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by P.F. Elson
J.R. Mac Donald

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P. F. Elson and J. R. MacDonald

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Methods for evaluating damage, by New Brunswick forest spraying programs, to salmon fisheries

by

P.F. Elson (Fisheries Research Board of Canada, St. Andrews)

and

J.R. MacDonald (Resource Development Service, Department of Fisheries, Halifax)

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C O N T E N T S

Introduction

How aerial spraying of New Brunswick forests against spruce budworm damaged Atlantic salmon production from streams in treated catchments has been reviewed by Elson and Kerswill (1966). In the same account the authors describe recent modifications in procedure which somewhat alleviate but do not eliminate these undesirable side effects.

After several years of spraying and just before there was opportunity for expected drastic effects to appear in salmon fisheries, an attempt was made to forecast the probable magnitude of these effects on salmon angling in several of the sprayed rivers (Kerswill, 1958). Spray damage to salmon fisheries, especially the sport fishery, has been identified (Elson and Kerswill, 1964) but factually based economic evaluation of this cost of the new forest conservation operation has not yet been attempted.

With no specific termination of spray programs in sight, it is not surprising that a need is now recognized for assigning an economic value to this debit against the forest spraying operation. The present analysis contributes to such an objective by offering methods for estimating numbers of full grown salmon lost to fisheries and spawning stocks. The spray program proposed for 1966 is used as an example.

One of the difficulties attendant upon such evaluation springs from the wide range of natural fluctuations in catches of Canadian Atlantic salmon (Figure 1). The first extensive effects of forest spraying, in the mid-fifties, came just after one of the lowest points in the history of the fishery (Elson, 1957a) and at a time when it appeared to be rising similarly to the trend on the Gulf of St. Lawrence coast of Newfoundland (Elson and Kerswill, 1964). Effects of spraying could thus function not only to depress normal catches but also, more tenuous to identify, by suppressing what might well have been a rising trend.

Two methods of evaluating damage to salmon stocks are offered here. Both hinge on damage to young stocks identified in research programs. The first method develops the manner in which the mortality factor to young is carried over into adult stocks and concludes with estimates of numbers of fish which will be lost to sport and commercial fisheries as well as to spawning escapements. No attempt is made to adjust for possible changing trends rooted in natural factors. The second method develops estimates of the numbers of young killed directly by the spray. This can in turn be used for estimating damage on an economic basis by taking account of the cost of providing artificially reared young to replace the losses.

An example of the chain of events that must be considered in evaluating relations between young salmon populations and harvest of mature fish is incorporated in the work tables accompanying this analysis (Tables I-V for the first method; Table VI for the second method). Final estimates of damage are to be found in Table V (columns 21 and 22) and in Table VI (columns 13, 14 and 15).

The 1966 spray program

Tentative plans, developed in the winter of 1965-66, were to spray some 1.6 million acres of central New Brunswick forest in 1966. The approximate area is outlined in Figure 2. The general spray was to be two applications, each of $\frac{1}{4}$ lb DDT/acre, in oil. A band, $\frac{1}{4}$ mile wide on each side of main-stem streams and tributaries equivalent to the lower and wider one-fifth of the total length of permanent tributary streams (i.e., excluding intermittent parts), would be protected against DDT by spraying, instead, an aqueous Phosphamidon solution. This was to be more or less a repetition of the 1965 operational technique. Stream sections sprayed that year were those reasonably identifiable to spraying pilots and not presenting undue flight hazards. Measurement of protected and unprotected proportions of tributaries was made by later reference to Government of Canada maps (1:50,000 scale). This spray plan had been adopted by the spraying agency as a practical compromise between earlier fisheries research findings and considerations of pilot safety, costs of application, effectiveness for budworm control, etc.

Two obstacles to an accurate forecast of 1966 spray damage to salmon were inherent in the planning. First, dependent on up-dated spring analysis of budworm infestation, the area to be sprayed might be increased by 25%. Second, an unstipulated portion with heavy infestation and away from larger streams might receive two 1/3 lb DDT/acre applications.

Effects of forest spray on indigenous young salmon

Annual variations in population densities of young salmon in a number of New Brunswick streams have been measured by electroseining sample areas and survival values have been calculated (Elson, 1957b; 1962, in preparation; Elson and Kerswill, 1964; 1966). For the unsprayed condition, underyearling fish average about 24 per 100 sq yd of stream bottom, small parr (10 cm = 4 inches and under in total length and usually yearlings) about 20 and large parr about 12. These densities, together with densities found under various conditions of forest spray application are shown in Figure 3.

Effects of the proposed 1966 spray program on indigenous populations of young salmon will be of two kinds. They will be most severe in those salmon-rearing areas which are above zones of Phosphamidon protection. Here, expected effects are about a 90-98% kill of underyearlings; a 70% kill of small parr usually between 1 and 2 years old, and a 50% kill of large parr. Effects on smolts, if the spray should be applied during the last 2 weeks of May or the first few days of June, have not been measured. They would probably be at least equivalent to effects on large parr but are not considered here because in the past most spraying has been done after the majority of smolts have migrated to sea.

Within areas given the kind of Phosphamidon protection outlined above, the effects are expected to approximate those observed with general application of $\frac{1}{4}$ lb DDT/acre but no Phosphamidon protection. This means about a 50% kill of underyearlings, a 20% kill of parr under 10 cm, and little if any effect on larger parr.

Electroseining studies have shown that young salmon are frequently killed a considerable distance down stream from the actual zone of spray deposition. This is presumed to be at least in part because the oil carrier deposited on water above floats down stream. Some DDT may pass into solution during this drift. But some of the oil mixture gets churned to the bottom in areas of even minor turbulence. It adheres to bottom objects like moss and sticks and may even work into interstices between stones. This has been seen in experimental sprayings when the oil vehicle was dyed red. The actual downstream extent of such effect seems to depend partly on the type of flow, partly on the amount and location of influent unpoisoned tributary water, and doubtless depends in part on the total area of stream within spray zones.

The mortalities described above occur soon after application of the insecticides and within 4 months at most. There is also substantial delayed mortality in the first winter after spraying (Elson and Kerswill, 1966). Such conspicuous winter mortality has not been observed under natural conditions. In an experiment with parr collected from a stream sprayed at ½ lb DDT/acre, then, in the laboratory, subjected to rapid chilling (52°F to 34°F in 24 hours) 80% of the fish died in 8 days, but there was no mortality among controls. The proportionate effect of such mortality in nature has yet to be measured. Its severity probably depends on the amount of sublethal exposure to DDT and on indirect effects, like starvation, etc., which the fish may have experienced. This delayed mortality has not been introduced into the present analysis because of lack of quantitative information.

First method - calculated effect on adult stocks

For this method the difference in treatment between the upper salmon-rearing reaches of tributaries not protected by Phosphamidon and the larger protected rearing areas below will be ignored. Entire river systems will be regarded as sustaining damage at levels associated with single spraying at $\frac{1}{4}$ lb DDT/acre. (Such unprotected reaches amount to about 10% of the total salmon-rearing area.)

