found in subsequent sculpin samples, plecopterans became less frequent and were not present in the 1981 samples (Appendix Tables A-19 and A-20). Table 1 indicates that the volumes of food items consumed by sculpins were variable. Although there were no sculpins present in the control stream with which to compare these data, the values obtained do not indicate substantial reductions in food consumption.

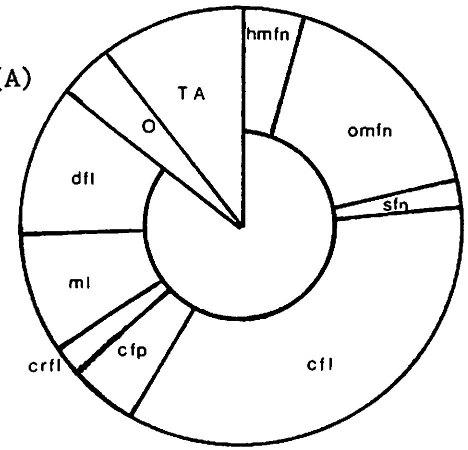
Condition coefficients calculated for brook trout at all treatment stations and the control varied considerably for each sample date and location (Appendix Table A-21). The condition coefficients of brook trout in the 70.0 g AI/ha stream fluctuated to a greater extent that those in the 35.0 g AI/ha stream, but the condition of trout in both treated streams tended to follow the pattern observed in the control (Figures 6 and 7).

A supplementary fish sample was collected from the two treated streams and the control on 8 October 1978 (16 months post-spray) to determine if the changes in feeding activity documented for the trout in the treated streams or other effects of the insecticide had produced

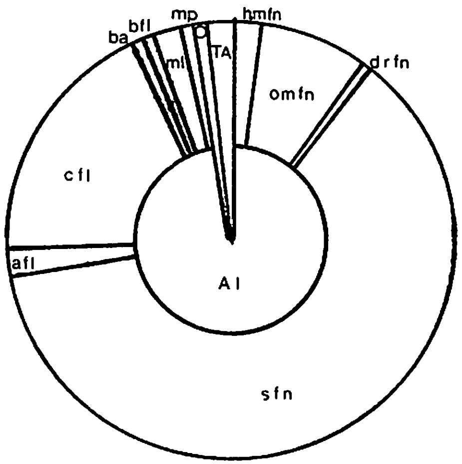
Table 1. List of codes used for representing brook trout stomach contents in graphic illustrations.

afl	- alderfly larvae - Megaloptera - Sialidae
athl	- snipefly larvae - Diptera - Athericidae
AI	= aquatic insects
ba	- beetle adults - Coleoptera
bfl	- blackfly larvae - Simuliidae
bfp	- blackfly pupae - Simmulidae
bl	- beetle larvae - Coleoptera
ccl	- culicoides larvae - Heleidae
cfl	- caddisfly larvae - Trichoptera
cfp	- caddisfly pupae - Trichoptera
crfl	- cranefly larvae - Tipulidae
crfp	- cranefly pupae - Tipulidae
dfl	- dancefly larvae - Empididae
drfn	- dragonfly nymph - Odonata - Anisoptera
hmfn	- heptagenid mayfly nymphs - Ephemeroptera - Heptageniidae
lepl	- aquatic larvae - Lepidoptera
misc	- miscellaneous aquatic insects
ml	- midge larvae - Chironomidae larvae
mp	- midge pupae - Chironomidae pupae
omfn	- other mayfly nymphs - Ephemeroptera
O	- other aquatic invertebrates
sfn	- stonefly nymphs - Plecoptera
syfl	- syrphidfly larvae - Syrphidae
TA	- terrestrial arthropods
udl	- unidentified Diptera larvae

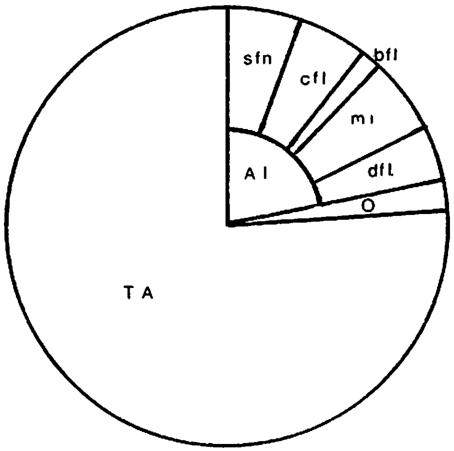
(A)



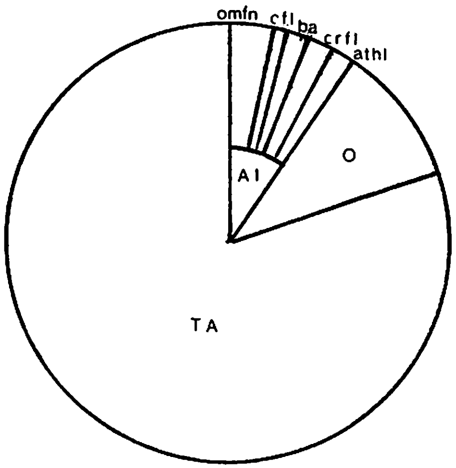
13 June 1977
(3 days pre-spray)



