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A review of the present status of Atlantic salmon in the northwest Miramichi River, New Brunswick.

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A REVIEW OF THE PRESENT STATUS OF ATLANTIC SALMON IN THE NORTHWEST MIRAMICHI RIVER, NEW BRUNSWICK

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I INTRODUCTION

A recent increase in mining activity on the watershed of the Northwest Miramichi River in northeastern New Brunswick prompted the Resource Development Branch of the Department of Fisheries to compile a summary of available knowledge on this important salmon river.

This report reviews the present status of Atlantic salmon in the Northwest Miramichi by describing the activities, particularly base metal mining, affecting the resource with regard to the following aspects: (1) fluctuations in juvenile salmon abundance, (2) movements of migrating adult salmon, (3) fluctuations in adult salmon abundance, and (4) salmon potential.

The assistance and co-operation of the Pollution and Anadromous groups of the Fisheries Research Board of Canada, Biological Station, St. Andrews, N.B. is gratefully acknowledged.

II HISTORY OF ACTIVITIES IN THE DRAINAGE BASIN.

The Northwest Miramichi has long been noted as an important Atlantic salmon stream. Prior to 1953, sylvicultural and industrial developments had not noticeably altered the fishery resource of this river system and the upper two-thirds of the watershed was largely inaccessible except by foot or horse and wagon. The forest was periodically cut in small blocks with about 30 or 40 years intervening between cuts on any one part. Because the river is for the most part rapid flowing and has few sections of stillwater, logs were floated down each spring without the use of large driving dams. Over the years the only visitors to the river were salmon anglers, woodsmen and occasional hunters and trappers.

In 1954 large - scale lumbering operations began with the opening of truck roads to the headwaters and the establishment of large lumber camps. In the next few years the valley was extensively cut for timber and pulpwood, and by 1961 approximately 200,000 cords had been cut, which is roughly equivalent to one-fifth of the initial forest resource in the upper half of the drainage basin. Most of the wood was driven to the pulp-mill at Newcastle via the Northwest Miramichi River; the drives beginning about April 15 of each year and lasting about two months depending upon weather conditions (pers. comm., New Brunswick Forest Service, Newcastle, N.B.).

The entire basin was sprayed to varying degrees with D.D.T. in six years since 1954 in an attempt to control spruce budworm infestations. In the fall of 1957 pulp-harvesting operations during a time of low water caused a log jam which formed a partial barrier to upstream - migrating Atlantic salmon.

In the summer of 1960, base-metal mining pollution appeared in the Northwest Miramichi from the Tomogonops tributary and this problem has persisted to the present.

The Northwest Miramichi has been the subject of a continuing research program by the Fisheries Research Board of Canada since 1950 when juvenile salmon densities were first assessed and a counting fence for upstream and downstream migrants was erected at Curventon, about seven miles above tide head. Stream bottom invertebrate studies began in the late 1950's and from 1957 to 1963 a second counting fence was operated at Camp Adams, about 33 miles upriver from Curventon. In 1964 a more efficient counting fence with a permanent concrete base was installed at Curventon, one-half mile upstream from the site of the old one.

Water chemistry in the river has been monitored almost daily since 1960 by the Board and this work has been supplemented in recent years by the Resource Development Branch of the Department of Fisheries who have placed particular emphasis on the analysis of stream water flowing through, or in close proximity to, the mine site.

Since 1950, Atlantic salmon frequenting this river have been influenced to varying degrees by other activities and factors in addition to base-metal mining. The listing which follows serves to indicate the extent of these other activities, some of which often tend to be overlooked.

(a) trapping and handling smolts at the counting fences,
(b) tagging and fin-clipping salmon,
(c) removal of parr and smolt from the river for experimental purposes,
*(d) hatchery plantings,
(e) differential survival of salmon between years,
(f) commercial fishing of N.W. Miramichi stocks in tidal waters,
(g) D.D.T. spraying,
(h) pulpwood cutting and driving,
(i) pulp-mill effluent in tidal water at Newcastle.

III BASE-METAL MINING

1. Historical

Heath Steele Mines Limited was incorporated in 1955 to develop an area of land along the Tomogonops River, a tributary to the Northwest Miramichi entering about 24 miles above head of tide (Figure 1). In January 1957 a 1,500 ton-a-day mill was opened which began producing copper, lead and zinc concentrates. In 1958, the price of base metal concentrates dropped and the mine was closed for two years until reactivitated in the early part of 1960. At this time, it was necessary to pump out flooded mine shafts and this operation released mine water to the Tomogonops at the rate of approximately 3000 gal./min. These activities coincided with the previously unobserved phenomenon in which large numbers of adult salmon were seen to be returning downstream through the Curventon counting fence in June.

The first water samples for chemical analysis were collected by the Fisheries Research Board on June 29, 1960, about two weeks after pumping had started and the results revealed that water being pumped from the shafts was very acid ($_{p}$H 4.1) with a high conductance indicating a heavy load of ionized material. Tests from the Tomogonops River itself indicated that the pumped material was causing a major upset in water quality. Further investigations confirmed that zinc and copper were present in high concentrations which could be traced in the Northwest Miramichi River for about 15 miles downstream from the mouth of the polluting tributary.

When the mining company was made aware of the situation, they discontinued pumping into the Tomogonops River and began pumping the mine water into the pit of a former strip mine. The mine property was subsequently examined by representatives of both federal and provincial agencies and it was found that the pollution had many and varied sources.

In 1960, a tentative estimate of 0.06 mg/l (60 µg/l) of zinc was used as a "safe" level of mining pollution (Sprague MS, 1961). This level was exceeded in the Northwest Miramichi throughout most of the year and on two occasions the zinc levels approached or exceeded the established lethal level which is 0.6 mg/l (600 µg/l).

2. Sources of pollution

The Resource Development Branch (formerly Fish Culture Development Branch) of the Department of Fisheries attempted in 1964 to accurately locate the sources of pollution at Heath Steele Mines (Anon. MS, 1965). Six stations (c.f. Fig. 2) were sampled weekly and an additional twelve were sampled once in May, August and November. Station A on the Little South Tomogonops River above the mine property and station B on the main Northwest Miramichi immediately above the mouth of the Tomogonops River served as controls. At these stations concentrations of copper ranged from 0 to 26 µg/l and zinc from 0 to 55 µg/l, lethal concentrations being 48 µg/l and 600 µg/l for copper and zinc respectively (Sprague 1964).

Station C, located at the mouth of the Tomogonops River, monitored the total contamination reaching the Northwest Miramichi from the mine. The concentrations of zinc and copper were extremely high throughout 1964, copper ranging from 27 to 176 µg/l and zinc from 380 to 1600 µg/l. If these values are expressed as toxic units 1/ it is evident that toxicity fluctuated between one-half and greater than twice the lethal level on the days that the samples were taken.

Station D, was located on the South Tomogonops below the second tailings pond which had been constructed in 1963. Toxic units were low throughout the test period May 17 to December 1, suggesting that this tailings pond was doing an adequate job of preventing zinc and copper from escaping into the receiving stream.

1/ "Toxic unit" is an index of pollution obtained by calculating the ratio between the actual concentration of the pollutant and its incipient lethal level or concentration. In the case of two chemicals such as copper and zinc in the same environment, the incipient lethal level of the mixture is attained when addition of toxic units contributed by each metal reaches a total of 1.0 (Sprague and Ramsey, 1965).

Station E was located on the Little South Tomogonops below the mine. Concentrations of copper and zinc were extremely high throughout the year, viz., copper fluctuated between 72 and 2460 µg/l and zinc between 1900 and 21000 µg/l. This is indicative of the large amount of toxicity that can be attributed to surface run-off from the mine property above this sampling site. Station F was located on the "Clean Water" Channel at Wedge Mine Road just below the concentrator which is the functional center of the mining operation here. Copper and zinc concentrations were considerably higher than at Station E shortly below; the concentrations being 36,000 µg/l and 388,000 µg/l for copper and zinc respectively. It seems clear that the major source of pollution is the concentrator and the operations immediately associated with it.

