EFFECTS OF DDT AERIAL SPRAYING OF THE FOREST ON THE
FOOD OF YOUNG SALMON (SALMO SALAR, L.) IN
NEW BRUNSWICK STREAMS

by

Donal A. Hurley

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I. INTRODUCTION

In the years 1952-1955 aerial applications of DDT spray have been made in connection with the control of the spruce budworm (Choristoneura fumiferana, Clem.) in New Brunswick forests. In 1954 this program included the spraying of approximately one million acres covering about one-third of the Miramichi watershed in the northcentral part of the province.

A preliminary survey was made of parts of the Miramichi system within the sprayed area in 1954, a few weeks following completion of the spraying. This survey showed a scarcity, and in some locations, absence, of immature stages of aquatic insects as far as the sampling method indicated, as compared with streams in the same system that were not sprayed.

A detailed investigation of the invertebrate aquatic fauna was undertaken during the summer of 1955 to determine the effect of the spraying of the previous year. Two methods were used in measuring this effect:

1. Account of the insects which emerged from unit areas of stream bottom was made in sections of both sprayed and unsprayed streams by daily collections during the period of the survey from June to September.

2. Series of samples of the aquatic stages of the bottom fauna were taken at various locations in streams in sprayed and unsprayed parts of the Miramichi system, making the collections on three occasions during the summer.
In order to determine the utilization of bottom fauna by Atlantic salmon parr and fry the contents of the stomachs of fish were analyzed from samples taken by electro-fishing from several locations along the North West Miramichi river, much of which had received DDT spray in 1954. The results of these analyses were compared with similar analyses for fish that had been taken from several of the same locations in 1953, the year previous to the spraying in this area.
II. DESCRIPTION OF AREA

The area that received DDT spray in June 1954 included about one-third of the Miramichi watershed in New Brunswick. The insecticide was applied from aeroplanes at a rate of one-half pound of DDT-in-oil suspension per acre. Sections about 10 to 20 square miles in area were sprayed as the weather permitted and the boundaries of these areas were, in general, marked by streams. The date of spraying in a particular area depended on the stage of development of local budworms and adjacent sections were sometimes sprayed on widely separated dates, as much as three weeks apart (16).

The map, Fig. 1, shows a part of the area that was sprayed in 1954 and the dates of spraying of sections adjacent to the rivers that were used in the investigation. Five streams were studied in the investigation, as follows: North West Miramichi River, North Branch of the Big Sevogle River, a small tributary of the North Branch of the Big Sevogle River, Trout Brook, and Millstream Brook. All or parts of the first three streams above had received spray in 1954, while Trout Brook and Millstream Brook were not sprayed and were used as controls in one part of the investigation.

The North West Miramichi River is about 75 miles in length and flows in a southeasterly direction toward Newcastle at the mouth of the Miramichi River. The upper 40 miles received insecticide in 1954. Areas adjacent to this river and its upper tributaries within the spray boundary received spray on dates ranging from June 8 to June 24.
FIGURE 1.

Map showing part of Miramichi watershed studied in 1955 with the boundary of the sprayed area. Dates of spraying of local areas are shown and also the fish and bottom fauna sampling stations.
The North Branch of the Big Sevogle River, a tributary of the North West Miramichi River, is about 35 miles in length and flows in a direction nearly parallel to it for a great part of its length. Almost 30 miles of this river lay within the spray boundary. The headwaters, except for a small area, and the tributaries of this river received spray on widely separated days from June 8 to June 25.

The small tributary of the North Branch of the Big Sevogle River that was investigated is about 1.5 miles in length. This stream and the area adjacent to it received spray on June 16.

Trout Brook and Millstream Brook are two tributaries of the North West Miramichi River. Trout Brook is about nine miles in length and flows in a southwesterly direction. Millstream Brook is about 23 miles long and flows in a southerly direction. Both these streams are tributaries of the North West Miramichi River lying completely outside the sprayed area.

These unsprayed streams were used as controls in the collections of emerging insects. Trout Brook was a control stream for the small tributary of the North Branch of the Big Sevogle River described above. However, the control stream was considerably longer and wider than the sprayed stream and also from 5 to 8°F. warmer than it. Trout Brook lay entirely outside the spray boundary and its closest approach to this boundary was a distance of six miles. Millstream Brook was studied as a control for the North Branch of the
Big Sevogle River and, although it was about 10 miles shorter in its total length than the latter, the collections were made about equal distances from the headwaters in both rivers. Millstream Brook was wider at the locations of the collections than the North Branch of the Big Sevogle River and about 3°F. warmer than it. The closest approach of Millstream Brook to the spray boundary was about 10 miles distant.

Some of the physical characteristics of the stream that were used in connection with Method I as stated in the introduction are given in Table I. These characteristics refer only to the particular locations in the various streams at which collections were made.

The type of bottom in the streams in the sprayed area from which collections of emerging insects were made consisted largely of metamorphic rocks, gneiss and shist, about 8 inches in diameter and poorly weathered for the most part with smaller fragments between the rocks. In Trout Brook the bottom consisted of flat brown sandstone rocks, many of them being from 7 to 10 inches in length and width and about 3 to 5 inches in depth. The interstices were filled with gravel and sand. The bottom in Millstream Brook also consisted of brown sandstone rocks but the rocks were well rounded in most cases and generally smaller in size than those from Trout Brook. Sand and gravel filled the interstices of the rocks in this stream also.
TABLE I

Description of streams used for collections of emerging insects with some physical characteristics of these streams at the locations of the cage-traps.

<table>
<thead>
<tr>
<th>Name of Stream</th>
<th>Total Length of Stream Miles</th>
<th>Distance of Cage-traps from Headwaters Miles</th>
<th>Spray Treatment</th>
<th>Width-feet June</th>
<th>July</th>
<th>August</th>
<th>Temperature Average Daily Mean for July</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tributary of North Branch of the Big Sevogle</td>
<td>1.5</td>
<td>1.5 - 100 ft.</td>
<td>Whole Sprayed</td>
<td>June 16</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>North Branch of the Big Sevogle</td>
<td>35</td>
<td>15</td>
<td>Headwaters and tribut. sprayed</td>
<td>June 8-25</td>
<td>50</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>Trout Brook</td>
<td>9</td>
<td>5</td>
<td>Unsprayed</td>
<td>20</td>
<td>17</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Millstream Brook</td>
<td>23</td>
<td>15</td>
<td>Unsprayed</td>
<td>60</td>
<td>55</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>
III. POPULATION OF AQUATIC INSECTS AND OTHER INVERTEBRATES

Emerging Insects

Method of Collection

The locations of the four streams from which emerging insects were collected have been described above and some of the physical characteristics of these streams at the collecting points are given in Table I.

The aquatic insects emerging from nine square feet of stream bottom were captured by means of a cage-trap of the type described by Ide (15), but some modifications were made in their construction. The height of each cage was increased to five feet and Windolite screening was substituted for copper screening on three of the sides and on the top. Copper or brass screening was placed on the remaining side to allow for ventilation. This screening was finer than that originally described by Ide (15), being 25 per square inch instead of 15 per square inch.

Two cage-traps were placed in each of the four streams mentioned above. Each cage was placed in a situation in each stream as similar as possible with respect to depth of water, velocity of flow and distance from the bank. All cages were placed in about 8 to 10 inches of water in medium to fast riffles. The distance from the bank was kept approximately constant for each cage by moving them out towards the center of the stream on three occasions during the summer as the streams became narrower with the falling water level.
FIGURE 2.

Photograph of one of the cage-traps in position.
There are some errors connected with this type of sampling of emerging insects as was pointed out by Ide (15) and Sprules (20). These errors were minimized as much as possible by taking several precautions. The door of the cage-trap was tapped several times before entering to prevent the escape of trapped insects. Spiders and empids which prey on insects, were removed from inside the cage-trap. Movements were restricted while inside the cage to prevent crushing immature insects on the bottom. A further precaution was made in the examination of the material. Female black flies were eliminated from the count of emerged material when no males accompanied them since they probably did not represent emergence but were carried into the cage-trap on the collector. When male and female black flies were taken in a collection, a sex ratio of 1:1 was assumed and the females which exceeded this ratio were eliminated from the count since these probably entered the cage-trap on the collector.

This method is valid only insofar as it gives comparative results since Sprules (20) showed that the number of emerged insects captured by each cage increases significantly if the cage is emptied at interval of less than 24 hours. As the interval between collections in these observations was approximately 24 hours, the absolute number of insects that emerged in this period would not be collected. However, comparisons can be made with the number that emerged into each cage.

The cage-traps were emptied six times each week and were visited in a regular sequence beginning about 10:00 A.M. A.D.T.
and ending about 1:00 P.M. A.D.T. of the same day. There were some
days when collections could not be made. For instance, the collapse
of the bridge in early August prevented collections being made in the
Sevogle area for a week; however, this was the longest period by which
the regular collections were interrupted.

Collections were made by entering each cage, picking
the emerged insects from the screening with forceps and placing them
in a vial in 95% alcohol. Identification was done using a binocular
microscope at the field laboratory and was carried to genus in general
but only to family for the Diptera. Specific determinations were made
in some groups of species which were extremely prevalent. The volume
of each collection from a single cage was determined by observing the
displacement of liquid in a 10 ml. graduated cylinder.

Results

The results of the collections of adult insects show
that there are significant differences in the percentages by numbers
of many groups of insects collected and in the corresponding total
volumes of these insects between streams which had received DDT and
those which had not. These differences are shown in Table II. Col-
lections made from the large streams show that the sprayed stream had
both a smaller number of individuals and a smaller volume of insects
in these collections than those made in the large unsprayed stream.

The small sprayed stream had a smaller average volume
for the collections than the small unsprayed stream; however, the
TABLE II.

Comparison of the insects emerged from sprayed streams together with their controls from June to September in 1955. The quantities are based on emergence over a 60 day period. Each cage-trap, lettered S1, S2, S3, S4, T5, T6, M7 and M8, covered one square yard of stream bottom.