18 June 1977
(2 days post-spray)



27 June 1977
(11 days post-spray)



5 October 1977
(112 days post-spray)

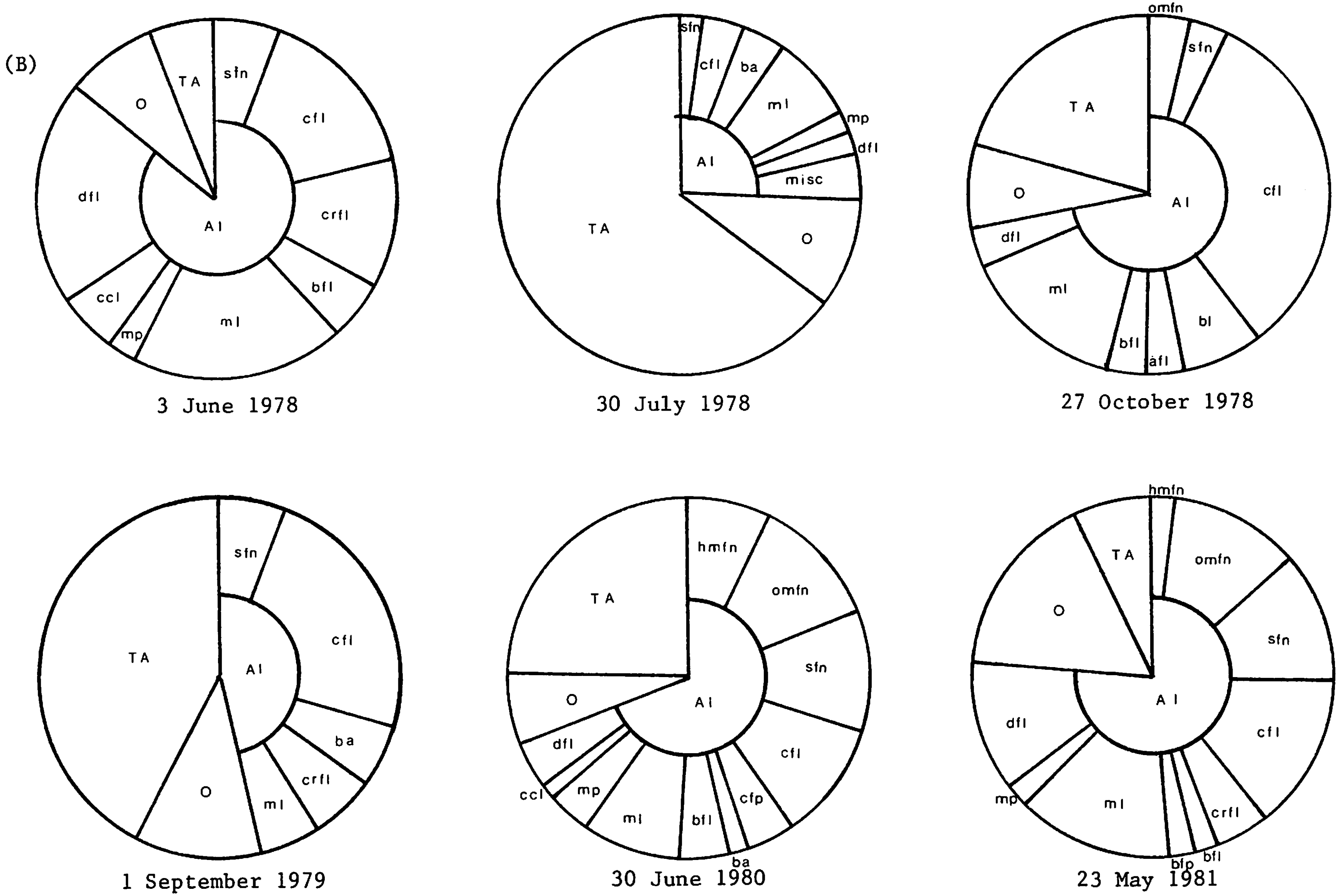
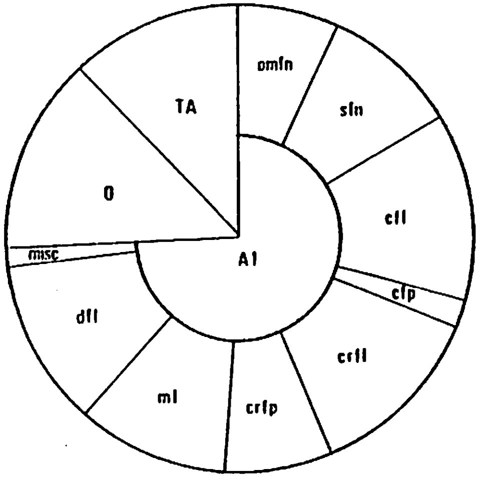
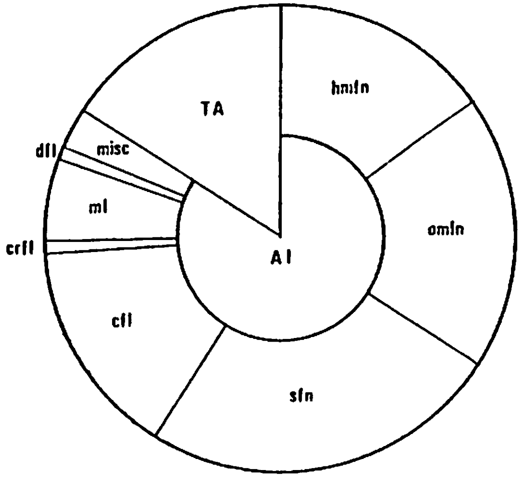


