PRODUCTION STUDIES ON THE YOUNG STAGES OF ATLANTIC SALMON (*Salmo salar* L.) IN AN EXPERIMENTAL AREA OF INDIAN RIVER, NOTRE DAME BAY, NEWFOUNDLAND

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by

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ABSTRACT

A preliminary assessment was made of the effect of a controlled flow spawning channel on Atlantic salmon parr production in Indian River, Newfoundland.

Fry production, in the channel, was compared with that in the river, under natural conditions, and found to be substantially higher. Post-hatching migration of fry was restricted to within two miles of the channel. Underyearling density is higher in the area of direct channel influence than in any part of the river where fry are provided solely on the basis of natural production. Underyearling to yearling survival in the area of direct channel influence was 9.7 percent, compared with 85.9 to nearly 100 percent in other areas. Parr density in the same area was 13 per unit compared with 19 per unit for the river as a whole. Parr densities ranged from 8.0 to 35.6 per unit. Parr production was correlated with predominant bottom type. Highest densities occurred in areas where large stones and boulders predominated.

Evidence is presented to show that the controlled flow spawning channel at Indian River can be best used for salmon management, if fry produced there are distributed to areas of the river which offer an abundance of good parr rearing area.

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I. INTRODUCTION

A. A BRIEF REVIEW OF ATLANTIC SALMON MANAGEMENT ATTEMPTS, WITH SPECIAL REFERENCE TO NEWFOUNDLAND

A good account of management activities, undertaken on behalf of freshwater game fishes in Newfoundland is given by Mr. V. R. Taylor in his Foreward to Scott and Crossman (1964). Referring to the island of Newfoundland, Mr. Taylor reports that in the early 1880's interest, and perhaps even concern, was being evidenced for the welfare of game fish stocks in freshwater areas. The Crown Lands Act of 1884 - 1885, Section 19, says, "It is enacted that for encouraging the breeding of fish, the right to use ponds, lakes and rivers may be leased together with necessary adjoining land". This Section has had an important effect on the freshwater fish fauna of the Avalon Peninsula, in particular, as it was under this provision that Newfoundland's first and only game fish hatchery was established. As a result, several species of non-native fish were introduced.

Under the Act referred to, a society known as the Game Fish Protection Society was established. The exact date of its establishment is not clear but a report in the St. John's Evening Herald, dated February 23, 1892, advises that the first importation of eggs for public purposes took place in January, 1886. This would indicate that the Society had already been formed and was functioning according to the provisions of the Act of 1884 - 1885. This account refers to the first importation of eggs for public purposes as taking place in January, 1886, but other records fix the likely date of the establishment of the hatchery as 1885, since it is assumed that it would not have been built prior to passage of the Act.

The Game Fish Protection Society subsequently obtained rights to Murray's and Butler's ponds on what is now the Portugal Cove Road and the hatchery was moved to the Murray's Pond location some years later (1895-1897). For rights to the waters of these ponds, the Society paid an annual rental of 10,000 fish fry which they were required to liberate in public waters.

Dr. C. W. Andrews, who has examined the records of the Game Fish Protection Society, advises that smelt (Osmerus mordax Mitchill 1815) eggs were imported from New York in 1893 and 1895, and planted as forage fishes in some local waters. It is also recorded that sticklebacks were planted for the same reason but it is not clear whether these were imported or collected locally, nor is the species involved known to us.

As a result of these introductions, populations of brown trout (Salmo trutta Linnaeus 1758), including many sea-run populations, and rainbow trout (Salmo gairdneri Richardson 1836) exist in the waters of the Avalon Peninsula. One population of whitefish (Coregonus clupeaformis Mitchill 1818) is also known to have become established. The Game Fish Protection Society is still active (as the Newfoundland Game Fish Protection Society) and their hatchery remains operative, though it seems that since the early 1900's only rainbow trout have been handled.

The Crown Lands Act of 1884-1885, which made possible the activities of the Game Fish Protection Society, marked the beginning of what might be called "management" activity in the field of freshwater fishes on the Island; although, of course, some regulations were in force prior to that time. Whether or not this was "wise" management is an academic question at this time since the results of these introductions are with us and no doubt will remain.

The next recorded interest in "management" of freshwater areas, other than regulatory, occurred in 1896 when Nielson, Superintendent of Fisheries for the Newfoundland Fishery Commission (established about 1889), suggested the construction of fishways for anadromous salmon (Salmo salar Linnaeus 1758) on the Terra Nova River and also the introduction of species of Pacific salmon to Newfoundland waters. Evidently no action was taken on either suggestion at the time. Both have been carried out, or attempted, in relatively recent years.

In the Newfoundland Guide Book of 1911, Prowse refers to the success of the hatchery practices carried out by the Game Fish Protection Society earlier and makes reference to Millais who, it says, reported catching brown trout in a pond near Terra Nova. If this report was correct, and it has not been confirmed to date, it would be the first confirmed record of this species off the Avalon Peninsula. The same book also refers to a... white trout, as game as salmon... being taken near Whitbourne. These were probably ouananiche since they are known to exist in that vicinity.

In 1930, Mr. W. L. Calderwood, a former official of the Scottish Fishery Board, made a brief examination of a few salmon rivers on the Island. A published report on this visit dealt mainly with physical obstructions in some of the rivers and also made reference to wastes from the pulp and paper mill at Grand Falls, Exploits River. Although his study was almost exclusively on sea-run salmon rivers, he also makes reference to ouananiche in Terra Nova Lake. His report recommended remedial action at obstructions in several streams, notably Terra Nova

River, Exploits River, South East Placentia River, LaManche River and Rocky River near Colinet. Some of these recommendations were acted upon.

Frost, writing in the Annual Report of the Fisheries Research Laboratory, 1936-37, stated that prior to 1936 no freshwater work had been done other than a few plankton tows.... In the Summer of 1936, however... some preliminary work was attempted including a series of plankton tows and a detailed examination of many mud trout.... A program of investigations was drawn up (Frost said) to determine such things as life history (for regulatory purposes), best pond and food types and the economy of existing hatchery and restocking methods. These studies were carried out at Murray's and Butler's ponds, near St. John's, and included the collection of various physical and chemical data. Johnson, in the same report, said that studies were also being made of the juvenile stages of sea-run salmon at Salmonier River, St. Mary's Bay.

Marine salmon had by now begun to be recognized as a valuable resource but one that was less productive than in former years. Thus, in 1937, the Province of Quebec established the Quebec Salmon Commission to study the salmon of the Gulf of St. Lawrence in co-operation with the Government of Newfoundland and that of other interested provinces of Canada. To carry out these investigations, study areas were set up in Newfoundland at Port aux Basques, Bay St. George, St. Anthony and Placentia. It seems, however, that most of the effort of this Commission was devoted to tagging studies in the sea. Four reports were published by Belding and Prefontaine from 1938 to 1961 adding considerably to knowledge of the marine migration routes of stocks of salmon in the Gulf.

Studies on purely freshwater species were begun in 1936 by the

Fishery Research Laboratory. This, together with the salmon investigations of 1931, marks for Newfoundland what might be called the beginning of scientific investigation into anadromous and freshwater fish stocks.

There is, then, somewhat of a gap in freshwater studies, though in 1942 a brief study of pulp and paper mill wastes on the Exploits and Humber rivers was carried out. Some effort was also being extended to the freshwater and marine stages of Atlantic salmon. In the freshwater areas this seems primarily to have been on river obstructions and on the commercial salmon fishery. There has been no significant break in Atlantic salmon studies since that time and much published and unpublished data has been accumulated by the successors to the Newfoundland Fisheries Laboratory and by the Department of Fisheries of Canada, as well as by other organizations.

In 1949, Newfoundland joined the Canadian Confederation and, under the British North America Act, all sea coast and inland fisheries came within the exclusive legislative jurisdiction of the senior government. The Department of Fisheries of Canada, therefore, and its scientific research arm, the Fisheries Research Board of Canada, took over the research and management functions previously assumed by former Departments of the Government of Newfoundland. Under this arrangement, the successor to the former Newfoundland Fisheries Laboratory became responsible for fisheries research and the Department of Fisheries of Canada assumed the major management and administrative functions. An exception was made in the case of purely freshwater fishes, where it was agreed that administration and management of this resource would be undertaken by the new Province.

In 1949, the Newfoundland Department of Natural Resources initiated a brief survey of some of the major freshwater areas on the Island, primarily in the nature of a sampling of their fish populations. The main aim of the survey was to determine species present and whether or not conditions might be suitable for establishment of commercial fishing operations (pers. comm., H. W. Walters). The survey did not indicate that such operations would be feasible. Waters examined included Mobile Big Pond, Hawco's Pond, Gull Pond, Oxley's Pond, Dildo Pond and Ocean Pond — all on the Avalon Peninsula. Also examined were Gander Lake and South Twin Lake in central Newfoundland, and Grand Lake on the West Coast of the Island. The most important information brought out by the survey was perhaps the discovery of landlocked Arctic char (Salvelinus alpinus Linnaeus 1758) in several of these waters, as well as the presence of landlocked salmon and landlocked smelts.

In 1951, the St. John's Biological Station of the Fisheries Research Board of Canada began an investigation of the major salmon rivers of the Island. These investigations, which emphasized enumeration of adult and juvenile runs of anadromous salmon, also included investigation of upstream areas of the rivers involved and sampling in lakes and ponds.

Surveys of the Terra Nova River System and the Bay du Nord River were carried out in 1952 and 1953. Investigations of the Little Codroy River began in 1953 and studies there have continued to the present time. After Confederation with Canada, research activity into the fishery resource became a function of the Fisheries Research Board of Canada and resource administration and management a responsibility of the Department of Fisheries proper. Thus the Department's Conservation and Development

Service assumed such "management" activity as fishway construction as well as routine protection and regulation enforcement. These functions were carried out by the Protection Branch of the Conservation and Development Service until 1954 when the nucleus of a Fish Culture Development Branch was established. While the Protection Branch is, primarily, an enforcement arm of the Service, the Fish Culture Development Branch (staffed by biologists, engineers and technicians) is an investigative arm designed to deal with ad hoc problems affecting the resource and to recommend remedial and development measures based on the best information available from research sources. The Fish Culture Branch (in Newfoundland) concerns itself primarily with the freshwater phase of anadromous fishes as well as with purely freshwater fishes. This latter function was not assumed until 1956 when, by agreement between the two governments, management and investigation of freshwater species was relinquished by the Provincial Government and assumed by the Department of Fisheries of Canada.

Perhaps one of the most significant things brought out in the foregoing paragraphs is that there is still much to be learned about the freshwater areas of the Island of Newfoundland and their fish populations. It is only in recent times that the existing and potential value of this resource has begun to be realized. This, of course, is the reason for the interest in it now — to make possible wise exploitation of what exists and where feasible, to develop its productive capacity to even higher levels.

Elson (1962-a) states, "In Canada, the supply of Atlantic salmon has for over a century been less than the demand. Public concern over supposedly declining stocks was noted by Perley (1852). The general situation does not appear to have changed much since then. During this time Canada has established one of the most extensive systems in the world for hatching, rearing and distributing young salmon. Artificial propagation of salmon, as developed by Samuel Wilmot (1869), was viewed with much optimism as a method of improving Canadian salmon fisheries (Wilmot, 1885). Increasingly severe legal restrictions on the taking of salmon were brought into practice in the hope of assuring greater numbers of spawners and hence more eggs and young salmon in the rearing grounds. But salmon catches continued to fluctuate over a wide range. Indeed, during the second quarter of the present century these fluctuations have taken the form of a rather steady decline, despite increased application of both the above methods of management (Elson, 1955). With recognition of the fact that such measures alone were not sufficient, more and more effort has been directed towards discovering factors which limit salmon stocks, so that appropriate new procedures for management could be developed."

The Fish Culture Development Branch in Newfoundland, which is now called The Resource Development Service of the Canada Department of Fisheries, is intimately involved with the development of appropriate new procedures for management which will protect our stocks of game fish (especially Atlantic salmon) from the perils of encroaching civilization.

One such management facility, which is comparatively recent in development, is the "controlled flow spawning channel". Lucas (1960) states that man-made spawning channels are a very recent advance in the field of fisheries conservation and development. The first large man-made spawning channel, according to Lucas (1960), was constructed at Jones Creek near Hope, British Columbia, in 1954. Since that date, controlled flow spawning channels have come into widespread use in the Pacific area as a facility to increase fish stocks, an achievement that could not, apparently, be realized with the use of convential hatcheries (Forester, 1938, and Elson, 1957).

A controlled flow spawning channel is basically a man-made spawning area in which spawning fish are provided with the best conditions in which the eggs can be deposited and undergo development through to emergence from the gravel as fry.

Two such controlled flow spawning channels have been constructed in Newfoundland to date. One was constructed on Noel Paul's Brook, in central Newfoundland during 1966-67 as part of a scheme to develop the upper part of the Exploits River for salmon production. The first controlled flow spawning channel for Atlantic salmon was built on Indian River during 1962-63, as a management facility designed to offset the possible effect that a hydro-development program on the upper reaches of that river (see page 17) was expected to have on its Atlantic salmon population.

This thesis represents a preliminary survey undertaken by the writer, on behalf of the Department of Fisheries of Canada, to analyze the immediate effects of this controlled flow spawning channel on salmon production in Indian River and to suggest ways that channel use may be improved if it is not, at present, satisfactory.

B. INDIAN RIVER

1. General

Indian River (Fig. 2) is a medium size stream flowing into Hall's Bay, Newfoundland. It is made up of three larger tributaries and a number of smaller ones. The three larger tributaries are: Upper Indian River, Black Brook and Burnt Berry Brook. Upper Indian River, until 1962, was accessible to Atlantic salmon up to a point about one mile above its confluence with the brook draining out of Gillards Lake. Black Brook and Burnt Berry Brook are accessible for only one mile from their mouths, at which point impassable falls present a total obstruction to salmon migrating upstream. Of the lesser tributaries; North Brook, Twenty-Three Mile Brook, Little Black Brook, Whitehorns Brook and Shoal Pond Brook are known to contribute to Atlantic salmon production.

A falls, which acts as a partial obstruction, is present on the main river about three miles from its mouth. A fishway constructed at this location in 1958 makes upstream movement easier for salmon and trout. A combined smolt-adult counting fence was constructed on the main river in 1967 at a point about six miles from its mouth. Construction of the controlled flow spawning channel on Upper Indian River about three miles above Indian Pond in 1963 made it impossible for salmon to migrate beyond this point.

2. Geographical Description

The drainage basin of Indian River includes 500 square miles. The total river length, not including standing water, is about 180 miles of which about 80 miles are accessible to Atlantic salmon.

The river has its source in a physiographic region called the "High Central Plateau" by Twenhofel and MacClintock (1940), and flows in a general northeasterly direction following the axis of a zone of Palaezoic faults and the paths of Pleistocene glaciers.

The rocks of the region range from Precambrian to Pennsylvanian with most of the intervening periods being represented. The stratigraphic and geologic sequence of the various rock formations are described by

Neale and Nash (1963).

The whole of the Indian River watershed area is part of the boreal forest formation. Within this context, it is highly diversified in plant associations that vary from pure birch (*Betula papyrifera*) and spruce (*Picea mariana* and *Picea glauca*) stands to bog and spruce savanna. In the deciduous stands and in marginal communities, the herb layer is prolific in species and luxuriant in growth. The dominant species whether tree, shrub or herb, are members of the following families; *Pinaceae*, *Corylaceae*, *Salicaceae*, *Cyperaceae*, *Ericaceae*, *Rosaceae* and *Compositae*.

An abundance of what might be termed good spawning area (i.e. areas of loose coarse gravel) is found in the main river below Indian Pond and in Upper Indian River. Burnt Berry Brook is quite similar to the main river with respect to bottom composition. The bottom composition of Black Brook is quite different, being composed mainly of large rubble and numerous boulders, with frequent outcrops of bedrock. All of the minor tributaries are similar to Black Brook in bottom composition.

The seasonal pattern of runoff for Indian River is presented in Figure 3. It can be seen that the highest water level occurs between April and June, with July and August, along with January and February, being the months of lowest water level (The annual smolt run commences with receding water level in late May and the rise in water level in September appears to act as a stimulus which induces salmon,resting in pools in the lower reaches of the river, to move upstream to the spawning grounds. Localized freshets during July and August appear to have the same effect. Hayes (1953) showed that freshets caused an increase in the number of salmon moving upstream in LaHave River, Nova Scotia).

C. FISH SPECIES IN INDIAN RIVER

Six fish species are known to occur in Indian River, these being: Atlantic salmon (*Salmo salar* Linnaeus 1758), Eastern Brook trout (*Salvelinus fontinalis* Mitchill 1815), American eel (*Anguilla rostrata* Lesueur 1817), Threespine stickleback (*Gasterosteus aculeatus* Linnaeus 1758), Arctic char (*Salvelinus alpinus* Linnaeus 1758), and American smelt (*Osmerus mordax* Mitchill 1815).

Atlantic salmon (parr) and brook trout are most numerous, with salmon parr being more abundant. Brook trout are confined mainly to the smaller tributary streams. Eels are found in moderate numbers throughout the whole river, and are most abundant in areas which offer good cover, such as boulders or thick aquatic vegetation. Sticklebacks are found mainly in areas of quiet water, like small ponds adjoining the river. American smelt and Arctic char were first noted in Indian River during the Spring of 1967 when one of the latter and twelve of the former were taken in a smolt counting trap being operated about six miles from the river mouth (Fig. 2).

D. THE SALMON OF INDIAN RIVER

To discuss salmon production, one must have a general grasp of the fish's life history (Elson, 1962-a). For Indian River salmon, spawning occurs in late October and early November. Tagging studies on spent salmon or kelts have shown that after spawning these fish begin to move down-river. Many have been observed passing through a smolt-counting fence, located about six miles from the river mouth (Fig. 2), in early Spring, on their way to the sea. Analysis of tag returns shows that most kelts are caught in the commercial fishery during the Summer following their spawning. Very few return to Indian River to spawn again.