<table>
<thead>
<tr>
<th>Stream Size</th>
<th>Treatment</th>
<th>Cage-traps</th>
<th>Total Volume mls.</th>
<th>Total Number Insects Emerged</th>
<th>Ave. Vol. per insect from each stream</th>
<th>Per Cent of Total Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>Sprayed</td>
<td>S1</td>
<td>6.8</td>
<td>1356</td>
<td>0.0041</td>
<td>28.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S2</td>
<td>4.7</td>
<td>1428</td>
<td>0.0055</td>
<td>18.6</td>
</tr>
<tr>
<td></td>
<td>Unsprayed</td>
<td>T5</td>
<td>6.2</td>
<td>1311</td>
<td>0.0055</td>
<td>14.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T6</td>
<td>9.1</td>
<td>1475</td>
<td></td>
<td>23.0</td>
</tr>
<tr>
<td>Large</td>
<td>Sprayed</td>
<td>S3</td>
<td>4.4</td>
<td>1603</td>
<td>0.0032</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S4</td>
<td>4.7</td>
<td>1326</td>
<td>0.0059</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td>Unsprayed</td>
<td>M7</td>
<td>12.9</td>
<td>2108</td>
<td>0.0059</td>
<td>12.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M8</td>
<td>10.0</td>
<td>1806</td>
<td>0.0059</td>
<td>12.0</td>
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reduction was not as great as for the large sprayed stream. The volume of insects collected from one of the cage-traps in the small sprayed stream was actually greater than that from one cage-trap in its control. The average numbers of insects collected from cage-traps in the small sprayed stream and its control were similar.

Examination of the two columns giving the total numbers and the total volume of insects collected shows a considerable variation between the two cage-traps located at one station in one stream. Attempts were made, as stated before, to place the cage-traps in as similar situations as was possible. However, the results of the collections from each location in each stream show similar qualitative characteristics, differing only in the proportional numbers of the components. These variations can thus be correlated with minor differences in the habitat between the two locations of the cage-traps in each stream. The variations are attributable to the variable numbers of Chironomidae collected from each cage-trap. When this group comprises a greater percentage of the total number of insects collected from one cage than in the other cage in the same stream, then in some cases the total number of insects collected is greater and the total volume is smaller in the former cage than in the latter.

The total number of days that collections were made was not the same for each stream and a correction has been applied so that a 60-day equivalent of the collections is given in the results.
for each cage-trap. The maximum correction that had to be applied was never greater than for a period of 5 days and in most cases was for only 2 days out of 60 days.

A value for the average volume in ml. per insect was calculated by dividing the total volume of insects by the total numbers of emerged insects for the collections from each cage-trap and then taking the average of this value for each stream. These values show that the volume per insect in the collections from the small sprayed stream was about 4/5 of the volume per insect in collections from its control stream. The reduction of this value was much greater in the large sprayed stream compared with its control, being somewhat less than 1/2.

A smaller total volume of insects was collected from one of the cage-traps in the large unsprayed stream than in the other. A part of this difference may have been caused by the fact that this cage was not in operation from July 4 to July 7 when several large stoneflies (*Acroneuria abnormis*, Newm.), averaging 0.3 ml., were collected from the operating cage-trap. It is possible that some individuals would have been collected by the cage-trap had it been in operation at that time, since this species was then emerging in rather large numbers and a few individuals would have caused a significant increase in the total volume of the collections and would have correspondingly increased the average volume of insects for that cage-trap.
The data of Table II show that some groups formed a significantly smaller percentage while others formed a greater percentage of the total insects collected from sprayed streams, compared with those collected from unsprayed streams of similar size. One of the most significant observations was that Trichoptera were absent from the collections from the large sprayed stream and contributed only an average of 0.4 percent of the total number of insects in collections from the small sprayed stream. This group of insects comprised an important part of the collections from both control streams. In the small unsprayed stream they formed an average of 13.9 percent of the insects collected from two cage-traps and in the large unsprayed stream an average of 11.2 percent of the insects collected. Since they are relatively large insects these percentages represent a significant portion of the total volume of the collections.

The average percentage numbers of the mayflies collected from the large unsprayed stream was about 60 percent more than for the sprayed stream. However, for the small streams, the percentage numbers of mayflies was about 80 percent greater in collections from the sprayed stream than those from its control. On the other hand, sprayed streams showed an increased percentage in the numbers of Plecoptera compared to their respective control streams. The small sprayed stream had a relatively greater increase in the numbers of insects of this group compared with its control stream than did the large sprayed stream. The increase in the percentage of this group in the small sprayed stream compared with its control was 7.7 times while the increase for the large sprayed stream was only 2.4 times.
The large sprayed stream also had a significant increase in the numbers of Simuliidae (Diptera) collected from it compared with its control stream. Both sprayed and unsprayed streams had so few black flies in the collections that valid comparisons cannot be made. In the large sprayed stream there were 15 times as many black flies collected, nearly all in late summer, as in the large control stream and Chironomidae were taken in smaller numbers from both sprayed streams than their respective controls. The large percentage of other Diptera found in the large control stream was mainly because of the emergence of a large number of individuals of the superfamily Tipuloidea.

There are significant differences in the percentage numbers of individuals of many species of insects for sprayed and unsprayed streams. These differences are noted especially among the Ephemeroptera. Among the Baetidae, Baetis spp. accounted for 42.7 percent of the total numbers of mayflies taken from the small control stream and 34.5 percent from the large control stream while there were no Baetis spp. taken from the small and they accounted for only 2.0 percent of the total in the large sprayed streams. Another example of the differences in fauna of sprayed and unsprayed rivers is in the numbers of Iron spp. collected from these rivers. In the small and large streams this group comprised 37.3 percent and 53.2 percent, respectively, of the total number of mayflies collected. In the small control stream they accounted for 21.5 percent of the total while in the large control stream they were only 2.1 percent of the
Large numbers of *Ephemera* spp. individuals were taken in the sprayed streams amounting to 61.1 percent of the total number of mayflies in the small and 35.5 percent in the large. The small control stream had only 1 percent of the mayflies belonging to this genus while collections from the large control stream had 30.7 percent of the mayflies belonging to *Ephemera*. One other genus of mayflies is worthy of mention here. There were only a few individuals of *Paraleptophlebia* taken from the large sprayed stream while they comprised 26.4 percent of the mayflies from its control stream. Both sprayed and unsprayed small streams had only a few individuals of this genus in the collections from them.

Among the species of Plecoptera, many of those having a one-year life cycle are well represented in both sprayed and unsprayed streams, especially *Leuctra* spp., *Nemoura* spp., *Alloperla* spp., and *Isogenus* spp. The small control stream had a large number of individuals of *Isogenus* spp. accounting for 14.4 percent of the Plecoptera collected while the small sprayed did not have any members of this genus in the collections. Many species having a two- or three-year life cycle were represented in the collections from the control streams, especially *Acroneuria* spp., *Paragnetina* spp., and *Phaeganophora* sp. while only one individual of *Acroneuria* was taken from the large sprayed stream.

The 11 individuals of Trichoptera collected in the small sprayed stream belonged to four families. There were no caddisflies collected from the large sprayed stream. In the control streams there
were 12 families of this order represented; of these the Rhyacophilidae and Hydropsychidae were the dominant families.

One other aspect of the reduction in aquatic insects in sprayed streams compared with unsprayed streams is the reduction in the number of species within each order. In Table III is given a conservative estimate of the numbers of species of three of the major orders represented in the collections from the four streams investigated. This table shows that for Ephemeroptera there were 11 fewer species in collections from the small sprayed stream as compared with its control and for the large sprayed stream this reduction was by 7 species. The reduction in the numbers of species of Plecoptera was a little less than this. There were 3 less in the small and 5 less in the large sprayed stream compared with their respective controls. The greatest reduction was in the Trichoptera, this group being entirely absent from collections in the large sprayed stream and only 4 species were found in the small sprayed stream.

The smaller total number of species found in the small sprayed stream was probably accentuated since being smaller and colder than its control there were probably fewer species inhabiting it originally as has been shown for some groups (13). The large streams were similar in size and temperature so that the reductions noted in the sprayed stream were probably caused by the insecticide alone.
TABLE III

Numbers of species of three orders of emerged insects collected from June to September, 1955, by cage-traps in sprayed and unsprayed streams in the Miramichi area. The numbers are those of a conservative estimate.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ephemeroptera</th>
<th>Plecoptera</th>
<th>Trichoptera</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Streams</td>
<td>Sprayed</td>
<td>5</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Unsprayed</td>
<td>16</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Large Streams</td>
<td>Sprayed</td>
<td>10</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Unsprayed</td>
<td>17</td>
<td>13</td>
<td>15</td>
</tr>
</tbody>
</table>
Discussion

The results of this study indicate that many species of aquatic insects have been reduced in numbers and in some cases entirely eliminated from areas investigated within the spray boundary. Some other species have greatly increased in numbers of individuals in spray areas compared with similar unsprayed areas and some of the factors accounting for the increases will be discussed below.

Spraying had eliminated all of the aquatic insects from this same location in 1954 as far as the sampling method showed (16). The relatively great distance of this location from similar habitats in other streams which did not receive spray and could act as sources of insects for re-introduction, is operating as an effective barrier to the re-population by many species of this section of the river. As an example of the degree of effectiveness of this barrier, the complete absence of Trichoptera from the collections made in the larger stream, North Branch of the Big Sevogle, and the great reduction of this group in collections made in the small tributary of this river, can be cited. The larval and pupal stages of members of this order are known to be extremely susceptible to the toxic effects of DDT spray (11, 12). This fact, together with the observation that the adults of this order seldom range much beyond the immediate area of stream from which they emerge, makes it improbable that they could traverse the 15 miles from streams outside the spray boundary to the location of the collecting cages. This conclusion assumes that the insects would traverse the intervening distance by following the course of the river.
and not by travelling by the direct route overland. If the latter happened, the distance from unsprayed streams would be about eight miles. This assumption is probably valid for most aquatic insects with the notable exception of the Simuliidae. Some adults could have been carried into the sprayed area by the action of winds and oviposited in these streams. The extent of this, however, had probably been insignificant.