The series of procedures used in computing effects on adult stocks follows. Tables I-V show the step-by-step computations applied to each stream. A. Essentially the same procedures developed in 1957 (Kerswill, 1958) to predict percentage effects of $\frac{1}{2}$ lb DDT/acre spraying on adult salmon of a number of New Brunswick streams have been followed in Tables I-III. B. An attempt to translate proportionate damage of stocks into actual number of fish, developed in Tables IV and V, is new.

A. Allocation of percentage damage to adult stocks

Step 1. Immediate loss to young (Table I). A map (1:500,000 scale) of the spray plan (Figure 2) was examined to determine the area sprayed in each catchment basin.

Column 1 - the proportion of the stream system included within the area.

Column 2 - the relative upstream or downstream location of the sprayed area was noted. Depending on this location and on the amount of unaffected tributary water entering below, a downstream effect, similar in severity to that within the area, was allocated to as much as 20 miles of the main stem below.

Column 3 - the relation of the damaged area (included plus downstream) to the total salmon-rearing area of the system was estimated on the basis of map measurements modified, where possible, by personal familiarity with the physical nature of the stream.

Columns 4 and 5 - the proportion of rearing area damaged was multiplied by the effect of spray patterns on particular stages of young salmon (see Figure 3 - with $\frac{1}{4}$ lb DDT/acre, 50% mortality for underyearlings and 20% for small parr) to arrive at an estimate of proportionate immediate loss in the total rearing area of the system. For the 1966 spray, since only underyearlings and small parr are likely to be greatly reduced, only two columns are necessary. Some probable kill of large parr in small tributaries not given Phosphamidon protection is ignored, as also is a heavier kill of smaller fish in these upper areas. For the earlier computations (Kerswill, 1958; Elson and Kerswill, 1964), which involved ½ lb DDT/acre spraying with no Phosphamidon protection, three factors and three columns were used at this stage - 90% mortality to underyearlings, 70% to small parr, and 50% to large parr.

Step 2. Consequent loss to smolt runs (Table II).

Columns 1 and 2 - overall mortality rates for the affected size-groups (= in general, age-groups), as applicable to each stream system, are transferred from Table I, columns 4 and 5.

Columns 3 and 4 - the next step is to allocate proportions of 2-year-old and 3-year-old smolts to each year's run. This is done on the basis of scale examination for smolts belonging to a river, or of adult stocks taken in the freshwater reaches, where such information is available. More often proportions must be allotted on the basis of similarity of stream conditions, especially summer water temperature and basic fertility to streams for which smolt age data are available. For this, personal acquaintance with the streams to be assessed is used when available; when not, arbitrary values are assigned on the basis of location and geological conformation of catchments (Elson and Kerswill, 1966). In general, New Brunswick streams rising in the central highlands are cooler, less productive, and produce a high proportion of 3-year smolts; whereas streams entirely within lowland areas tend to be warmer, may have more food in salmon-rearing reaches, and appear to produce a high proportion of 2-year smolts.

Columns 5, 6 and 7 - mortality rates are combined with smolt ages to give an estimate of overall effect on smolt runs the year after spraying.

Columns 8, 9, 10 and columns 11, 12, 13 - similar procedures are used to calculate the effects on succeeding smolt runs until spray effects disappear.

Columns 7, 10 and 13 thus give a measure of effects of a single year's spraying on each of the three following affected smolt runs.

Note that Table II assumes a single year's spraying on the streams. When spraying is repeated in an additional year or years within the freshwater life-history of a year-class, as pertained to the earlier evaluation (Kerswill, 1958; Elson and Kerswill, 1964), it is necessary to add appropriate computations of further mortality for each spraying.

Step 3. Consequent loss to adult stocks (Table III).

Columns 1, 2 and 3 - proportionate reduction of smolt runs, as derived from Table II, columns 7, 10 and 13, are entered in Table III. The 1966 spraying effect will be spread over smolt runs in 1967, 1968 and 1969.

Columns 4 and 5 give the relative proportions of mature salmon returning to the rivers as grilse or salmon. These proportions have been allotted, where possible, on information provided by Department of Fisheries' records of grilse versus large salmon taken by angling or passing through those fishways in which such information is recorded. Grilse return in the year following smolt descent. In the New Brunswick area under consideration, most larger salmon return after 2 years at sea. The comparatively small contribution made by 3-sea-year and older salmon has been ignored in this analysis, as has also been the contribution of respawners (generally under 5 to 10% of the total).

Columns 6, 7 and 8 indicate the losses, respectively, of grilse and salmon to be expected, in 1968, from the first affected smolt run, and the magnitude of loss to the total run for the year in comparison to what the run would have been in the absence of any spray effect.

Columns 9, 10 and 11 give proportions of grilse and salmon and total estimated percentage reduction in stock for the second affected crop of adults, in 1969.

Columns 12, 13 and 14 give the grilse-salmon breakdown and total estimated percentage loss for the third adult crop, in 1970.

Columns 15, 16 and 17 give the same values for the fourth and last crop to be directly affected by the 1966 spray program, in 1971.

A test of predictions based on percentage loss of young

Prediction of the effects of 1952 to 1958 sprayings was carried through only the above phase of computations. Effects were expected to be exerted through 1962 returning runs and most noticeably on the 1960 to 1962 runs into rivers. With stocks in violent natural fluctuation, the predictions for reduction could be difficult or impossible to verify. In fact, New Brunswick Atlantic salmon stocks were apparently holding at a fairly constant level. Observed angling catches in the affected years followed the course of predictions moderately well (Figure 4). Two noticeable exceptions, however, were the Northwest Miramichi River and the Upsalquitch, a large tributary of the Restigouche system. In both these streams much higher proportions of grilse than had been anticipated returned in 1958 and subsequently. For the individual streams and systems shown, the correlation coefficients for estimate and catch are about 0.5, suggesting that about one-quarter of the variability in catch was directly related to effects of spraying. Probabilities of the individual relations shown occurring purely by chance lie between 1 in 5 and 1 in 20. The probability of <u>all</u> these relationships appearing simultaneously by chance is less than 1 in 1000

(Elson, unpublished, a). For the Tobique River, where reliance could be placed on counts through a fishway at the mouth of the river, the correspondence between expected and observed trends was particularly close (Figure 5).

B. Conversion of percentage loss into numbers of returning fish

Reference to Figure 1 will show the risk inherent in assuming that one year's commercial catch of Atlantic salmon will resemble the next. Figure 6 illustrates equally well the pitfalls attendant on assuming that the magnitude of catch in any one year will reflect the catch in the parent generation (on the average, 6 years before) or be reflected in the catch of the next generation (Elson, 1957a). While there have been both short- and long-term trends in previous catches, these are not so well defined that there appears to be much better basis for any kind of short-term prediction than immediately preceding short-term averages.

In converting the percentage loss of adult stocks, caused by the 1966 spraying, to numbers of fish, averages of two recent series of catches were used.

Angling catches served as a guide to adult populations entering rivers and to allocate contributions of specific rivers to commercial catches. Relative angling catches, between Miramichi streams especially, became seriously unbalanced about 1959 as a result of earlier forest spraying. Hence, data for the 10 years from 1949 to 1958 were used in this series.