The alevins hatch from the eggs around late April or early May and fry emerge from the spawning gravel in early June, the time of emergence depending apparently on the springtime warming of the river water. Most of these young fish (about 68 percent) spend three years as river dwelling parr, before migrating to sea as smolts, at the beginning of their fourth year. Sturge (1966) found that most young salmon in Tote Brook, Newfoundland, migrated as smolts after spending three years in the river. Andrews (1965) describes similar conditions for the Gander River, and Murray (1967) obtained similar results for Little Codroy River. Some (about 30 percent) migrate as smolts after spending only two years in the river and a very small percentage migrate as smolts after spending as little as one or as many as four years in the river. Smolts migrating from Indian River in 1967 had an average fork length of six inches.

Smolts, which were tagged on their downstream migration in Indian River, have been taken by fishermen (usually caught by tag entanglement in commercial nets or by angling) at various locations in Notre Dame Bay as far away as Snook's Arm and Beaumont (Fig. 1).

Mature salmon returning to Indian River for their first time do so mostly as grilse, a little more than a year after going to sea as smolts. These adults begin to pass through Indian River fishway (located at a partial obstruction about three miles from the river mouth) around the first of July and continue to do so until sometime around the middle of September, reaching a peak in late July (Table VIII, Appendix). They are then about 20 inches (50 centimeters) long (Table IX, Appendix) and weigh an average of 2.5 to 3.0 pounds.

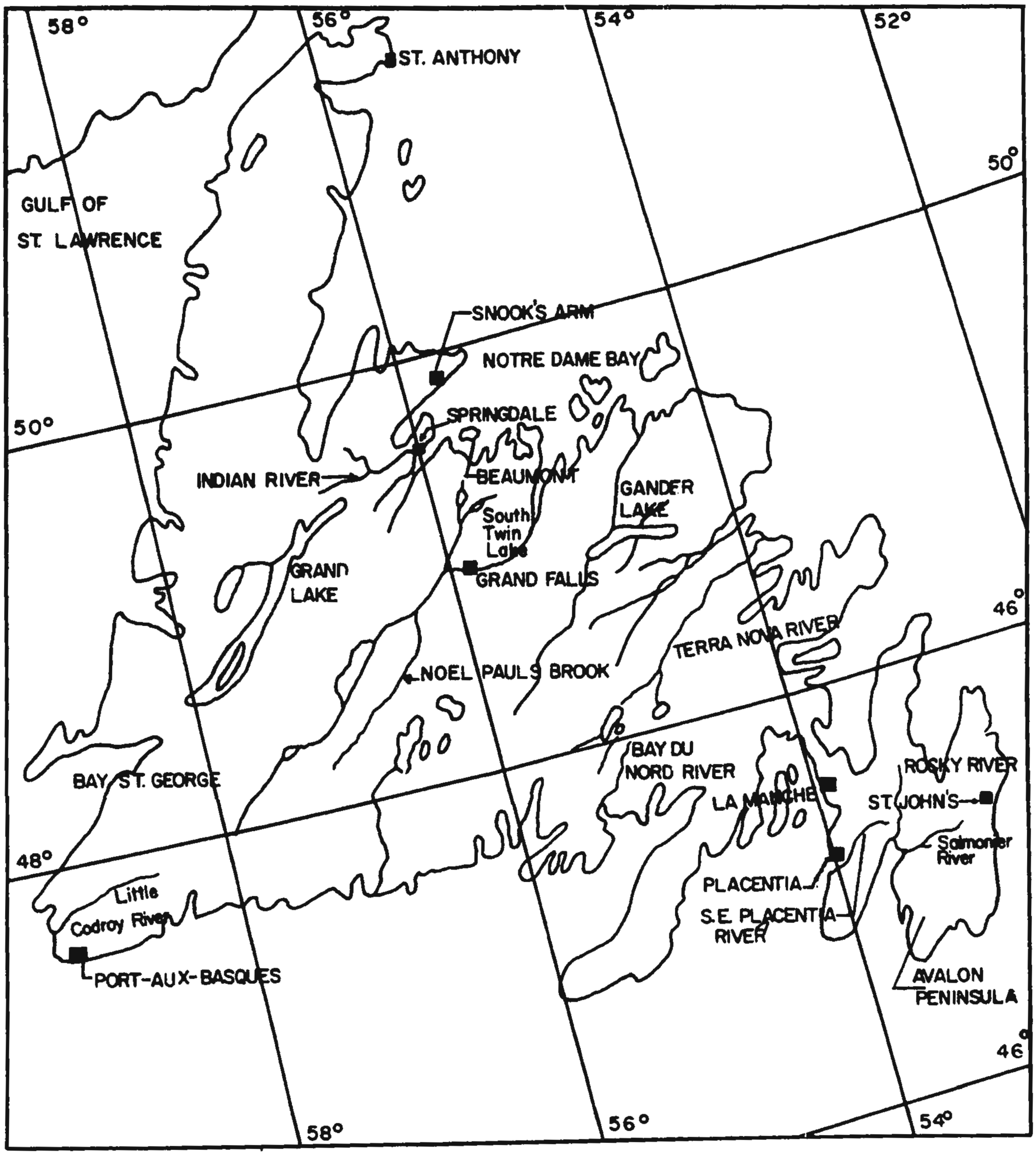

Fig. 1. Map of Newfoundland showing place names mentioned in the text.

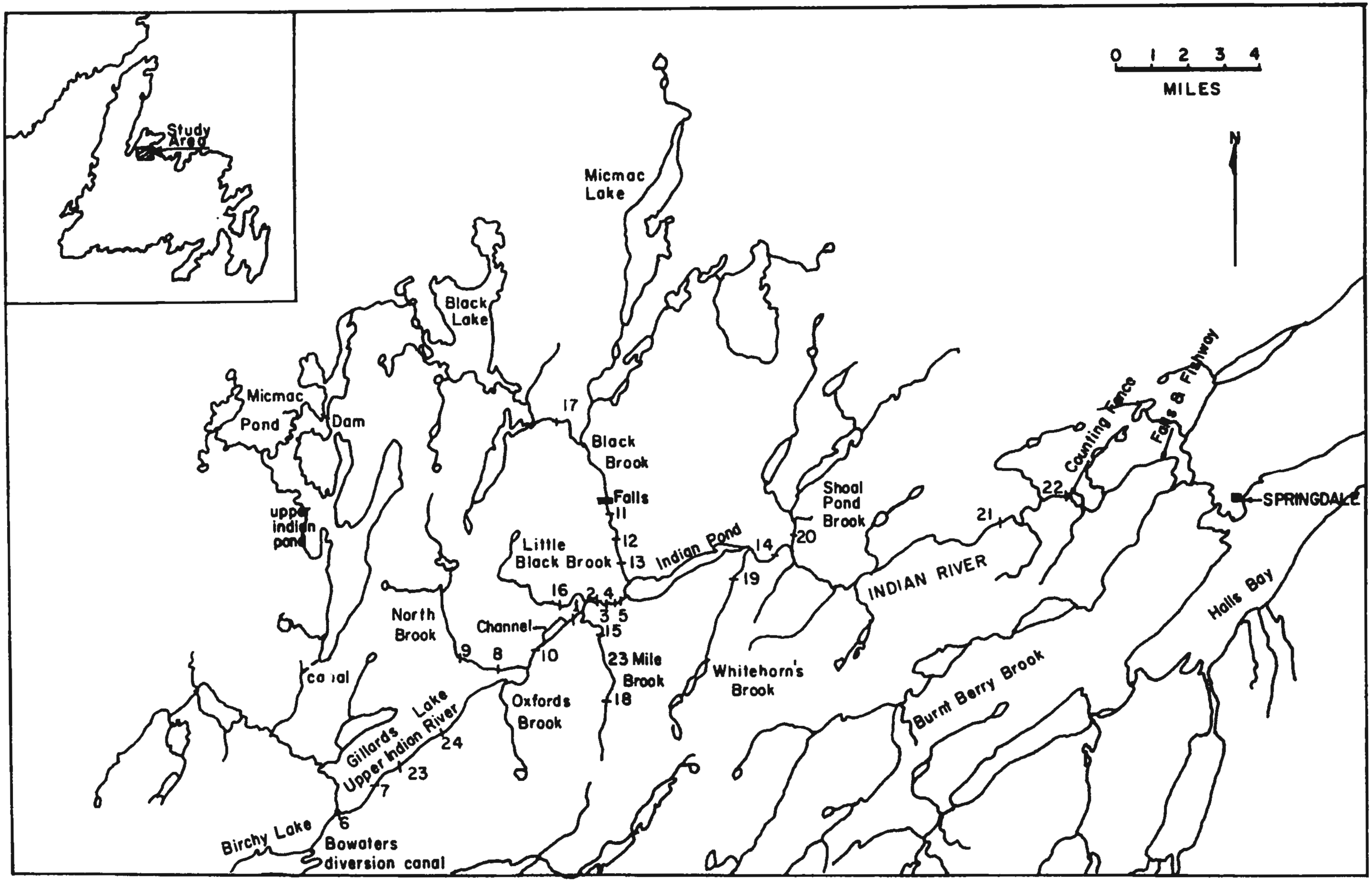

Fig. 2. Indian River and adjacent watershed showing location of electrofishing stations 1 - 24, and place names mentioned in the text.

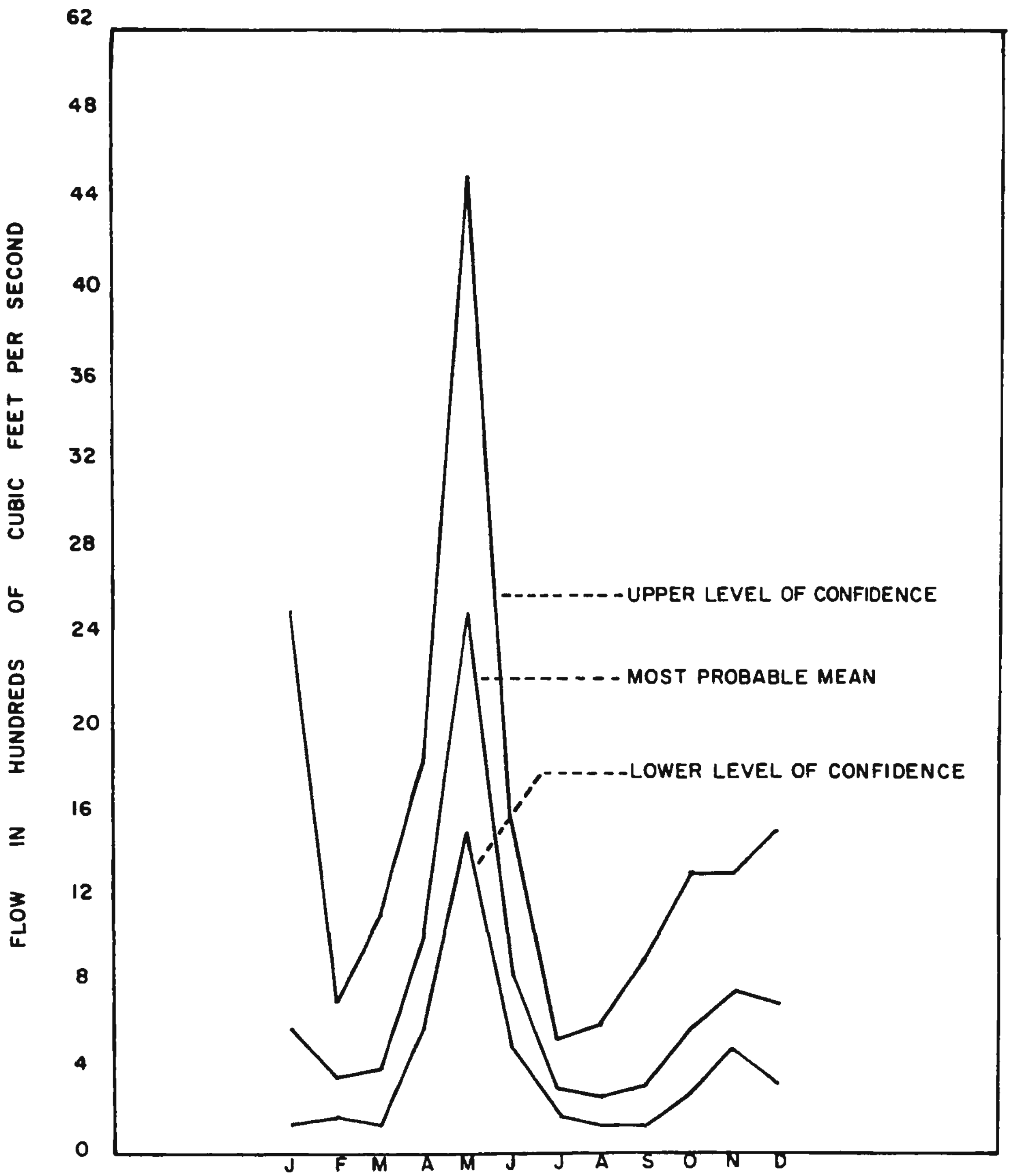

Fig. 3. Most probable mean monthly runoff and the 95% confidence range for Indian River, Newfoundland, 1954 - 1964. Data from gauge at Indian Falls.

E. A SPECIAL PROBLEM RELATING TO SALMON MANAGEMENT IN INDIAN RIVER

In 1961, the Department of Fisheries of Canada was approached by Bowater's Pulp and Paper Company, Limited with a plan for power development to supply new mining areas coming into production on the Baie Verte Peninsula. For this development the company wished to divert part of the flow of Indian River into Birchy Lake. The plan, which was subsequently given Departmental approval, resulted in the construction (Fig. 2) of a diversion dam across Upper Indian River and a canal from Upper Indian River to Birchy Lake. In addition, a canal was built to connect Upper Indian Pond to Upper Indian River, and a dam was constructed at the outlet of Micmac Pond. This arrangement causes water from the Upper Indian Pond--Micmac Pond complex (which formerly flowed into Black Brook) to flow into Upper Indian River and subsequently into Birchy Lake.

It was known that a sizable portion of the Atlantic salmon run to Indian River utilized Upper Indian River as a spawning area. The Department of Fisheries of Canada reasoned that with the completion of the diversion project <u>many</u> of these salmon would be deprived of suitable spawning area in Upper Indian River. As an effort to ensure that such would not become the case, a controlled flow spawning channel was constructed at a point 2.8 miles above Indian Pond on Upper Indian River. (This controlled flow spawning channel is subsequently referred to as "the channel").

The channel, located nine miles downstream from the Bowater's Diversion Dam, was completed in 1963, being ready to receive salmon in August of that year. It is approximately 1,100 feet in length, running parallel to Upper Indian River (Fig. 4) and provides some 10,000 square feet of spawning area. A dam (Fig. 5) placed across the river provides a head pond for water regulation, while a water intake valve (Fig. 6), situated above the dam, controls flow, depth and velocity of water entering the channel. A wooden platform and counting trap placed at the downstream confluence of the river and channel make possible the capture and retention of salmon migrating upstream. Upstream migrants are diverted into the channel by a fence placed across the river near the downstream end of the channel. Spawning riffles run the length of the channel with five holding pools interspersed at regular intervals. Gravel placed in the channel was screened of "fines" below one half inch. Hydraulic features incorporated in the channel design are as follows:

(a) Channel discharge............... 15 - 50 cubic feet per second

(b) Riffle velocities............... 1.0 - 2.5 feet per second

(c) Riffle depths................... 0.5 - 2.0 feet

(d) Holding pool depths............. 3 - 6 feet

The channel, in essence, was designed to provide nearly ideal conditions for adult spawning and incubation of eggs. Figures 4, 5, 6 and 7 show some of the physical features of the channel.

Fig. 4. View of Indian River Controlled Flow Spawning Channel.

Fig. 5. Wooden control dam, at channel headworks, Indian River.

Fig. 6. Water intake structure, Indian River Spawning Channel.

Fig. 7. Water diffuser situated at lower end of water intake structure, Indian River Channel.

II. WHAT USE SHOULD BE MADE OF CHANNEL PRODUCED FRY

Each year, since it has been in operation, the channel has produced a sizable number of fry which have been available for contribution to the salmon stock of Indian River (Table IV).

Before the beginning of this study, it was the policy of the Department of Fisheries of Canada to allow these fry to migrate out of the channel into the 2.8 mile section of river between the channel and Indian Pond (Fig. 2) where they would necessarily enter into competition with fry that were produced from natural spawning in this area. Gradually, it became apparent that this might not be the best policy, considering that in the average year as many or more adult salmon spawn naturally in this area as in the channel.

It was decided, therefore, to initiate, during the summer of 1966, a field survey designed to provide an answer to the question of what was the best way to utilize the fry being produced in the channel.

The problem was approached in two ways:

(a) It was necessary to determine the extent of fry migration after they left the channel, to ascertain whether or not they were staying in the area between the channel and Indian Pond, or if they were distributing themselves throughout the river system;

(b) It was necessary to determine the parr density between the channel and Indian Pond and to compare parr density in this section with parr densities in other sections of Indian River, so that the probable effect of channel fry production on parr production in this section could be assessed.

During the summers of 1966 and 1967, a systematic study was made of all fish species living in Indian River. The method of study is described on page 24. To facilitate study of the changing abundance of fish, a "population index" has been calculated as the average number of fish per 100 square yards of stream. (This area is subsequently referred to as a "unit"). Such an area is large enough that indices can be considered to only one decimal point without getting any grossly wrong impression, unless fish are very sparce indeed (Elson, 1962-a).

III. MATERIALS AND METHODS

A. FRY MIGRATION OR DISPERSAL

As fry moved out of the channel they were captured for enumeration with the aid of a modified Wolfe trap (Wolfe, 1951) which was installed annually at the downstream end of the channel (Fig. 8) before the start of the annual fry migration. Fry were counted visually until they became too numerous, at which time they were estimated volumetrically. A 1000 ml. graduated cylinder was filled with water to the 900 ml. mark, and fry were added until the water level in the cylinder reached the 1000 ml. mark. Every fifth cylinder of fry was counted and noted. It was assumed that the four preceding cylinders contained the same number of fry.