A few Trichoptera individuals representing four species were collected from the small sprayed stream as compared with none from the large adjacent sprayed stream. Almost certainly this is an example of the survival of some individuals of this order and is not the result of introduction of these species from unsprayed streams. The factor of survival of some insects through the spraying period is an important consideration in the interpretation of the presence of many of the species found within the sprayed area and will be returned to presently.

The quantitative reduction in the Ephemeroptera recorded for the large sprayed stream when compared with the control stream is also an example of the inability of certain groups of insects to repopulate areas of stream after having been eliminated by selective killing of their larvae or nymphs.

In addition to the reductions in the numbers of individuals of certain groups of insects in sprayed streams compared with control streams, there has also been a considerable reduction in the
numbers of species represented in sprayed streams compared with control streams. Survival in large numbers has been confined in most cases to a few species of each order, especially in Ephemeroptera. Since there were no collections made in the sprayed area before the spraying occurred, it is impossible to know the composition of the aquatic insect fauna in these streams at that time. However, it can be stated that shortly following the time of spraying, some insects were found dead and these belonged to species which were not found subsequently in the same areas in 1955. Moreover, streams in the same vicinity, forming a part of the same drainage system, of similar characteristics show significant differences both in the number of species and in their proportional representation in the collections when compared with streams which had received spray. Therefore, it is probable that much of the repopulation noted in the sprayed streams has been caused by the survival of some species in some stage of their life cycle and with the subsequent persistence of their population after the initial selective killing of the larval or nymphal stages by DDT was completed.

Some characteristics of the organisms which may have contributed to their survival of the toxicant are included in the following:

1. The relative resistance of the toxic effects of DDT spray of the egg stages of many species of aquatic insects and, coupled with this, is
2. The time of oviposition in relation to the time at which the toxicant was applied in upstream parts of the river.
3. The particular habitat of the egg and nymphal or larval stages of each species. Other conditions besides these may also have prevented the lethal effects of the toxicant from being manifested.

The eggs of many species of aquatic insects in their normal habitat are known to be resistant to the toxic effects of DDT spray when this is added to the water (12); therefore, those individuals of the species which have DDT-resistant eggs, which had emerged and laid their eggs shortly before the application of the toxicant would insure that some members of those species would survive the effects of the spray. As an example of this, the mayfly *Iron pleuralis* (Banks) can be cited. This species comprised over 50 percent of the total number of mayflies collected from the cage-traps in the large sprayed stream and emerged from June 7 through July 29 with the maximum numbers on June 13. Although the time of emergence of this species in 1954 from this location is not known, members of this species are known to be early emerging (13) and were emerging on the first date of collecting from the control streams, June 7, 1955. Therefore, it is reasonable to assume that emergence took place at about the same time from this location in 1954. The map, Fig. 1, shows that parts of the North Branch of the Big Sevogle River above the locations of the cage-traps did not receive spray before June 16, 1954. As a result of the early emergence of this species, many individuals had probably laid their eggs before spraying was begun in this area. This
habit of adults of this group may also have been an important factor in their large survival as will be explained below. The early emergence of the adults of some other species has similarly been an important factor in their rapid recovery, e.g., Nemoura spp., and some species of Alloperla and Leuctra.

The habitat of the various stages in the life histories of many of the species is an important factor in their surviving the effects of the toxicant. DDT-in-oil solution becomes emulsified by the churning action of water in the riffle sections of streams and its toxicity is enhanced (17). Those insects which live on the upper exposed surfaces of stones in these riffles are probably the most exposed to the spray and therefore the most vulnerable. Examples of insects that live in these situations are, among the mayflies, several species of Baetis and Pseudocloeon (4, 14), and among the caddisflies many species of the families Rhyacophilidae, Hydropsychidae, Philopotamidae and Psychomyiidae (19). The mayfly Baetis vagans, (McD.) one of the most prevalent species of this genus collected in the control streams and absent in sprayed streams, not only lives as a nymph on the exposed surfaces of stones in riffles but the adult females lay their eggs on these stones by entering the water and applying the eggs directly to them (14, 18). In some families of caddisflies the adult females enter the water and lay their eggs directly on stones and other objects. This has been shown for Rhyacophilidae, Philopotamidae, Psychomyiidae, Hydropsychidae and Hypodroptilidae (19). Thus hatching
larvae or nymphs from eggs which had been laid prior to the time of spraying would have received the full effect of the toxicant and would have been killed. This would be particularly significant for Trichoptera species having two generations in the summer with little separation of their emergence seasons. Although it is not known if any adults of these families of caddisflies had emerged before spraying occurred in 1954, individuals of Rhyacophilidae and Hydropsychidae were taken from the control streams in mid-June 1955. In another unsprayed stream in the same area, Wildcat Brook, similarly sampled from May 21 through May 29, 1955, four individuals of Rhyacophilidae and two of Philopotamidae had emerged. Therefore, it is probable that some individuals had emerged from the sprayed streams and laid eggs before spray was applied in 1954.

Another factor important in determining the ability of some species of aquatic insects to survive the toxicant may have been protection afforded by particular niches in the riffle habitat. Protection would be given to insects which at some stage of their life cycle live in the interstices of sand and gravel in riffles. These insects, living in a micro-habitat with stagnated water among the stones, may have escaped much of the concentration of the toxicant as it flowed past in the fast water above them. The ability of some species to live under more deeply placed stones in riffles probably gave them some protection. For the three and possibly four species of Ephemerella found in the sprayed streams, the maximum emergence from the large stream was on July 12 and in the small stream there were two
maxima, one on July 11 and the other on July 25. These dates are nearly a month after the dates on which spraying had started in this area in 1954 as shown in Fig. 1. Introduction of members of this genus from unsprayed streams and a large build-up in their numbers of individuals would be unlikely in the first year following spraying, and it is probable that there was a considerable survival of nymphs following the spraying and the habit of living under more deeply placed stones in riffles has undoubtedly been a significant factor in this survival. The fact that no nymphs of this genus were taken in sampling immediately after spraying in 1954 (16) does not exclude their presence as deeply placed nymphs which would not be easily detected.

The females of some Iron species deposit their eggs a few at a time by flying over riffles and dropping the eggs which then sink and stick to pebbles on the bottom (18). This latter method probably gave better protection to the hatching nymphs since species of Iron make up more of the mayflies collected in the large stream which, as will be explained below, was more adversely affected by the spray than the small stream. The genera of Plecoptera which were taken in the sprayed streams also oviposit by flying over the stream and dropping their eggs (8).

Finally, the survival of some individuals of certain species has probably resulted from either their chance escape at the time the toxicant was in the streams or the differential resistance of
some individuals to the toxicant. The collection of 11 individuals of Trichoptera from the cages in the small sprayed stream can possibly be for either one or both of these reasons. However, this stream is much shorter in length than the adjacent sprayed stream, thus the total amount of spray per unit volume of water that entered the stream may have been less than that received by the large stream.

The length of time that the toxicant was in each stream would also be important in determining the degree to which each was affected. The large sprayed stream in the regions above the locations of the cage-traps received the toxicant on several dates from June 16 through June 24, 1954. This stream would have received DDT from spraying along its course on these dates and in addition from the spraying along its tributaries. The spray as it passed through the tributaries would affect the insect fauna of those streams and when it reached the main river would either increase the concentration of the spray in that river or lower it. The end effect, then, would be several doses of the toxicant passing through the river over an extended period of time. In this case the large river would receive more spray than the smaller tributaries and the insect fauna would be more seriously affected than in the small streams. The continued entry of toxicant into the large river over an extended period would probably have a more adverse effect on it than one dose in a smaller stream. The small sprayed stream that was studied had received spray directly on only one date, June 16. This differential effect has already been observed in the results of the cage-trap collections for the small and large sprayed streams.
The length of the nymphal stages is an important factor in the reduction of various groups of insects in streams which had received DDT spray in 1954. All of the species mentioned so far that belong to the Ephemeroptera and the Plecoptera have a life cycle of one year or less. There are several genera of Plecoptera, such as Acroneuria, Paragnetina and Phasganophora (8), which have a two-year life cycle. Only one individual of the genus Acroneuria was collected from the cages in the large sprayed stream in 1955 while all of these genera were represented in collections from the large control stream and relatively large numbers of Acroneuria individuals were taken from the small control stream. Following the spraying in 1954 some nymphs of Acroneuria were found killed in the region studied in the large sprayed stream in 1955 so that these nymphs were present in this river before the spraying occurred. In this case, therefore, it is quite probable that the one application of DDT had practically eliminated two generations of these species. The capture of one Acroneuria individual from a cage in the sprayed area means that there has been some survival of this genus.

Some of the species of insects that escaped elimination in 1954 because of one or more of the reasons mentioned above, have been able to increase their numbers of individuals in the sprayed streams. Three main reasons for these increases can be given. The reduction in the numbers of individuals of the Plecoptera, some species of which are predatory, and more especially the nearly total absence
of Trichoptera, some species of which are predatory, has resulted in
the large survival in the numbers of individuals of many species
which were not in evidence in the sampling done shortly after spraying
in 1954. It was also observed shortly after the spraying that there
was a marked increase in the amount of algae, diatoms and bacterial
on the surface of the stones in streams which had received DDT (16).
This is correlated with the fact that nymphs of many species of
Ephemeroptera and Plecoptera and larvae of Trichoptera which would
have fed on these algae and diatoms were either much reduced or elimi-
nated by the spray in 1954. The fact that many predatory insects
were eliminated and that there was abundant food meant that those
species which survived could take advantage of this situation in pro-
curing more food without serious predation.