Figure 4. Contribution of various food organisms to stomach contents of brook trout from Ruisseau Landry Mainstream in (A) year of application, and (B) 2 to 4 years post-spray

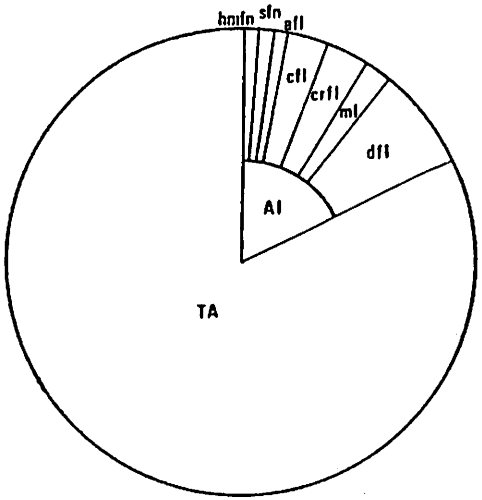
(A)



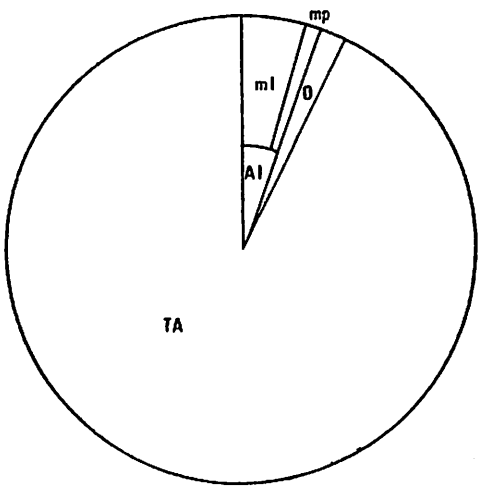
14 June 1977
(2 days pre-spray)



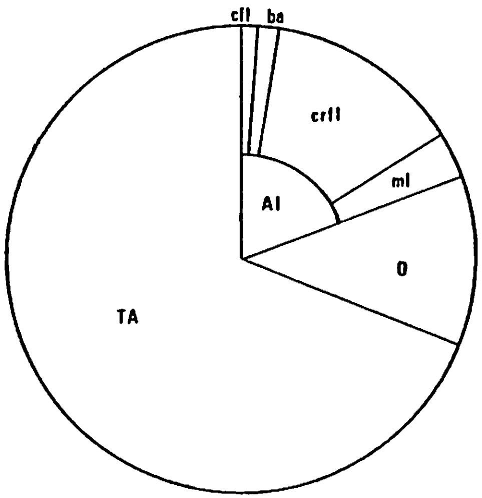
18 June 1977
(2 days post-spray)