Estimates of contribution to commercial fisheries were based on the assumption that the 1949-1965 average commercial catch is a reasonably valid representation of recent unaffected catches. That this is not strictly true is indicated not only by angling catches but also by the fact that commercial salmon catches in the estuary of the Miramichi, one of the most affected systems, dropped to comparatively low levels between 1959 and 1962, the years when the early spraying should have exerted its worst effect. These estuarial catches were as follows (in '000 lb):

1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
103	155	162	108	104	69	86	108	152	146

However, some offshore catches between 1959 and 1962 involving both Miramichi and other fish were sufficiently good throughout this period that the 1950-65 average total commercial catch for the area differs by only about 10% from the average if questionable years for the Miramichi are removed. (Break-down into estuarial and offshore catches is not available for 1949.)

The above averages were used to provide bases for estimating numbers of fish lost as a consequence of spraying. Relations computed for the Miramichi system were used as a basis for evaluating relative contributions to fisheries of all affected streams. The steps used for developing estimates of salmon stock produced by individual systems are shown in Table IV.

Step 1. Estimation of adult river stocks from angling catches (Table IV, columns 1-6).

Column 1 gives the average annual catch of salmon by angling, from Department of Fisheries records.

Column 2 gives an estimate of the average total population of mature grilse and salmon entering rivers each year. Published records of angling catch in relation to river population indicate approximately these average rates of exploitation: Margaree River about 20% (Hayes, 1949); LaHave River about 30% (Hayes, 1953); Tobique River about 20% (Elson and Kerswill, 1964). In streams for which there are records of angling catch, total river population was estimated as 4 x the catch by angling. For the Bartholomew, with no reported angling, the tabulated figure is the run recorded, by the Department, through the fishway at the mouth of this river in 1965, this being the first year for which such records are available. For the Tobique, Department records of entry through the fishway at the mouth are available from 1953 on. For the years from 1957 through 1962, Tobique entry was low primarily as a result of forest spraying in 1953-58 (Elson and Kerswill, 1964). Fishway records for 1953 to 1956, years before serious spray effect, and for 1964 and 1965, by which time all direct effect of the spray had passed off, have been combined with sport catch records for 1949 to 1952. The latter, rather than being treated as 25% of the angling catch, have served as a basis for estimating river populations in these earlier years by reference to the Elson-Kerswill 1953-1962 curve relating angling success to numbers of fish in the river. For several streams neither angling nor fishway records are available. For these an arbitrary figure for total river population has been assigned on the basis of physical similarity to streams for which records are available.

Columns 3 and 4 give the proportions of grilse and salmon recorded in angling and fishway records, if available, or if not available, guessed by reason of similarity of streams to others for which records are available.

Columns 5 and 6 - using the estimates of total river population in column 2 and the proportions of grilse and salmon in columns 3 and 4, estimates of the numbers of grilse and of salmon in each river population have been calculated as in columns 5 and 6.

<u>Step 2. Allocation of river contributions to Miramichi commercial fisheries</u> (Table IV, columns 7 and 8).

Streams of the Miramichi system contribute to both sport and commercial fisheries. More data relating to contributions to fisheries have been gathered here than for most other Canadian Atlantic salmon rivers. It is possible, because of proximity to an intensive commercial fishery in the large Miramichi estuary, that these stocks may be more heavily exploited than others. However, in the absence of more specific data, it will be assumed for the present purpose that exploitation here represents the general situation. Streams of the Saint John system also contribute to intensive fisheries located in the area of river discharge through estuary and into the Bay of Fundy, so the assumption of similarity to the Miramichi condition seems reasonable here, too.

The average recorded annual sport catch of salmon and grilse in the Miramichi system for 1949-1958 was 33,196 fish. Assuming the catch was 25% of the total river population, this implies yearly runs of about 135,000 fish into the system.

Column 7 - the percentage which the estimated river population of each Miramichi stream (column 2) contributes in the total Miramichi river population is listed under column 7.

A breakdown of the sport catch for that part of the Miramichi lying in Northumberland County (and which provides substantially more than half of the sport catch) shows 80% grilse and 20% salmon. Transferring this percentage to the total Miramichi river population, it should include 27,000 2-sea-year and older large salmon.

Column 8 - the percentage of large salmon which each tributary contributes to the total river population of large salmon is taken as the percentage which its estimated annual run of large fish (column 6) contributes to the total Miramichi river population of 27,000. These percentages are listed in column 8.

Step 3. Estimated river contributions to commercial fisheries (Table IV, columns 9 and 10).

The next step is to derive an estimate of river contributions to commercial fisheries. As for Step 2, data from the Miramichi system seems, with the present state of knowledge, best adapted for developing standards useful for the immediate objective. Relations estimated for the Miramichi are used as a standard for other streams.

Commercial landings of Atlantic salmon in Canada are reported by weight. Regulations of commercial fisheries in the Maritimes (this excludes Newfoundland) are such that few salmon under 2-sea-years of age are landed. Because the present analysis deals largely with numbers of fish, landings are given as equivalent numbers of 10-lb salmon. This may be as much as 20% below actual numbers involved, but data to improve the conversion are lacking.

The fact that some New Brunswick salmon landed in Newfoundland and Labrador fisheries are taken as grilse rather than 2-sea-year salmon is here ignored. Relations, given below, between Miramichi fish caught in a substantial segment of the Maritime fishery and in the Newfoundland-Labrador fishery are based on comparative numbers of marked fish caught in both areas (Kerswill, 1955); hence are not subject to error arising from conversion of weight to numbers. But the distant captures do involve some grilse and may introduce errors related to survival at sea into the comparison. Again, however, these are the best data available at the present time.

Contributions of the Miramichi system to commercial fisheries are estimated as follows:

The average annual (1950-65) catch in the Miramichi estuary, probably almost entirely salmon of Miramichi origin, was 11,210 fish.

The average annual take by offshore drift-nets (1950-65) was 23,940 fish. Formerly, about one-half of the drift-net catch was of Miramichi origin and half of Bay of Chaleur and Quebec origin, according to an analysis of 1937 catches in this fishery (Belding and Prefontaine, 1939). An examination of reported commercial recapture, as adults, of smolts marked in the Northwest Miramichi River in 1951 shows almost identical numbers taken in the Miramichi drift-net fishery and in more distant fisheries, chiefly in Newfoundland and Labrador (Kerswill, 1955). Hence, total Miramichi contribution to commercial fisheries is estimated as:

$$\text{estuarial catch} + \frac{\text{drift-net catch}}{2} + \text{a number equal to } \frac{\text{drift-net catch}}{2}$$

Using the above average values, this amounts to the equivalent of 35,150 10-lb fish.

Column 9 - assuming stream contributions to commercial fisheries are at ratios similar to their contributions of large salmon in the overall Miramichi large salmon population, as shown in column 8, commercial contributions are computed as in column 9.

As calculated above and in Table IV, column 9, the contributions of Miramichi streams to commercial fisheries amount to 1.3 x the estimated river populations of large salmon, including those taken by angling.