The great increase in the numbers of black flies in the
large sprayed stream over those taken in the control streams is of
special interest in view of similar results from other studies of the
effect of DDT on Simuliidae populations. The emergence data from one
cage in the large affected stream show that a few males emerged there
on June 6 and June 10, 1955. However, the large emergence of males
and females began in both cages in this stream on July 11 and con-
tinued through the last day of collection on September 4, 1955. The
predominant species in these collections was *Simulium venustum* Say.
This species is known to have two generations each year, as determined
by Davies (5) from studies of this species in a stream in Algonquin
Park, Ontario. In his observations made in 1947 the first generation
began to emerge about June 6 and the second generation began on July 20. In July 1944 DDT spray was applied by air to a section of this stream and this effectively eliminated the second generation of this species in that year; however, in the following year, 1945, this species was again present in this stream but now the first date of emergence for males was July 28 and the last date was August 21. Thus the spray had eliminated the first generation of black flies in 1945. The first generation of any year for this species is, according to Davies (5), the result of oviposition of the second generation of the previous year, these eggs going into diapause until the time they hatch early the next spring. Black fly larvae and pupae were not found in sections of the large sprayed river examined in 1954 following the spraying (16). The spray largely eliminated larvae of the first generation and consequently there would be little or no indigenous second generation of black flies in this section of the river in 1954. The few black flies that were taken from the large sprayed stream in June 1955 may have been either the results of a few females that entered the area after the spraying in 1954 from unsprayed streams and oviposited in this river or the result of survival of a few individuals of the indigenous population. Black flies range widely as adults and their presence in numbers in this stream in 1955 is the result of oviposition of the few that emerged in June as the first generation in the same river and may also be the result of the introduction of black flies that had emerged in unsprayed streams as the first generation of 1955 and migrated into the sprayed area and ovi-
posed there. This latter possibility has probably been important in explaining the presence of black flies in sections of another sprayed river to be discussed below in connection with the sampling of the bottom fauna. The presence of large numbers of black flies in the year following spraying does not corroborate the findings of Hocking (10) who found few, if any, larvae in streams the year following DDT spraying. He correlated this with the probability that small amounts of DDT continued to enter the streams from surface drainage after spraying had occurred. The great increase in the numbers of black flies collected from mid-July through August from the large sprayed stream may have been the result of the favourable conditions of food and lack of predators mentioned above. For instance, Hydropsychid larvae are reported to prey heavily on the aquatic stages of Simuliidae so that the absence of this group would allow an increase in the numbers of black flies (Davies, 5).

The reduction in the total volume of insects collected and in the average size of the individuals in both sprayed streams compared with their respective controls has been noted above. The absence of larger insects, mainly the Plecoptera and Trichoptera, from sprayed streams has been the main reason for these reductions rather than smaller numbers of all insects. This effect is greater for the large than the smaller sprayed stream. This is a further indication that the large stream was more adversely affected than the small sprayed stream for the reasons that were stated above.
Although there are no data available as to the composition of the aquatic insect fauna before the spraying was begun in 1954, it is reasonable to assume that a representative fauna was present in these areas of the streams that were studied before the toxicant was applied. Kerswill and Elson (16) reported that stones in the North Branch Sevogle River, near the site of the collections made in 1955 from the same river, had dead larvae of caddisflies (Glossoma), net-veined midges (Blepharocera) and Chironomids on them. At the same time, a few individuals of the larger stonefly (Acroneuria) and mayfly nymphs, and alderfly larvae were found dead in this vicinity. Similar eliminations of aquatic insects from rapids of streams following DDT applications have been reported by several investigators (2, 6, 11, 12, 17). In all of these studies, however, small sections of streams were sprayed and in no instance were the headwaters or tributaries sprayed. Thus, Hoffman and Merkel (12) studied the effects of an aerial application of 1 pound per acre of DDT-in-oil spray to 0.9 mile of a river in Virginia. They reported a 90% reduction in the numbers of aquatic invertebrates three weeks after spraying, compared with samples taken two weeks before spraying. In samples taken one year later, a station in the middle of the 0.9 mile section showed only a 39 percent reduction in the numbers of insects as compared with pre-spray samples and a station at the lower end of the section a 60% increase at the same period over the pre-spray samples. They further reported that the lethal effects of the spray were observed for at least 4 miles downstream beyond the end of the spraying. This has been noted by other investigators, notably Arnason
(2) who reported the effects of spraying a relatively short section of a stream were definitely observed for a distance of 90 miles downstream.

Although the reductions in the numbers of aquatic insects were, according to their studies, in evidence shortly after spraying, Hoffmann and Merkel (12) reported that one year later all the streams studied had recovered from these reductions and in some cases had even more insects in them than before the spray had been applied. Also, the species that were most abundant one year later were those that had been severely reduced the year before. Some of the species were affected by the spray, as follows: Ephemeroptera - Baetis spp., Heptagenia sp., Iron sp., Isonychia sp., were eliminated, Pseudocloeon sp. greatly reduced, and several species of Stenonema possibly eliminated; Plecoptera - Acroneuria sp., greatly reduced and Phasganophora sp. reduced; Trichoptera - Chematopsyche spp. eliminated, Hydropsyche spp. and two species of Chimarra were greatly reduced. In only one stream they reported that some of the forms with a longer life cycle had been replaced by others with a shorter life cycle. Those with the longer life cycle had been almost eliminated in the previous year by the spray.

The results of the present study do not corroborate several of the findings of these authors. Many species have definitely not recovered one year following the spraying and some of the species which had been most affected by the spray in 1954 were definitely not
abundant in 1955. In all of these other studies, only small sections of stream were involved in the spray treatment and repopulation could occur by migration of either adult or immature stages of insects from unaffected parts of the stream above the sprayed section and perhaps from below the section, although much of this was also affected by the spray. Thus, introduction and repopulation of the affected parts of the stream was quite rapid even in cases of insects which do not range widely, e.g. caddisflies. However, the great length of the large river considered in the present investigation and the large area sprayed in 1954, including the headwaters and tributaries, has prevented repopulation by many species of insects in this particular section of river. This has resulted because sections of rivers which might have acted as sources of supply of individuals of these species were too far removed. The notable exception is in the black flies.

Bottom Inhabiting Aquatic Invertebrates

Methods

This method of investigation was not as extensively utilized as that used in the collections of emerging insects. The advantages underlining this method were two-fold:

1. Observations could be made on sections of another river within the sprayed area which could not have been sampled by the cage-trap method.
2. The presence of immature stages of aquatic insects and other invertebrates which did not emerge could be determined.

Samples of the bottom inhabiting invertebrates were taken at intervals during the summer of 1955. The main series of these samples was taken at locations designated I, II and III along the North West Miramichi River as shown in Fig. 1, and as follows: a point about 4 miles above Fraser Company's Base Camp, at the Base, Camp and at the Elbow Pool. In addition, one series of samples was taken near the locations of the cage-traps in each of the four streams mentioned earlier.

The samples were taken with a Surber bottom sampler as described by Hess (9) which encompassed one square foot of the stream bottom. The sampler was placed in the stream bottom to be sampled, in water from 5 to 7 inches deep and in moderate to fast riffles. The stones in the square foot area were picked up and rinsed so that the attached organisms were dislodged and swept by the current into the distended collecting sock which trailed downstream. The collecting by this method was carried out over a period of five minutes for each sample. In general, two samples were taken at each station in each series.

The organisms which had collected in the sock were picked from it and placed in vials in 95% alcohol. The identification was done at the field laboratory using a binocular microscope and the individuals of each species collected were counted and the volume of each collection was determined by the displacement of liquid in a 10 ml. graduated cylinder.
Results

The results of this study agree with many of the findings from collections of emerging insects trapped from sprayed streams. Only one caddisfly larva was taken in 14 samples taken from June to September on the North West Miramichi River, and this was taken at the Fraser Company's Base Camp. One other caddisfly larva was collected in two samples taken in September in the North Branch of the Big Sevogle River near the location of the cage-traps. This is compared with an average of 54 caddisfly larvae per square foot in two samples from each of the Trout Brook and Millstream Brook, both of which were unsprayed streams.

In two samples taken in mid-September on the North West Miramichi River at the Base Camp, there were 112.5 Simuliidae larvae per square foot while in samples from the two unsprayed streams mentioned above, there were only 1.5 black fly larvae per square foot. In samples taken at the same location in the sprayed river in late June there were no black flies collected; however, one sample in early July at the Elbow Pool several miles downstream from the Base Camp but still within the sprayed area, had 16 black flies in it. An average of 44 black fly larvae per square foot was found in samples taken at the Base Camp, II, and four miles above it, I, on July 20.

Within the limits of the few samples that were taken, the average number of Ephemeroptera nymphs per square foot in samples from the North West Miramichi River within the spray boundary at the
three stations were 6.0, 0.3 and 14.5 in June, July and September, respectively. However, one genus, *Ephemerella*, comprised nearly all of the nymphs at these stations.

The small numbers of Chironomidae collected in samples by this method was because of their small size. Consequently, many of them passed through the mesh of the collecting sock and, being less conspicuous than the other forms, were frequently overlooked and thus not counted. Examination of some stones in these areas where collections were made showed that this group of organisms was abundant at all the stations and this is in agreement with the results from cage-trap samplings in other treated streams.

Fresh water Mollusca of the family Physidae were in some of the collections made at the Base Camp and a few miles above it on the North West Miramichi River. Only one individual of this group was taken in samples in June and July at these stations, but in two samples in September taken at the Base Camp the average per square foot was 12.5 individuals. A few Mollusca of the family Ancylidae were taken in samples from an unsprayed stream, Millstream Brook, but no Physidae were taken there.