To follow the downstream migration of fry, two methods were employed: (a) Special traps were constructed and placed in the river at convenient locations to capture and enumerate fry as they migrated downstream. These traps were essentially diagonal screen fences (Fig. 9) constructed of wood and 1/4" oval mesh nylon netting with holding boxes to retain fish. During 1966, three traps were used, and during 1967 two were used. The location of these traps is shown in Figure 10. During 1966, traps 1 and 2 were designed to capture only a portion of the fry moving downstream, while trap number 3 was set to capture all downstream migrants. In 1967, both traps were designed to capture only a portion of the run. So that fry would be identified as channel progeny, approximately 10,000 fry were marked each year, by removal of the dorsal fin, before being released below the channel. (b) Known numbers of fry were distributed manually in two areas of Upper Indian River which were inaccessible to spawning adults. Fry were placed in ten gallon containers along with a sufficient supply of fresh water and transported by truck to these points. These fry were released at a point immediately below the Bowater Diversion Dam and a point approximately one mile downstream from the diversion dam, where Hewlett's Road crosses Upper Indian River (Fig. 2). Approximately two months after fry were released in these areas, electrofishing gear was used to fish at regular intervals of "one-tenth mile" downstream from the release site to determine how far fry had migrated downstream. By continuous fishing at one-tenth mile intervals from the point below Bowater's Diversion Dam to the point at Hewlett's Road crossing, it was also possible to determine if any upstream migration had occurred. In 1966, approximately 6,000, and in 1967, approximately 3,000 fry were released at each site. In addition, the observed decrease in fry density between the channel and Indian Pond (Fig. 13) during electrofishing studies in 1966 and 1967 contributed to knowledge of fry migration.

The electrofishing gear used to determine population indices was operated at an output of approximately 350 volts pulsed D.C. at approximately 0.5 amps.

B. POPULATION INDICES

To determine parr (as well as other fish) indices in Indian River, twenty-two stations were fished quantitatively in 1966 and twenty-four in 1967. Fishing was done with the aid of barrier nets and electrofishing gear. An attempt was made to choose these stations to represent the whole of the Indian River system and the interpretation of data depends on the reliability of the assumption that this was accomplished.

The station to be fished was approached and secured at both the upstream and downstream end by means of barrier nets constructed of 1/4 inch oval mesh nylon netting, so that no fish could emigrate or immigrate once fishing began.

When a station had been secured at both ends by barrier nets, a man holding the positive electrode of the electrofishing gear would walk the length of the station moving the electrode back and forth across the width of the stream as he walked, so as to cover the entire area of the station. (This action is referred to as a "sweep"). As fish were narcotized by the current, they were retrieved by another man using a dipnet and placed in a bucket of water. Each station was given at least three sweeps with the usual number being four. Figure 11 shows the electrofishing crew at work. The number of each species captured during each sweep was recorded. During the 1966 field season, all salmon parr larger than underyearlings were scale sampled, before being returned to the stream, to determine the age structure of the population. Experience gained in 1966 enabled us, in 1967, to determine how many parr were 1+ and 2+ by reference to the length. During 1967, only those parr that were considered to be older than 2+ were scale sampled. After a station had been completed, most of the fish were returned to the river. A sample was kept for future study of length, weight, sex and food.

Because time in the field was usually limited, it was decided not to attempt to catch all the fish within a particular station, but to estimate the total index by a catch per unit of effort regression method, described by DeLury (1947) and Ricker (1958).

The essence of this method is that as fish are removed from a closed population by successive units of fishing effort, the catch per unit of effort decreases in proportion to the population remaining at the time

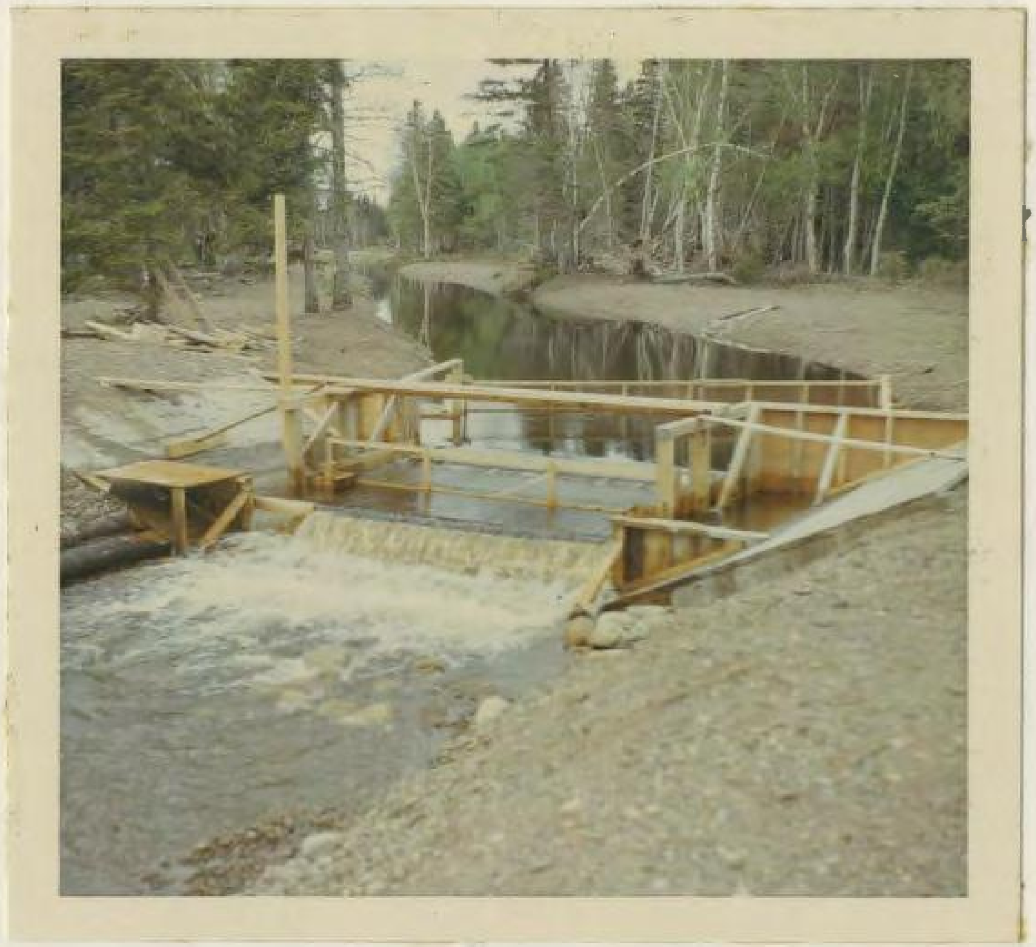

Fig. 8. Modified Wolfe trap, located at lower end of channel, used to capture fry as they move out of channel.

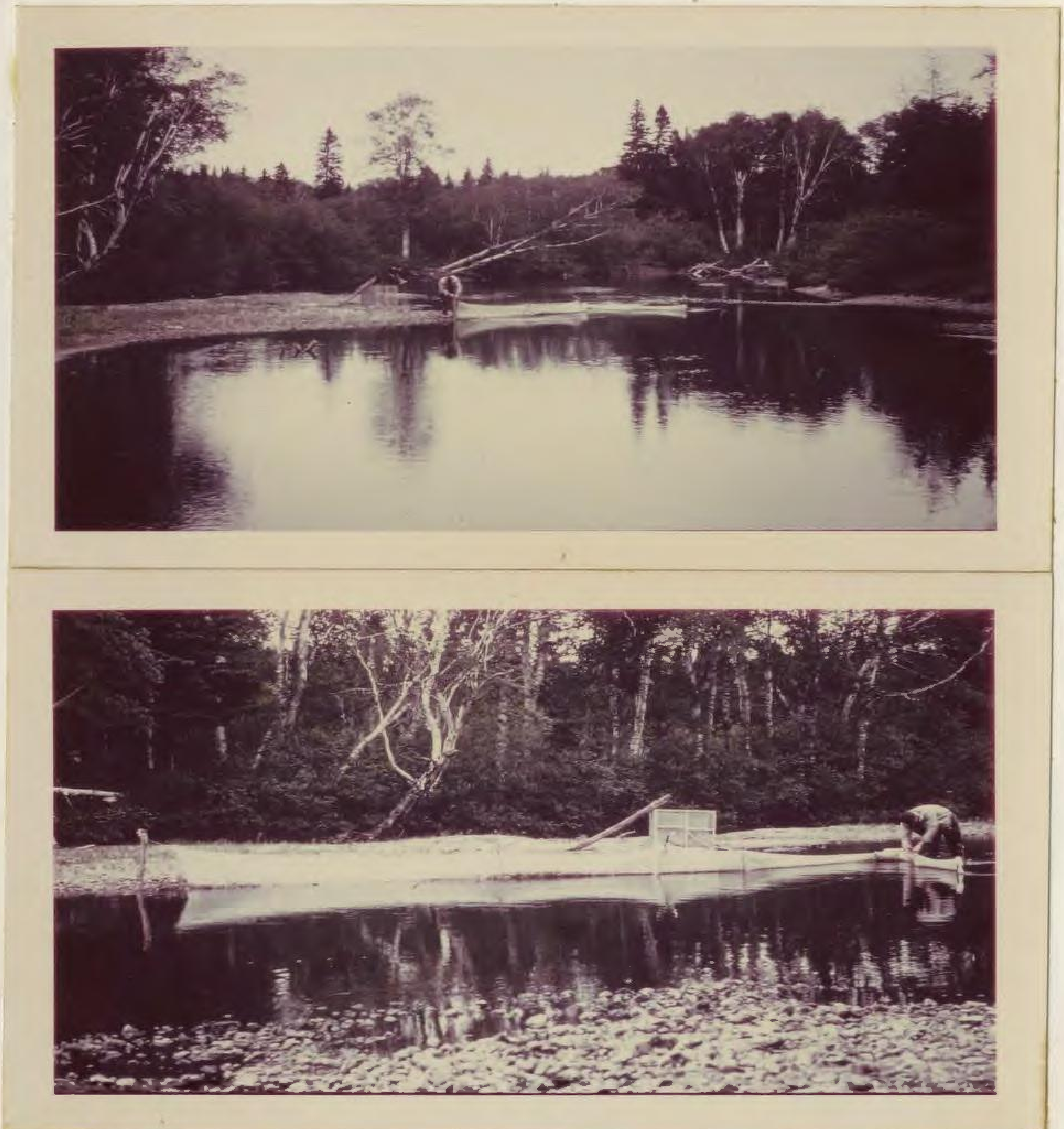

Fig. 9. Trap used to study downstream migration of fry.

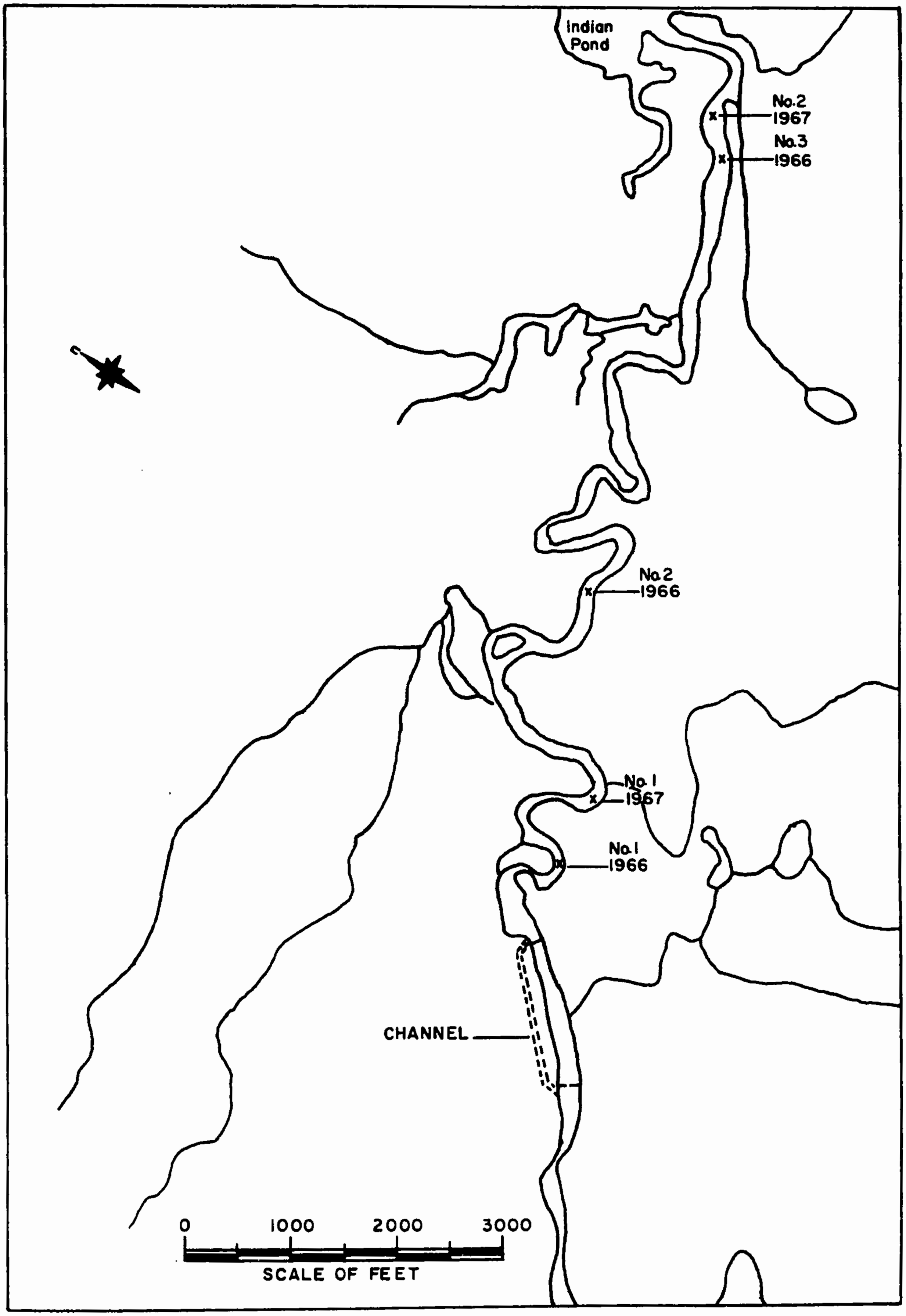

Fig. 10. Map of Indian River, between Indian Pond and the channel, showing location of traps used to study downstream migration of fry.

each effort is applied. Several sweeps of each area were made with the electrofishing gear. The several sweeps of the electrofishing procedure represent very nearly uniform efforts to catch fish. Hence the capture figures for each sweep can be treated as catches per unit of fishing effort (Elson, 1962-a).

A general outline of the method, as described by Ricker (1958), is presented here, with a typical example taken from electrofishing data obtained at Station 5, Indian River, during 1966. The concepts and symbols employed are as follows:

N_o	=	Original population size
N_t	=	Population surviving at the start of time t
C_t	=	Catch taken during time interval t
K_t	=	Cumulative catch, to the start of time t
C	=	Total catch (sum of C_t)
c	=	Catchability - the fraction of the population taken by 1 unit of fishing effort
b	=	1 - c: the compliment of catchability
f_t	=	Fishing effort during time t
E_t	=	Cumulative fishing effort, up to the start of time t
f	=	Total fishing effort for the whole period of the experiment
C_t/f_t	=	Catch per unit of effort during time t.

By definition, the catch per unit of effort during time t is approximately equal to the catchability multiplied by the population present at the beginning of that time:

$$\text{i.e.} \quad C_t/f_t \quad = \quad cN_t$$

The population at the start of time t is equal to the original population less the catch to date:

$$\text{i.e. } N_t = N_o - K_t$$

$$\text{then } C_t/f_t = cN_o - cK_t$$

The latter equation indicates that catch per unit of effort during time t, plotted against cumulative catch up to the start of time t, should give a straight line whose slope is the catchability, c. Also, the X - axis intercept is an estimate of original population, N_o, since it represents the cumulative catch if C_t/f_t, and hence the population also, were reduced to zero by fishing. The Y - axis intercept is the product of the original population, N_o, and the catchability, c.

A special case of this method occurs when equal units of effort are used to make the successive catches, so the latter can be plotted directly against cumulative catch:

$$C_t = cN_o - cK_t$$

Since the nature of the gear used in this study was such that variations in units of effort, used to make the successive catches, would be at a minimum or non-existent, it is assumed that ours is an example of this special case, and the data has been treated as such.

A rough estimate of N_o is given by the intercept of a straight line (fitted by eye to the plotted points) on the K_t axis. This procedure is not recommended, however, since large errors may be made in locating the line. When accuracy is desired, the line should be fitted by the method of least squares, DeLury (1951).

The following example is taken from the parr collection data for

Station number 5, Indian River, 1966. The data is conveniently arranged in Table I below.

Table I. Computation of the regression line used in the estimation of total number of parr in Station number 5, Indian River, 1966. $C_t = C_t/f_t$ = catch per unit of effort, K_t = cumulative catch, n = number of sweeps.

Sweep No.	K_t^2 (X^2)	K_t (X)	K_tC_t (XY)	C_t (Y)	C_t^2 (Y^2)
1	0	0	0	35	1225
2	1225	35	770	22	484
3	3249	57	912	16	256
4	5329	73	949	13	169
Totals	9803	165	2631	86	2134

Representing the K_t values by X and C_t values by Y, and representing the same quantities, measured from their means, by x and y, the formulae for the squares, products and primary regression statistics are as below:

$$\text{sum of } xy = \text{sum of } (XY) - \frac{(\text{sum of } X)\ (\text{sum of } Y)}{n}$$

$$\text{sum of } x^2 = \text{sum of } (X^2) - \frac{(\text{sum of } X)^2}{n}$$

$$\text{sum of } y^2 = \text{sum of } (Y^2) - \frac{(\text{sum of } Y)^2}{n}$$

$$\text{Slope} = \hat{b} = \frac{\text{sum of } xy}{\text{sum of } x^2}$$

$$\text{Intercept} = \hat{a} = \frac{(\text{sum of } Y) - b\ (\text{sum of } X)}{n}$$

The numerical statistics are as follows:

$$\text{sum of } x^2 = 9{,}803 - (165)^2/4 = 2996.75$$

$$\text{sum of } y^2 = 2{,}134 - (86)^2/4 = 285.00$$

$$\text{sum of } xy = 2{,}631 - \frac{(165)(86)}{4} = -916.50$$

$$\hat{b} = -916.50/2996.75 = -0.306$$

$$\hat{a} = \frac{86 - (-0.306)(165)}{4} = 34.123$$

These quantities determine the equation:

$$C_t = 34.123 - 0.306\ K_t$$

$$\text{Catchability} = \hat{c} = -\hat{b} = 0.306$$

$$\hat{N}_o = \hat{a}/\hat{c} = 34.123/0.306 = 112$$

1. Some Precautions

The question of gear efficiency is an important one when this method is being employed. To use C_t and C_t/f_t interchangeably, it is necessary to assume that catchability, c, is constant throughout the fishing period. To make c constant, the efficiency of the gear must remain constant throughout the fishing period. To ensure that gear efficiency remains constant throughout the fishing period, it is necessary that the current output of the gear remain constant and the technique used in fishing remain the same. Our experience, during electrofishing studies on Indian River, was that the electrofishing gear fished with approximately the same current output throughout the fishing period, but variations in efficiency did occur at different stations. This is to be expected because of variation in such factors as water conductivity, size of station, ease

Fig. 11. Electrofishing crew at work. (Barrier net can be seen at left centre).