The twelve supplementary stations referred to earlier were located in close proximity to the sources of pollution and discussion of the data is summarized here using zinc as the criterion of pollution: (1) Only a small amount of zinc is contributed by Camp Stream above the mine property; most of the contamination occurring between the road through the mine property and the Wedge Mine Road where considerable amounts of tailings and other waste material were dumped on the drainage basin of Camp Stream and subsequently leached out into the stream. (2) A large amount of heavy metal contamination is contributed periodically by the No. 2 shaft area where some construction and either pumping or overflowing occurs. An illustration of this is the high heavy metal concentration in Pumping Grounds Brook which receives much of the sump-water from No. 2 shaft. (3) The tailings pond is functioning adequately by retaining the bulk of the heavy metals which are pumped into it.

A major point arising from this study by the Resource Development Branch is that copper and zinc pollution from base-metal mines can be moderated, in large part, by conveying all wastes, both solid and liquid, to a tailings pond. A properly functioning tailings pond has proven to be an effective means of reducing the amount of metal ions released into a waterway.

3. Control efforts by the mining Company

A tailings discharge line from the concentrator to the first or "old" tailings pond was built in 1953 and difficulties were soon experienced with this system when it was discovered that the pond was too small. A larger "new" tailings pond was completed in 1963 along with a pipeline and pumping station to remove Camp Brook "dirty" water from the settling ponds near the concentrator to this second pond. The "new" tailings pond was enlarged in 1964 but freezing of the pipeline conveying waste to the pond has caused cessation of this operation during the winter months each year up to the present.

Settling ponds were constructed in 1960 and liming operations began for the water being discharged from No. 2 shaft and "A" pit. This system proved to be very inadequate especially during extreme freshets. Late in the Fall of 1960 a larger series of settling ponds was completed and fairly good control of pollution was achieved during the winter of 1960 and the spring of 1961. A "clean" water channel was constructed in 1961 to carry uncontaminated Camp Brook water from near "A" pit to the Tomogonops, thus by-passing the settling ponds and liming operation. In 1965 an overhead launder was completed to carry waste from No. 3 shaft to Camp Brook settling ponds from which it is pumped to the "new" tailings pond.

4. Degree of Pollution

Copper-zinc pollution in the Northwest Miramichi has been monitored regularly since 1960 by the Fisheries Research Board and the results are summarized in Table I and Figure 3. Highest average monthly toxic unit values were recorded for the months November through May. Average monthly values greater than 1.0 toxic units indicating lethal conditions occurred for eight months during the study period which covered 79 months. However, monthly maxima in toxic units were above the lethal level for 36 months, between the lethal and avoidance levels for 32 months and below the avoidance level for only 11 months. The yearly average for pollution in the year 1966 is almost identical to the six and one-half year average revealing that there has been no marked improvement in the situation.

IV JUVENILE SALMON POPULATIONS

1. Year-to-year changes

Year-to-year changes in the densities of young salmon populations as determined by electroseining techniques at ten stations along the Northwest Miramichi River for the period 1951-1965 are illustrated in Figure 4. D.D.T. forest-spraying to control the spruce budworm occurred in 1954 on the upper river and in 1954, 1956, 1957, 1962 and 1964 on the lower river (for analysis of effects to 1963, see Elson 1967); a partial barrier to upward-moving adult salmon occurred in 1957 due to pulp wood harvesting at a time of low water; and mine-sump water containing high concentrations of base metals was discharged into the river beginning in 1960. These harmful factors have reduced underyearling populations drastically in the year of occurrence, but there is some tendency for the effects to be partly ameliorated for larger fish, and thus presumably for smolt production in any one year, by variable growth rates (Elson MS, 1963).

Little industrial encroachment of any consequence to salmon had occurred in the Northwest Miramichi up to the year 1953 and juvenile salmon densities were thought to have been normal during the years 1951 to 1953 inclusive as shown in Figure 4 and Table 2. Severe reductions occurred in 1954 when the forest of the entire basin was sprayed with D.D.T. at ½ lb. per acre. In 1955 a substantial increase in underyearling populations was evidenced which may be attributed to the absence of D.D.T. forest-sparying during that year and possibly excellent seeding in 1954 (Keenleyside 1959). However, small and large parr populations continued to be low throughout the river, reflecting the 1954 crash.

Underyearling densities for the upper river were similar in 1956 to those recorded for pre-spray years while small parr were extremely abundant as expected from high 1955 underyearling estimates. Large parr in the upper river, being from the 1954 year-class, were the lowest on record. The lower part of the river presented trends similar to the upper river in young salmon densities in 1956, although an overall reduction seems to have occurred following D.D.T. forest-spraying here during that year. In the upper portion of the Northwest Miramichi in 1957, parr populations approached normal levels but fry density was lower than anticipated. Young salmon populations in the lower part of the river continued to be affected by D.D.T. spraying as evidenced by reduced populations.

The partial barrier to adult migrating salmon caused by pulp-wood in 1957 resulted in a reduction in the number of spawners to the upper river. Consequently there were lower than normal densities of underyearlings there in 1958 and the disturbance was reflected again by low small parr densities in 1959 (Elson MS, 1963). On the other hand, particularly good numbers of underyearlings were recorded in the lower river in 1958, probably resulting from increased numbers of spawners in 1957. Small parr densities were unusually high here in 1959. There was almost complete recovery from the effects of heavy D.D.T. spraying in the Northwest Miramichi by 1959 (Sprague and Elson MS, 1961).

The greater numbers of small parr in the lower part of the river in 1959 did not appear as corresponding numbers of large parr in 1960. This is associated with poisonous mine effluent throughout the summer of 1960, which appears to have seriously reduced fish of all age groups in the lower part of the river (Elson MS, 1963). Continued recovery from D.D.T. spraying was evidenced in the upper river by a return of populations to the levels of pre-spray years. The 1960 population of underyearlings was derived from an abnormally large run of nearly 8,400 adults of which 5400 went to the upper half and over 2900 stayed below. This did not result in a better population of underyearlings in the lower river sampling stations, which are all within the area affected by the mine effluent in 1960 (Elson MS, 1962b)

The base-metal mine pollution is known to have hindered upward migration of spawners in 1960 (Sprague et. al.1965). This can be seen by the reduced numbers of underyearlings in the upper part of the river in 1961. However, in contrast to the 1957 pulp blockage, there were not greater numbers of underyearlings in the lower part in 1961. Over 2400 adults entered the river in 1960 and just over 650 went to the upper part, leaving nearly 1800 below. Although this number is nearly twice as great at that for 1958 in the lower river, only one quarter as many underyearlings were produced in 1961. The correlation between the beginning of serious base-metal mine pollution and poor juvenile salmon populations despite excellent seeding is obvious (Elson MS, 1962b).

There were moderately good numbers of underyearlings throughout the river in 1962 explained by the fact that the mine pollution was somewhat ameliorated throughout 1961 and into 1962. During the three-year period 1963 through 1965 young salmon maintained fairly good populations in the upper river but were depressed in lower part reflecting continued pollution from the base-metal mine.

2. Changes in large parr abundance

Variations in juvenile Atlantic salmon densities in the Northwest Miramichi River are well illustrated by an examination of large parr densities since it is this age group which resides in the river for three years and constitutes the smolt run early in its fourth year. There has always been a great disparity between juvenile salmon abundance of the upper versus the lower part of this river. Prior to industrial encroachment on the Northwest Miramichi, indices of juvenile salmon populations at sampling stations above the mouth of the Tomogonops River were approximately three times greater than those for stations below. Indices for populations of large parr were about four and one-half times greater in the upper part of the river.

Mining pollution first occurred in June 1960 and juvenile salmon in the lower part of the river were affected directly in that year and each year thereafter. Young salmon in the upper part of the river were first affected in 1961 when fry population indicies showed reductions, possibly due to delay and reduction of spawners in 1960. Consequently, any changes in numbers of large parr in the upper part of the river might be sought in 1963. A summary of these changes is presented as follows:

	Above Tomogonops 1/		Below Tomogonops 2/		Entire River
	Large parr per 100 sq. yds.	Total No. large parr ($X10^4$)	Large parr per 100 sq. yds.	Total No. large parr ($X10^4$)	($X10^4$)
1951-53	18	25.9	4	3.1	29.0
1954-59			2	1.6	
1954-62	11	15.8			17.4
1960-65			1	0.8	
1963-65	16	23.0			23.8

The data presented above indicate that under normal conditions about 89 per cent of the large parr were being produced in the upper part of the river above the mouth of the Tomogonops. With the advent of D.D.T. spraying in 1954 and base-metal pollution in 1960, this differential favoring the upper river increased to over 90 per cent.