An average of 3 nymphs of *Gomphidae* (Odonata) were taken from two samples in the North Branch of the Big Sevogle River in mid-September.
There were no Plecoptera nymphs taken in samples from either of the sprayed rivers in June and July. However, in September an average of 3.4 individuals per square foot was taken in a total of four samples in these rivers at the Base Camp and in the North Branch of the Big Sevogle River near the cage-traps. In samples from both of the unsprayed streams the average value for this group was 4.0. These seasonal differences are in agreement with the seasons of emergence of these insects as illustrated by the cage-trap collections.

The observations are only to be considered insofar as they show qualitative similarity with the more extensive collections made by the cage-trap method and in this respect they do show a similarity.

A more complete investigation of sprayed and unsprayed streams from the standpoint of their invertebrate fauna was carried out on streams in the Upsalquitch and Carlo watersheds in northern New Brunswick by crews from the Department of Agriculture of Canada and the results, made available through the courtesy of Dr. F. E. Webb, are discussed here. The same method of collecting was used in this case as is described above.

During the period from June to August, 1955, collections of aquatic invertebrates were made on the Upsalquitch and Carlo watersheds in northern New Brunswick by crews of the Fredericton Laboratory, Division of Forest Biology, Department of Agriculture of Canada. These samples were taken using the Surber apparatus for five minutes and at three different times, July 11-14, June 25 - July 1, and July 26 -
August 1. Spray applications to some of the streams that were examined had occurred during the period from June 15 to June 24 and the three sampling periods were designated pre-spray, early post-spray and late post-spray respectively, depending on their relation to this spray period. Six different streams were used in this investigation. One of these had received spray in 1952, 1953, 1954 and 1955; two had received spray in 1952 and 1953; two more in 1953 and 1955; the remaining stream had never been sprayed and was used as the control. In each of the three sampling periods four square-foot samples were taken in each stream except one and, in this case, two samples were taken in each of the periods.

The results in most respects corroborate the findings reported from collections on the Miramichi watershed. In a total of 54 samples taken during the three collecting periods from five sprayed streams, no individuals of Trichoptera were taken. The sampling from the one unsprayed stream had no Trichoptera in the pre-spray sampling but in the early post-spray sampling there were an average of 1.5 individuals per square foot and the late post-spray sampling showed 1.2 per square foot. There was also a reduction in the numbers of Ephemeroptera in collections from the sprayed streams compared with the unsprayed stream. Reductions in the numbers of this group were noted in the samplings in sprayed streams at the three periods but the greatest reduction was noted in the early post-spray sampling. In these collections the largest value for this group in a sprayed stream was 6.0,
the average of two samples. The range of values for the other four sprayed streams was from 2.5 to 4.5 individuals per square foot. The unsprayed stream had an average of 53.5 mayflies per square foot in the same early post-spray sampling. Another significant finding was the increase in the numbers of Diptera (Simuliidae ?) in the last post-spray sampling in a stream that had been sprayed in 1952 and 1953. The average number of Diptera in this stream was 25.0 per square foot (two samples). In another similarly treated stream, the number of this group per square foot was 11.8 (four samples). The control stream had an average of 10.3 Diptera per square foot in collections made from it during the same period. In two rivers that had been sprayed in 1953 and 1955 there were about 2.7 Diptera per square foot and in one river that had been sprayed in each of the four years from 1952 through 1955 there were 1.5 Diptera per square foot. The same errors are inherent in these counts, especially for the Chironomidae, as was noted above in collections made by this method from the Miramichi system.

The numbers of individuals per square foot of other groups of invertebrates found in these collections was small in all cases and varied considerably so that comparisons were not attempted.

The average volumes in mls. of these collections also show a significant reduction in the volume of insects in streams which had been sprayed, compared with the unsprayed stream. This reduction was not noted in the pre-spraying sampling but in the early post-spray
sampling the average volume for all the collections from all five sprayed streams was 2.7 ml, while the collections in the control stream during the same period had a volume of 11.3 ml. In the late post-spray samples there was a slight decrease in the volume of invertebrates per square foot in sprayed streams compared with an unsprayed stream.

The most important single finding from the collections made in 1955 is that there is a reduction in the total numbers of insects and their total volume in all sprayed streams, compared with an unsprayed stream. This reduction was noted in a stream that had been sprayed either in four consecutive years, 1952-1955, or in two consecutive years, 1952 and 1953, or in two alternate years, 1953 and 1955.

Some orders of insects are more adversely affected by the insecticide than are others. Ephemeroptera seem to be unable to build up their numbers even two years following the application of the spray, although members of this order were found in all the streams which had been sprayed. Trichoptera were not taken in any of the collections from streams that had been sprayed and are probably the most affected by the spray treatment.
Discussion

Most of the results obtained by the collection of adult insects from the North Branch Sevogle River and one of its tributaries within the sprayed area are corroborated by these further observations. The nearly complete absence of Trichoptera in these situations was therefore expected.

The large numbers of Simuliidae in the samples taken on the North West Miramichi River are significant because they show that a similar situation with regard to this group exists in this river as existed on the North Branch Sevogle River. The absence of this group from samples taken shortly after the spraying in 1954 was reported by Kerswill and Elson (16). Their continued absence from the samples of parts of this same river in late June of 1955 is an indication that they had not survived there or had not been reintroduced by that time. As it was pointed out above, the adult males that emerged from the North Branch Sevogle River in early June of 1955 were probably the results either of oviposition by introduced females after the spraying in 1954 or by a few survivors of the indigenous population. However, the sections of the North West Miramichi River that were sampled are about 15 miles inside the spray boundary at its closest approach to the unsprayed area so that introduction of black flies to this section may not have occurred in 1954 following the spraying. Assuming that this introduction was caused by black flies that had emerged from streams outside the spray area and had migrated into this section of the Miramichi River, then this second generation would
not emerge until mid-July. The large numbers of larvae present in September may also be the result of late introduction into this part of the river because of the great distance of this section of the river from unsprayed streams.

The large numbers of individuals of *Ephemerella* spp. collected from the sprayed areas corresponds with the large numbers of this group taken in the collections of adults from the sprayed rivers. The absence of this group in the collections made in mid-July in the North West Miramichi River is probably the result of emergence having taken place before the sampling. The data from the emergence cages in the two sprayed streams show emergence of this group occurred in July.

The presence of two groups of organisms, Odonata and Mollusca, in collections made from within the sprayed area is of considerable interest because, according to several authors, both these groups show little or no effect from DDT spray in small concentrations (3, 12). Odonata are apparently able to escape the lethal effects because of the burrowing habit as it occurs in the gomphines. The only group of dragon flies that was collected from the riffle sections that were sampled was the Gomphidae, some species of which are characteristically found in flowing water.
IV. UTILIZATION OF AQUATIC INVERTEBRATES BY YOUNG SALMON

Methods

Collection of young salmon

The Atlantic salmon parr and fry, the contents of whose stomachs were studied in the determination of the utilization of the bottom fauna, were taken from six locations along the North West Miramichi River. These locations, marked A, B, C, D, E, and F, are shown on the map (Fig. 1), and the dates of the collections and the size of the fish are given in Table IV. One of these stations, C, was within a mile and above the location of one of the series of bottom samplings, while station B was about two miles below station I from which another series of bottom samples were taken.

The fish had been captured by electro-fishing using a U.S. Dineen generator rated at approximately 400 volts and a little less than 1 ampere under load. These fish had been taken in connection with population studies being carried out by the Fisheries Research Board of Canada. Ten parr and ten fry, representative of the sample taken from each of the six locations, were preserved in 40% formalin and made available for stomach analysis. There were 120 salmon examined from the collections made in August and September of 1955. The results of these analyses were compared with those of fish that had been taken at four of the same locations in 1953 prior to the application of DDT. The fish used in the control series had been captured in August by the same method. Their sizes and dates of collection are given in Table IV.
TABLE IV

Location and date of collection and size of Salmon parr and fry captured in 1953 and 1955 from the North West Miramichi River for analysis of their stomach contents.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>DATE OF COLLECTION</th>
<th>NO. OF FISH EXAMINED</th>
<th>AVE. LENGTH CMS.</th>
<th>RANGE OF LENGTH CMS.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little Bald Mountain</td>
<td>Aug. 20, 1953</td>
<td>10 parr</td>
<td>9.2</td>
<td>7.0 - 10.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 fry</td>
<td>4.3</td>
<td>4.0 - 4.8</td>
</tr>
<tr>
<td></td>
<td>Aug. 18, 1955</td>
<td>10 parr</td>
<td>12.1</td>
<td>11.2 - 13.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 fry</td>
<td>4.9</td>
<td>4.0 - 5.3</td>
</tr>
<tr>
<td>Crawford Station E</td>
<td>1953</td>
<td>None Examined</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aug. 16, 1955</td>
<td>10 parr</td>
<td>14.3</td>
<td>12.3 - 16.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 fry</td>
<td>4.9</td>
<td>4.0 - 5.6</td>
</tr>
<tr>
<td>Camp Forty-two Station C</td>
<td>Aug. 22, 1953</td>
<td>5 parr</td>
<td>11.9</td>
<td>11.2 - 14.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 fry</td>
<td>4.4</td>
<td>4.0 - 4.7</td>
</tr>
<tr>
<td></td>
<td>Aug. 17, 1955</td>
<td>10 parr</td>
<td>13.8</td>
<td>11.8 - 14.9</td>
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<tr>
<td></td>
<td></td>
<td>10 fry</td>
<td>4.9</td>
<td>4.4 - 5.7</td>
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<tr>
<td>At Little River Station D</td>
<td>Aug. 27, 1953</td>
<td>5 parr</td>
<td>9.6</td>
<td>8.1 - 12.1</td>
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<tr>
<td></td>
<td></td>
<td>5 fry</td>
<td>4.5</td>
<td>4.1 - 4.7</td>
</tr>
<tr>
<td></td>
<td>Aug. 12, 1955</td>
<td>10 parr</td>
<td>10.0</td>
<td>8.2 - 14.3</td>
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<tr>
<td></td>
<td></td>
<td>10 fry</td>
<td>4.6</td>
<td>4.3 - 4.8</td>
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<tr>
<td>Wayerton Bridge Station E</td>
<td>1953</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Sept. 16, 1955</td>
<td>10 parr</td>
<td>11.0</td>
<td>8.1 - 16.8</td>
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<tr>
<td></td>
<td></td>
<td>10 fry</td>
<td>4.9</td>
<td>4.5 - 5.5</td>
</tr>
<tr>
<td>LOCATION</td>
<td>DATE OF COLLECTION</td>
<td>NO. OF FISH EXAMINED</td>
<td>AVE. LENGTH CMS.</td>
<td>RANGE OF LENGTH CMS.</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------</td>
<td>----------------------</td>
<td>------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>At Trout Brook Station F.</td>
<td>Aug. 15, 1953</td>
<td>5 parr</td>
<td>9.5</td>
<td>7.8 - 12.2</td>
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<td></td>
<td></td>
<td>5 fry</td>
<td>4.3</td>
<td>4.0 - 4.5</td>
</tr>
<tr>
<td></td>
<td>Aug. 10, 1955</td>
<td>10 parr</td>
<td>9.6</td>
<td>7.2 - 12.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 fry</td>
<td>4.1</td>
<td>3.6 - 4.7</td>
</tr>
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</table>
Each area from which a sample of fish was taken had been disturbed several times over a four-to six-hour period before the collection was made. This may have resulted in somewhat atypical feeding; however, all of the samples were taken by the same method so that the results of the analyses are comparable and significant differences in the results would not be caused by these disturbances. The area of stream from which each of the samples of fish was taken was from 630 to 1,500 square yards.