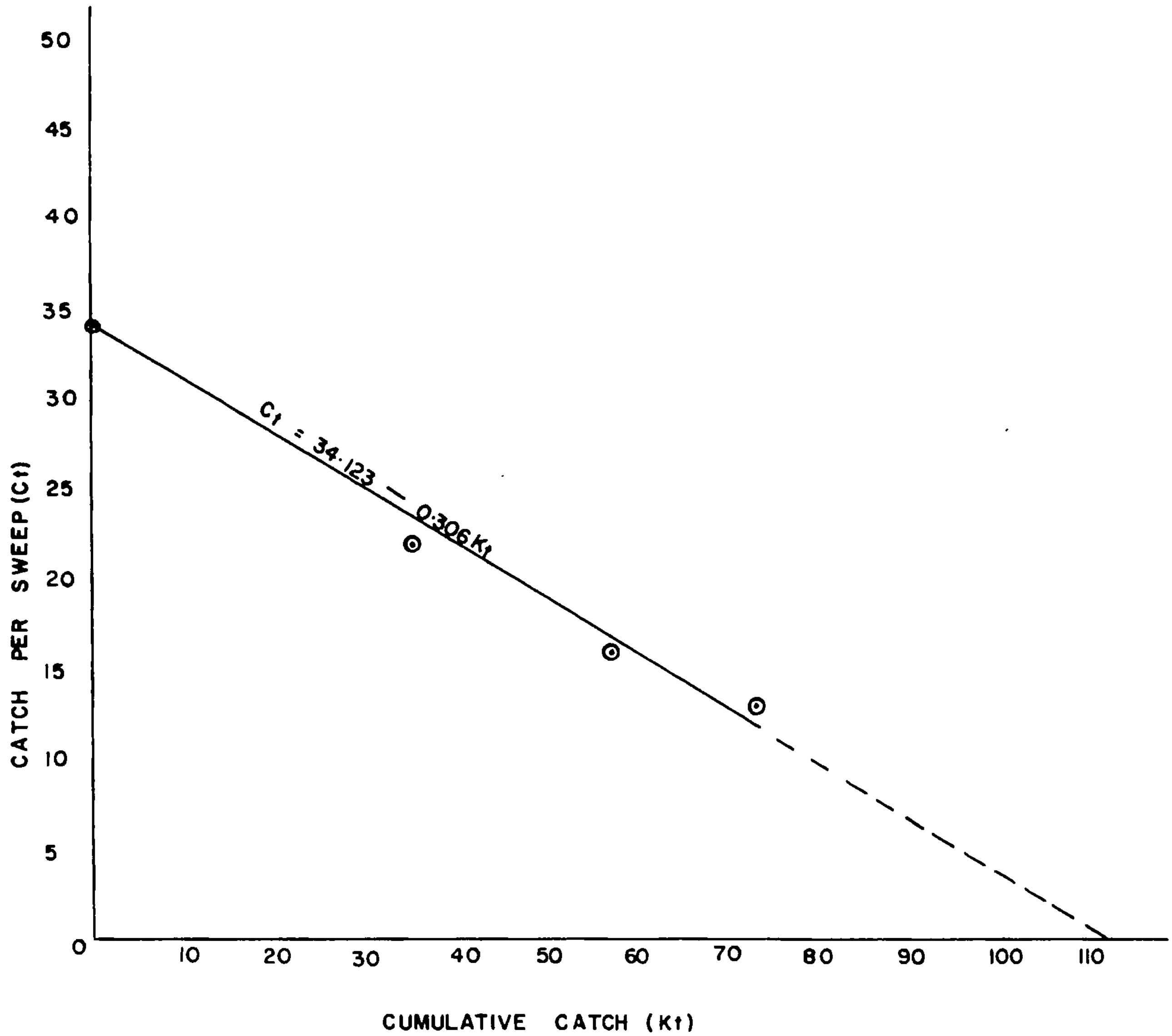

Fig. 12. Regression line, fitted by method of least squares, to parr collection data, station number 5, Indian River, 1966.

of movements, etc. However, since it is constant efficiency within the station that matters, the variation from station to station has no influence on the results obtained at any particular station. An effort was made at all times to keep the fishing technique constant so as to eliminate or reduce to an absolute minimum any possibility of efficiency variation within stations.

Equally important is the assumption that the population is closed, that is, recruitment, mortality and the like may be ignored. The fact that our sampling stations were secured at both ends by small mesh nets, through which no fish could move, eliminates this as a source of error.

If these two assumptions hold, the line fitted to the collection data (as in Figure 12) will pass through all the points. To quote DeLury (1951), "It may be expected, therefore, that if observed (C_t, K_t) values satisfy reasonably well a linear relation, the assumptions are supported and estimates of cN_o and c, and hence N_o are obtained from this straight line".

Observation of the data collected at Indian River during 1966 and 1967 show that in all cases the observed values of C_t and K_t did conform well to a straight line. It is assumed, therefore, that the above mentioned assumptions were reasonably well satisfied.

Ricker (1958) states that an obviously important condition for application of this method is that the vulnerability of the population should not exhibit significant seasonal trends, within the time of the experiment. This situation might apply to a population which is being fished over an extended period, but it seems reasonable to assume that there were no variations in vulnerability with the sampling method used at Indian River, where a small area was enclosed and fished entirely in a matter of a couple of hours. Ricker (1958) also states that equally important is the condition that the whole of the population shall be available to capture or, if not, adjustment for the different vulnerabilities of different sections of the stock must somehow be applied. It seems reasonable here to assume that with such a small area and such a small population that was usually fished, this condition warrants little consideration.

IV. DESCRIPTION OF THE STATIONS FISHED

Descriptive details, concerning each station fished during the Summers of 1966 and 1967, are given in Table II. It is considered desirable to present this description in tabular form to maintain clarity in what might otherwise be a long, involved description which could be confusing. Location of each station (numbers 1 - 24) is given in Figure 2.

Table II. Description of electrofishing st

Station number	Year	Ave. length (yd.)	Ave. width (yd.)	Area (sq. yd.)	Depth (ft.) Min.	Ave.	Max.	Surface velocity (ft./sec.)	
1	1966	84.7	10.4	880	0.25	1.03	2.00	2.12	Mostl fine fine spers
	1967	40.0	8.7	350	0.50	1.04	2.00	2.07	
2	1966	98.0	22.8	2,230	0.33	1.06	2.42	1.00	Consi fine No ru
	1967	40.0	19.7	790	0.30	0.83	1.50	1.33	
3	1966	46.6	22.4	1,040	0.50	1.21	2.25	0.58	Varie coars rubbl Mainl grave
	1967	40.0	20.0	800	1.00	2.16	3.40	0.72	
4	1966	43.4	22.1	960	0.25	0.85	1.67	1.00	Varie coars fine Abund veget
	1967	40.0	27.3	1,090	0.50	1.21	1.80	1.33	
5	1966	44.0	14.9	660	0.25	0.81	2.00	1.89	Varie coars fine Abund veget
	1967	40.0	15.7	630	0.50	1.37	2.50	1.29	

shing stations, Indian River, 1966 and 1967

)	Bottom type	Predominant surrounding vegetation	Location
	Mostly coarse gravel to fine rubble, with some fine gravel and interspersed boulders.	Dense alder beds on immediate shoreline. Left bank supports dense growth of paper birch and balsam fir.	Situated about 180 yards downstream from the channel.
	Consists entirely of fine to coarse gravel. No rubble or boulders.	Left bank supports dense alder beds. Right bank supports dense growth of paper birch, black spruce and balsam fir.	Situated about 700 yards downstream from the channel.
	Varies from silt to coarse gravel; no rubble or boulders. Mainly sand and fine gravel.	Dense alder bed covering upper part of right bank. Left bank supports dense stand of paper birch on lower half. Upper left bank supports good growth of swamp grass. Lower right bank is open.	Situated about 1,500 yards downstream from the channel.
	Varies from silt to coarse gravel. Mostly fine gravel and sand. Abundant aquatic vegetation.	Both banks support dense alder beds. Bed on right bank is about 30 feet back from river.	Situated about 2,100 yards downstream from the channel.
	Varies from silt to coarse gravel. Mostly fine gravel, and sand. Abundant aquatic vegetation.	Both banks support dense alder beds. Bed on right bank is about 30 feet back from river.	Situated about 4,000 yards downstream from the channel.

Table II. (Cont'

Station number	Year	Ave. length (yd.)	Ave. width (yd.)	Area (sq. yd.)	Depth (ft.) Min.	Depth (ft.) Ave.	Depth (ft.) Max.	Surface velocity (ft./sec.)	B
6	1966	121.3	2.9	350	0.50	0.84	1.50	1.63	Stream l coarse rubble. shoreli fair si Stream l channel dozer.
	1967	40.0	2.3	90	1.00	1.00	1.00	2.40	
7	1966	55.4	8.1	450	0.50	0.67	1.00	1.66	Consist rubble
	1967	40.0	6.8	270	0.50	0.77	1.00	-	
8	1966	50.0	4.7	230	0.25	0.54	1.00	1.50	Consist coarse boulder
	1967	40.0	1.3	50	-	-	-	-	
9	1966	50.0	11.0	555	0.50	0.58	0.67	1.03	Consist ly of c boulder amount
	1967	40.0	8.0	320	-	-	-	-	

II. (Cont'd.)

Bottom type	Predominant surrounding vegetation	Location
Stream bottom is mostly coarse gravel and fine rubble. Immediate shoreline consists of fair size boulders. Stream bed has been channelized by bull-dozer.	Both banks support very little vegetation. Highly disturbed area due to construction of diversion dam, and cut-over. Regeneration is mostly balsam fir.	Situated immediately below Bowater's Diversion Dam in channelized portion of stream.
Consists of coarse rubble and boulders.	Because of bulldozer action in channelizing river bed, no vegetation on immediate banks. Surrounding banks are cut-over with regeneration of balsam fir and black spruce on left bank. Alders predominate on right bank.	Situated about 2 miles downstream from the diversion dam.
Consists entirely of coarse rubble and boulders.	Both banks are adjacent to cutover. Immediate shore-line on right bank consists mostly of alders. Sparce growth of black spruce and paper birch occupies left bank.	Situated on North Brook, about one mile from where this tributary flows into Indian River.
Consists almost entire-ly of coarse rubble and boulder, with a small amount of bedrock.	Both banks are high and steep. Both banks are cutover, with paper birch, pin cherry, black spruce and balsam fir being the dominant regeneration.	Situated on North Brook, about one-half mile up-stream from Station 8.

Table II. (Cont'd

Station number	Year	Ave. length (yd.)	Ave. width (yd.)	Area (sq. yd.)	Depth (ft.) Min.	Depth (ft.) Ave.	Depth (ft.) Max.	Surface velocity (ft./sec.)	Bo
10	1966	50.0	12.9	650	0.50	0.79	1.25	1.50	Consists fine to
	1967	40.0	7.3	290	0.50	0.59	0.75	-	
11	1966	33.3	20.4	680	0.50	0.89	1.50	2.00	Consists coarse r boulder.
	1967	40.0	17.3	690	0.40	1.06	2.20	1.82	
12	1966	28.3	19.3	550	0.50	1.08	1.67	1.70	Varies b rubble a mostly c
	1967	40.0	44.0	1760	0.20	0.38	0.50	0.98	
13	1966	36.7	24.7	900	0.17	0.50	0.83	-	Varies f gravel t mostly r
	1967	40.0	23.7	950	0.50	1.11	1.50	1.14	
14	1966	33.3	20.0	670	0.83	1.66	2.50	2.50	Consists rubble a mostly r
	1967	40.0	34.3	1370	1.00	1.50	2.00	2.61	

II. (Cont'd.)

Bottom type	Predominant surrounding vegetation	Location
Consists entirely of fine to coarse rubble.	Left bank is highly disturbed by cutover and an access road. The right bank supports good growth of black spruce, balsam fir and paper birch. Alders predominant at river edge.	Situated on Upper Indian River, about one-half mile above the channel.
Consists entirely of coarse rubble and boulder.	Both banks support good stands of black spruce, balsam fir and larch.	Situated on Black Brook, immediately below falls, about 1.3 miles from Indian Pond.
Varies between gravel, rubble and boulder, mostly coarse rubble.	Black spruce, balsam fir and larch are dominant species.	Situated on Black Brook, about 0.7 miles from Indian Pond.
Varies from coarse gravel to boulder, mostly rubble.	Some dominant species, as mentioned in 11 and 12 cover left bank. Right bank is on small island with no significant vegetation.	Situated on Black Brook, immediately upstream from Indian Pond
Consists entirely of rubble and boulders, mostly rubble	Right bank is cleared for a cabin site. Predominant species on left bank is paper birch, with some black spruce and balsam fir.	Situated on main river about 1.3 miles below Indian Pond.

Table II. (Cont'

Station number	Year	Ave. length (yd.)	Ave. width (yd.)	Area (sq. yd.)	Depth (ft.) Min.	Ave.	Max.	Surface velocity (ft./sec.)	Bo
15	1966	50.0	3.0	150	0.50	0.66	1.00	-	Varies f to coars boulders rubble.
	1967	4.0	3.0	120	0.50	1.00	1.50	0.60	
16	1966	50.0	3.0	150	0.25	0.58	1.00	-	Varies f fine gra rock bei prevalen
	1967	40.0	2.1	80	0.50	0.60	0.80	0.92	
17	1966	44.0	12.0	530	0.30	1.07	1.50	1.00	Varies f coarse r dominant to coars
	1967	40.0	11.2	450	0.50	0.75	1.00	1.20	
18	1966	50.0	3.0	150	0.50	0.78	1.00	0.90	Ranges f boulder, percent
	1967	40.0	2.2	90	0.50	0.50	0.50	0.50	
19	1966	60.0	4.0	240	0.50	0.50	0.50	1.50	Ranges f and sand with gre rubble.
	1967	40.0	4.6	180	0.50	0.75	1.00	1.50	

.e II. (Cont'd.)

' y :.)	Bottom type	Predominant surrounding vegetation	Location
.	Varies from fine gravel to coarse rubble and boulders, mainly rubble.	Both banks support dense stands of paper birch; some balsam fir and black spruce occur.	Situated on Twenty-Three Mile Brook, immediately above Trans Canada Highway.
.	Varies from bedrock to fine gravel, with bedrock being quite prevalent.	Overhanging left bank supporting good growth of paper birch with some balsam fir and black spruce. Right bank supports luxurient alder growth.	Situated on Little Black Brook, immediately upstream from Old Bay Verte Road about one-half mile from where this stream enters Indian River.
.	Varies from mud to coarse rubble. Predominantly fine rubble to coarse gravel.	Left bank adjacent to small island. No immediate vegetation. Right bank supports good growth of alders.	Situated on Black Brook where Bay Verte Road crosses, about 5.0 miles upstream from Indian Pond.
.	Ranges from mud to boulder, with about 20 percent being boulder.	Both banks support good growth of alders which overhang stream bed.	Situated on Twenty-Three Mile Brook where old highroad crosses, about 2.0 miles from where this stream enters Indian River.
.	Ranges from fine gravel and sand to boulder, with greater part being rubble.	Disturbed by road construction. Both banks being devoid of vegetation except at extreme lower end where good growth of spruce and fir occurs.	Situated on Whitehorn's Brook where highway crosses it, about 0.3 miles from Indian River.

Table II. (Cont'd

Station number	Year	Ave. length (yd.)	Ave. width (yd.)	Area (sq. yd.)	Depth (ft.) Min.	Depth (ft.) Ave.	Depth (ft.) Max.	Surface velocity (ft./sec.)	Bot
20	1966	50.0	6.0	300	0.50	1.19	2.00	1.33	Ranges fr coarse gr dominantl gravel.
	1967	40.0	5.1	200	0.50	0.75	1.00	0.29	
21	1966	50.0	40.0	2000	0.50	0.72	1.00	1.50	Varies fr gravel to rubble, w being pre
	1967	40.0	71.1	2840	0.50	1.11	2.00	1.07	
22	1966	53.0	35.0	1860	0.75	1.28	2.50	1.00	Ranges fr rubble, w gravel be inant.
	1967	40.0	35.3	1410	1.00	1.67	3.50	0.21	
23	1966	-	-	-	-	-	-	-	Ranges fr to boulde and coars predomina
	1967	40.0	7.3	290	0.50	0.61	1.00	-	
24	1966	-	-	-	-	-	-	-	Consists coarse ru boulder.
	1967	40.0	15.8	630	0.50	0.75	1.00	-	

II. (Cont'd.)

Bottom type	Predominant surrounding vegetation	Location
Ranges from mud to coarse gravel, predominantly fine gravel.	Left bank supports dense growth of alders. Right bank also supports dense alder growth about 10 feet back from the shoreline.	Situated on Shoal Pond Brook just upstream from where this stream enters Indian River.
Varies from fine gravel to coarse rubble, with rubble being predominant type.	Both banks support shrub spruce and alders about 20 feet back from river bank.	Situated on Main River below Indian Pond about 8.5 miles from river's mouth.
Ranges from mud to fine rubble, with coarse gravel being predominant.	Both banks are heavily wooded with black spruce.	Situated on Main River below Indian Pond about 7.0 miles from the river mouth.
Ranges from fine rubble to boulder, with fine and coarse rubble being predominant.	Immediate bank supports no vegetation. North bank is adjacent to cutover. South bank has some growth of birch.	Situated on Upper Indian River about one mile below Hewlett's Road crossing.
Consists entirely of coarse rubble and boulder.	No vegetation on immediate shoreline; North bank is adjacent to cutover. South bank supports good growth of alders and spruce.	Situated on Upper Indian River about 2 miles below Hewlett's Road crossing.