27 June 1977
(11 days post-spray)



12 August 1977
(58 days post-spray)



5 October 1977
(112 days post-spray)

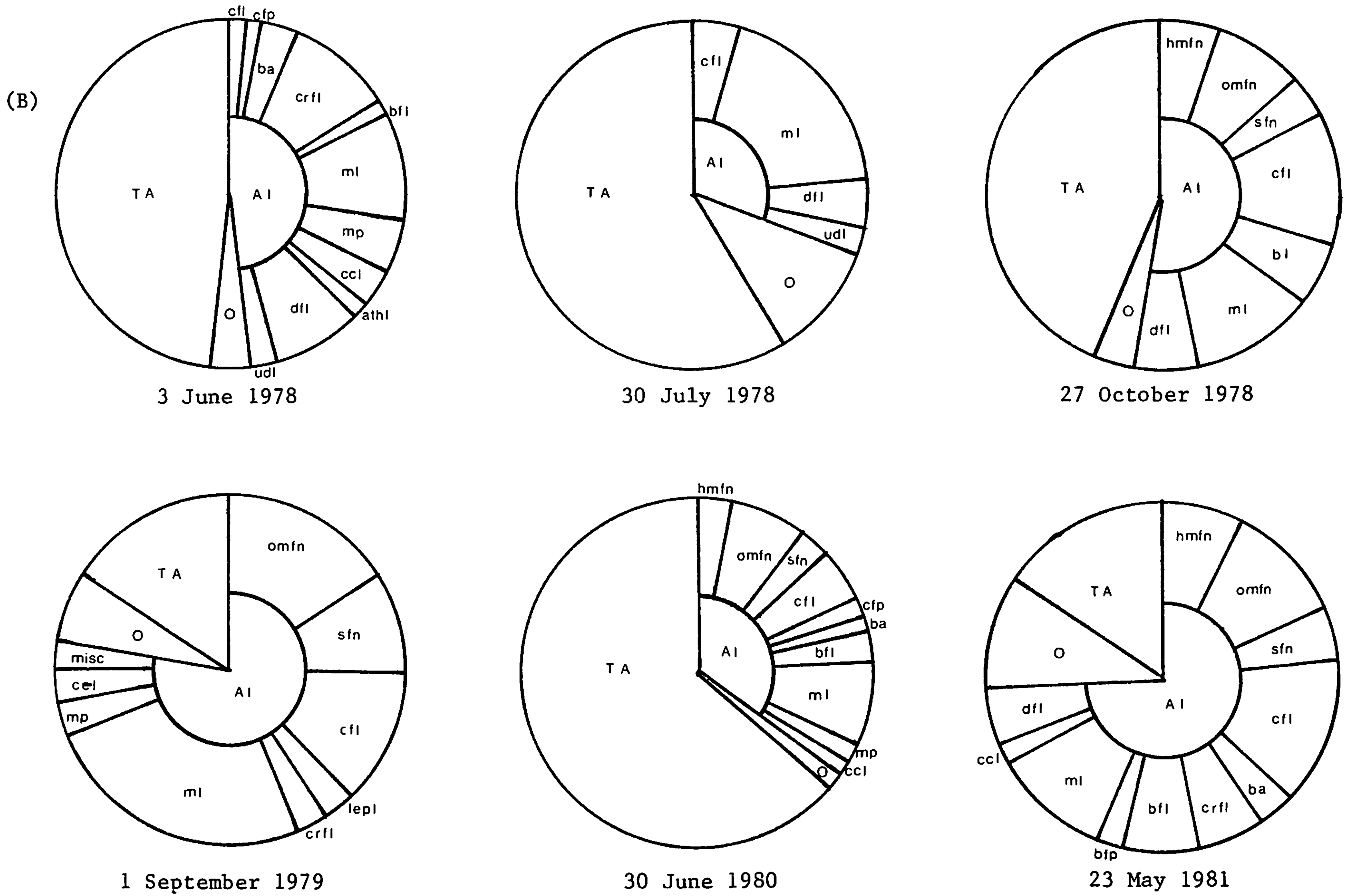


Figure 5. Contribution of various food organisms to stomach contents of brook trout from Ruisseau Landry Tributary in (A) year of application, and (B) 2 to 4 years post-spray

Table 2. Relative values expressing volumes of food organisms* consumed by resident fish in treatment and control streams, Gaspe Ouest County, Quebec.

	13-19 June 1977 (pre-spray)	3-4 June 1978	30 July 1978	27 October 1978	31 Aug-1 Sept 1979	30 June 1980	23 May 1981
Control brook trout	1.38	2.01	2.63	1.44	5.88	3.09	3.98
35.0 g Al/ha tributary brook trout	2.36	2.84	2.53	1.23	0.96	6.27	6.22
35.0 Al/ha mainstream brook trout	2.58	4.46	2.62	1.06	0.76	2.52	3.76
70.0 g Al/ha tributary brook trout	2.38	5.99	2.42	1.51	0.69	7.33	3.29
70.0 g Al/ha mainstream brook trout	1.29	1.26	4.21	1.29	0.70	3.05	4.08
70.0g Al/ha tributary slimy sculpins	1.14	1.83	2.33	0.37	0.83	0.69	1.09
70.0 g Al/ha mainstream alimy sculpins	1.00	1.03	0.34	1.51	3.25	2.27	0.82

* $\frac{\text{mean volume of stomach contents} \times 10^3}{\text{mean fork length}}$