An interesting by-product of the present exercise is, therefore, the suggestion that the rate of commercial exploitation of Miramichi large salmon is expressed by the ratio $\frac{35,000}{27,000 + 35,000}$, a rate of about 55%, and angling plus commercial exploitation by $\frac{5,000 + 35,000}{27,000 + 35,000}$ or about 65%. Similarly, exploitation of grilse and salmon, together, by both sport and commercial fisheries would be $\frac{33,000 + 35,000}{135,000 + 35,000} = 40\%$

Column 10 - for streams not in the Miramichi system, contributions to commercial fisheries are assumed to bear the same relation to their estimated river populations of large salmon (i.e., 1.3x) as is estimated for Miramichi streams. These values are listed in column 10.

Step 4. Estimated total salmon production, by rivers (Table IV, columns 11-15).

At this stage only a little rounding of estimated values is introduced into computations. Angling catches have been rounded to 10 fish; commercial catches to the nearest 50 or 500 fish, depending on numbers involved, and spawning escapements are derived by subtraction of columns 11 or 12 from estimated river populations appearing in columns 5 and 6.

Column 11 gives an estimate of average annual yield of grilse to anglers, computed by combining columns 1 and 3.

Column 12 gives an estimate of average annual yield of large salmon to anglers, computed by combining columns 1 and 4.

Column 13 gives the estimated average commercial yield expressed as numbers of 10-lb salmon.

Column 14 gives an estimate of grilse in the average spawning escapement.

Column 15 gives a similar estimate for large salmon.

Step 5. Effect of loss of adult stocks on sport and commercial fisheries and on spawning escapements (Table V).

Data for developing estimates of the losses of adult fish to each of the sprayed streams are in Tables III and IV.

Losses will be spread over the 4 years from 1968, the first year of effect on grilse, to 1971, the last year of noticeable effect on 2-sea-year salmon. In no case do they appear likely to be of such great magnitude, i.e., all losses are under 50% (Kerswill, 1958), as to have recognizable direct reflection in a second generation as a consequence of dearth of spawners (Elson, 1962). Table V lists calculated losses by years and rivers. Suggestions for rounding values are given later in the text.

Procedure for arriving at the values in Table V was to multiply the average annual number of grilse or salmon taken in fisheries or available as spawning escapement (Table IV, columns 11-15) by the appropriate percentage loss for grilse or salmon (Table III, columns 6 or 7 for 1968; columns 9 or 10 for 1969; 12 or 13 for 1970 and 15 or 16 for 1971). As an example, for the Tabusintac in 1970, the loss of large salmon to the sport fishery is computed as 10% (Table III, column 13, row 1) of 1,310 (Table IV, column 12, row 1) = 131 fish.

Estimated total losses of grilse and salmon to each river over the 4-year period are given in the two right-hand columns of Table V.

Overall estimated losses for each year, as grilse and salmon, are given at the foot of the table, as direct sums of the columns for a year.

Any attempt such as this, which involves prediction of populations several years in advance, must surely include unrecognized as well as recognized errors. It is suggested that confidence to be placed in the estimates developed in Tables I through V does not warrant accuracy beyond one significant digit. For the purpose of economic evaluation of these losses they might be expressed as follows:

Loss to sport fisheries	Loss to spawning escapement	Loss to commercial fishery
10,000 grilse	40,000 grilse	equivalent to
1,000 salmon	3,000 salmon	5,000 10-lb salmon
10,000 fish	40,000 fish	50,000 lb

Estimates of loss to fisheries are computed on actual records of catch and are considered acceptable to one significant figure, as given. But estimates of loss to spawning escapement depend both on records of catch and on the assumption of a 25% exploitation by anglers; they are therefore much less precise than estimates of loss to fisheries. It is suggested that an appropriate degree of confidence to be placed in the estimates of loss to spawning escapement would be one-half to double the numbers derived by computation, i.e., loss of spawners = 20,000 to 80,000 fish and total loss = 40,000 to 100,000 fish.

Second method - hatchery stock needed to replace wild young salmon killed by spray

A. Estimation of loss from spraying

For the second method, only early, direct losses of young attributable to spraying will be considered. As described on pages 5-6, there are other losses apparently associated with the impact of certain natural stresses on fish which have survived but been weakened by exposure to the spray. There is reason to believe that such delayed and indirect mortalities can be substantial, but until better quantitative data are available, it would be difficult to bring them into an accounting.

For the second method, no attempt is made to relate losses due to spraying to adult production from streams.

Data pertinent to each step are assembled in Table VI where the final estimates appear at the bottom of columns 13-15.

Step 1. Determination of rearing area protected by Phosphamidon (Table VI, columns 1-5).

The method depends on an assumption that under normal conditions populations of young salmon are spread rather evenly over the length of a stream. Densities found at different places in any one stream have varied over a wide range. But commonly the average value for 3 or more stations selected in characteristic young salmon habitat of one stream resemble the average for another. The first step, then, is to assign a value for areas of stream bottom affected by spray.

No New Brunswick salmon streams have been completely surveyed and catalogued in respect to area of young salmon rearing habitat, although partial information is available for many. However, by using topographic and geological maps coupled with individual acquaintance with some streams, figures have been assigned which should have utilitarian value.

Main-stem streams in the area under consideration usually have average widths of 30-50 yd. Such streams frequently have tributaries as much as 20 yd wide, or even wider at their confluence. Based on intimate knowledge of one system, tributary widths average about 15 yd for 20% of total tributary length, about 7 yd for 30% and about 2 yd for 50%. These standards, modified by personal acquaintance with some streams, and by consideration of the parts of streams within spray zones have been used here for calculating rearing areas.

In the spray plan for 1966 the upper, narrow parts of tributaries, which still provide some young salmon habitat, were not expected to receive Phosphamidon protection but would get a total application of ½ lb DDT/acre. For this reason, areas in the smaller streams are computed separately and a different kill-factor is employed. (In the first method no such distinction was employed, which could contribute an error of about 10% on the low side.)

Columns 1 and 2 - these give the estimated length (miles) of streams having average widths of 7 and 15 yd respectively within spray zones.

Column 3 gives the length and average width of main stem within spray zones.

Column 4 - as described on page 5, the killing effect of spraying DDT-in-oil extends some distance down stream. This downstream effect, in length (miles) and width (yards), has been assigned under column 4.

Column 5 - the total stream area within spray zones, plus the area affected by downstream transport of spray, is listed under column 5. Values have been rounded to the nearest 1,000 sq yd (approximately 0.2 acre).

For the Canaan River, much of the area is known to be marginal for young salmon because of high summer temperatures and physical habitat characteristics. Nevertheless, it is known to rear some salmon. So for this stream, adjustment has been made by reducing the allowance for width of stream to about one-tenth of its actual value.

Step 2. Numbers killed in protected areas.

Column 6 - using the values for unsprayed and sprayed population densities as outlined on pages 4-5, the total loss of underyearling salmon for each stream, within and below spray zones, is calculated as 50% of 240 x area in thousands of square yards. Values are given to the nearest 1,000 fish.

Column 7 - similarly, losses of parr of 10 cm (4 inches) and less total length are calculated as 20% of 200 x 1,000 yd^2.

Step 3. Determination of unprotected rearing areas in tributaries.