For the entire river, the apparent reduction from previously normal levels of

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1/ Total rearing area above Tomogonops is 14.4×10^5 sq. yds.

2/ Total rearing area below Tomogonops is 7.8×10^5 sq. yds.

large parr was approximately 40 per cent throughout the period 1954 to 1959 inclusive and approximately 20 per cent from 1960 to 1965 inclusive. Large parr populations rearing in the Northwest Miramichi below the mouth of the Tomogonops were severely reduced from normal levels by approximately 50 per cent in years of heavy D.D.T. spraying and by approximately 75 per cent in the mine pollution period. However, any conclusions regarding specific effects of base-metal mine pollution on juvenile salmon in this river are further complicated by the fact that some D.D.T. spraying has occurred since 1960 in the lower part of the river.

V MOVEMENTS OF ADULT SALMON

Saunders and Sprague (1967) and Henderson et. al. (1965) provide a thorough treatment of salmon movements in the Northwest Miramichi River prior to 1963. Salmon movements during the years 1964 to 1966 have been provided through the courtesy of the Director, Fisheries Research Board of Canada, Biological Station, St. Andrews, N.B.

1. Mining pollution and adult salmon movements

Saunders and Sprague (1967) found that a major consequence of the disturbed migration through the polluted section of the Northwest Miramichi was that early runs of salmon to Camp Adams were delayed and reduced in number. Saunders (1967) has shown that under normal conditions and with few exceptions only the early (June-July) run of salmon reaches Camp Adams, 40 miles above tidehead and 18 miles above the polluted tributary. In 1960, no salmon were seen at Camp Adams counting fence by July 10 whereas during the three previous years substantial numbers of salmon had reached that area of the river by the end of June. Accordingly, on July 10, 1960, 24 grilse were tagged by the Fisheries Research Board at Curventon, transported upriver and released in the main river five miles above the mouth of the Tomogonops. Within 12 days, 18 of them had reached Camp Adams, 3 were taken by anglers below Camp Adams and the remaining 3 were not seen again. Apparently once salmon were past the outflow of the Tomogonops they moved quickly upriver (Keenleyside MS, 1961).

The percentage relations between ascending Atlantic salmon at two counting fences on the main river are tabulated below (source: Saunders and Sprague, 1967).

YEAR	CURVENTON	CAMP ADAMS	C.A./CURV. x 100
1957	1,581	711	45
1958	3,000	2,133	71
1959	8,357	5,409	65
1960	3,169	663	21
1961	1,831	626	34
1962	2,509	1,113	44
1963	6,397	2,484	39

In pre-pollution years, between 45 and 71 per cent of the number of salmon counted at Curventon were subsequently observed at Camp Adams, while the comparable figure for 1960 was only 21 per cent. During the seasons 1961 to 1963 the situation was improved somewhat but fewer salmon reached the upper part of the river than in pre-pollution years. The Camp Adams counting fence was not operated after 1963.

Saunders and Sprague (1967) compared salmon movements through Curventon fence during 1960 to 1963 with 1955 which was chosen from the pre-pollution years to illustrate a typical seasonal pattern of movement past the Curventon fence, viz; a large upstream run of salmon in the spring, little activity during summer, and a variable run in autumn. It was found that movements generally coincided with changes in river flow, and large runs of fish were usually associated with freshets. Downstream movements were few. Judging by concentrations of zinc and copper in the unpolluted part of the Miramichi during several years (Sprague and Carson MS, 1964) total toxic units for these metals would have been only about 0.03 at Curventon throughout 1955 when there was no mining pollution.

In the years 1960-1963 there was significant downstream movements whenever pollution exceeded about 0.35 to 0.43 toxic units (Saunders and Sprague, 1967). Figure 3 illustrates the frequency at which such avoidance levels occurred. Data on the upstream and downstream movements of grilse and large salmon at Curventon are presented in Table 3. There are two types of downstream movement; one occurring after spawning in autumn and the other due to unexplained straying behavior or unsuitable environmental conditions. Salmon which might have just spawned have not been included in downstream movement counts during recent years. There is no evidence that successive year classes of salmon are growing accustomed to the pollution. Many of the adults moving upstream in 1962, and most of those moving up in 1963, had swum down through the polluted section of the river on their way to sea as young fish in the spring seasons of 1961 and 1962. However these workers found little or no difference between avoidance reactions of these fish and those which had moved upstream in 1960 and 1961. These findings also serve to eliminate the possibility that avoidance reactions resulted merely from confusion as to whether the metal-contaminated Northwest Miramichi was actually the home stream being sought by the fish (Saunders and Sprague, 1967).

When the level of pollution rises above 0.8 toxic units, there is some indication that it acts as a complete barrier to upstream migration. Saunders and Sprague (1967) present circumstantial evidence which supports this hypothesis. After several periods during which there were no upstream movements, high toxicity (greater than 0.8 toxic units), and flows which were suitable for upstream migration, they report that most of the salmon ascending through the Curventon fence were dark colored, indicating that they had been in freshwater for several weeks. Moreover, many of them bore tags which had been applied earlier in the season as they descended through the counting fence (ibid).

The effect of various levels of base metal pollution on movements of adult salmon in the Northwest Miramichi for the period 1960 to 1963 inclusive has been discussed above. It was therefore deemed unnecessary to present data for 1964 to 1966 inclusive in the same fashion. Suffice it to say that there has been no striking improvement in pollution conditions in this river (c.f. figure 3). However, Sprague and Carson (MS, 1967) note that during this later period, pollution was for the most part low enough during the spawning migration of salmon to avoid disturbances to upstream migrating adults.

2. Fates of descending salmon and loss of spawners

Table 4 presents the results of a study designed to determine the fates of descending adult salmon during the period 1960 through 1963. Slightly more than half (1077) of the descending salmon were tagged over the four year period. These fish were observed moving downstream at a time when little such descent was observed in 1959 and earlier (Saunders and Sprague, 1967). Sixty-two per cent of the tagged descending salmon were not observed again during the respective seasons of descent, thirty-one per cent of the total were finally observed reascending in the season of descent, and seven per cent were removed by angling and commercial fishing at various points below the counting fence. It would therefore seem that during the period 1960 through 1963, 69 per cent of the descending fish were lost from the stock available in the upper part of the river. By applying the average loss of 69 per cent to the yearly totals of descending adult salmon, estimated losses from the upper part of the river are: 489, 188, 195 and 650 salmon. These losses are 15, 10, 8 and 10 per cent of the numbers ascending in 1960 through 1963 respectively (ibid). Extending the percentage average loss of 69 per cent to the succeeding years 1964 through 1966, the estimated losses to the upper river are: 161, 117 and 20 salmon. These losses are 3, 7 and 1 per cent of the numbers ascending at Curventon during the years in question. It would appear that salmon losses have been smaller in recent years.

During the years 1957 through 1959, prior to pollution, Keenleyside (MS, 1961) found that the first grilse passed Camp Adams counting fence on June 25, 15 and 25 respectively. In 1960 the first grilse passed this fence on July 11, but such a delay was not noticeable in the succeeding three years when first grilse appearances occurred on June 17, 24 and 21. Table 5 shows the proportion of the grilse run passing Camp Adams during the seven-year period 1957-1963. The greatest upset in the annual migration appears in 1960 while very slight disturbances may be detected in 1961 and 1962. Base metal pollution was more severe in the river in 1960 than in the next succeeding two years. Tagging experiments in two pre-pollution years showed that 53.3 per cent (1958) and 44.4 per cent (1959) of grilse passing Curventon in June eventually pass through the Camp Adams fence and, presumably, spawn in the upper reaches of the river (ibid.). In 1960 the comparable figure was 5.0 per cent. Similar tagging data are not available for succeeding years.