V. DESCRIPTION OF EACH SECTION

To maintain clarity in discussion, Indian River has been divided into eight arbitrary sections, each containing a number of electrofishing stations. This division makes possible a comparison of abundance indicies in different areas of the river where;

(a) fry are produced naturally and large numbers of fry have been introduced from the channel,

(b) no fry are produced by natural spawning but limited numbers of fry have been introduced from the channel,

(c) fry are produced from natural spawning but none have been introduced from the channel,

(d) no fry are produced from natural spawning and none have been introduced from the channel, but parr are able to migrate into the area,

(e) no fry are produced naturally, none have been introduced from the channel and no parr can migrate into the area.

Section One includes electrofishing stations one to five, and is representative of the situation mentioned in V (a). A summary of the number of fry produced naturally and the number introduced annually from the channel, since 1964, is presented on page 49 (Table V).

Section Two is comprised of electrofishing stations six and seven. This section is best described by the situation mentioned in V (b), and represents that part of Upper Indian River between the channel and Bowater's Diversion Dam, which was rendered inaccessible to adult salmon with the completion of the channel in 1963, but where limited numbers of fry have been introduced. Prior to 1963, migrating salmon could, and did, move readily into this section of river to spawn. The number of fry introduced into Section Two, since the channel went into operation in 1963, is given in Table III.

Table III. Number of fry introduced from the channel into section two since the beginning of channel operation in 1963.

Year of release	Number of fry introduced at	
	Bowater's Diversion Dam (Electrofishing Station 6)	Hewlett's Road Crossing (Electrofishing Station 7)
1964	0	0
1965	20,000	18,000
1966	6,000	6,000
1967	3,000	3,000

<u>Section Three</u> represents the one and one-half miles of river, on Black Brook, between Indian Pond and Black Brook Falls. This section is representative of the situation described in V (c) and includes electrofishing stations eleven, twelve and thirteen.

<u>Section Four</u> includes electrofishing stations fourteen, twenty-one and twenty-two. This section represents the main river below Indian Pond and is considered representative mainly of the situation described in V (c), although 10,000 fry were introduced near station twenty-one in 1965. (This is, however, considered insignificant because of the large area represented by section four).

<u>Section Five</u> is representative of the situation mentioned in V (b). This section includes electrofishing stations eight and nine, and is

considered representative of small tributary streams where limited numbers of fry have been introduced from the channel. Approximately three thousand fry were released near station eight in 1965 and another three thousand were released here in 1967.

Section Six includes electrofishing stations fifteen, sixteen, nineteen and twenty. These stations are all located on small tributary streams where a few salmon are known to spawn in the lower reaches, but where parr are free to move various distances upstream. This section is considered to be mainly representative of the situation mentioned in V (d).

Section Seven, including electrofishing stations seventeen and eighteen, represents that part of Indian River which is characteristic of the situation described in V (e), i.e., those areas which are inaccessible to Atlantic salmon.

Section Eight, including electrofishing stations twenty-three, twenty-four and ten, represent that part of Upper Indian River, between the channel and Bowater's Diversion Dam, which is best described by the situation mentioned in V (d). Less than three thousand fry were released near station ten in 1965, but this is considered insignificant.

VI. FRY PRODUCTION

A. IN THE CHANNEL

Under the conditions provided in the channel for egg incubation, egg-fry survival rate has ranged from 29 percent in 1963-64 to 65 percent in 1965-66. Details concerning egg-fry survival rate and the number of fry produced annually in the channel are given in Table IV.

Table IV. Annual egg-fry survival and fry production in the channel, 1963 - 1967. (Number of eggs deposited is calculated on the basis of 700 eggs per pound of female fish and an average weight of three pounds per fish, as determined by direct egg counts and weighing of selected samples).

Year	No. of females in the channel	No. of eggs deposited	No. of fry produced	Percent egg-fry survival
1963-64	76	160,000	46,000	29
1964-65	201	425,000	168,000	40
1965-66	110	230,000	150,000	65
1966-67	114	240,000	90,000	38

B. IN THE RIVER

To study fry production in the river is difficult to say the least. Unlike in the channel, where the adults have spawned in a concentrated area and from which fry migrate "en masse" each Spring, there is rarely, if any, such concentration of spawning in the river under natural conditions. Consequently, there is no clear-cut migration of naturally produced fry that can be counted with the aid of traps. Also, during the period of fry emergence from the gravel, high water levels make estimation of fry indicies, by electrofishing or seining, impractical. Consequently, no definite information is available on the number of fry produced naturally in Indian River. It is possible, however, to estimate, within reasonable limits of certainty, the number of fry produced under natural conditions. This has been done for section one of Indian River. The results are presented in Table V.

The average egg production for Atlantic salmon has been reported at approximately 750 eggs per pound of female fish by Calderwood (1930) and Belding (1940). Day (1887) estimated that Atlantic salmon produced about 900 eggs per pound of body weight. Jones and King (1946) found a range of 418 to 770 eggs per pound of body weight for two fish. Jones (1959) concluded that the accepted average is 650 to 700 eggs per pound of body weight. Elson (1957) has quoted 800 eggs per pound. Meister (1962) used 750 eggs per pound of female fish for Cove Brook, Maine. Egg counts on ripe female salmon in Indian River Spawning Channel indicate that 700 eggs per pound is the best figure to use for Indian River salmon. This latter figure has been used for calculations in Tables IV and V.

Water levels and bottom composition in section one make it quite feasible to count the number of "redds" constructed, by spawning females, during the spawning season. Pratt, J.D. (personal communication) working on the spawning behavior of Atlantic salmon in Indian River Spawning Channel, has determined that the construction of one "redd" can be attributed to one female salmon. It is quite possible that several females may have deposited eggs in any one "redd", but on the average, the number of "redds" constructed in any particular area is equal to the number of females spawning in that area. Thus, by counting the number of redds constructed between the channel and Indian Pond, and assuming that the mean weight and fecundity of females spawning in this area is the same as in the channel (there is no reason to suspect otherwise), it is possible to compute Table V. It is also assumed that egg-fry survival under natural conditions lies somewhere in the range of ten to thirty percent. Table XI shows that egg to mid-summer young-of-the-year survival in section one is about fourteen percent. Considering that the period when fry are emerging from the gravel is one of relatively high mortality, it seems reasonable to assume that egg-fry survival, under natural conditions, in section one of Indian River is around twenty percent.

Table V. Estimation of the number of fry produced naturally, and the total

Year	No. of fry released from channel	No. of redds constructed in section one	Estimated no. of eggs deposited in section one	Min.
1963-64	46,000	123	260,000	26,0(
1964-65	90,000	240	505,000	51,0(
1965-66	130,000	130	275,000	28,0(
1966-67	17,000	85	180,000	18,0(

1 the total number of fry present in section one, Indian River; 1963 - 1967.

Estimated no. of fry produced naturally in section one			Total no. of fry deposited in section one		
Min.	Mean	Max.	Min.	Mean	Max.
26,000	52,000	78,000	72,000	98,000	124,000
51,000	102,000	153,000	141,000	192,000	243,000
28,000	55,000	83,000	158,000	185,000	213,000
18,000	36,000	54,000	35,000	53,000	71,000

VII. FRY DISPERSAL AFTER LEAVING THE CHANNEL

Table VI presents a summary of the number of fry, taken in the "fry migration traps" (Figs. 9 and 10), as they moved downstream from the channel during 1966 and 1967. One hundred thirty thousand fry were released below the channel in 1966, approximately seven thousand of which were marked by removal of the dorsal fin. In 1967 approximately seventeen thousand fry, ten thousand of which were fin-clipped, were released below the channel.

Table VI suggests that, although some fry do move the 2.8 miles from the channel to Indian Pond, most of the fry released from the channel limit their distribution to within one to two miles of the channel.

Although trap number two was not operated on the nights of June 16, 17 and 18, and trap number one was not operated on the night of June 16 during 1966, the data for that year indicate that there was a progressive downstream movement of fry, with the daily number taken in each trap decreasing as distance downstream from the channel increased. In 1966, the low number of fry taken in trap number three, which was designed to capture all downstream migrants, indicates that not many fry migrated this far downstream.

Traps one and two were removed in 1966, early in July, but trap number three was operated until around the last of July when a local freshet washed it out. Both traps were removed around the middle of July in 1967. No fry were captured after the last dates listed in Table VI.

Table VI. Number of fry taken in "fry migration traps" at Indian River, 1966, 1967.
(- indicates trap was not in operation)

1966							1967				
Date	Total no. of fry caught in trap no.			No. of marked fry caught in trap no.			Date	Total no. of fry caught in trap no.		No. of marked fry caught in trap no.	
	1	2	3	1	2	3		1	2	1	2
June 16	-	-	10	-	-	0	June 22	8	0	0	0
June 17	865	-	6	2	-	0	June 23	24	0	0	0
June 18	273	-	0	6	-	0	June 24	21	0	0	0
June 21	0	435	11	0	1	1	June 25	4	0	0	0
June 22	1	98	57	0	1	2	June 26	0	5	0	0
June 23	0	44	52	0	0	0	June 27	0	1	0	0
June 24	0	70	0	0	2	0	June 28	1	1	0	0
June 25	0	2	5	0	0	0	June 29	1	1	0	0
June 26	0	1	1	0	0	0	June 30	0	0	0	0
June 28	0	0	6	0	0	0	July 1	0	0	0	0
June 29	0	0	5	0	0	0	July 2	0	0	0	0

Figure 13 summarizes abundance indicies of underyearlings (mid-summer young-of-the-year) in Section One of Indian River during 1966 and 1967. The obvious decrease in density of underyearlings with distance downstream from the channel indicates that fry restrict themselves to a limited distribution. Elson (1962-a), studying dispersal of underyearlings from planting sites in Pollet River, Nova Scotia, concluded that, in the main river, underyearlings distributed themselves fairly uniformly over the stream bottom for about one-half mile above and one mile below planting stations within about ten weeks. White and Huntsman (1938) found that newly-planted fry in Apple River, Nova Scotia, had little tendence to move through pools during their first summer. Mills (1964) however, concluded that, in the River Bran, Scotland, there was considerable dispersion of fry after planting, with the fish tending to distribute themselves over the available river and stream beds. Mills does not state definitely if dispersion took place mainly as underyearlings or older parr.

Mills (1964) further suggests that downstream migration of fry, which he observed in two tributaries of the River Bran after fry had been planted there, was related to the stocking density. It should be noted, however, that Mills stocked fry at extremely high densities of about 1,200 per unit, in his study area. This is about 4 to 6 times as great as the stocking density of fry in Section One of Indian River.

Further information pertaining to fry dispersal is contained in Figure 14. Electrofishing studies at the Hewlett's Road crossing point and below the Bowater Diversion Dam suggest that no fry moved more than one-half mile downstream from the release point and that upstream migration is limited to much less than this.

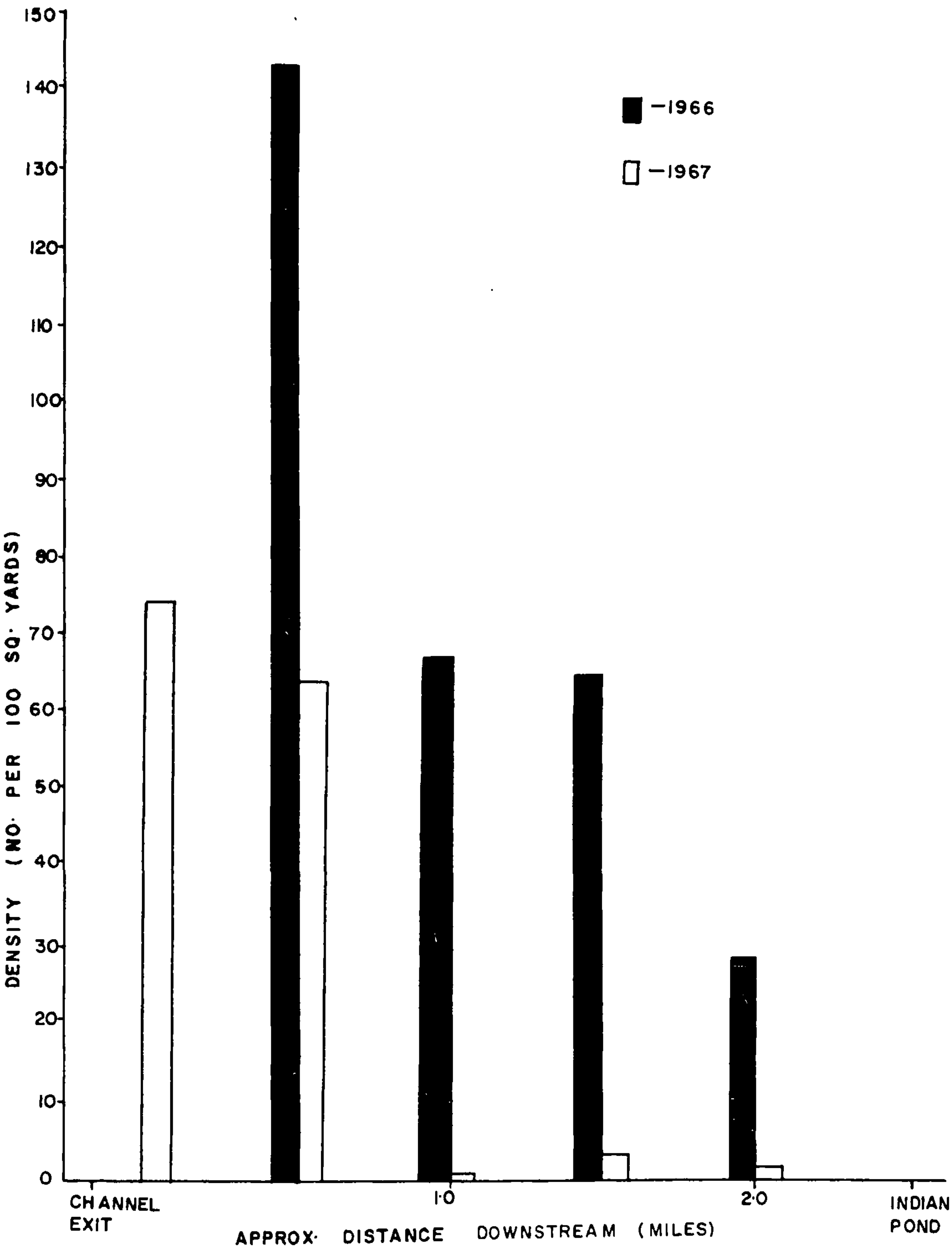

Fig. 13. Density of underyearlings between Indian Pond and the channel; 1966, 1967. (Each vertical bar represents one electrofishing station).

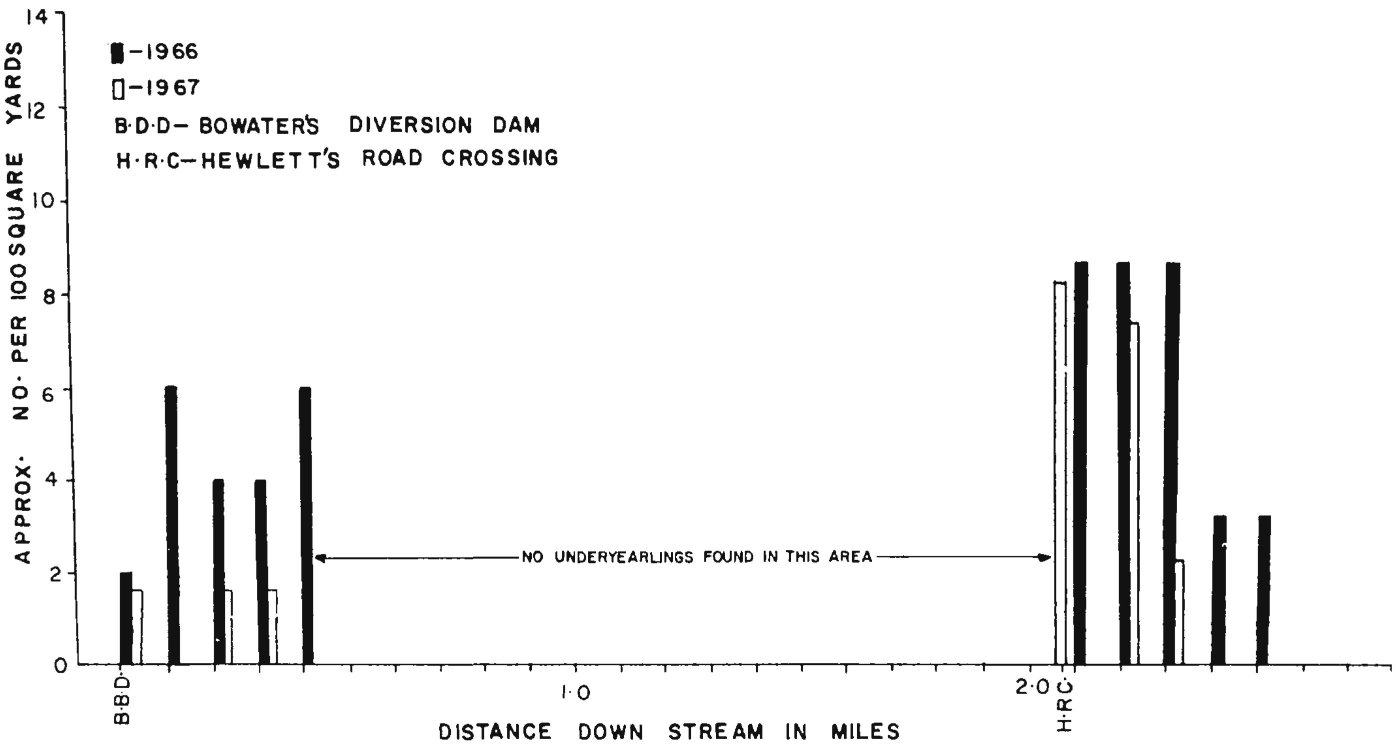

Fig. 14. Density of underyearlings near fry-release points at Bowater's Diversion Dam and Hewlett's Road crossing, Indian River; 1966, 1967. (Fishing was done approximately three months after fry were released).