Columns 8 and 9 - the length of tributary stream not expected to receive Phosphamidon protection is given in column 8 and the rearing area involved, at an average width of 2 yd, appears in column 9.

Step 4. Numbers killed in unprotected tributaries.

For these upper tributary reaches, the rates of kill are expected to be higher than in those parts given a Phosphamidon safe-guard strip (pages 4-5). Moreover, in contrast to the lower reaches where it is not anticipated that parr over 10 cm long will be killed, experience has shown that a substantial proportion of large parr will be killed (Figure 3).

Column 10 - losses of underyearlings in these upper tributary reaches are estimated as 90% of 240 x 1,000 yd^2.

Column 11 - losses of small parr (10 cm and under) are estimated as 70% of 200 x 1,000 yd^2.

Column 12 - losses of large parr (over 10 cm) are estimated as 50% of 12 x 1,000 yd^2.

Step 5. Total losses of young salmon.

Total losses for each of the 3 size-groups of young salmon are obtained by adding losses in protected and unprotected areas as follows:

Column 13 - for underyearlings, add values under column 6 and column 10.

Column 14 - for small parr, add values under columns 7 and 11.

Column 15 - for large parr, values under column 12 are transferred to column 15.

Overall totals for the 1966 spray plan are given at the foot of each column.

Total losses of young salmon, as given in Table VI, columns 13, 14 and 15, should probably be rounded to one significant digit, as follows:

Underyearlings	Small parr	Large parr
4,000,000	2,000,000	100,000

B. Calculation of hatchery stocks needed to replace loss

The losses cannot be expressed directly in terms of replacement by hatchery-reared stock. Studies have shown that because of mortality factors associated with adaptation to their new environment, the relative requirements of hatchery to native stock of equivalent size are about 2.5:1.0.

Reducing this to simplest terms, about 3 hatchery-reared late-summer underyearlings are required to replace 1 established native underyearling. About the same ratio has appeared for parr, even those of a late-autumn pre-smolt stage (Elson, 1957c).

For replacement directly by hatchery-reared smolts, the best procedure would seem to be to estimate requirements in terms of the number of salmon to be replaced, assuming conversion of smolts to adults at a rate of between 5 and 10%. Approximately this range of survival has been reported for wild smolts in Canada (Elson, 1957a). Most Canadian liberations of hatchery-reared smolts have given only a small fraction of this rate. But using the best material and techniques, a survival rate of 5% or a bit more from hatchery-reared smolts appears possible (Elson, unpublished b). At a 5% rate from smolts, the 40,000 to 100,000 grilse and salmon lost as a result of spraying would require replacement by something between $\frac{3}{4}$ million and 2 million hatchery-reared smolts.

Discussion

It is the authors' hope that this analysis can serve more than one purpose.

Its immediate objective is to provide alternative bases for introducing one cost of a proposed New Brunswick forest spraying operation, that involving damage to salmon in sprayed rivers, into a general cost-benefit analysis of the operation. The costs in salmon as estimated here are believed to incorporate the most complete quantitative information now available.

While we believe that the final results offered here are realistic, it is obvious that there is room for improvement of basic data on a number of points. A cataloguing of stream systems, including their tributaries, in respect to physical characteristics and salmon rearing potentials would be useful. As newer spraying techniques and formulations decrease initial mortality, the need for quantitative evaluation of delayed mortality, secondary mortality and sublethal effects assumes increasing importance. Better information on life histories pertinent to particular streams would assist evaluations. Proportions of smolts in different age groups and proportionate returns of smolts as grilse or larger salmon comprise key information for such management efforts. There is need for much more information of this kind for nearly all river systems.

Development of the estimates given here has been presented in detail sufficient to indicate how similar evaluations might be made of past or future programs. The type of approach should also be profitable in attempting to assess effects of other man-made or natural factors operating within river systems, which may control abundance of Atlantic salmon, whether these tend to decrease or improve production.

Summary

Two methods for evaluating the harmful effect of recent New Brunswick forest spraying programs on salmon production from sprayed streams have been described. Both are illustrated using the proposed 1966 forest spraying program as an example.

Suggestions are offered for improving background data useful for such evaluations. Similar methods could be applied to evaluating changes brought about by other artificial or natural alteration in environmental conditions.

Losses of mature fish from the 1966 program will be spread over 4 years - 1968 to 1971.

They will amount to between 40,000 and 100,000 (possibly around 60,000) grilse and salmon, in all. Losses will be distributed approximately as follows: to anglers - 10,000 grilse and 1,000 larger salmon; to commercial fishermen - 50,000 lb; to spawning escapement - 20,000 to 80,000 (possibly around 40,000) grilse and larger salmon.

These losses are much lighter than those which must have followed some of the 1952-1958 spray programs. It is doubtful that within the ordinary trends of fisheries the 1966 losses will be positively identifiable as directly attributable to spraying. They will be present none the less.

Immediate loss of young, which might provide a standard for cost in terms of replacement from hatchery stocks, will be approximately 4 million underyearlings, 2 million parr

under 10 cm (4 inches) long and 100,000 larger parr. Replacement for each of the size groups should be at a ratio of 3 hatchery fish planted for each wild fish destroyed, i.e., 12 million underyearlings, 6 million small parr and 300,000 large parr.

Hatchery replacement designed to compensate the loss could theoretically be made in 1966; or it might possibly be spread over 3 years, 1967 to 1970, by supplying over this period not less than about one million (actual computation, ¾ million to 2 million) smolts to the various streams.

Acknowledgements

We take this opportunity of thanking those members of the Maritime staffs of the Fisheries Research Board and the Resource Development Service (formerly Fish Culture Development Branch) of the Department of Fisheries who have, over the past sixteen years, assisted in the assiduous gathering and organization of data pertinent to young salmon populations and the effects on these of forest spraying. We are grateful to our colleagues in these organizations who have supported these efforts and offered helpful advice along the way. We also acknowledge the ready co-operation of the Department of Forestry of Canada and of Forest Protection Limited, without which much of the background research would not have been possible. The authors, however, accept responsibility for the validity of the data used and for interpretations placed on the analyses.

References

Belding, David L., and Georges Prefontaine. 1939. Studies on the Atlantic Salmon - III. Report on the salmon of the 1937 Miramichi (New-Brunswick) drift-net fishery. Contributions de l'Institute de Zoologie de l'Université de Montreal, No. 4.

Elson, P.F. 1957a. The role of hatcheries in assuring Maritime stocks of salmon. The Canadian Fish Culturist, No. 21, pp. 25-32.

1957b. Number of salmon needed to maintain stocks. The Canadian Fish Culturist, No. 21, pp. 19-23.

1957c. Using hatchery-reared Atlantic salmon to best advantage. The Canadian Fish Culturist, No. 21, pp. 7-17.

1962. Atlantic salmon can be maintained in Maritime rivers. Atlantic Salmon Journal, No. 2, June 1962, pp. 16-18.

(in preparation). Effects on wild young salmon of spraying DDT over forests. J. FRB, April 1967, Vol. 24(4).

(unpublished a). Effect of forest spraying on salmon angling. Fish. Res. Bd. Canada, Biol. Sta., St. Andrews, Annual Report for 1961-62, pp. 162-164.