VI ABUNDANCE OF ADULT SALMON

The most reliable counts of Atlantic salmon in the Miramichi River system are available from the counting fence at Curventon (Henderson et. al. MS, 1965). In the seventeen year period 1950 - 1966, the number of large salmon and grilse migrating upstream through the fence has averaged 3400 fish annually (Table 9); the average number remaining almost constant during the periods prior to and following 1960. Obviously there has been no ostensible decrease in the total number of adults in recent years. On the other hand, a breakdown of the counts into grilse and large salmon reveals that grilse increased by 12 per cent in the same period whereas large salmon decreased by 61 per cent. In other words, the large salmon to grilse ratio changed from 1:3.5 prior to pollution, to 1:10.2 after pollution. However, a change of the same order of magnitude occurred in the estuary of the Miramichi River at Millbank experimental trap. The Millbank results revealed a change in the large salmon to grilse ratio of 1:1 before 1960 to 1:6.6 afterwards. The implication here is that factors other than mining pollution are influencing stocks of Miramichi salmon; possible over-exploitation by the commercial fishery has been suggested as a contributor in this regard (Saunders MS, 1965).

There are indications of a pronounced relative decrease in the number of adult salmon in the Northwest Miramichi after 1960. Since that year, total numbers of Atlantic salmon, including both grilse and large salmon, have increased 38 per cent at Millbank while at Curventon the numbers decreased 4 per cent. Referring to the statistics for 1965, Allen (MS, 1966) states that "in view of the well sustained catches in the Miramichi system as a whole, the decrease in the numbers of grilse at the Curventon trap appears to be a local effect in the Northwest Miramichi which may well be associated with the effects of pollution from the Tomogonops tributary". A further indication of a relative decrease is obtained when angling statistics for this river are compared with those for the Little Southwest Miramichi, a neighbouring tributary. A rough analysis (c.f. Table 6) reveals that in more recent years the average number of salmon angled per year has increased 6 per cent in the Northwest Miramichi while the comparable figure for the Little Southwest Miramichi is an increase of 118 per cent. One obvious contributing factor to this disparity is the increase in angling pressure on the Little Southwest Miramichi and the corresponding decrease on the other river, but this cannot be the only explanation for it is axiomatic that anglers are more likely to fish in areas where there is a relatively better chance of success.

Since base metal mine pollution affects the behavior of adult salmon in the river, it is probable that an indirect causal relationship exists between the presence of such pollution and angling catches. For example, during periods when avoidance levels of pollution were present it appears (Saunders and Sprague, 1967) that significant numbers of salmon were obliged to remain in lower river pools until conditions became more favourable for continuation of their upstream migration. It is conjectured that while concentrated in these pools salmon were more vulnerable to anglers. Furthermore, it is known that some salmon reversed their direction of migration in the presence of pollution and that they subsequently entered rivers other than the Northwest Miramichi and were angled there.

VII ESTIMATES OF PRESENT AND POTENTIAL SALMON RUNS

1. Present Run

Two methods have been used to estimate the present size of the salmon run in the Northwest Miramichi: (a) escapement plus catch and (b) calculating expected adult return from data on large parr densities. The first method is preferable and would offer a very good estimate if all the background data were available but there are certain inherent weaknesses which will reveal themselves in the assumptions outlined below.

(a) Escapement plus catch. The assumptions used in this calculation are as follows: (i) insignificant numbers of salmon are angled above Curventon and the number counted at this point is equivalent to the spawning escapement; (ii) 25 per cent of the salmon reported angled in the Northwest Miramichi are actually destined for the Little Southwest Miramichi and Sevogle [1/] rivers since much of the angling on the Northwest Miramichi is concentrated near the mouths of the other two rivers; and (iii) based on preliminary work by Saunders (MS, 1965) it appears that less than one per cent of the Northwest Miramichi large salmon stock is taken by commercial fisheries. Based on these assumptions, the annual escapement (1960-1965) is 3500 fish, the number angled each year (1960-1965) is 2200 fish and the number taken commercially is negligible. The estimated present run size by this method is 5700 salmon.

(b) Large parr densities. The assumptions used in this calculation are as follows: (1) present total number of large parr in the Northwest Miramichi is 238,000 (c.f. Section IV (2)); and (ii) survival rates (Elson, 1962a) are: large parr to smolt (40 per cent) and smolt to returning adults (8 per cent). The estimated present run size by this method is 7600 salmon.

According to the two methods outlined above, the total adult salmon run presently supported by the Northwest Miramichi may range from 5700 to 7600 fish.

1/ Sevogle River, although tributary to the Northwest Miramichi, is not included in any of the run estimates since fence counts and large parr densities are not available for this river.

2. Potential Run

It is believed that under optimum environmental conditions the Northwest Miramichi could support a larger run of Atlantic salmon. For the purpose of this calculation average large salmon parr densities for the years 1951 to 1953 inclusive are used because it was in this period that exploitation of the forest and mineral resources was least evident and as a result optimum production of salmon could be expected. As calculated in Section IV (2), the total number of large parr in the river each year during that period (1951-1953) was 290,000. Using Elson's (1962a) survival rates, the estimated potential run size is 9300.

It appears from the above calculations on present and potential run sizes that with improved environmental conditions, particularly pollution abatement, the salmon stock supported by the Northwest Miramichi could be increased by at least 20 per cent.

VIII SUMMARY

Industrial encroachments in the form of DDT forest spraying, pulp-wood cutting and driving, and base-metal mine effluent have affected the production of Atlantic salmon in the Northwest Miramichi River at different periods since 1954.

Heath Steele Mines Limited first produced copper, lead and zinc concentrates in 1957 at a site located on the Tomogonops River. The effects of the effluent on Atlantic salmon were first noticed in June 1960 when adult fish were observed descending past a counting fence, located on the Northwest Miramichi 17 miles below the tributary in question, shortly after they had ascended. Monitoring of water quality has been carried out daily, almost without exception, since 1960 and although certain control efforts have been undertaken by the mining company, there has been no great improvement of the pollution situation to date.

Population estimates of juvenile salmon are available from 1950 to the present and these data reveal that large salmon parr populations were reduced by an estimated 40 per cent throughout the Northwest Miramichi River during the six-year period 1954-1959 when DDT forest spraying and pulp wood blockage were evidenced. After 1960, large parr populations in the upper river rebounded, approaching levels of the pre-spray years. Populations in the mine-polluted portion were further depressed; the reduction of large parr throughout the entire river during the first six years of mining pollution 1960-1965 is estimated to be about 20 per cent.

The upstream spawning migration of Atlantic salmon through the polluted section of the Northwest Miramichi River was disturbed following 1960 and a major consequence was that early runs of salmon to the upper river were delayed and reduced in number. It has been demonstrated that during the period 1960-1963 there were significant downstream movements of adults whenever pollution exceeded about 0.35 to 0.43 toxic units and there is some evidence to suggest that when the level of pollution rose above 0.8 toxic units, it acted as a complete barrier to upstream migration.

Tagging studies show that 69 per cent of the salmon which descended through the lower counting fence at irregular times were lost from the stock available to the upper part of the river. These losses ranged from one to fifteen per cent of the total number ascending during 1960 through 1966, with some indications that salmon losses have been smaller in the last three years of that period.

There is no evidence of a pronounced decrease in the total run of adult salmon migrating to the Northwest Miramichi each year but there are strong indications that a relative decrease has occurred. Data on the annual abundance of upstream migrating salmon in Miramichi River estuary reveal that numbers have increased 38 per cent while Northwest Miramichi runs appear to have decreased 4 per cent. Additional evidence from angling statistics indicates that there has been a slight increase of 6 per cent since 1960 in the number of fish angled from the Northwest Miramichi compared with a gain of 118 per cent on a neighbouring river, the Little Southwest Miramichi.

The present run of adult salmon to the Northwest Miramichi each year is estimated to range from 5700 to 7600, while the river has supported an estimated run of 9300 salmon when natural habitat conditions prevailed.