Even further evidence of limited fry dispersal is presented in Figure 19. Three thousand fry were released near station eight on North Brook during the summer of 1967. Electrofishing studies approximately one month later showed a very high fry index (448) at station eight, while at station nine, which is not more than a half mile upstream from station eight, there were no fry present. Unfortunately no fishing was done on North Brook, below station eight.

Mills (1964) states that some of the reasons for the downstream movement of fry are suggested by the observations made by Kalleberg (1958) in a stream tank. He found that salmon fry tend to disperse when they begin to feed, that feeding was common among the fry three to four days after emergence from the gravel, and that during the first two weeks the feeding behavior exhibited an increasing specialization by being directed towards open water. LeCren (Freshwater Biological Association, Twenty-nineth Annual Report, pp. 33-4 (1961)) found that experimental populations of brown trout fry also tended to disperse in the limited area available to them and considered that dispersal was probably more important under completely natural conditions. Wynne-Edwards (1962) discusses the effect of shortage of food on a population and states that instead of this resulting in a general and uniform debilitation of all the members of the Society alike, and perhaps their ultimate extinction, the dominant animals are given a preferred chance of sustaining life and vigour throughout the period of famine. 'This dominance behavior', he says, 'ensures that only as many as the remaining sources can sustain are allowed to partake of the food....; the excluded subordinates either perish quickly or emigrate to search for subsistance elsewhere'. Mills (1964) further found that increasing the density of fry in a given area resulted in a sharp increase in downstream migration.

Kalleberg (1958) found that, at moderate population density and normal current velocity, all juvenile salmon in an aquarium occupied territories and suggested that the reason why territories were finally abandoned might be either, increasing competition within the population because the individual had outgrown its environment, or changes of water current. He suggested that the velocity of current influences young salmon by:

(a) Forcing the fish to leave exposed stations, and so acting directly on territoriality, and

(b) Affecting the special adjustment of juvenile salmon and trout to drifting prey.

He found that, in an aquarium, if fry density exceeds a critical limit, the population splits into two fractions, one occupying territories and the other, with no territories, being markedly unstable. This suggests a critical density for stocking fry and is supported by LeCren's results (1961). Saunders and Gee (1964) found that fry were most numerous in shallow riffles and appeared to remain within small areas of the stream during summer but moved into parr habitats, the pools and deep riffles, in the autumn. In Indian River available information supports the idea that, during the first summer of life, fry tend to limit their distribution to a range of one-half to two miles. The fact that only eight fry were taken in "fry migration trap" number two (Table VI) in 1967, and that fry indicies drastically decreased (Fig. 13) beyond one mile downstream from the channel in 1967, suggests that the degree of dispersion is influenced by the stocking density.

VIII. PRODUCTION OR STANDING CROP

A. GENERAL

Elson (1962-a) states, "Our dictionary meaning of production is 'bear' or 'yield'. We are all familiar with the idea of production from a factory, or a farm, or even the production of hay or grain from one field of a farm. By good management we can increase production. But we must know what we are about. Planting more seed is not always the answer. An acre of good land will produce more oats if seeded at 1 to 2 bushels per acre than if seeded at 10 bushels per acre. With too heavy seeding the young plants tend to smother themselves and we end up with a smaller crop than if we seeded properly. A salmon stream is just some rather stony land covered by flowing water. It can produce just so much plant life which in turn can support just so much animal life per acre. With good management we can get the most production from our underwater 'field'. But, to accomplish this we must know enough about production possibilities of our 'field' that we do not either expect something impossibly large or settle for something far below what we might get. We must also know what form of management to apply and how to apply it".

B. STANDING CROP OF PARR IN EACH SECTION

Abundance indices for juvenile salmon are presented, according to section of river, in Table VII and Figures 15 to 21 inclusive. Tables I and II of the appendix present the same information not arranged according to section.

Although these graphs and Table VII are self-explanatory, some features are worthy of special note. Perhaps the most striking feature is that, in spite of the fact that large numbers of channel-produced fry have been released into section one since operation of the channel began, this section is relatively poor with respect to parr production. Of all the parr-producing areas of Indian River, only section four has a lower mean parr index than section one (section 7, it will be remembered, is inaccessible to salmon). It is also noteworthy that all sections except section one have depended, since 1963, on natural production, manual

Table VII. Indices of abundance of juvenile Atlantic salmon in Indian River, 1966, 1967. (Data has been arranged according to section)

Section	1		2		3		4		5		6		7		8	
Year	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967
No. of stations fished	5	5	2	2	3	3	3	3	2	2	4	4	2	2	1	3
Underyearling mean index	76.5	28.9	33.2	30.4	8.6	14.6	9.2	7.3	0	224.0	0.8	8.8	0	0	0	0
Parr mean index	12.7	13.3	28.9	42.2	20.5	17.1	9.7	6.3	18.2	19.9	22.4	15.6	0	0	23.9	10.3
Average of underyearling mean indices	52.7		31.8		11.6		8.3		112.0		4.8		0		0	
Average of parr mean indices	13.0		35.6		18.8		8.0		19.6		19.0		0		17.1	

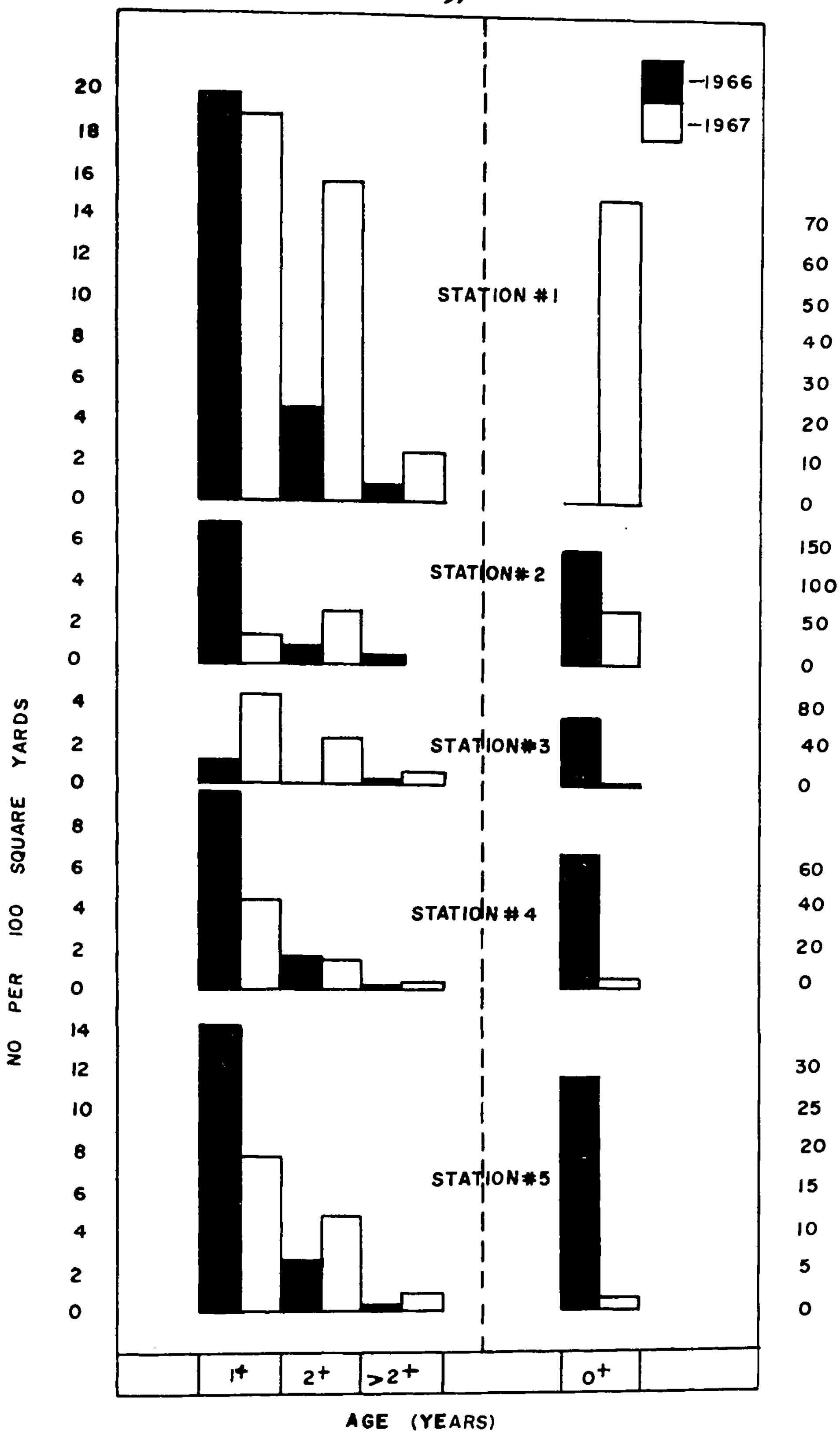

Fig. 15. Indices of abundance of juvenile Atlantic salmon in section one, Indian River; 1966, 1967.

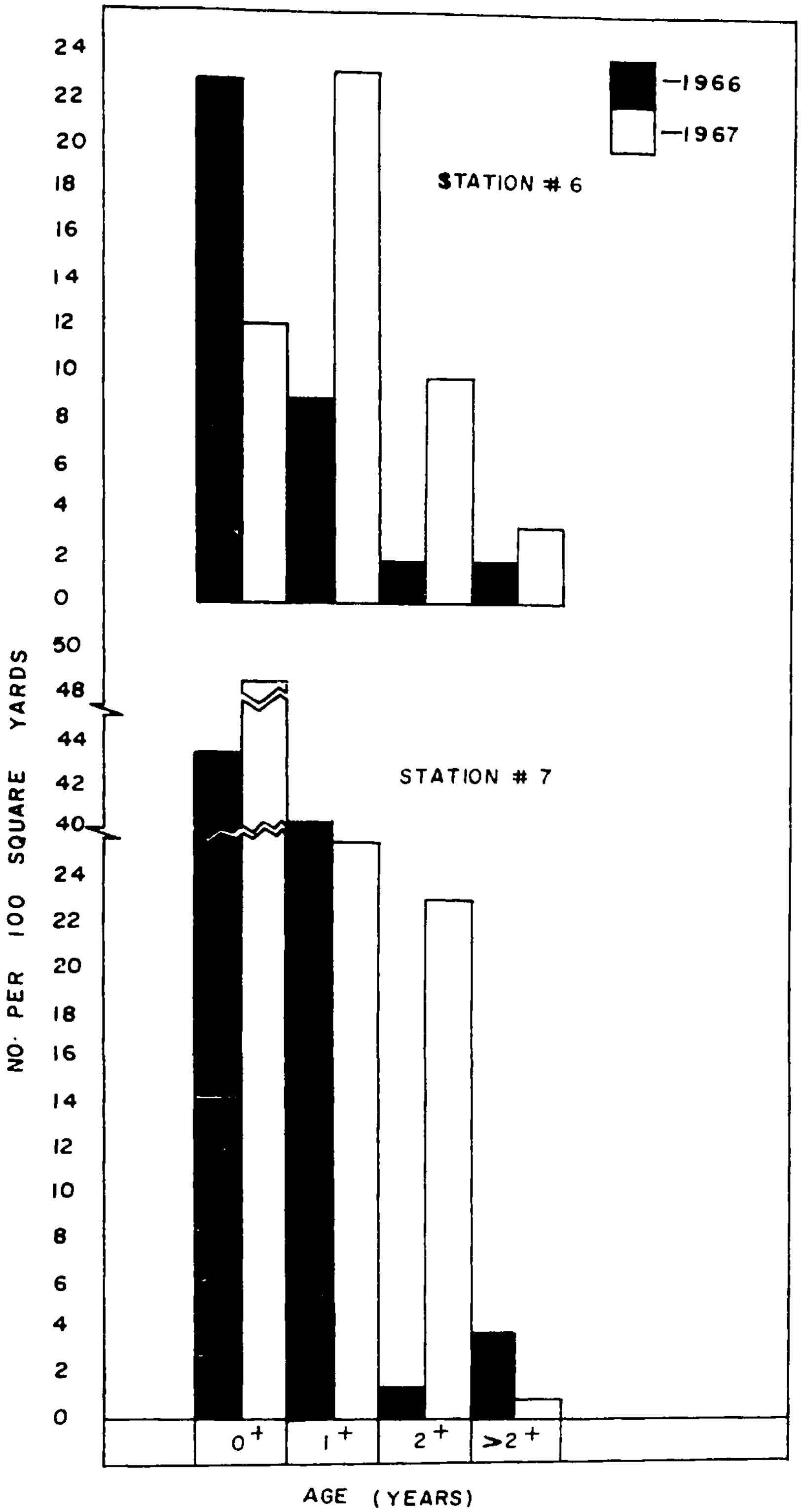

Fig. 16. Indices of abundance of juvenile Atlantic salmon in section two, Indian River; 1966, 1967.

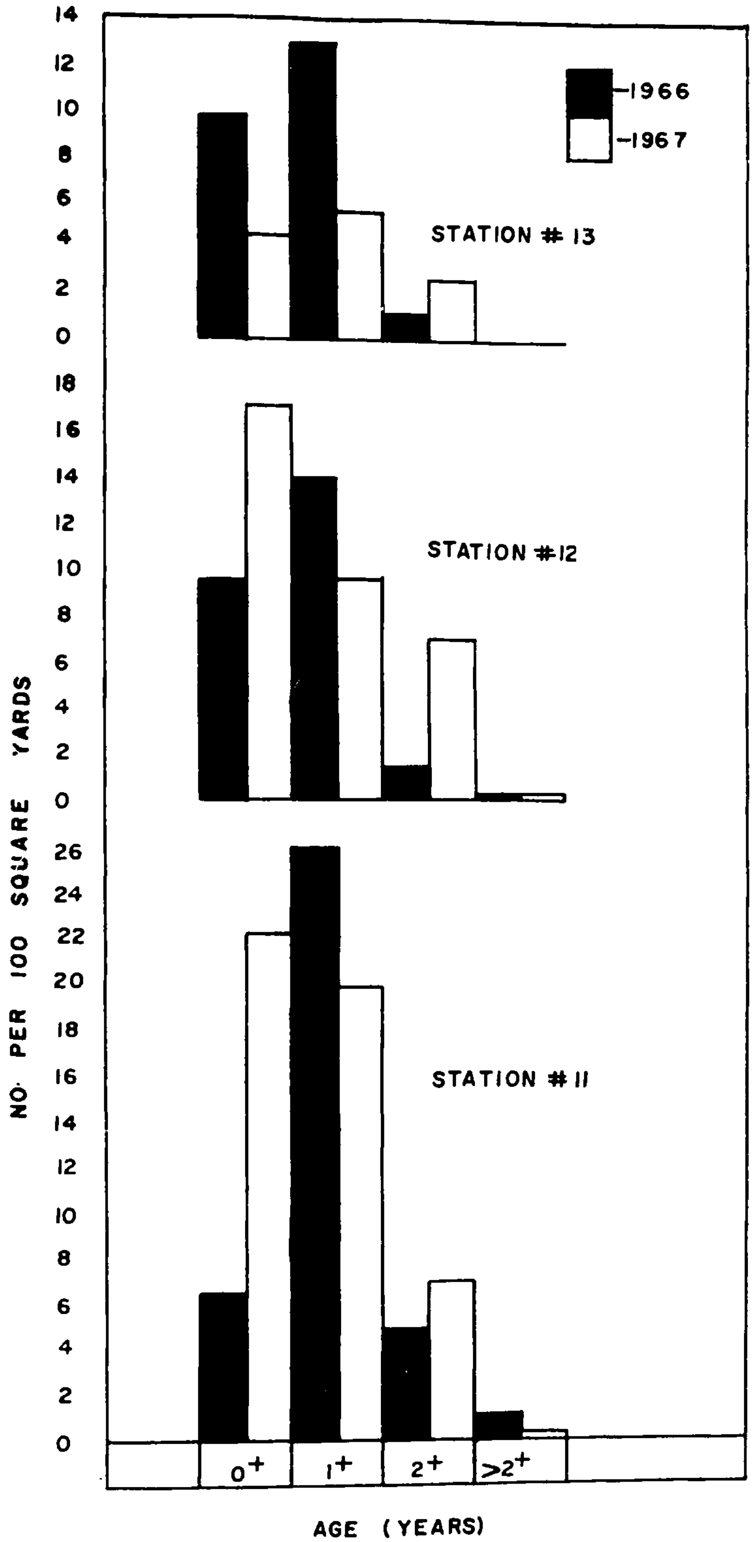

Fig. 17. Indices of abundance of juvenile Atlantic salmon in section three, Indian River; 1966, 1967.