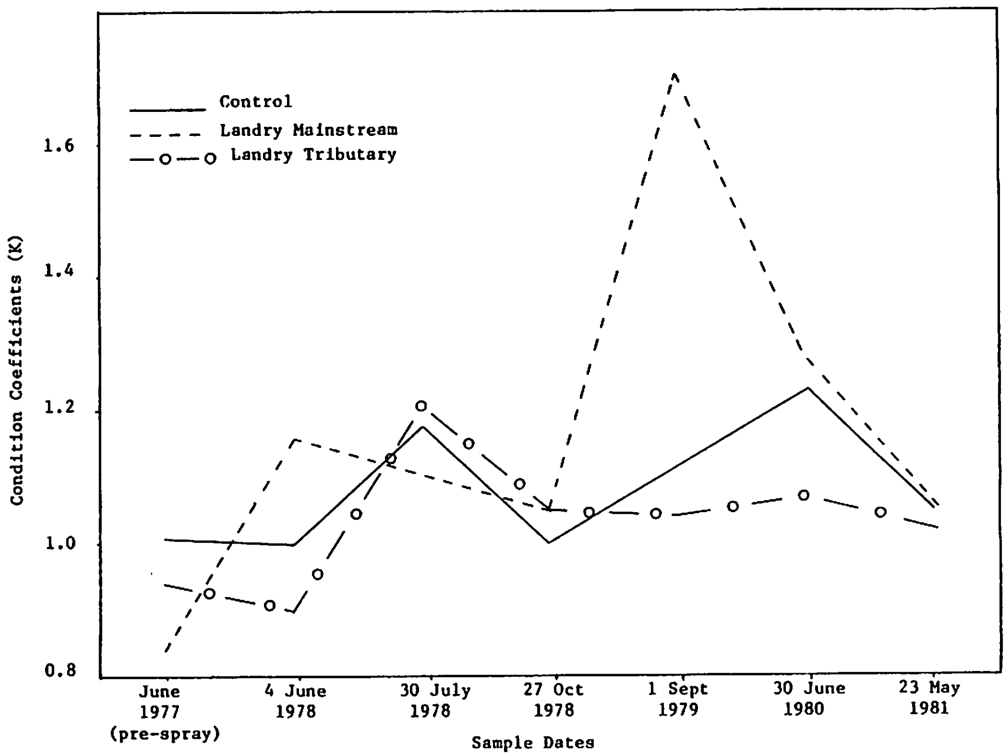


Figure 6. Condition coefficients of brook trout collected from the control and 70.0 g AI/ha treatment streams, Gaspé-Ouest County, Quebec.

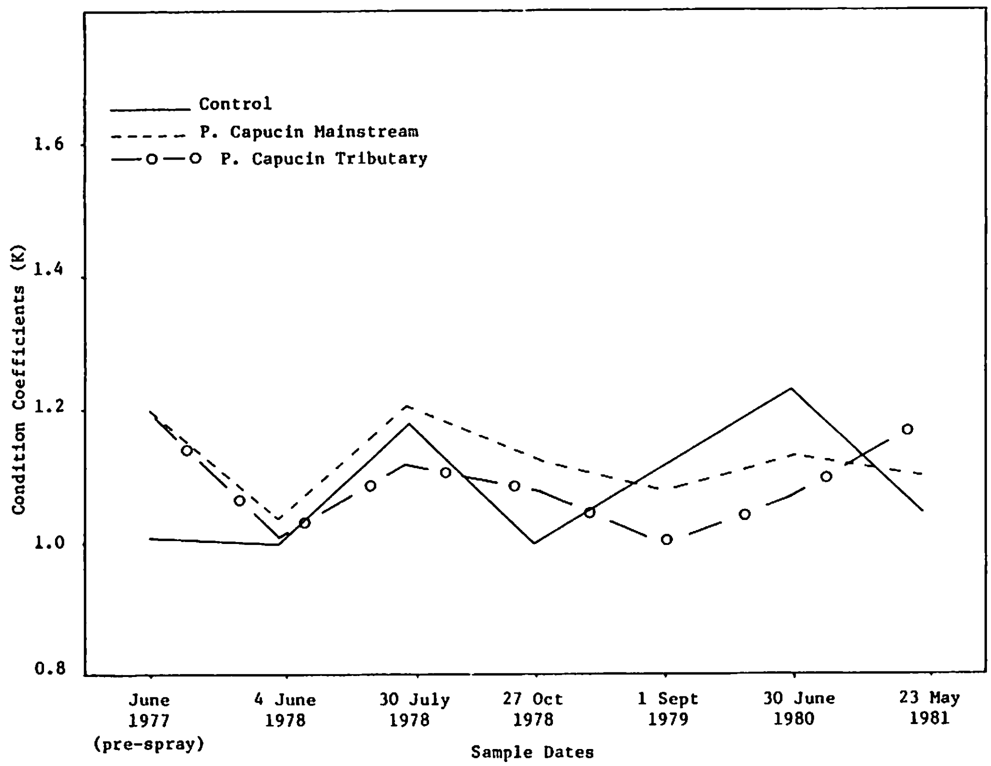


Figure 7. Condition coefficients of brook trout collected from the control and 35.0 g AI/ha treatment streams, Gaspé-Ouest County, Quebec.

measurable reductions in the gamete production of female brook trout. A total length/ovary weight linear regression line was plotted for each of the three samples (70.0 g, 35.0 g AI/ha treatment streams and the control) and a comparison of the resulting lines was tested with an analysis of covariance. Figures 9 and 10 illustrate that the slopes of both treatment stream regression lines were lower than the control and that the 70.0 g AI/ha stream was lower than the 35.0 g AI/ha stream regression line. The differences, however were not significant ($p < 0.05$). The data used for these calculations are contained in Appendix Table A-22.

DISCUSSION AND CONCLUSIONS

Benthic invertebrates in the 35.0 g AI/ha treatment stream, including ephemeropterans which had remained suppressed during the late season sampling in the year of application, returned to normal levels by the one-year post-spray sampling date. Repopulation of bottom fauna in the 70.0 g AI/ha stream was considerably slower and with the exception of chironomids, was not evident among most groups until the fall of the year following the permethrin application (16 months post-spray). These recolonization periods are substantially longer than the recovery times documented for lower dosage permethrin applications (Kingsbury and Kreutzweiser 1979, 1980b, 1982, and Kreutzweiser 1982) and may have resulted from both the application dosage and procedure.