The length of each fish was measured from the tip of the snout to the fork of the tail. The stomach was removed by slitting the ventral body wall, severing the alimentary tract directly behind the pyloric valve and again well up on the oesophagus. The mouth was opened in each fish to discover any organisms that might have been lodged there.

The contents of each stomach were examined under a binocular microscope in the laboratory at the University of Toronto. The identification was carried as far as the condition of preservation of the contents would allow, and the number of organisms and the total volume was recorded for the contents of each stomach, and the proportion of the volume of each group of food organisms for each stomach was estimated.
Results

The results of the analyses of the stomach contents of salmon parr and fry captured on the North West Miramichi River show that there are considerable differences in the percentages which various organisms contribute to the total volume of the food eaten by fish taken in 1953, the year before spraying, and by those taken in 1955, the year after spraying, as outlined below.

The composition of the food of 10 parr and 10 fry taken from each of six linearly placed stations on the North West Miramichi River in the late summer of 1955 is given in Fig. 3 and appendix I for parr and Fig. 4 and appendix 2 for fry. For comparison, the contents of the stomachs of a few parr and fry that had been taken in the late summer of 1953 from four of these six stations were analysed. These results are also given in Figs. 3 and 4 and Appendices 1 and 2. The results for each station in each year are placed together so that comparisons can be readily made. There were only slight variations in the quantities of different groups of food organisms eaten by individual parr and fry from any one station so that the average percentages by volume of different groups of food organisms eaten by each size class were calculated for each station. The locations of these stations and their relation to the spray boundary are shown on the map, Fig. 1. The dates of collection of the fish, the number taken in the sampling and their size are given in Table IV.

(i) Parr

A smaller volume of food was found in the stomachs of parr from stations C and D of the 1953 series compared with that found
in fish from other stations of the 1953 and 1955 series (Appendix I). Parr from station A of both series had eaten the next smallest and those from station B in 1955 the largest volume of all fish. Fish from the other stations in both series had similar amounts of food in their stomachs.

The histogram (Fig. 1) and the table (Appendix I) show that some groups of food organisms were either entirely absent or present in greatly reduced amounts from parr taken within the spray boundary when compared with parr taken from the same stations before the spraying. An example of this is in the absence of Trichoptera in the stomachs of parr from the upper three stations and the small amount of these organisms at the fourth and lowest station within the spray boundary. On the other hand, at two stations, E and F, which were outside the spray boundary, Trichoptera formed a substantial part of the volume of food eaten. In the samples of parr taken in 1953 this group was an important component of the food at all of these same stations.

The Ephemeroptera are another group of organisms that comprised a reduced proportion of the volume of food in the stomachs of parr from locations in the sprayed area as compared with those of the control series. This group formed over 50 per cent of the volume of food in parr from station F in the 1953 control series, and this was the result of heavy feeding on one species that was emerging at that time. Of the parr taken within the spray boundary in 1955, those
Percentage volume of five groups of food organisms in stomachs of a series of salmon parr taken from six locations on the North West Miramichi River in the late summer of 1955. The data from parr taken from four of the same locations in August 1953 are compared.
from stations B and C showed a smaller reduction in the percentage volume of mayflies taken as compared with parr from stations A and D. But one type only, *Ephemerella* spp. of the *invaria* group, was extensively utilized. In contrast, mayflies eaten by parr taken in 1955 from outside the spray boundary at stations E and F were nearly equally distributed among six genera and the same condition existed at all the stations in the pre-spray control series.

There was also a reduction in the percentage volume of Plecoptera eaten by parr in the series taken in 1955 from within the spray boundary as compared with those eaten by the control series. At stations A, B and D within the sprayed area, there were no Plecoptera eaten, while at station C they formed less than 6.05 percent of the food. At stations E and F outside the boundary, Plecoptera were taken in small quantities, 3.7 percent at E, and 0.3 percent at F. This contrasts with the control series of parr stomachs which were analysed. In these fish Plecoptera made up from 8.2 to 34.7 percent of the food. The small amount of stoneflies taken by parr at the F station in the 1953 series probably was correlated with the increased feeding on mayflies that were emerging at the time.

The utilization of molluscs by parr at all of the stations within the spray boundary is especially marked. At the station farthest upstream, they formed over 90 percent by volume of the food eaten; at station B, 50 percent; and at C, over 75 percent. Of the two stations outside of the spray boundary molluscs were not
eaten by parr from station E and, at station F they formed about 1 percent of the food. There were no molluscs found in the stomachs of the control series of parr taken in 1953 from stations A, C, D and F.

Simuliidae were found in the stomachs of parr taken from the four locations within the spray boundary. They formed a consistent but small volume of the food at these stations, averaging about 2.6 percent. There was no gradation in a downstream direction in the amount of black flies eaten at these stations. At the two stations outside the boundary, black flies were not eaten at E and formed less than 0.05 percent of the food at F. In the control series of parr, black flies were taken in small quantity at station A, farthest upstream, but were not taken at the other stations in this series.

These results show that there was a gradation in a downstream direction in the volume of different organisms eaten. The generally decreasing percentage of molluscs eaten by parr from the uppermost station, A, to the lowest station, F, and the generally corresponding increasing percentage of Ephemeroptera and Plecoptera eaten is significant.

Chironomidae and other Diptera formed part of the food of parr at all stations of both the 1953 and 1955 series. The largest volume of Chironomidae taken by fish in the 1955 series was at station C where they formed about 5 percent of the food. At all the other stations in this series they formed less than 1 percent of the food.
Parr of the control series from station A had eaten about 8 percent by volume of Chironomidae but these fish were about half a centimeter shorter, on the average, than parr from the other stations in the control series which may explain this difference. Parr from the other stations in this series had eaten much less of Chironomidae than those taken at station A. Other Diptera formed less than 7 percent of the food at all the stations, both in the 1953 and 1955 series, and showed no gradation in the volumes eaten at various stations.

Some other groups of organisms formed a high percentage of the food at some of the stations and were entirely absent at others. Thus, Oligochaeta formed 37 percent and 51 percent of the food by volume at stations D and E, respectively, in the 1955 series. At station F this group formed about 4 percent of the food by volume, while at the other stations, it was absent. In the control series of parr, Oligochaetes were absent from the food at all stations but one, F, and here they formed less than 0.5 percent of the food. The volume of Cyprinidae eaten by parr was extremely variable. At stations where they were eaten they formed a large part of the food, ranging from 19 to 45 percent by volume. This group was eaten by parr only at station A in the control series; however, the smaller average size of the parr in this series compared with those from 1955 may have been an important factor in fish not being eaten at stations other than A in the control series. The Odonata were another group of food organisms that represented a varying amount in the stomachs. They were taken by parr at all stations except A in the 1955 series.
largest volume of them was eaten at station F where they formed 14 percent of the food. Parr from stations B, C, D and E had eaten amounts of this group ranging from 0.4 to 2.4 percent by volume. In parr taken in the control series of 1953, Odonata were eaten at only one station, F, and here they formed about 22 percent by volume of the food.

Various other organisms such as larvae and adults of Coleoptera and Hymenoptera adults were sometimes eaten by parr from nearly all the stations, both in the 1953 and 1955 series, but these groups never formed more than 1 percent of the food eaten.

ii. Fry.

The percentages which several groups of organisms contribute to the total volume of stomach contents are shown by the histogram, Fig. 4, and similar data for all food organisms are given in Appendix 2. The average volume of food eaten by fry of both series examined from all stations varied from 0.01 ml. to 0.04 ml. This variation is much less than that noted for parr although both were captured from the same locations in the North West Miramichi River and at the same time.

The analyses of the stomach contents of fry captured in 1955 show that Trichoptera were absent in individuals from the three upper stations in the sprayed area, while at the fourth station, D, also inside the spray boundary, they formed only 0.5 percent by volume of the food. At station E outside the boundary they comprised
FIGURE 4.

Percentage volume of five groups of food organisms in stomachs of a series of salmon fry taken from six locations on the North West Miramichi River in the late summer of 1955. The data from fry taken from four of the same locations in August 1953 are compared.
- 55 -

MOLLUSCA
PLECOPTERA
EPHEMEROPTERA
TRICHOPTERA
DIPTERA

% OF TOTAL VOLUME

OF TOTAL VOLUME

100 1953 1955
90
80
70
60
50
40
30
20
10

STATIONS

A  B  C  D  E  F 1953/1955

1953 1955

1953 1955

1953 1955
an increased part of the food, while at the station farthest down-
stream they formed about 39 percent of the food. In fry taken in
the control series of 1953 from all stations except the station
nearest the source, A, this group formed about 25 percent of the
food eaten and in fry from this upstream station they formed nearly
one-half of the total food eaten.