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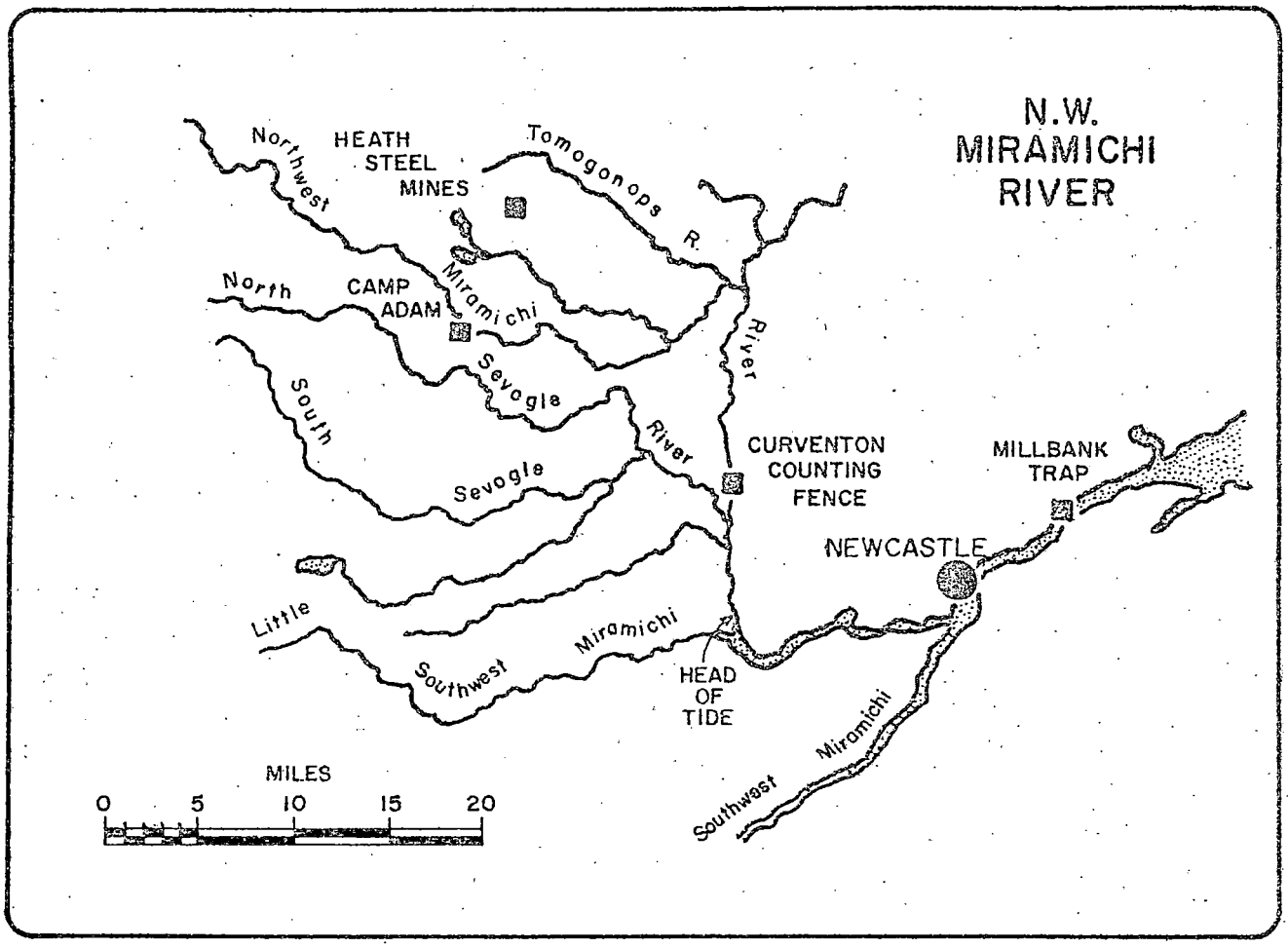

Figure 1. Map of the Northwest Miramichi River system showing locations of base metal mine, salmon counting fences, estuarial trap and major tributaries.