Initial impact assessment of the 35.0 g and 70.0 g AI/ha treatment streams indicated pesticide-induced catastrophic drift and a severe depletion of bottom fauna, consequently limiting the residual population available for recolonization. The recovery of benthos may have been further impeded by the virtual elimination of upstream **refugia** from which drifting invertebrates could move downstream to repopulate the affected area. Waters (1962), Townsend and Hildrew (1976), Williams and Hynes (1976), and Bird and Hynes (1981) have all demonstrated the importance of invertebrate drift in the recolonization of denuded or severely disturbed areas. Their results indicate that repopulation of bottom fauna is rapid, provided the introduction of drifting invertebrates from upstream areas is possible. Elliott (1967) concurred and stated that recolonization is accomplished largely by invertebrate drift except where an insecticide has been applied to the source of the stream. During the permethrin applications to the 35.0 and 70.0 g AI/ha streams, the application aircraft initiated the spray swath on the mainstream portion of the treated stream and continued up the main tributary for the distance that the stream was observable from the air. This procedure greatly reduced any refuge area that would have occurred above the treated section of the stream. Although the untreated tributary of both streams (see Figure 1) could have provided a source of invertebrate drift for recolonization, there was little observable difference in the recovery rate of benthos between the sampling stations below the confluence with the untreated tributaries and the stations on the treated sections above the tributaries. Recovery of benthos in the lower dosage stream was not noticeably different between the two sampling stations (Appendix Tables A-1 to A-4), but the rate of recovery in the 70.0 g AI/ha stream showed some evidence of the untreated tributary contributing to invertebrate recolonization. Although only small numbers of invertebrates were collected in one year post-spray samples (3 June 1978) from the treated stations both above and below the confluence with the untreated tributary, the samples from below the tributary did contain a slightly greater variety of organisms and consequently a higher diversity (Appendix Tables A-7 to A-11, Figure 3).

In order to more clearly determine the influence of the untreated tributary on recolonization of the higher dosage stream, several impromptu Surber samples were collected from a section of the treated stream, up to 150 m above and below the confluence with the untreated tributary, and in the tributary itself on 31 July 1978. These samples contained noticeably greater numbers of benthic invertebrates, including two of the most affected taxa (Ephemeroptera and Trichoptera) than concurrent samples collected from the actual sampling stations on

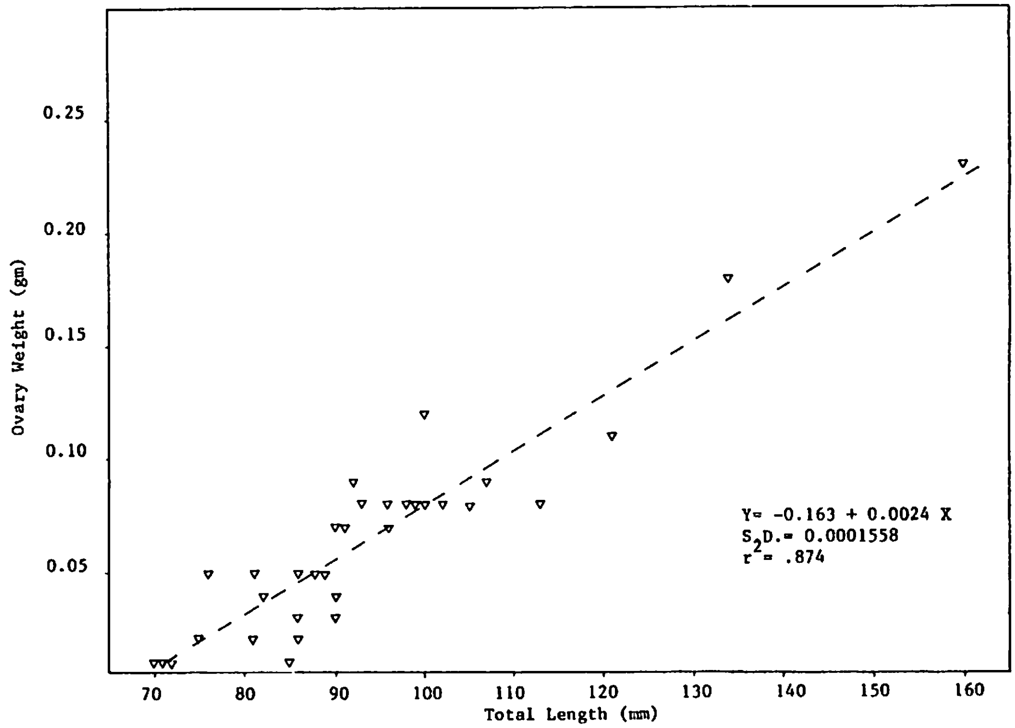


Figure 8. Total length/ovary weight linear regression for a sample of brook trout collected from Ruisseau Landry (70.0 g AI/ha permethrin appalication) on 28 October 1978.