Ephemeroptera are an important source of food for fry
of this size. In the series taken in 1955, fish from the station
farthest upstream ate less of mayflies than did the fish from the
lower stations in this series. Fry from the other three stations
within the spray boundary had about 50 percent by volume of mayflies
in their stomachs. Station E outside the boundary had over 50 per-
cent by volume of this group in their stomachs, while the farthest
downstream station, F, had about 40 percent of this group in their
stomachs. In the control series of fry, mayflies did not form such
a large proportion of the bulk of food at stations C and D as in
the 1955 series, while at station A the proportion was greater than
for fry from that station taken in 1955. The large volume of this
group in the stomachs of fry from station F farthest downstream in
the 1953 series, was the result of heavy feeding on emerging subimagos
of one species.

Chironomidae, in their immature stages, were found
to be somewhat less important in the food of fry of this age in the
1953 series than the immature stages of both Ephemeroptera and
Plecoptera. However, in the series taken in 1955, Chironomidae formed over one-half the food eaten by fry at station A farthest upstream, while at stations C and D in the sprayed area they formed an average of about 23 percent of the food. This group averaged about 17 percent of the food of fry captured in 1953 from these latter two stations. At station B, fry of the 1955 series had only 7 percent of this group in their stomachs. At station E outside the boundary there were no Chironomidae found in the stomachs; however, collections in 1955 were made here about a month later than at the other stations so that comparisons are not as valid as those made from the other collections.

Large volumes of larvae of Simuliidae were eaten by fry of the 1955 series from stations B and C. Both these stations are within the spray area. At B, black flies formed 32 percent of the food, while at C they formed 19 percent. In contrast to this stations A and D within the area had fry with about 2 percent of black flies in the food, while fry from stations E and F outside the boundary had no black flies in their stomachs. This group was not eaten by fry taken in 1953 except at station A where they were less than 1 percent by volume of the food.

Mollusca were absent from the food of fry at all except station C of the series taken in 1955 and in this sample they formed 1 percent of the food. They were entirely absent from the stomachs of the control series.
The volume of Plecoptera eaten by fry at four of the stations in the 1955 series was about 1 percent of the total and at two stations, D and F, none was eaten. In the control series of fry, stonefly nymphs were eaten at stations C and F. At C they formed 14 percent and at F, 3 percent of the food. Stoneflies were not eaten by fry from station A or D.

The remaining groups of organisms in the food of fry taken both in 1953 and 1955 are quite variable in the proportions in which they were eaten. Diptera, other than the two families mentioned above, formed between 0.3 and 23.8 of the food in the 1955 series without a pronounced gradation in these figures among the stations. On the average, however, a greater volume of these insects were eaten by fry from the two stations outside the spray boundary than from those within it. Oligochaeta, Odonata and Coleoptera were groups which varied greatly in the proportions eaten from one station to the other and comparisons in these cases were not attempted.

Discussion

The effects of DDT spray on the invertebrate fauna of streams which were studied in 1955 is reflected in the percentage by volume of certain groups that were taken as food by salmon parr and fry at locations within the sprayed area in 1955. Those species which were shown to be reduced in numbers in sections of the sprayed streams were either totally absent or formed only a small part of the food of fish from sprayed streams.
As an example of this, the complete absence of Trichoptera in the food of both parr and fry from three stations in the sprayed area and their small representation in fish from the fourth and farthest downstream location in the sprayed section can be correlated with the complete absence of caddisflies in many places and their negligible numbers in others in sprayed streams. In sampling for insects, both for bottom inhabiting stages and emerging stages in sprayed streams of the Miramichi system, only 13 caddisfly individuals of all species were taken from June to September. Furthermore, this is a general condition found in other streams that had been sprayed with DDT since no Trichoptera were found in sampling for bottom fauna in treated streams in the Upsalquitch and Carlo watersheds. This represents a highly significant reduction in this group when compared with unsprayed streams.

The reduction in the volume of Ephemeroptera eaten by parr can be related to the reduction of this group that was noted in the collections of emerging insects from the North Branch of the Big Sevogle River which was similar in many respects to, but somewhat smaller in size than, the North West Miramichi River. This relationship was not, however, observed for fry taken in the sprayed area. In both groups of fish, however, there was a reduction in the numbers of species of mayflies that were eaten compared with the numbers present in the food of fish taken outside the spray boundary in 1955 and of those taken in the 1953 series. This reduction was also noted in the collections of emerging mayflies made from sprayed streams.
A reduction in the numbers of larger Plecoptera was noted in collections from sprayed streams by cage-traps and this reduction is reflected in the percentages of stoneflies in the food of parr. Although large numbers of small stoneflies were taken as adults from the sprayed streams early in the season, the nymphs of these species would be recently hatched small individuals at the time of the year that collections of fish were made and so would not be eaten to any large extent. In the series of parr taken in 1953 there were several large stoneflies found in stomachs at some stations. These belonged to the genera Pteronarcys, and Acroneuria which have life-cycles of more than one year (8).

The nearly complete absence of some species of food organisms in sprayed areas of this river has been compensated for by the greatly increased feeding of the parr on Mollusca, principally of the family Physidae. The relatively large size of these snails in comparison with the size of the fry has probably been the main reason for their not being eaten by them. In the samples of the bottom inhabiting fauna reported above, there were large numbers of this group taken near stations B and C in the North West Miramichi River and the feeding on them by parr can be ascribed to the abundance of snails in this section of the river.

Another group of organisms that had increased greatly in the sprayed streams as was shown by the collections of both adults and immature stages, was the Simuliidae. There has been an increased feeding on this group by both parr and fry at locations within the
spray boundary compared with the feeding on this group by parr and fry of the control series. Furthermore, at stations outside the spray boundary the fish taken in 1955 had not eaten black flies except for a few taken at station F, the station farthest downstream and outside the boundary.

Although stations E and F were outside the spray boundary and did not receive any DDT spray directly, it is almost certain that both these sections of the river were affected to some degree by the toxicant that had entered from within the boundary and was carried downstream by the current. There are no data available to show the extent of this effect on this river. Samples of the bottom inhabiting fauna were taken shortly after the spraying in 1954 on the Dungarvon River, a tributary of the South West Miramichi River, below the limit of spraying. These showed that depletion had occurred in the numbers of individuals of various species and the numbers of kinds comprising the population, as compared with a stream of similar size lying entirely outside the spray area (Kerswill, per. comm.). Moreover, Aranson (2) showed that the effect of DDT spraying was evidenced 90 miles downstream from the point of spraying. Since both stations mentioned above are only a few miles beyond the spray boundary, the invertebrate fauna of these stations had probably been affected by the spray.

The average composition of the food of all parr from all stations A to F of the 1953 series shows that Trichoptera, Ephemeroptera and Plecoptera formed about 35, 29 and 20 percent, respectively, of the volume of food. The remaining 15 percent of the
food was made up of Diptera, Odonata, Coleoptera and fish. But, the small amount of food found in the stomachs of parr from stations C and D in the 1953 series as noted earlier has probably caused greater fluctuations in the percentage of each component group of the food, thus giving less representative results, than if larger numbers of organisms had been found in the stomachs.

The results of other investigations on the food of salmon parr and fry are in agreement with the results for the control series of fish that were studied in this investigation. As the result of studies of the food of salmon taken from Goldmine Brook, N.S., Elson (7) reported that the principal food items of parr are aquatic stages of Plecoptera, Ephemeroptera, and Trichoptera. Each of these groups accounted for up to 25 percent of the food in June, July and August. Furthermore, Chironomidae and Simuliidae in their aquatic stages, formed up to 10 percent of the food of parr through the summer. Trichoptera form a more important source of food in most cases in the fish taken in 1953 on the Miramichi than for those reported on by Elson, while Simuliidae and Chironomidae are a much less important source of food for these fish.

White (21), from the studies of the food of salmon fry in several rivers in N.S. and N.B., reported that Chironomidae in their immature stages comprise the most important food for newly emerged fry but that during the mid-summer growing period Ephemeroptera become an important source of food for these fry and that Trichoptera
also become important toward the end of the summer growing season.
The contents of the stomachs from the control series agree with these findings. Comparing these results with those obtained for fry that had been captured in 1955 at about the same time of year as the 1953 series, it is apparent that Chironomidae continue to form a major proportion of the volume of the food of fry of the 1955 series at some locations within the spray boundary. At two of these latter stations, B and C, where the analyses showed that this group of food organisms was less important than at the other stations within the boundary, there has been a significant increase in the volume of Simuliidae eaten. This was expected since bottom samples in parts of the river near these stations showed that great numbers of black fly larvae were present. White (21) and Allen (1) reported that black flies are taken in small quantities, while Elson (7) reported finding no black flies in the stomachs of fry which he examined.

The lack of sufficient quantities of Trichoptera at the stations within the spray boundary has resulted in the fry feeding more heavily on Chironomidae, Ephemeroptera and, in some cases, Simuliidae. Chironomidae continued to form a large proportion of the bulk of food of fry at three of the stations in the 1955 series, A, C and D, after the time of year when fry would normally turn to Trichoptera and Ephemeroptera for the bulk of their food. Station B, which showed a great increase in the volume of black flies eaten by fry, also showed a decrease in the volume of Chironomidae eaten.
These differences in the composition of the food of fry in the sprayed area compared with that of those from the same locations prior to spraying have been the result of the reduction in the numbers of some species and the elimination of other species of food organisms in the sprayed streams. Large numbers of some forms such as Simuliidae and Ephemerella spp., that were present in sprayed streams have been taken as food by both parr and fry at some stations.