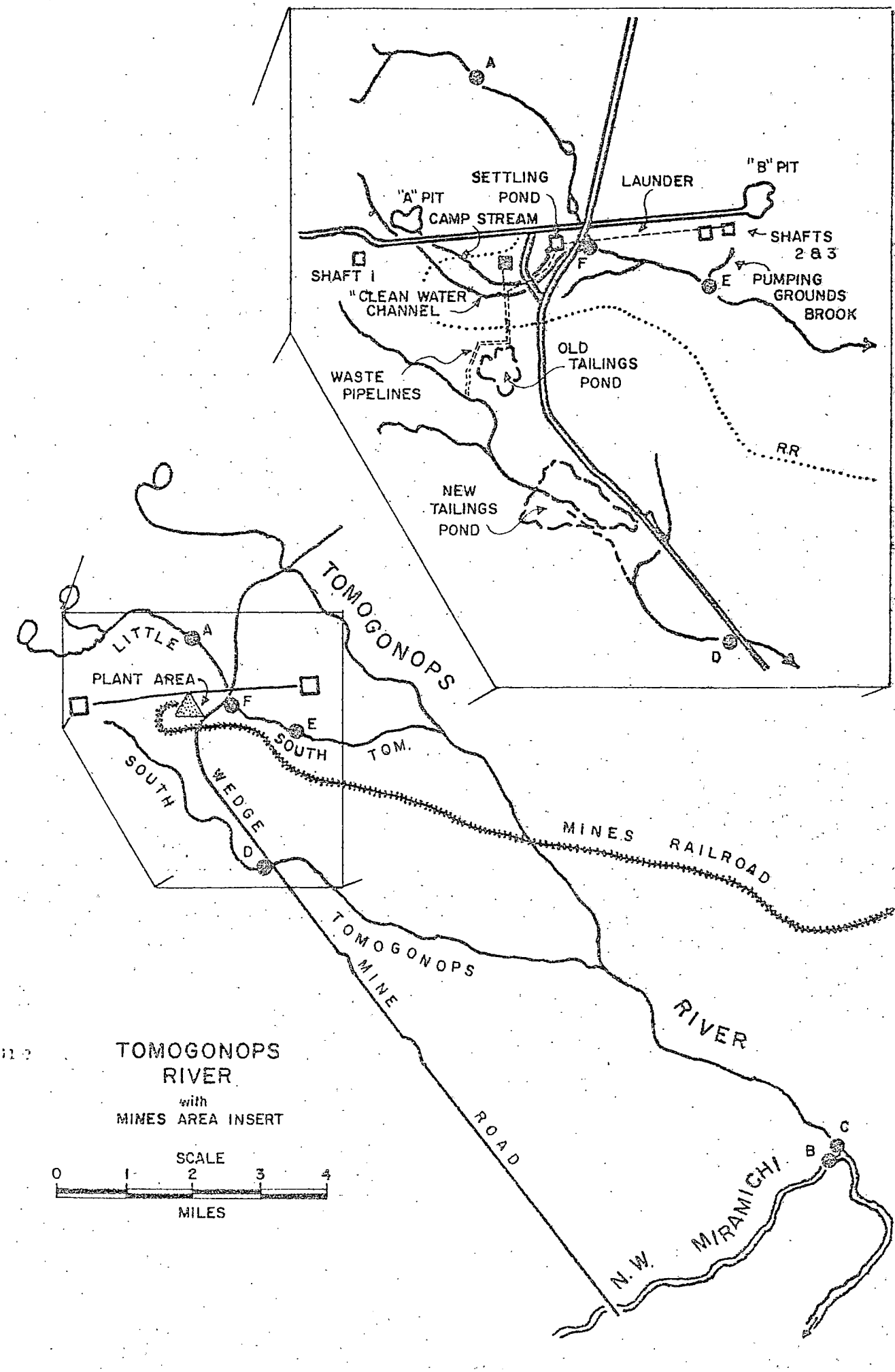

Figure 2

TOMOGONOPS RIVER
with
MINES AREA INSERT

SCALE
0 1 2 3 4
MILES

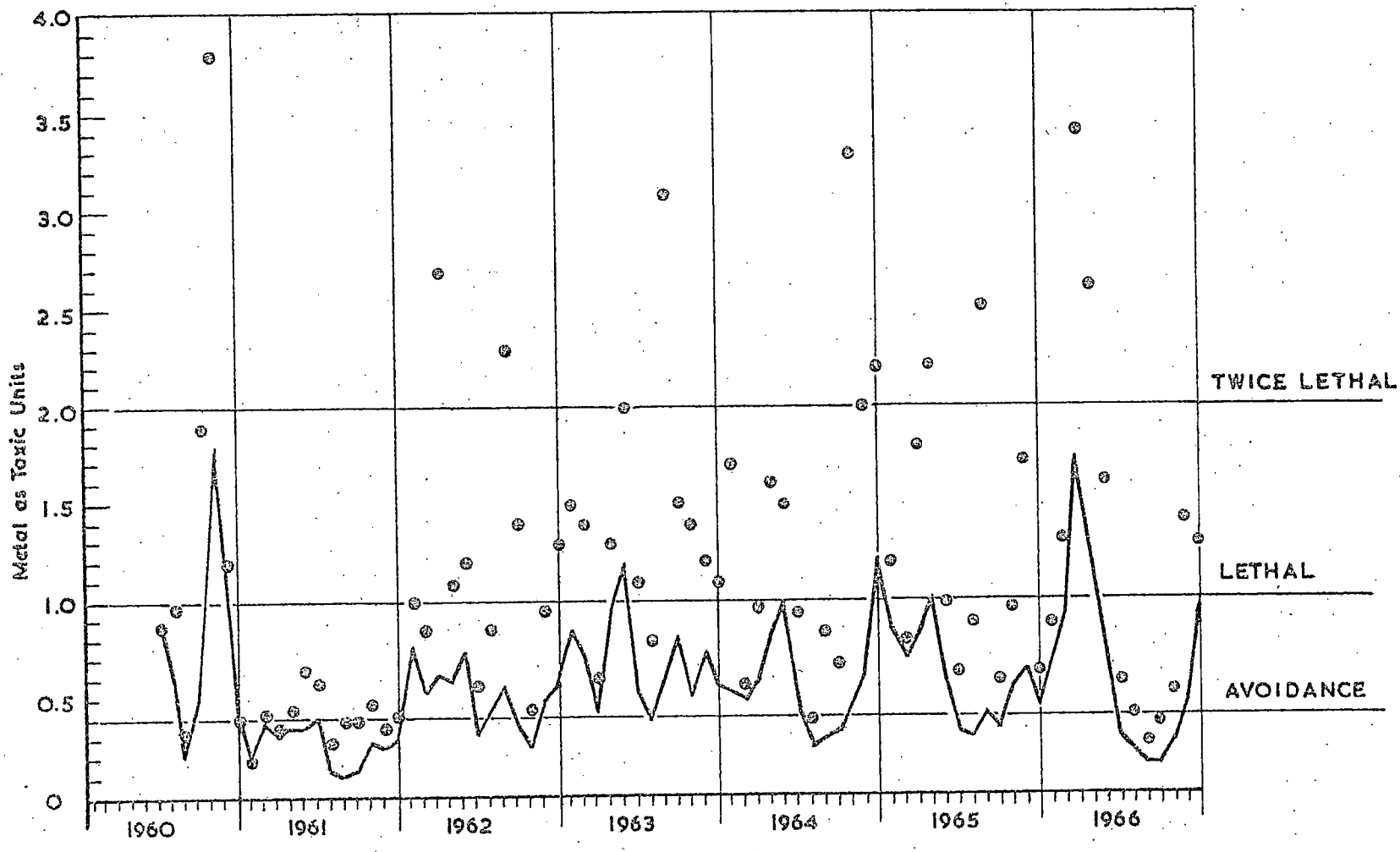

Figure 3: Monthly average of toxic units for mining pollution of the Northwest Miramichi River, 1960-1966. The black line represents averages, while the points represent monthly maxima.

From: Fisheries Research Board of Canada, St. Andrews, N.B, Annual Report and Investigators' Summaries, 1966.

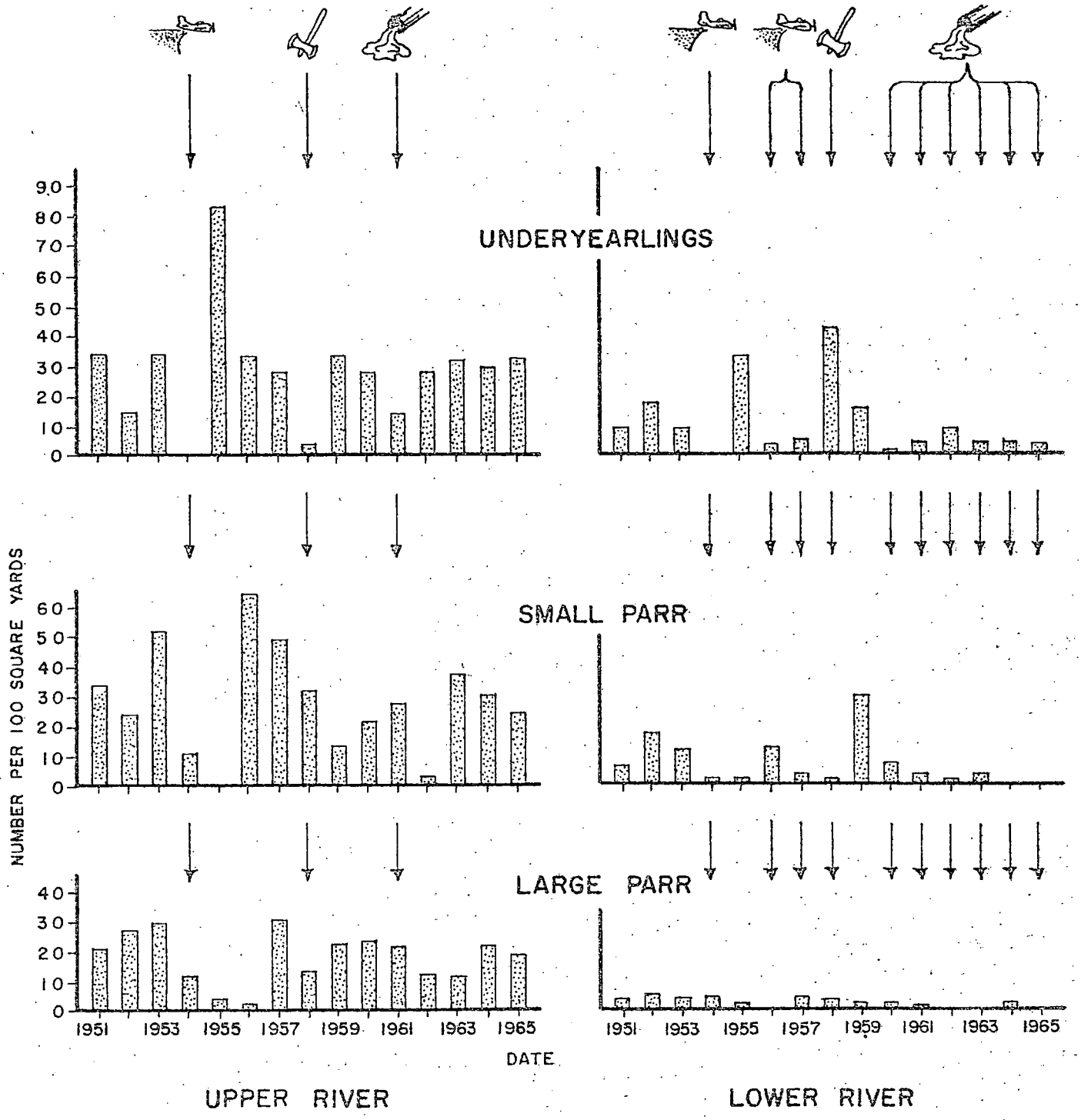

Figure 1. Populations of young salmon in the upper and lower parts of the Northwest Miramichi River as estimated from electro-seining. Figures for the upper river are averages of 3 stations, except in 1951, 2 stations; figures for the lower river are averages for 4 stations except 1951, 1964, and 1965, 3 stations; 1953, 1958 and 1963, 2 stations; 1954 and 1964, 1 station. Symbols: plane = DDT spraying axe = stream blockage; drainpipe = mine pollution.