(unpublished b). Good returns in 1964 from planted hatchery smolts. Fish. Res. Bd. Canada, Biol. Sta., St. Andrews, Original MS No. 1005, pp. 18-23.

Elson, P.F., and C.J. Kerswill. 1964. Forest spraying and salmon angling. The Atlantic Salmon Journal for 1964, No. 3, pp. 20-29.

Elson, P.F., and C.J. Kerswill. 1966. Impact on salmon of spraying insecticide over forests. Third International Conference on Water Pollution Research, Munich, Germany, Sept. 5-9, 1966. Preprint. (Abstract in J. Water Pollution Control Federation, March 1966.)

Hayes, F.R. 1949. II Margaree River report of the consultant on inland fisheries for 1949, pp. 19-30.

1953. Artificial freshets and other factors controlling the ascent and population of Atlantic salmon in the LaHave River, Nova Scotia. Bull. Fish. Res. Bd. Canada, No. 99, 47 pp.

Kerswill, C.J. 1955. Recent developments in Atlantic salmon research. The Atlantic Salmon Journal for 1955, No. 1, pp. 26-30.

1958. Effects of DDT spraying in New Brunswick on future runs of adult salmon. The Atlantic Advocate, 48(8): 65-68.

Table I. Immediate (first 4 months) losses to young salmon populations in sprayed streams, as per cent of what populations would probably have been without spraying, likely to result directly from proposed 1966 aerial forest spraying program in New Brunswick. Spray formulation expected is ¼ lb DDT in ¼ gal oil per acre applied twice, except streams marked * may receive 2 applications at 1/3 lb/acre: Phosphamidon used in ½ mile wide belt along streams as in 1965. No serious mortality anticipated for parr over 10 cm long.

Stream	Rearing area in spray zone (%)	Distance of downstream effect in main-stem	Total rearing area damaged (%)	Overall mortality rate for under-yearlings assuming a *50% kill (%)	Overall mortality rate for small parr assuming a *20% kill (%)
	(1)	(2)	(3)	(4)	(5)
Tabusintac	25	15 miles	50	25	10
N.W. Miramichi	5	0 "	5	2.5	1
Dungarvon	20	12 "	40	20	8
Bartholomew	95	5 "	100	50	20
S.W. Miramichi	80	20 "	90	45	18
Cains	50	12 "	75	38	15
Taxis	70	7 "	90	45	18
Tobique	under 1	(to mouth)	negligible	----------	----------
Nashwaak	80	15 miles	90	45	18
*Salmon	90	(to mouth)	*90	*54	*27
*Gaspereau	100	" "	*100	*60	*30
*Canaan	30	20 miles	*70	*42	*21

Table I. (cont'd.)

*Richibucto	25	8 miles	*50	*30	*15
*Kouchibouguacsis	50	15 "	*90	*54	*27

*Mortality rates of 60% for underyearlings and 30% for small parr have been allowed for streams receiving two 1/3 lb DDT/acre treatments; this allowance for small parr may also absorb some effect of the heavy dosage on large parr.

Table III. Loss to returning adult stocks, as per cent, to be expected from 1966 spraying as a result of loss of smolts shown in Table II, through loss of young shown in Table I. Cols. 1, 2 and 3 from Table II, cols. 7, 10 and 13, respectively.

Stream	Loss to smolt runs in years			Per cent of adult returns		Loss of mature fish, by years											
						1968			1969			1970			1971		
	1967	1968	1969	as grilse	as salmon	As grilse (cols. $\frac{1x4}{100}$)	As salmon (little loss)	Total	As grilse (cols. $\frac{2x4}{100}$)	As salmon (cols. $\frac{1x5}{100}$)	Total	As grilse (cols. $\frac{3x4}{100}$)	As salmon (cols. $\frac{2x5}{100}$)	Total	As grilse (no loss)	As salmon (cols. $\frac{3x5}{100}$)	Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Tabusintac	4	16	15	40	60	2	0	2	6	2	8	6	10	16	0	9	9
N.W. Miramichi	1	2	1	90	10	1	0	1	2	0	2	1	0	1	0	0	0
Dungarvon	2	10	16	80	20	2	0	2	8	0	8	13	2	15	0	3	3
Bartholomew	8	32	30	80	20	6	0	6	26	2	28	24	6	30	0	6	6
S.W. Miramichi	7	29	27	80	20	6	0	6	23	1	24	22	6	28	0	5	5
Cains	8	27	19	70	30	6	0	6	19	2	21	14	8	22	0	6	6
Taxis	13	37	14	80	20	10	0	10	30	3	33	11	7	18	0	3	3
Tobique	-	-	-	50	50	------- No loss unless smolts affected by spray in Tobique head pond ---------											
Nashwaak	11	34	18	50	50	6	0	6	17	6	23	9	17	26	0	9	9
Salmon	22	48	11	80	20	18	0	18	38	4	42	9	10	19	0	2	2
Gaspereau	15	45	30	80	20	12	0	12	36	3	39	24	9	33	0	6	6
Canaan	19	40	4	80	20	15	0	15	32	4	36	3	8	11	0	1	1

Table III. (cont'd.)

Richibucto	11	66	9	80	20	9	0	9	21	2	23	7	5	12	0	2	2
Kouchibouguacsis	19	46	16	80	20	15	0	15	37	4	41	13	9	22	0	3	3

Table IV. Estimates of total adult salmon produced by rivers, based on use of some of these stocks in fisheries. (Total Miramichi river population (column 7) estimated as 4 times the 1949-1958 average sport catch of 33,196 and equals approximately 135,000 fish. Commercial contribution of streams not in the Miramichi system estimated on the same basis as for Miramichi streams to Miramichi commercial fishery, i.e., 1.3 times river population of large salmon. In headings, salmon = large salmon as opposed to grilse.)

Stream	Mean (1949-1958) sport catch (1)	Est'd. total river population: total number (approx. cols.1x4) (2)	per cent of total as gls. (3)	per cent of total as sal. (4)	Est'd. no. in runs: gls. (cols. 2x3) (5)	sal. (cols. 2x4) (6)	Contribution to Miramichi stocks: to Mira. river pop. (% of 135,000) (7)	to Mira. river pop. of sal. (% of 27,000) (8)	sal. to Mira. comm. fishery (35,150 10-lb fish) (9)	Other streams: sal. to comm. fisheries (col.6 x1.3) (10)	Av. annual yield to fisheries: sport gls. (cols. 1x3) (11)	sport sal. (cols. 1x4) (12)	comm. 10-lb sal. (from col.9 or 10) (13)	Av. annual spawning escapement: gls. (cols. 5-11) (14)	sal. (cols. 6-12) (15)
Tabusintac	2179	9000	40	60	3600	5400				7020	870	1310	7000	2730	4090
N.W. Miramichi	3596	15000	90	10	13500	1500	11.1	5.6	1968		3240	360	2000	10260	1140
Dungarvon	411	2000	80	20	1600	400	1.5	1.5	527		330	80	550	1270	320
Bartholomew	0	1000[1]	80	20	800	200	0.7	0.7	246		0	0	250	800	200
S.W. Miramichi	23111	100000	80	20	80000	20000	74.1	74.1	26046		13500	4600	26000	61500	15400
Cains	1649	7000	70	30	4900	2100	5.2	7.8	2742		1150	500	2700	3750	1600
Taxis (included in S.W.M.)		1000[2]	80	20	800	200	0.7	0.7	246		(included in S.W.M.)		250	300	200
Tobique (from fishway)	1237	4200[3]	50[4]	50[4]	2000	2000				2600	600	600	2600	1500	1500
Nashwaak	231	1000[2]	50	50	500	500				650	120	120	650	380	380

Table IV. (cont'd.)