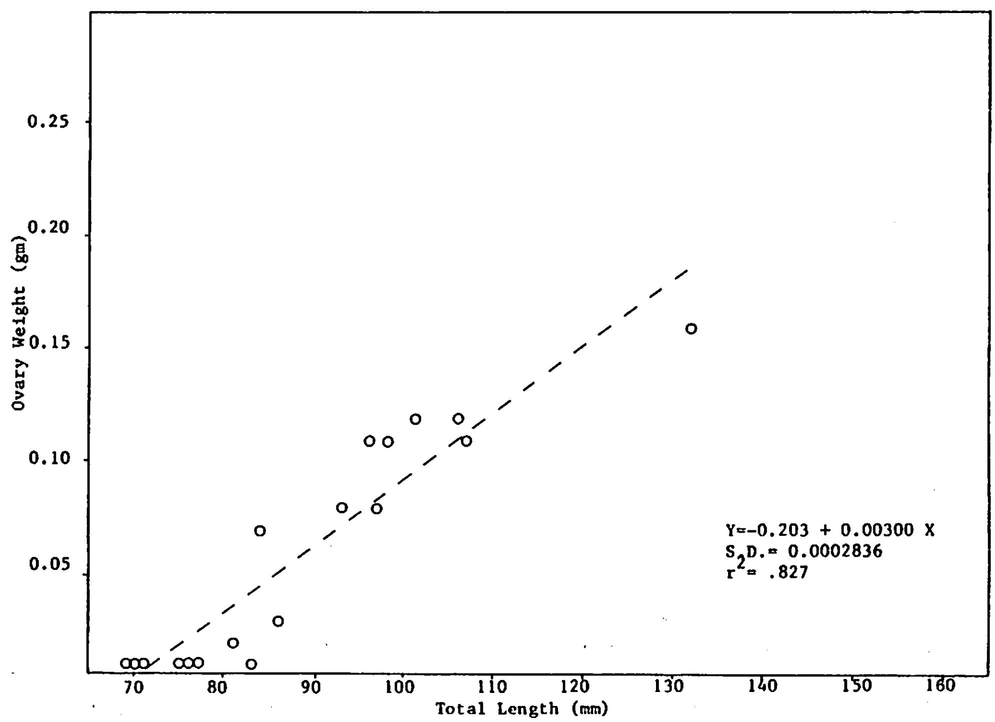


Figure 9. Total length/ovary weight linear regression for a sample of brook trout collected from Ruisseau Petit Capucin (35.0 g AI/ha permethrin application) on 28 October 1978.

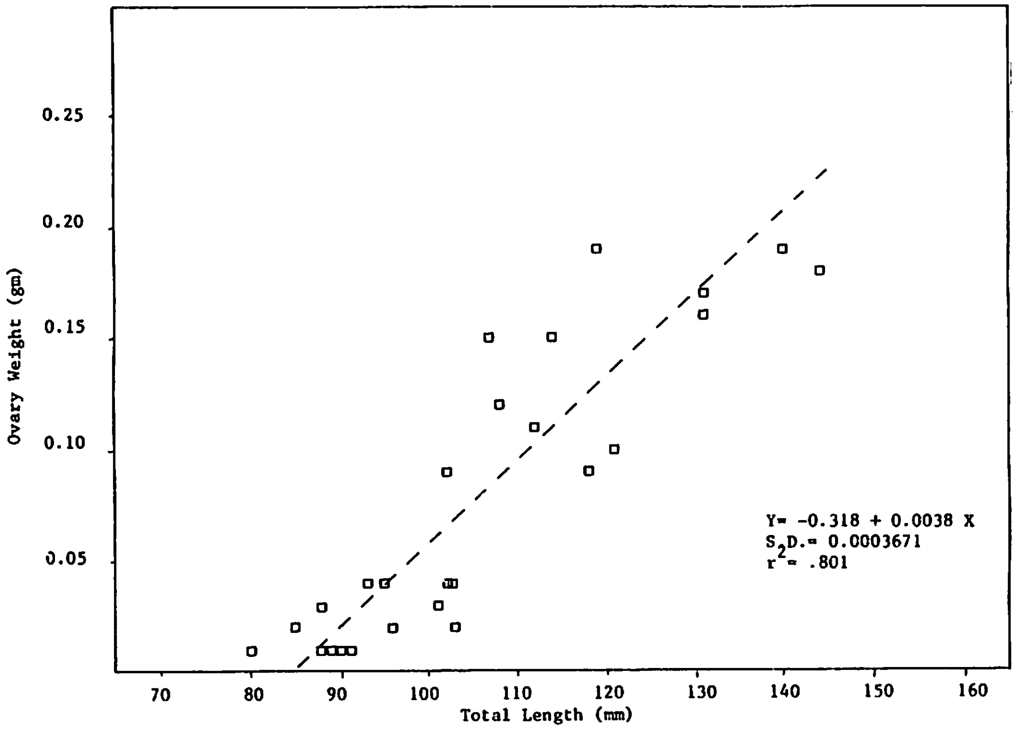


Figure 10. Total length/ovary weight linear regression for a sample of brook trout collected from Ruisseau Grande Tourelle (untreated control) on 28 October 1978

the treated stream (Appendix Table A-23). The small number of samples precludes a definite conclusion but the results suggest that a certain degree of recolonization had occurred within a short distance above and below the confluence with the untreated tributary before recolonization was evident at the sampling stations.