Modified from: Fisheries Research Board of Canada, St. Andrews, N.B. Ann. Rept. and Invest. Summ., 1963.

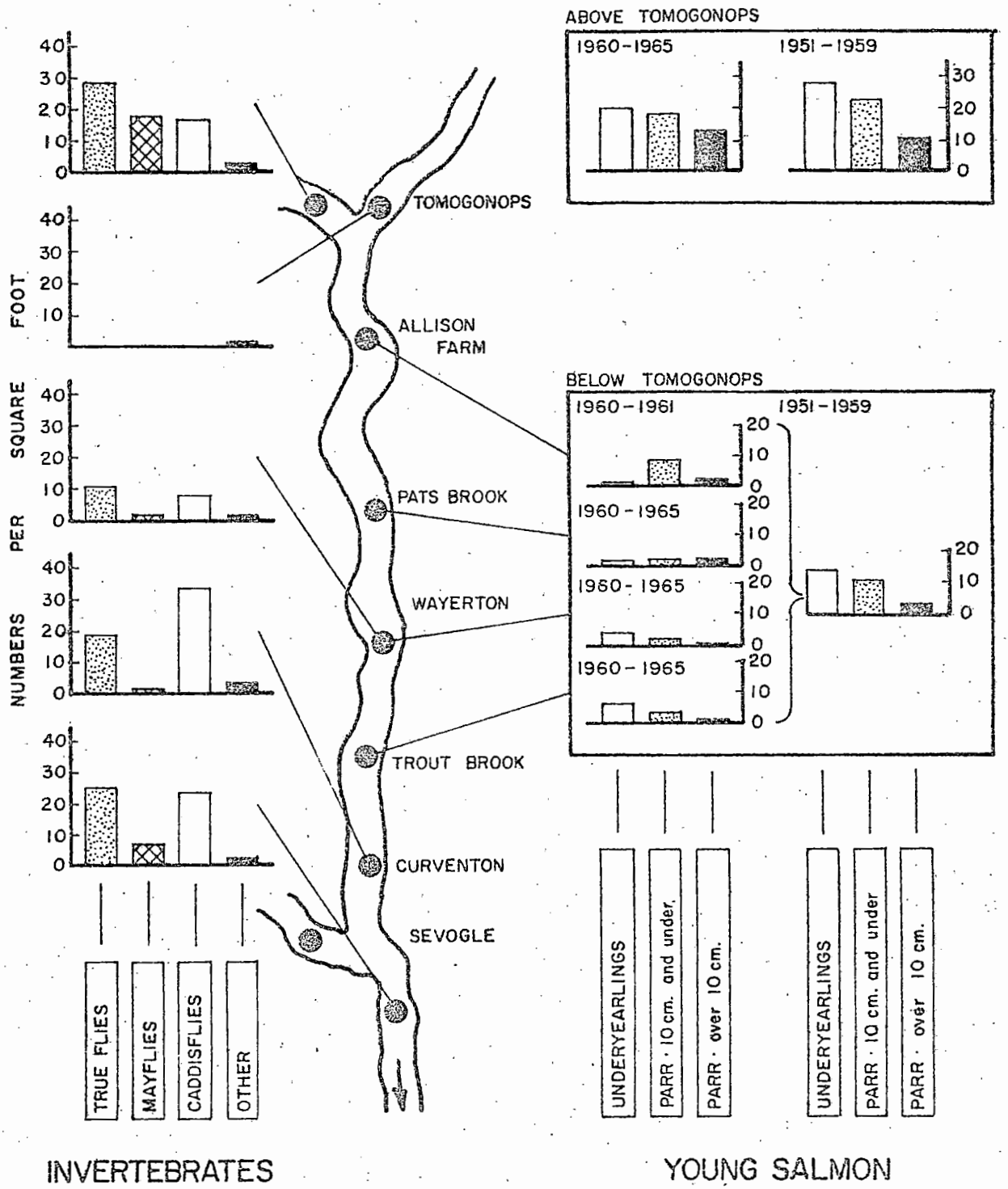

Figure 5. Damage by pollution to fauna of the Northwest Miramichi River. Invertebrate samples taken in July and November 1960; young salmon population estimates made annually in autumn. Histograms for the region above Tomogonops are averages for six stations.

Modified from: Fisheries Research Board of Canada, St. Andrews, N.B. Ann. Rept. and Invest. Summ., 1961: 193.

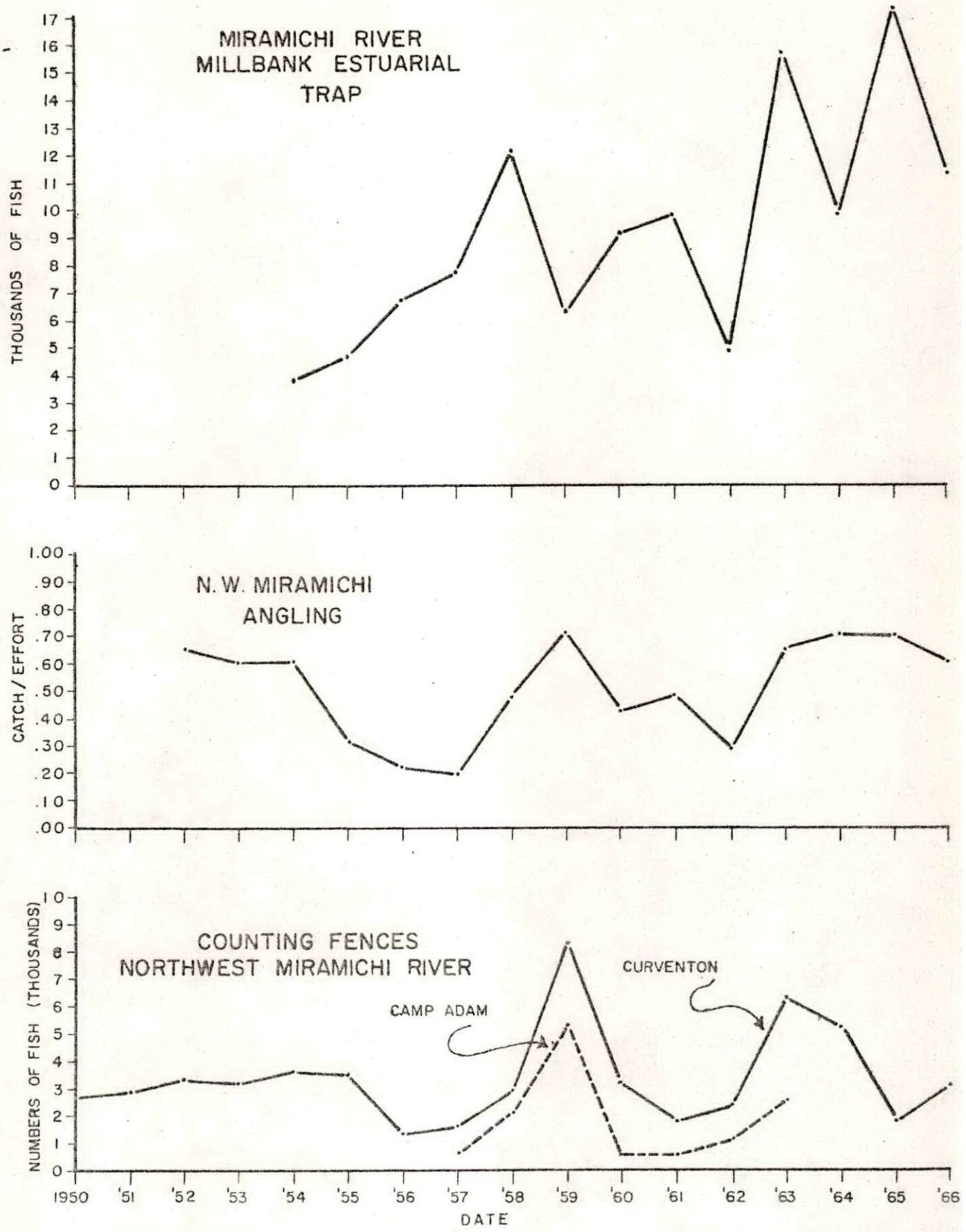

Figure 6. Abundance of Atlantic salmon in the main Miramichi River (estuarial trapping 1954-1966) and in the Northwest Miramichi (angling catch per unit effort 1952-1966 and counting fences; Curventon 1959-1966, Camp Adam 1957-1963).