Stream	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Salmon	No record	500[2]	80	20	400	100				130	0	0	150	400	100
Gaspereau	"	500[2]	80	20	400	100				130	0	0	150	400	100
Canaan	"	500[2]	80	20	400	100				130	0	0	150	400	100
Richibucto	"	1000[2]	80	20	800	200				260	0	0	250	800	200
Kouchibouguacsis	"	1000[2]	80	20	800	200				260	0	0	250	800	200
											24210	6970	42950	86290	26030

Total grilse 110,500 }
" salmon 75,950 } 186,450

[1]Fishway count

[2]Guess

[3]Tobique total river stock is rounded average estimated river stock from angling, 1949-52 (using curve of Elson and Kerswill in Atlantic Salmon Journal for October 1964) plus fishway counts, 1953-1956 and 1964, 1965.

[4]Tobique proportions of grilse and large salmon entering fishway available 1960-1965, only.

Table V. Loss in numbers of fish as a direct result of 1966 spraying.

	1968					1969					1970					1971					Total loss from 1966 spray	
	Fisheries			Spawn.		Fisheries			Spawn.		Fisheries			Spawn.		Fisheries			Spawn.			
	Sport		Comm.	escape.		Sport		Comm.	escape.		Sport		Comm.	escape.		Sport		Comm.	escape.			
Stream	as gls.	as sal.	as 10-lb sal.	as gls.	as sal.	as gls.	as sal.	as 10-lb sal.	as gls.	as sal.	as gls.	as sal.	as 10-lb sal.	as gls.	as sal.	as gls.	as sal.	as 10-lb sal.	as gls.	as sal.	gls.	sal.
Tabusintac	18	0	0	55	0	52	26	140	164	82	52	131	700	164	409	0	118	630	0	368	505	2604
N.W. Miramichi	32	0	0	103	0	65	0	0	205	0	32	0	0	103	0	0	0	0	0	0	540	0
Dungarvon	7	0	0	25	0	26	0	0	102	0	43	2	11	165	6	0	2	17	0	10	368	48
Bartholomew	--in S.W.--		0	48	0	--in S.W.--		5	208	4	--in S.W.-		15	192	12	--in S.W.--		15	0	12	448	63
S.W. Miramichi	1110	0	0	3690	0	4255	46	260	14145	154	4070	276	1560	13530	924	0	230	1300	0	770	40800	5520
Cains	69	0	0	225	0	219	10	54	713	32	161	40	216	525	128	0	30	162	0	96	1912	768
Taxis	--in S.W.--		0	80	0	--in S.W.--		8	240	6	--in S.W.-		18	88	14	--in S.W.--		8	0	6	408	60
Tobique	-------------------------No loss anticipated unless smolts affected by spray in head pond-------------------------																					
Nashwaak	7	0	0	23	0	20	7	39	65	23	11	20	111	34	65	0	11	59	0	34	160	369
Salmon	--none--		0	72	0	--none--		6	152	4	--none--		15	36	10	--none--		3	0	2	260	40
Gaspereau	--none--		0	48	0	--none--		5	144	3	--none--		14	96	9	--none--		9	0	6	288	46
Canaan	--none--		0	60	0	--none--		6	128	4	--none--		12	12	8	--none--		2	0	1	200	33

Table V. (cont'd.)

Richibucto	--none--		0	72	0	--none--		5	168	4	--none--		8	56	10	--none--		5	0	4	296	36
Kouchibouguacsis	--none--		0	120	0	--none--		10	296	8	--none--		23	104	18	--none--		8	0	6	520	73
Totals	1260	0	0	4675	0	4637	89	538	16640	324	4369	469	2703	15105	1613	0	391	2218	0	1315		
Total loss from	grilse		5918					21,367					19,474					0			46,705	
1966 spraying,	salmon		0					951					3,785					3,924			9,660	
by years	total		5918					22,318					23,259					3,924			56,365	

Total loss to sport fisheries	Total loss to commercial fisheries	Total loss to spawning escapement
grilse - approx. 10,000 (10,249	(5,459 10-lb fish)	grilse - approx. 40,000 (36,366)
salmon - approx. 1,000 (949)	approx. 50,000 lb	salmon - approx. 3,000 (3,252)

Table VI. Losses of young salmon anticipated as a direct and early result of the proposed 1966 forest spray program (1.6 million acres) in New Brunswick. (Calculations are based on assumptions that average unsprayed population densities are 24 underyearlings, 20 small parr (10 cm and under and mostly yearlings) and 12 large parr per 100 yd^2 of stream bottom.)

	Protected by Phosphamidon							Not protected by Phosphamidon							
	Length (miles) and average width (yd)														
	Within spray zone			Affected by downstream drift,	Total affected area,	Losses (x1,000) of young salmon in protected part		Tributaries with average width of 2 yd		Losses (x1000) of young salmon in unprotected part			Total losses (x1000) of young salmon		
Stream	tributaries width 7 yd	tributaries width 15 yd	main stem miles x yd	miles x yd	yd^2 x 1000	underyearlings @ 50%	small parr @ 20%	length miles	yd^2 x1000	underyearlings @ 90%	small parr @ 70%	large parr @ 50%	underyearlings	small parr	large parr
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Tabusintac	4	2	6x30	15x30	1211	145	48	6	21	5	3	1	150	51	1
N.W. Miramichi	8	5	14x40	0	1216	146	49	14	49	11	7	3	157	56	3
Dungarvon	4	3	9x30	12x30	1237	148	49	6	21	5	3	1	153	52	1
Bartholomew	10	6	24x20	5x20	1302	156	52	16	56	12	8	3	168	60	3
S.W. Miramichi	60	40	80x50	20x50	10600	1272	424	100	352	76	49	21	1348	473	21
Cains	40	30	41x30	12x30	4083	490	163	70	246	53	34	15	543	197	15
Taxis	12	8	26x30	7x30	2101	252	84	20	70	15	10	4	267	94	4

Table VI. (cont'd.)