There are definite indications that the differences in the food of fish of the 1955 series compared with fish of the 1953 series at the same locations become less at successive downstream stations. The food of parr and fry taken from station F in 1955 does not differ as much with the food taken by the same size class of fish in 1953 from this same station as do stations farther upstream from it. By the same criterion, the station farthest upstream, A, shows the greatest differences in the composition of food eaten between these two years.

The other stations between these two extremes show a general gradation in a downstream direction of this effect. Thus, if station F has been affected by the spray, and this is quite probable as was explained above, it would quickly become repopulated because of the migration of insects from unaffected streams in the area. However, it is probable that this station being about 13 miles outside the spray boundary, was less affected by the toxicant originally, than those stations within the boundary. Station E was about
9 miles downstream from the boundary and fish taken from it in 1955 showed a decrease in the volume of Trichoptera taken as food as compared with those from station F; however, the fish were taken at the former station about a month later than at the latter when the emergence of many individuals of this order had probably depleted their numbers. Moreover, the great bulk of terrestrial Oligochaeta taken especially by parr from station E may have accounted for the lesser volume of Trichoptera taken. It cannot be concluded, therefore, that these differences were due to the adverse affects of DDT on the invertebrate fauna at this station.

Station D, while inside the spray boundary, is only about a mile from a stream that was not involved in the spray treatment and this relatively short distance may have allowed for the introduction of a few species that had been adversely affected by the spray. It is also possible that this section had a greater survival of insects after the spraying. The presence of Trichoptera in the food of both parr and fry could be interpreted as an indication that either one or the other, or both, was the case. At this station also, as at station E, large volumes of Oligochaeta and Cyprinidae were eaten by the parr and this could be a complicating factor; however, fry did not feed as heavily on Oligochaeta as did the parr, and the small volume of Trichoptera eaten by fry may mean this group was less abundant here than at stations outside the boundary. The contrasting large percentage of this group in the food of both parr and fry from
this station in the 1953 series also points to the reduction in this
group at this station in 1955.

The uppermost three stations, A, B and C, in the
sprayed area are still badly affected as indicated by the composition
of the food of both parr and fry from these stations. The approximate
number of miles that these stations are inside the spray boundary is
32, 25 and 24 for A, B and C, respectively. Thus, introduction of
many species of food organisms over these distances can be expected
to be slow. Those species which did not survive the spray treatment
in sufficient numbers have not repopulated the river to an extent
where they can become a source of food for fish in these areas. On
the other hand, those species which did survive the treatment in suf-
ficient numbers, or in the case of black flies were probably introduced,
have become important food for the fish. The food organisms that
survived and subsequently formed a large bulk of the food in fish of
the 1955 series were not necessarily the species which formed the
bulk of the food in fish before the spraying in this river and, for
parr in particular, this was definitely the case.
V. GENERAL CONCLUSIONS

It is apparent from these studies that DDT applied in relatively small concentrations over vast areas of watersheds has a marked effect on the fauna of the rivers, not only shortly following the spraying but even one year later.

Substantial reductions in the total volume of emerged insects and in the average size of insects were noted in collections from sprayed compared with unsprayed streams in the same watershed.

As a group, the Trichoptera are most adversely affected by the spray treatment and were virtually absent from the sprayed streams that were studied. In one sprayed stream, out of a total of about 3000 emerging insects that were captured from June to September there were no caddisflies collected, while in an unsprayed stream of similar size there were nearly 450 of these insects in a total of 4000 insects collected. From a small sprayed tributary, however, a few caddisflies were collected. Some species of Ephemeroptera and Plecoptera were well represented in numbers of individuals in sprayed streams. However, other species of both these orders normally present in unsprayed streams of similar characteristics as illustrated by the controls were either absent or represented by few individuals in the collections from sprayed streams.

One group of insects, the Simuliidae, were represented by large numbers of individuals in the larger sprayed streams from
mid-July to September 1955, although they were absent or nearly so in samples, taken at the same places, shortly after the spraying in 1954 and also in ones taken from early June to mid-July 1955. The results of a study by Davies (5) on the effect of DDT on black fly populations indicate that the numbers of this group may be expected to rise sharply in the second year following the spraying.

Since aquatic insects form the bulk of the food of salmon parr and fry, the expectation is that any change in the proportional representation of their various groups in streams would be reflected in the food of these fish. Many of the differences between the composition of the food of fish taken in 1955 and that of those taken in 1953 from some of the same location in the same river are correlated with the changes in the invertebrate fauna of this river. Although few samples of the invertebrate fauna were taken in the same river from which the fish were taken, the results of collections from other streams in the same watershed that had been sprayed, and others which had not been involved in the treatment, indicate that the fauna of this stream has followed the same trend as that of other sprayed streams.

It is apparent that a greater change has occurred in the food of parr than in the food of fry in similar situations. Parr have fed on Mollusca, principally of the family Physidae, thus compensating for the lack of other species which were taken as food in the same river before spraying. From the analyses of the stomach
contents of salmon parr from the control series of fish, and from the results of other investigations (1, 7) it is seen that Mollusca do not normally comprise an important source of food for these fish. Fry of the 1955 series, on the other hand, in some of the stations within the spray boundary, have continued to feed heavily on Chironomidae beyond the stage in their life cycle when feeding on this group becomes less, as was noted by White (21). At those stations in the sprayed area where Chironomidae comprise a small proportion of the bulk of food taken, there has been an increase in the volume of Simuliidae eaten, which may be because of the greater availability of the latter group resulting from their more exposed position and their greater numbers, and not because of a scarcity of Chironomidae.

The lack of Trichoptera appears to have been instrumental in bringing about these changes in the composition of the food of both parr and fry at locations within the sprayed area in 1955.
VI. SUMMARY

1. Streams in sprayed and unsprayed parts of the Miramichi watershed were studied the summer following the treatment of the forest by DDT. Estimates of the effect of the spray on the aquatic insects and other invertebrates were made by sampling the emerging insects by a cage-trap method and by sampling the bottom fauna in both types of streams.

2. The utilization of food by salmon parr and fry was studied by the examination of the stomach contents of a series of fish taken in the latter part of the summer in 1955 and the results were compared with a similar series taken in 1953, the year previous to the spraying.

3. The spraying has resulted in an overall reduction in the total volume of insects collected in sprayed streams as compared with unsprayed streams. This was most notable in large sprayed streams. The reduction has been brought about by the eradication of some forms, notably all of the Trichoptera, and has not been fully compensated for by the increase in numbers of some surviving species.

   In general, large species have been more adversely affected than have small species. Small mayflies, small stoneflies, Chironomidae and Simuliidae were well represented in sprayed streams.

   Special features of their life cycle and habitat are significant in the ability of many species to survive the effects of the spraying.
Reintroduction in sprayed streams would appear to have taken place in the Simuliidae and possibly in some other species.

4. The analysis of the stomach contents of salmon parr from both pre-spray and post-spray samples indicate that their diet was much changed in correlation with the change in the food available. In the absence of Trichoptera, larger stoneflies and larger mayflies they have utilized snails in large quantities at stations where the effect of the spray was most pronounced. Salmon fry, on the other hand, feeding on smaller organisms, have been provided with a diet which, except for the absence of caddisflies, was more nearly like that of the control series.

5. The difference between the diet of fish of the 1955 series as compared with that of fish of the 1953 series is most pronounced at upstream stations which were more seriously affected by the spray, and least pronounced in the lower reaches particularly outside the spray boundary where the diet approaches that of the controls.
ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Dr. F. P. Ide of the University of Toronto for his many helpful suggestions both in connection with field work and in the preparation of this thesis.

I am also grateful to Dr. C. J. Kerswill and Dr. P. F. Elson of the Atlantic Biological Station, St. Andrews, N. B., for supplying necessary equipment and specimens for the investigation.

Dr. F. E. Webb, of the Department of Agriculture of Canada, Fredericton, N. B., supplied the information on the sampling of the Upsalquitch and Carlow watersheds for my use here, and his kindness is appreciated.

Dr. W. E. Ricker, of the Pacific Biological Station, Nanaimo, B. C., assisted in the identification of many species of Plecoptera that were collected.

This work was assisted during the winter months by a bursary from the Fisheries Research Board of Canada administered by the National Research Council.
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APPENDIX
### APPENDIX 1.

Percentage of volume of various groups of food organisms found in stomachs of salmon parr taken in 1953 and 1955 from stations along the North West Miramichi River. The 1954 spray boundary lay between Stations D and E.

<table>
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<th>Station</th>
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<th>Sphingemoptera</th>
<th>Plecoptera</th>
<th>Trichoptera</th>
<th>Odonata</th>
<th>Chironomidae</th>
<th>Simuliidae</th>
<th>Other Diptera</th>
<th>Ciprinidae</th>
<th>Oligochaeta</th>
<th>Miscellaneous</th>
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APPENDIX 2.

Percentage by volume of various groups of food organisms found in stomachs of salmon fry taken in 1953 and 1955 from stations along the North West Miramichi River. The 1954 spray boundary lay between Stations D and E.

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<th>Plecoptera</th>
<th>Trichoptera</th>
<th>Odonata</th>
<th>Chironomidae</th>
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</table>
Dr. P.F. Elton,
Atlantic Biological Station,
St. Andrews, N.B.

Dear Paul,

During the examination of my thesis several changes were found to be necessary and I am including them on a separate page. These were the changes which were thought to be important.

I sent the data cards for the salmon themselves to you last week together with the fish. The information on the cards were often written in short form but I think they will be clear.

Yours sincerely,

[Signature]

AE May 14/56
Last paragraph: Middle — add underlined words.

It is possible that —— by the former cage trap ——

Bottom of page —
"increased the value for the average size per
insect for that cage trap."

P 15
First paragraph—"comprise"—change to "made up."
Second paragraph—"increased percentage in the
numbers"—change "increased" to "greater."

P 23
Top of page—"effects from being manifested"
Middle of page—"comprised" change to "made up."

(Handwritten notes)