Table 1 Monthly average of toxic units for mining pollution of Northwest Miramichi River at Curventon, 1960-1966. (from Sprague and Carson 1967)

Year	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Yearly average
1960	-	-	-	-	-	.38	.63	.22	.50	1.3	1.0	.41	.77
1961	.20	.39	.31	.36	.36	.40	.14	.11	.14	.28	.25	.30	.24
1962	.77	.53	.63	.59	.74	.33	.44	.56	.37	.26	.49	.57	.49
1963	.85	.70	.44	.95	1.2	.54	.38	.61	.81	.52	.74	.57	.67
1964	.54	.48	.59	.82	1.0	.43	.24	.29	.32	.45	.63	1.2	.54
1965	.82	.69	.82	1.0	.57	.32	.28	.40	.34	.53	.62	.44	.51
1966	.70	.92	1.7	1.1	.68	.28	.21	.14	.14	.26	.46	.89	.48
Average for all years	.72	.65	.81	.84	.82	.38	.30	.35	.36	.39	.52	.65	.50

Table 2 Average numbers of young salmon per 100 sq. yds. in the Northwest Miramichi River above and below the Tomogonops River tributary, 1951-1965. (Data from P. F. Elson, pers. comm.)
Above Tomogonops: 5 stations except 1951, 4 stations
Below Tomogonops: 4 stations except 1951, 3 stations; 1953, 1958 and 1963, 2 stations; 1954 and 1962, 1 station; 1964 and 1965, 7 stations.

	1951	1952	1953	1954	1955	1956	1957
Above Tomogonops				DDT*			
Underyearlings	39	16	29	0	67	20	20
Small parr	25	22	41	6	0	53	37
Large parr	15	19	20	8	3	1	20
Below Tomogonops				DDT		DDT	DDT
Underyearlings	8	17	8	0	32	2	5
Small parr	7	18	12	1	1	13	4
Large parr	3	5	3	4	1	0	4

*DDT : Forest spraying with DDT.

**P.W. : Partial barrier to salmon spawning migration by pulpwood blockage.

***M.P. : Base-metal mining pollution.

(Continued on next page).

Table 2 (cont'd.)

	1956	1959	1960	1961	1962	1963	1964	1965
Above Tomogonops	P.W.**/DDT			M.P.***				
Underyearlings	7	31	18	9	29	22	19	21
Small parr	24	13	16	20	1	30	21	20
Large parr	10	16	19	16	11	10	21	17
Below Tomogonops	P.W.		M.P.	M.P.	M.P./DDT	M.P.	M.P./DDT	M.P.
Underyearlings	41	15	1	4	8	4	4	5
Small parr	1	30	7	3	1	3	2	0
Large parr	3	2	2	1	0	0	3	1

*DDT : Forest spraying with DDT.

**P.W. : Partial barrier to salmon spawning migration by pulpwood blockage.

***M.P. : Base-metal mining pollution.

Table 3 Movement of adult Atlantic salmon past the Curventon Counting fence, 1954-1966 (Provided courtesy Fisheries Research Board of Canada, Biological Station, St. Andrews)

	Grilse			Large salmon		
Year	No. Up	No. Down	d/u** x 100	No. Up	No. Down	d/u x 100
*1954	2,600	37	1.4	1,081	5	0.5
1955	2,756	58	2.1	778	11	1.4
*1956	775	14	1.8	587	13	2.2
*1957	875	38	4.3	706	7	1.0
1958	2,420	61	2.5	580	12	2.1
*1959	7,355	40	0.5	1,002	11	1.1
*1960	2,775	665	24.0	376	39	10.4
1961	978	85	8.7	866	168	19.4
1962	2,285	246	10.8	224	40	17.9
1963	6,088	897	14.7	309	51	16.5
1964	5,127	219	4.3	146	14	9.6
1965	1,676	162	9.7	113	7	6.2
1966	2,913	27	0.9	111	2	1.8

*Fence washed out for short periods by floods

**d/u = no. down/no. up

Table 4 Fates of tagged adult salmon after they descended through Curventon counting fence, 1960-1963. Data are for recaptures during the same year and do not include a few records for fish caught one or two years later. Percentage to nearest whole number. (from Saunders and Sprague 1967)

YEAR	Tagged salmon descending	Finally reascended	No further record	Caught commercially in Miramichi estuary	Angled in Miramichi below counting fence	Angled in other rivers
1960	156	70 45%	64 41%	5 3%	8 5%	9 6%
1961	54	22 41%	27 50%	3 6%	1 2%	1 2%
1962	133	27 20%	92 69%	6 5%	6 5%	2 2%
1963	734	210 29%	489 67%	10 1%	17 2%	8 1%
Totals	1,077	329 31%	672 62%	24 2%	32 3%	20* 2%

* Of this number 16 were angled in the Sevogle River which is a major tributary joining the Northwest Miramichi ¼ mile below the counting fence.

Table 5 Proportion of grilse run past Camp Adams, by months, 1957- 1963, (after Keenleyside MS, 1961)

Month	1957	1958	1959	1960	1961	1962	1963
June	1.6	10.5	1.3	0.0	8.5	3.2	13.0
July	74.3	76.2	82.4	29.5	59.9	70.3	69.6
August	17.1	8.1	10.9	58.7	22.2	19.5	6.0
September	3.2	3.0	3.7	4.0	6.3	4.9	3.0
October	3.8	2.0	1.4	7.7	3.1	2.0	7.4
November	0.0	0.2	0.2	0.0	0.0	-	0.0
Total number of grilse	560	2033	5202	647	282	1051	2375

Table 6 Comparison of numbers of Atlantic salmon captured by three methods in the Northwest Little Southwest and Main Miramichi rivers, 1954-1966. (a plus sign indicates an increase, a minus sign a decrease)

Location		Number of Fish: Grilse	Large Salmon	Grilse and Large Salmon	Rod-days	Catch per Rod-day	Large Salmon: Grilse Ratio
N.W. Miramichi							
Curventon Fence Counts							
	A*	2797	789	3586			1:3.5
	B*	3121	306	3427			1:10.2
	C*	+12.0	-61.0	-4.4			
Angling	A			3000	6810	.45	
	B			3187	5683	.55	
	C			+6.0	-17.0	+10.0	
L.S.W. Miramichi							
Angling	A			2134	5304	.41	
	B			4660	6960	.62	
	C			+118.4	+31.2	+20.4	
Millbank (Miramichi Estuary)							
Experimental Trap Net	A	3444	3479	6923			1:1.0
	B	8286	1252	9533			1:6.6
	C	+140.6	-64.0	+37.8			

*A Yearly average 1954-1959
B Yearly average 1960-1966
C Per cent change between periods.

Table 7 Numbers of Atlantic salmon counted at Curventon and angled from Northwest Miramichi River, N.B., 1950-1966.

Year	No. Angled	Fence Counts		
	Large salmon and grilse	Large salmon	Grilse	Total
1950	4779	726	1971	2697
1951	3089	812	2183	2895
1952	3565	1307	2142	3449
1953	3718	1033	2165	3298
1954	4103	1081	2601	3682
1955	2446	782	2756	3538
1956	1754	563	774	1337
1957	1221	706	875	1581
1958	3147	580	2420	3000
1959	4617	1002	7355	8357
1960	1707	377	2792	3169
1961	1269	877	954	1831
1962	2039	224	2285	2509
1963	2545	309	6088	6397
1964	4060	144	5117	5261
1965	5604	120	1669	1789
1966	5099	99	2913	3012
Yearly Average	3221	632	2768	3400