Tobique	---------- No important rearing ground in or below spray area ----------														
Nashwaak	60	40	29x30	15x30	4118	494	165	95	334	72	47	20	566	212	20
Salmon	80	55	39x30	0	4497	540	180	150	528	114	74	32	654	254	32
Gaspereau	25	15	37x20	0	2006	241	80	40	141	30	20	8	271	100	8
Canaan	0	0	15x3*	15x5*	211	25	8	15	53	11	7	3	36	15	3
Richibucto	6	4	6x20	8x20	672	81	27	10	35	8	5	2	89	32	2
Kouchibouguacsis	4	2	13x20	15x20	612	73	24	6	21	5	3	1	78	27	1
Totals	313	210	339 miles	124	33,864	4063	1353	548	1927	417	270	114	4480	1623	114

*Width reduced from 20-40 yd to compensate for long unproductive reaches in this stream

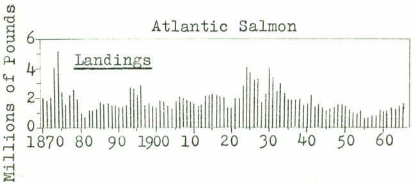
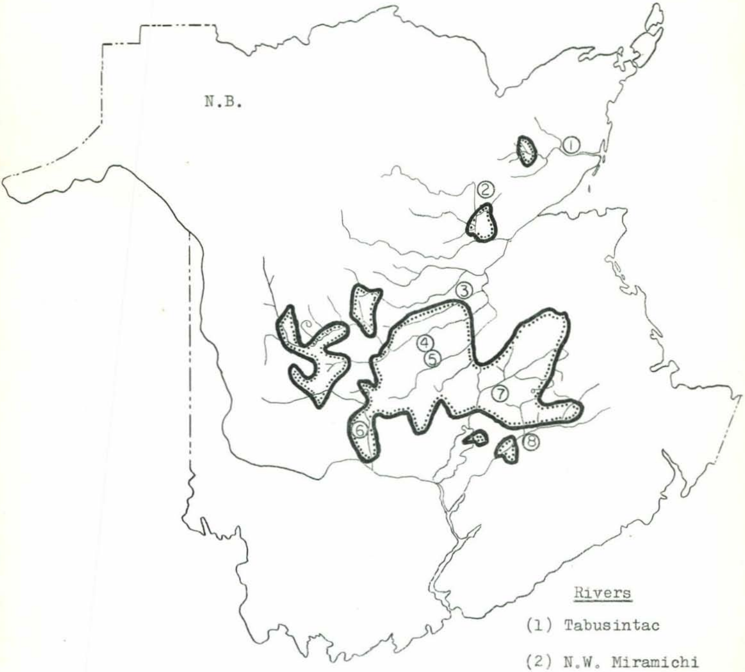


Figure 1. Commercial landings of Atlantic salmon in the Gulf Area (Cape Gaspé to northern tip of Cape Breton) of the Maritime Region, 1870-1965. (Adapted from Elson, 1957a)



Rivers

(1) Tabusintac

(2) N.W. Miramichi

(3) Bartholomew

(4) S.W. Miramichi

(5) Cains

(6) Nashwaak

(7) Salmon

(8) Canaan

Figure 2. Proposed area for aerial forest spraying in New Brunswick in 1966 and affected rivers.

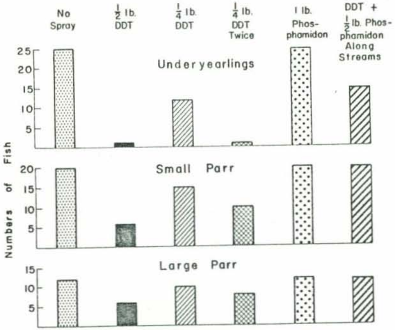


Figure 3. Average abundance, per 100 sq of stream bottom, of wild young salmon found in New Brunswick streams under natural conditions and 3 months after surrounding forests were sprayed with insecticide at the rates shown. (From Elson and Kerswill, 1966)

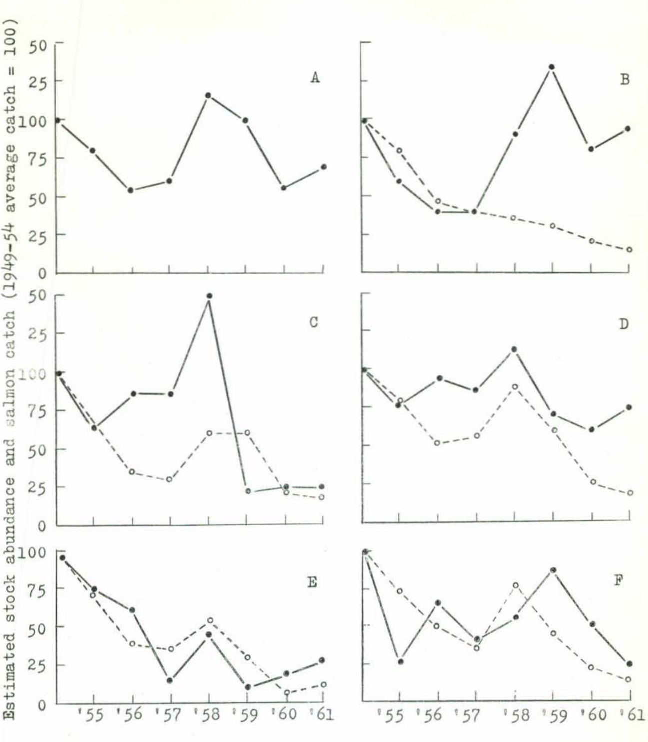


Figure 4. Angling catches per rod-day (—) and predicted stock abundance (--) as affected by DDT: original estimate of DDT effect adjusted to conform to angling success trend, shown in A, in 3 unsprayed Nova Scotia rivers. B - Northwest Miramichi; C - Restigouche system; D - Miramichi system; E - Kedgwick; F - Tobique. (From Elson, unpub.a)

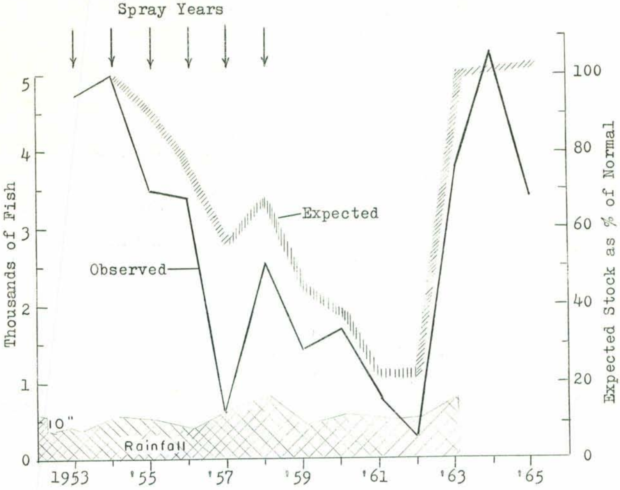


Figure 5. Numbers of salmon entering the Tobique River in comparison to expected effect of DDT spray on returning stock. (From Elson and Kerswill, 1966)

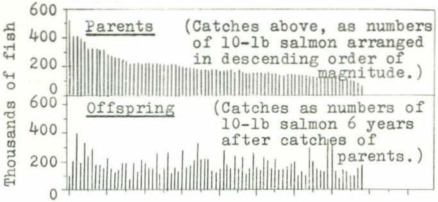


Figure 6. Relations between magnitudes of commercial landings of Atlantic salmon in one year and 6 years later (directly under), which is average time between commercial landings of one generation and the next for this area. Data for 1870-1954 for the Gulf Area of the Maritime Region, similar to Figure 1. (From Elson, 1957a)