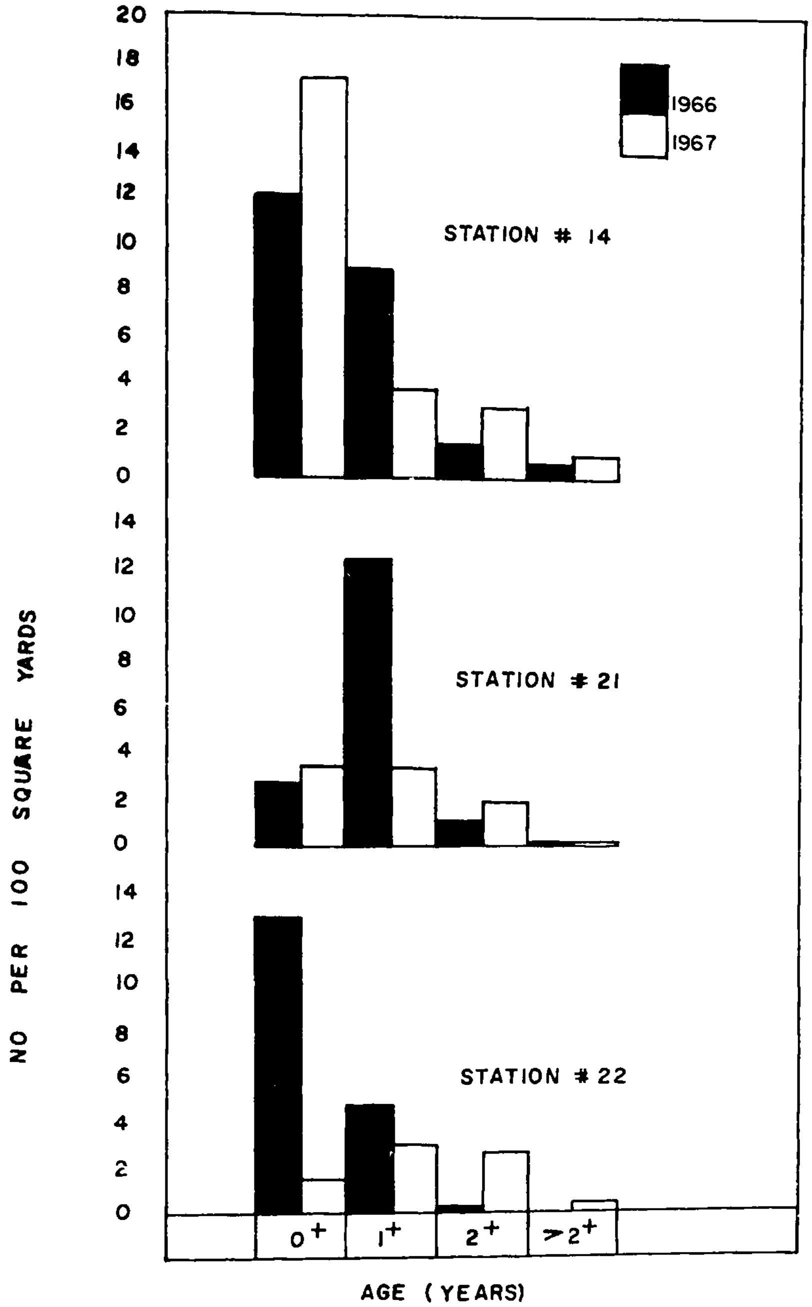

Fig. 18. Indices of abundance of juvenile Atlantic salmon in section four, Indian River; 1966, 1967.

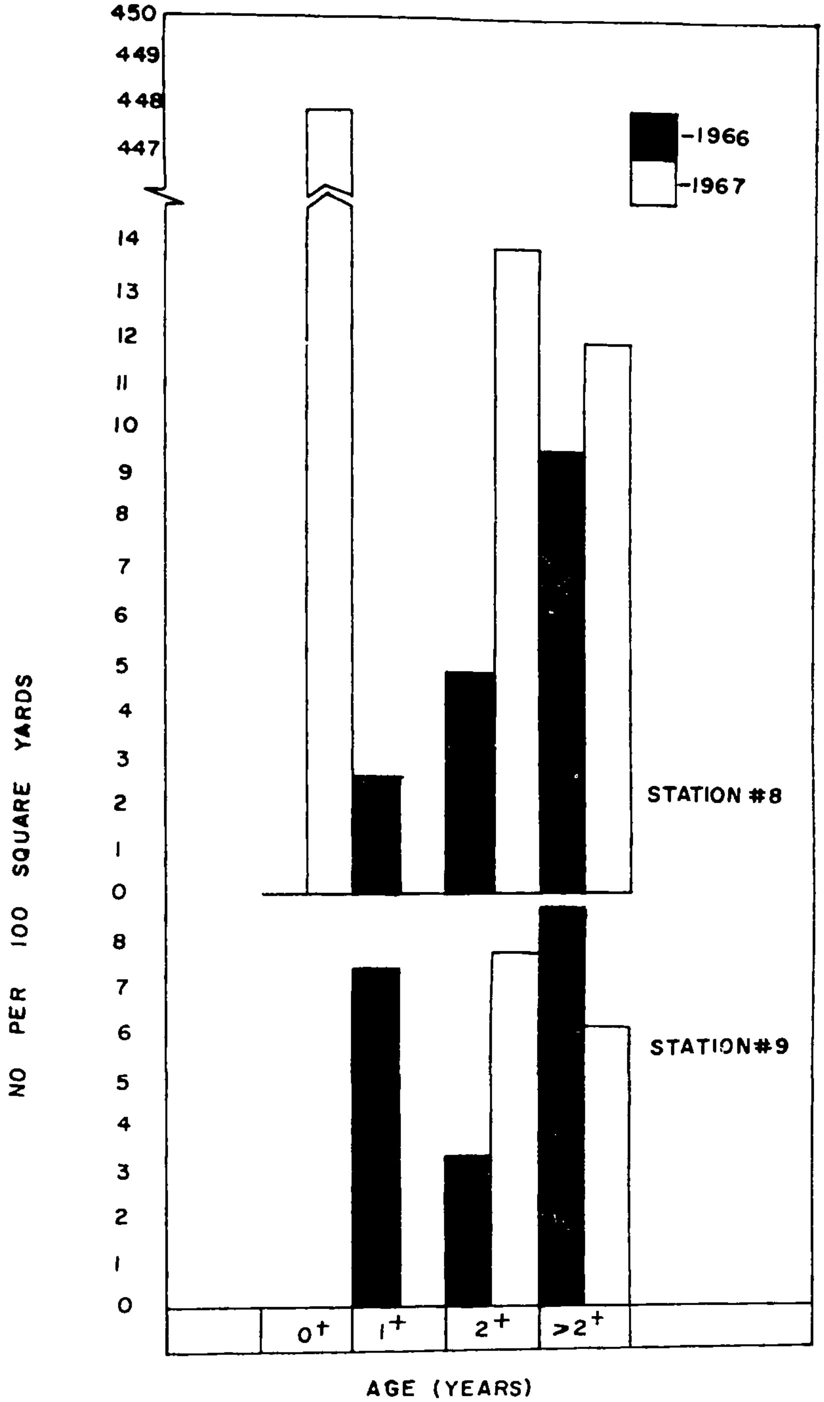

Fig. 19. Indices of abundance of juvenile Atlantic salmon in section five, Indian River; 1966, 1967.

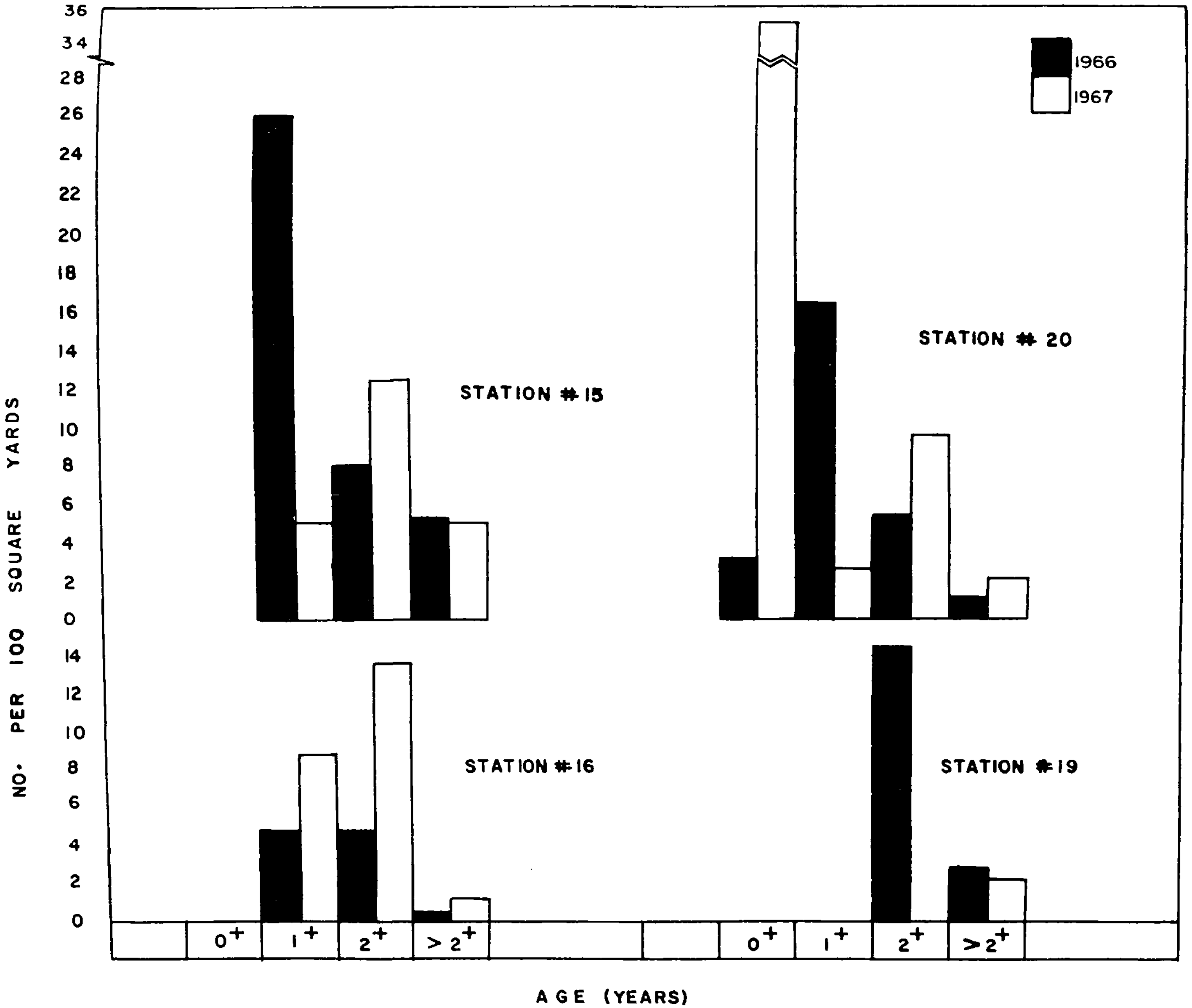

Fig. 20. Indices of abundance of juvenile Atlantic salmon in section six, Indian River; 1966, 1967.

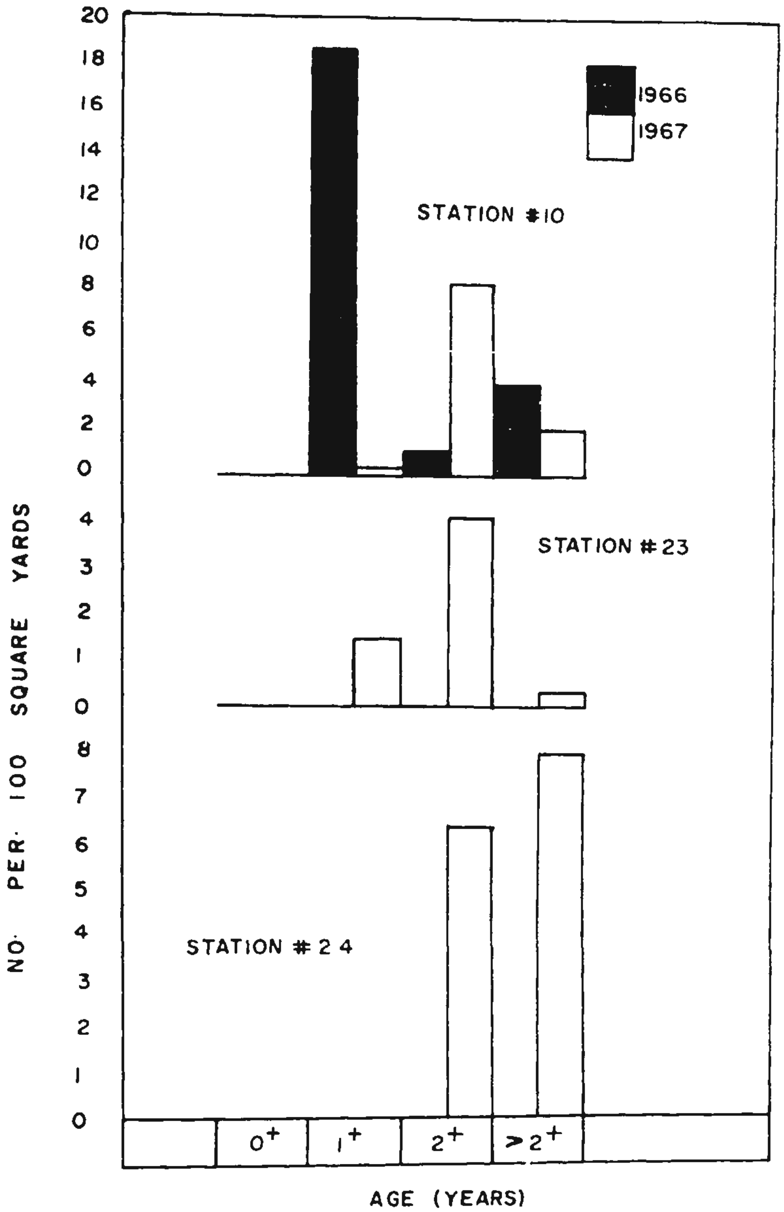

Fig. 21. Indices of abundance of juvenile Atlantic salmon in section eight, Indian River; 1966, 1967.

distribution of channel fry, or recruitment of parr from other areas of the river. It is also interesting to observe that although only 17,000 fry were released in section one in 1967, the mean underyearling index in this section in 1967, compared favourably with underyearling indices in any of the other sections except section 5 where survival of 3,000 fry released here during 1967 appears to have been extremely high. Comparison of the mean parr index in section one during 1966 and 1967, by the t - test (Table V, appendix), indicates that there is no significant difference in the parr indicies recorded during these two years. This would indicate that the highest level of production of parr that can be expected from this area is in the order of 13 per unit. These observations suggest that the large numbers of channel-produced fry which have been released into section one since operation of the channel began, have not added much to parr production.

This situation is by no means confined to Indian River. Larsen (1942), writing about salmon and trout fry liberations in Denmark, states,

> "Liberations of fry with government grants by fishermen's associations and more or less philantropic societies for the advancement of fisheries were formerly carried out from the principle; the more fry the better - a rather objectionable principle from our present knowledge, though it is still followed in some few localities".

Elson and Kerswill (1955) state that maximum smolt yield in Pollett River, Nova Scotia, could be obtained by planting hatchery fingerlings at a rate of about 30 per one hundred square yards of river. Elson (1962-a) showed that plantings of underyearlings in Pollett River, Nova Scotia, at a rate greater than 20 - 30 per unit of stream did not increase smolt production. Rounsefell and Everhart (1953) states, "The total productivity of any body of water is limited. This fact sets a very positive theoretical limit to the maximum abundance obtainable by any species".

All things being considered, then, it seems unlikely that favourable results can be achieved by stocking large numbers of fry in section one of Indian River.

C. STANDING CROP OF ALL SPECIES IN EACH SECTION

Indices of abundance for all species are presented in Table I of the appendix, and in Table VIII according to section.

It can be seen that eels and sticklebacks are minor contributors to the standing crop in Indian River. Trout are a major contributor to total standing crop in the smaller tributary streams, but contribute relatively little to production in the main river. This is not surprising, since trout tend to concentrate in smaller, cooler streams during the summer. Rounsefell and Everhart (1953) state, "Thus on Atlantic salmon rivers, the brook trout (Salvelinus fontinalis) cannot endure such high temperatures as the salmon parr. In mid-summer, while parr are thriving in the main stream, the brook trout desert these warm waters and gather in cool spring holes or enter cooler spring-fed tributaries".

Elson (1962-a) states that the tributaries of Pollett River are small trout brooks. Studies on Twenty-three Mile Brook during the summer of 1967 showed that large numbers of trout moved from the main river into this tributary during the period of water warming from June 1 to July 15. On the smaller tributaries, it was noted that trout were particularly abundant upstream from obstructions that would perhaps block upstream migration of salmon parr. For example, on Twenty-three Mile Brook, there is a small falls about one and one-half miles above where this stream

Table VIII. Indices of abundance for all species in Indian River;

Section	1		2		3	
Year	1966	1967	1966	1967	1966	1967
No. of stations fished	5	5	2	2	3	3
Mean underyearling index	76.5	28.9	33.2	30.4	8.6	14.6
Average of mean underyearling indices	52.7		31.8		11.6	
Mean parr index	12.7	13.3	28.9	42.2	20.5	17.1
Average of mean parr indices	13.0		35.6		18.8	
Mean trout index	1.9	1.0	1.6	1.7	1.2	0.1
Average of mean trout indices	1.5		1.7		0.7	
Mean eel index	0.4	0.4	4.4	5.9	0.7	0.7
Average of mean eel indices	0.4		5.2		0.7	
Mean stickleback index	1.6	2.0	2.7	0.9	0.1	0.2
Average of mean stickleback indices	1.8		1.7		0.2	

ı River; 1966, 1967. (Data has been arranged according to section).

	4		5		6		7		8	
.967	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967
3	3	3	2	2	4	4	2	2	1	3
.4.6	9.2	7.3	0	224.0	0.8	8.8	0	0	0	0
	8.3		112.0		4.8		0		0	
.7.1	9.7	6.3	18.2	19.9	22.4	15.6	0	0	23.9	10.3
	8.0		19.6		19.0		0		17.1	
0.1	0.2	0	6.5	21.0	34.7	43.2	44.3	89.0	0.3	0
	0.1		13.8		39.0		66.7		0.2	
0.7	0.3	0.4	0	0.2	0	0.8	0	0	1.7	1.6
	0.4		0.1		0.4		0		1.7	
0.2	3.1	0.3	0	0	1.8	2.1	0	0	0.5	0.1
	1.7		0		2.0		0		0.3	

drains into Upper Indian River. In 1966, trout production below the falls (electrofishing station 15) was 37.4 per unit, and parr production was 39.4 per unit. Above the falls (electrofishing station 18) trout production was 75.4 per unit and parr production was nil. In 1967, trout production below the falls was 68.3 per unit and parr production was 22.5 per unit, while above the falls, trout production was 162.2 per unit and parr production was nil.

Table IX. Indices of abundance for trout and salmon parr in five tributary streams of Indian River. Data obtained by electrofishing 1966, 1967.