It is apparent from the comparatively long recovery time documented for the 70.0 g AI/ha stream that both the high dosage and the virtual absence of upstream **refugia** contributed to the lengthy suppression of benthic invertebrates to the extent that repopulation may have been largely dependent on the progeny of migrating adults from lower sections of the stream or adjacent waterways. During the 16 month post-spray sampling period when the numbers of invertebrates in the 70.0 g AI/ha stream had demonstrated a substantial increase, most collected organisms, especially ephemeropterans and plecopterans, were recently hatched insects. Although actual size measurements were not taken, it was evident during the collection and identification of the benthic invertebrates that most of the organisms were first or early instar life stages.

The feeding activity of fish in the two treated streams reflected the availability of food organisms. As the abundance and diversity of benthic invertebrates increased, the selection of various fish food organisms by both brook trout and sculpins also increased, with a preference demonstrated for Ephemeroptera and Plecoptera nymphs and Trichoptera larvae. When the preferred taxa were absent or scarce, the fish utilized alternate food sources such as Diptera larvae, especially Chironomidae, and various terrestrial arthropods. The feeding patterns of native fish appeared to have returned to normal by the one year post-spray sample date (3 June 1978) in the 35.0 g AI/ha stream, but did not indicate complete recovery in the 70.0 g AI/ha stream until the following year. Although benthos sampling in the higher dosage stream in the fall of 1978 demonstrated a substantial increase in Ephemeroptera nymphs, these organisms were virtually absent from the stomach contents of brook trout. The uniformly small, early instar sizes of the nymphs may have made them unattractive to the trout during the one-year post-spray season. Sculpins were utilizing these nymphs to a substantial extent at this time, which conforms to their normal selection of smaller sized food items than brook trout.

The volume of food intake by brook trout did not appear to reflect the availability of preferred food items. Even during the period of low benthos numbers and diversity in the higher dosage stream, brook trout, feeding on alternate non-aquatic insect food sources, maintained a level of food consumption comparable to or exceeding either pre-spray or control levels. The substantially reduced food intake by trout in both treated streams in the fall of 1979 (2 years post-spray) concurred with a noticeable increase in the stomach content volumes of trout in the control stream, but did not appear to be pesticide impact related. The documented recovery of benthos by the 2 year post-spray samples, and the previously sustained levels of food intake suggest that the reduced food consumption resulted from factors other than the permethrin impact.

Calculations of condition coefficients of brook trout in the streams did not demonstrate reductions in condition attributable to the changes in feeding activity. The calculated values varied considerably, and have been previously shown to be greatly influenced by a large range in the lengths of fish in the sample (Bagenal and Tesch 1978), and by season, sex, sexual maturity, age, and various other factors (Carlander 1969). Consequently, the determination of condition coefficients may not have been an appropriate means of assessing long term effects of changes in food availability on the growth or condition of brook trout. With the reductions in food availability, especially in the higher dosage stream, it was possible that gamete production by brook trout could have been reduced in the year following the application. A comparison of total length/ovary weight regression lines for female trout collected from each stream 16 months post-spray did not, however, show significant differences in ovary production by the trout. in the treatment streams. ~~It is possible that a much larger sample size might have revealed subtle differences, as there was an indication that the ovary production by the trout in the treatment streams.~~ It is possible that a much larger sample size might have revealed subtle differences, as there was an indication that the ovary weights of trout over 110 mm in length from the 70 g AI/ha treated stream were lower than those of trout of similar size from the control stream. The extent to which reduced gamete production might be attributable to a pesticide-induced change in food availability is not known.

Despite severe depletion of benthos and documented changes in diet composition of native fish in the high dosage permethrin treatment streams, the resulting effects on resident brook trout and slimy sculpins appeared minimal. The post-spray fish populations were observed to have adapted well to the drastic reductions in aquatic invertebrates by utilizing alternative food sources. No pesticide-induced fish mortality in the treated streams occurred and impact related effects on growth, condition, and fecundity have not been substantiated. This may reflect to a certain extent limitations of the sampling and assessment techniques employed. Although it was apparent that a viable post-spray fish population was present in both treatment streams, there was no attempt made to assess the population size and age class structure before and after the applications. For this reason the possibility that the post-spray populations comprised healthy individuals, but in reduced numbers, cannot be excluded. Soslak (1982) and Kreutzweiser (1982b) have reported evidence that following permethrin applications to salmon nursery streams in New Brunswick, a reduced food supply resulted in a migration of juvenile Atlantic salmon and brook trout out of the treated areas. Despite the limitations of the fish population assessment in the present study, the sampling procedures and the data generated indicate that a healthy resident fish population was sustained through the period of major changes in food availability.

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