Tributary	Electrofishing station	Parr index		Trout index	
		1966	1967	1966	1967
North Brook	8	17.0	26.0	9.1	26.0
	9	19.3	13.8	3.8	15.9
Twenty-three Mile Brook	15	39.3	22.5	41.1	68.3
	18	0	0	75.4	164.0
Little Black Brook	16	10.0	23.7	52.6	77.5
Whitehorn's Brook	19	17.5	2.2	26.2	25.0
Shoal Pond Brook	20	22.6	14.0	18.7	2.0

No underyearling salmon were found in any of the tributary streams except near the mouth of Shoal Pond Brook (electrofishing station 20). It seems, then, that parr living in the tributary streams move upstream from the main river or from regions near the mouth of the tributaries, where a few redds have been located. Upstream migration of parr seems to be effectively stopped by small obstructions. Table IX, which has been computed from Table I of the appendix, indicates that parr living in the smaller tributary streams must compete with brook trout for living space and the available food supply.

D. PRODUCTION IN INDIAN RIVER COMPARED TO THAT IN SOME OTHER STREAMS

Elson (1962-a) quotes Hayes (1953) as suggesting relative values of abundance of fish in the salmon rearing grounds of LaHave River, Nova Scotia as being: salmon underyearlings - over 3, parr - about 1, speckled trout - about 3, and coarse fish other than eels - about 50 per unit. Larsen (1955) has given figures for a number of small Danish trout streams. Average numbers per unit according to his observations are: indigenous salmonidae - 44 (brown trout being the dominant); eels - 7; minnows, etc. - 5. Elson and Kerswill (1955) show 39 and 53 parr per unit for native stocks of the Miramichi, the latter occurring after Merganser and Kingfisher control had been initiated. Elson (1962-a) quotes values for the Pollett River of 20 - 30 young salmon, of all age classes, per unit, presumably after bird control had been initiated on that river. Murray (1967) estimates parr production in Little Codroy River to be about 15 per unit. (This figure does not include underyearlings). Meister (1962) estimates average standing crops of young salmon (including underyearlings) in Cove Brook, Maine, to be 56 per unit in 1956, 60 per unit in 1957 and 22 per unit in 1958. Saunders (1960) found that parr indices in Ellerslie Brook, P.E.I., ranged from less than 1 to 70 per unit. Saunders (1960) quotes Keenleyside (1959) as showing parr production in Northwest Miramichi, in 1953, to average 30 per unit, with bird control.

Indices of abundance for young salmon and all other species, in Indian River, are presented in Table VIII, and for young salmon only in Table VII.

Parr production in Indian River compares favourably with production in the Danish streams listed by Larsen (1955), is about the same as that listed for Cove Brook (Meister, 1962) and Ellerslie Brook (Saunders, 1960) and is perhaps a little better than that listed for Little Codroy (Murray, 1962). It is below that listed by Keenleyside (1959) and Elson and Kerswill (1955) for the Miramichi. It does, however, rate far above that listed for LaHave River by Hayes (1953). It is generally lower than that listed for the Miramichi and perhaps higher than that cited for the Pollett.

In Table X, the number of fish per unit in Indian River has been converted to pounds per acre so that Indian River standing crop can be compared to standing crops of other rivers as reported by other authors. The average standing crop in Indian River of about 35 pounds per acre appears low compared to Elson's figure of 70 pounds per acre for the Pollett (Elson, 1962-a), and 170 pounds per acre for Ellerslie Brook, Prince Edward Island, as quoted by Saunders and Smith (1955). However, only one-third of the trout streams listed by Carlander (1953) had standing crops of more than 70 pounds per acre, while about one-half had standing crops of less than 30 pounds per acre. Elson (1962-a) concluded that the Pollett should be classed as a moderately productive stream and that it probably rated

Table X. Weight of standing crop of fish in Indian River; 1966, 1967, expressed as pounds per acre (to the nearest one-half pound). Mean weights of fish sampled are presented in Table VI of the appendix.

Section	Salmon parr (lb./acre)		Salmon fry (lb./acre)		Trout (lb./acre)		Eels (lb./acre)		Sticklebacks (lb./acre)		Total (lb./acre)	
	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967
1	6.0	11.5	3.5	1.5	1.5	1.0	2.0	3.5	0.5	0.5	13.5	18.0
2	12.5	37.0	1.5	1.5	1.0	2.0	24.0	50.0	0.5	0	39.5	90.5
3	9.0	15.0	0.5	0.5	1.0	0	4.0	6.0	0	0	14.5	21.5
4	4.0	5.5	0.5	0.5	0	0	1.5	3.5	0.5	0	6.5	9.5
5	8.0	17.5	0	11.0	4.5	24.5	0	1.5	0	0	12.5	54.5
6	10.0	13.5	0	0.5	23.5	50.0	0	7.0	0.5	0.5	34.0	71.5
7	0	0	0	0	30.0	100.0	0	0	0	0	30.0	100.0
8	10.5	9.0	0	0	0	0	9.5	13.5	0	0	20.0	22.5
Mean	7.5	13.6	0.8	1.9	7.7	22.2	5.1	10.6	0.3	0.1	21.4	48.4
Av. of Means	10.6		1.4		15.0		7.9		0.2		34.9	

well up in a listing of Atlantic salmon streams. Mills (1964) lists parr population densities in the River Bran (Scotland) and its tributaries as being similar to those in the Pollett after bird control was started.

It must be remembered that Elson's figure of 70 pounds per acre for the Pollett was obtained after bird control had been in effect for four years. Before bird control was started, total weight of standing crop on the Pollett was in the order of 15 pounds per acre, while parr standing crop averaged about 5 pounds per acre. On this basis, it appears that Indian River is a moderately productive stream. As a producer of Atlantic salmon it would rank better than the Pollett, before bird control was started on that river.

IX. SURVIVAL STUDIES

Elson (1957) reported a survival of 6 to 8 percent from egg to late summer young-of-the-year for naturally produced native salmon in the Pollett and Miramichi Rivers. Reported survival of native young-of-the-year to 1+ parr was in the neighbourhood of 54 percent for the Pollett River. Elson (1962-b) has given the following figures for survival rates of Atlantic salmon based on the average of several rivers which he studies:

Potential egg deposition to underyearlings...........	6%
Underyearlings to small parr.........................	60%
Small parr to large parr.............................	40%
Large parr to smolts.................................	40%
Smolts to adults.....................................	8%

Meister (1962) reported survival rates for Cove Brook, Maine. Survival from egg to midsummer young-of-the-year was nine percent in 1956 and eleven percent in 1957. Survival from midsummer young-of-the-year to 1+ parr was about 59 percent in 1957 and 41 percent in 1958, and survival from 1+ parr to 2+ parr was 25 percent in 1956 and 38 percent in 1957. Mills (1964) studied survival of fry planted in three tributary streams of the River Bran, Scotland. In 1960, he found that just over one percent of the fry planted four months earlier were present in his study area at sampling time. In 1961, he found that the number of fry present, some four months after planting, ranged from 0.2 to 1.3 percent of the number that had been planted. Mills showed that, allowing for the fry which moved out of his study area, mortality, four months after planting, was over 98 percent in 1960 and as high as 99.6 percent in 1961. He suggests that the heavy mortality which occurred in these streams may well have been due to the high rate of stocking, and quotes Le Cren (1961) as finding mortality as high as 97 percent in brown trout populations if the stocking rate were very high. Horton (1961) also found a mortality of between 92 and 96 percent between the alevin and yearling stages of brown trout under natural conditions. Mills (1964) quotes Le Cren as finding that deaths probably occurred mainly between 20 and 40 days after the fish began to feed, and states that, in one of his study areas, less than one percent of the fry planted in 1961 remained 60 days after stocking. Mills (1964) suggests that the period of heavy mortality in young salmon may well be similar to that for young trout.

Survival of young salmon in Indian River is discussed here mainly in connection with results obtained in section one, since this is the area where management attempts have been concentrated. Survival is discussed only to the 2+ stage, because relatively little information exists on smolt production and migration, which occurs mainly after the 3+ stage has been reached. Survival figures were calculated as percentages of fish remaining from the preceding year's estimates for each class. The figures given for survival to the 1+ and 2+ stages should not, therefore, be considered strictly as survival rates since some fish migrate as smolts at age 2+ and there is evidence that some parr move out of the area before reaching the 1+ stage. (The presence of 1+ and older parr in tributary streams such as Twenty-three Mile Brook and Little Black Brook, and in Indian Pond, suggests that this is the case). Survival rates which have been computed for section one are presented in Table XI.

Table XI. Calculation of survival rates (percent remaining in study area) for young Atlantic salmon in section one, Indian River.

	1966	1967
Estimated number of eggs deposited in study area	180,000	-
Estimated number of midsummer young-of-the-year present in study area	67,000	25,000
Estimated number of 1+ parr present in study area	9,200	6,500
Estimated number of 2+ parr present in study area	1,700	4,600
Survival rates		
Egg to midsummer young-of-the-year (1966 - 1967)....	13.8%	
Midsummer young-of-the-year to 1+ parr..............	9.7%	
1+ parr to 2+ parr..................................	50.0%	

In section one, Indian River, survival from egg to midsummer young-of-the-year was 14 percent. Survival from midsummer young-of-the-year to 1+ parr was 10 percent, and survival from 1+ parr to 2+ parr was 50 percent.

One hundred thirty thousand fry were released from the channel into section one in 1966. An estimated additional 55,000 were produced naturally (Table V) in the same area, comprising a total of 185,000 fry. Electrofishing studies showed that by midsummer of 1966, 67,000 of these fry remained in the area as midsummer young-of-the-year. No fry were observed moving out of the area during this period. Therefore, it is estimated that there was 36 percent survival between fry and midsummer young-of-the-year. In 1967, an estimated 36,000 fry were produced naturally in section one (Table V). An additional 17,000 were released from the channel into this area, 10,000 of which were marked by removal of the dorsal fin. Only three marked fry were recovered during electrofishing studies in 1967. It is assumed, therefore, that mortality was extremely high on marked fry, and only 7,000 of those released from the channel in 1967 are considered in survival calculations. During the electrofishing period in 1967, an estimated 25,000 midsummer young-of-the-year remained in section one. It is estimated, therefore, that 58 percent of the fry present in section one in 1967 survived to the midsummer young-of-the-year stage. These figures are much higher than those listed by Mills (1964), suggesting, as Mills states, that survival of fry is dependent on the stocking density. Mills stocked fry into his study area at a density of about 1,300 per unit. Stocking density in section one of Indian River in 1966 (including naturally produced and channel-produced fry) was about 400 per unit, and in 1967 was less than 100 per unit.

Survival of underyearlings to the 1+ stage is considerably lower than the figures listed by Meister (1962) and Elson (1962-b), suggesting either that there is high mortality on young salmon in section one of Indian River at this stage of their life cycle, or there is considerable emigration of young salmon from this area between the underyearling and 1+ stages. Figure 15 is also suggestive of this. It is possible that some parr may migrate into Twenty-three Mile Brook and Little Black Brook, and that some may move into Indian Pond between the underyearling and 1+ stages.

No information is available on how many 1+ parr inhabit Indian Pond, since quantitative fishing for parr in such a large body of standing water is impracticle if not impossible. During limited electrofishing studies and seining along the shoreline of this pond, however, sizeable numbers of 1+ parr were caught. Saunders (1960) showed that a small pond on Ellerslie Brook, Prince Edward Island, acted as a rearing area for parr. Huntsman (1945) concluded that lakes, as well as inner fresh or brackish parts of estuaries, may become populated with parr, through descent of a portion of the stock in streams. The number of 1+ parr living in Twenty-three Mile Brook and Little Black Brook would not improve underyearlings to 1+ parr survival by much more than 2 percent. It is also possible that young salmon migrate upstream from the channel, between the underyearling and 1+ stage. This possibility, however, seems to be ruled out by that fact that no 1+ parr were found, during electrofishing, in areas above the channel other than those near which fry had been distributed during the preceding year. 1+ parr were found at electrofishing stations 6 and 7, in both 1966 and 1967, but fry were distributed at these locations in 1965 and 1966. 1+ parr were found in North Brook (electrofishing stations 8 and 9) in 1966 but none were found there in 1967. This can be explained by the fact that some 3,000 fry were released near station eight in 1965 while none were released there in 1966. In 1965, some 3,000 fry were released near electrofishing station 10. None were released there in 1966. This accounts for the fact that, while this station is only about half a mile above the channel, only one (0.3 per unit) 1+ parr was found there in 1967 although 121 (18.8 per unit) were found there in 1966 (presumably survivors from fry introduced there in 1965). No fishing was done at electrofishing stations 23 and 24 in 1966, but in 1967 no 1+ parr were taken at station 24, although some were taken at station 23. (This is probably due to the fact that station 23 is only about one and one-half to two miles downstream from station 7, where fry were released in 1966).

Comparison of the survival rate of underyearlings to 1+ parr, in section one of Indian River, with survival rates in other areas of Indian River further indicates that, unless there is considerable emigration of young salmon sometime between the underyearling and 1+ stage, unusually high mortality occurs at this stage of the life cycle in section one. Table XII summarizes underyearling to 1+ parr survival for four sections of Indian River. The survivals listed for station six and section three are undoubtedly too high. This is probably caused by the nature of the bottom composition in these areas. At station six, the river bed has been channelized by bulldozer. Large rubble and small boulders lie on the immediate shoreline. When fry were narcotized by the electrofishing gear, some of them drifted under these rocks and were impossible to retrieve. Consequently, it is suggested that the underyearling estimate for this station in 1966 is too low. No difficulty is experienced in retrieving 1+ parr, hence the high estimate of survival. This also may explain the unrealistic survival listed for Black Brook (section 3) in Table XII, except here the whole river bed is covered with rubble and large boulders. It is also possible that yearling parr (1+) may migrate into Black Brook from Indian Pond. These parr may have moved out of Upper Indian River between the underyearling and yearling stage. Unfortunately no information exists to substantiate this point. Huntsman (1945) concluded that some

Table XII. Comparison of survival (underyearling to 1+ parr) in section one of Indian River, with other areas of Indian River.

Location	Underyearling to 1+ parr survival
Section one	9.7%
Section three	130.0%
Section two (Station six	about 100.0%
Section two (Station seven	58.5%
Section four	35.9%

salmon parr descend streams, particularly during freshets, to populate lower waters such as lakes and fresh or brackish parts of estuaries. Thence, they ascend and populate available streams for variable distances, depending upon conditions, such as falls.

From Table XII, however, it is quite apparent that, unless parr move out of section one before reaching the 1+ age group, mortality is much higher than in other sections of Indian River. It is suggested, therefore, that releasing fry from the channel into section one results in overcrowding which, in turn, may be responsible for unnecessary mortality. It is difficult, under these conditions, to envisage how the channel can contribute much to parr production in Indian River.

X. SOME FACTORS AFFECTING PARR PRODUCTION

A. MIGRATION OF FRY

Referring to movements of fry, Saunders and Gee (1964) state, "The observed tendence of young salmon to remain within narrow limits may have an important application in the management of this species". Mills (1964) states that the heavy mortalities experienced by fry, which he had stocked in three tributaries of the River Bran, may well have been due to the high rate of stocking. Mills suggests also that the availability of territories affects the survival of fry. It seems quite likely, though, that the reasons listed by Mills (1964) for heavy fry mortality in his study area may be directly related to fry migration. Certainly, it appears likely that competition for available food and territories would be less severe if fry undertook extensive migrations. Available evidence, however, seems to imply that fry have an inborn tendency to remain within a given area of stream (Elson, 1962-a). This being so, it can be expected that no beneficial results will come from stocking fry in a particular section of stream beyond a certain maximum density which the stream is capable of supporting.

B. MIGRATION OR DISPERSAL OF PARR

While in fresh water, salmon parr are often observed defending territories in flowing water (Kalleberg, 1958; Keenleyside and Yamamoto, 1962) but few observations have been reported on their movements outside of these territories (Saunders and Gee, 1964). In a review of the subject of restricted movements of fish populations, Gerking (1959) lists four salmonid species believed to have limited movements within streams. Carlin (personal communication, cited in Kalleberg, 1958) observed that juvenile Atlantic salmon have restricted movements. Saunders and Gee (1964) found that throughout the summer parr tended to remain in a small area of stream, some parr were known to return to a particular area after being moved up river or down river as much as 700 feet. The same workers observed that parr tended to be scarce in autumn in areas where they were abundant during the summer. They suggest that this may be because the parr had hidden among the gravel from which it was difficult to dislodge them or that they may have moved out of the study area. Allen (1940) states that when water temperature is below 7°C., young salmon remain quiet in deep pools; when water temperature is higher, they lead an active life in shallower water with a moderate current. Saunders and Gee (1964) state that Lindroth (1955, and personal communication) observed that salmon parr in winter may be found in the gravel below the surface of the stream bed. Pratt (personal communication) has reported seeing parr emerge from rubble after being disturbed by workers searching for salmon redds, in Indian River, in autumn. This writer has, with the use of electrofishing gear, found parr on riffles during the winter months in Indian River. All parr caught during the winter months appeared to be well hidden under rocks.

Jones and King (1948) observed that male parr move upstream to areas where adults are spawning. At Indian River, ripe male parr have been observed moving into the channel prior to spawning time. Saunders (1960) reports that from 10 - 20 percent of the resident population of salmon parr in Ellerslie Brook, Prince Edward Island, moved downstream in autumn and these migrants were predominantly ripe males. Meister (1962) observed in Cove Brook, Maine, that many more salmon moved downstream in autumn as parr than in spring as smolts. Mills (1964) showed that in the River Bran, Scotland, there was a downstream movement of parr in spring and again in autumn. Reference has already been made to Huntsman's (1945) conclusion that some parr descend streams to populate lower waters such as lakes and fresh or brackish parts of estuaries from where they ascend and populate other available streams. Mills (1964) stated that even in those streams where up to 1959 no salmon fry had been planted, the salmon population which had moved upstream from the main river, outnumbered the trout. Murray (1967), commenting on the suitability of gravel covered stream bottom as parr rearing areas, states that areas with small stones provided shelter for small parr only; the larger parr may have migrated to more suitable habitats elsewhere in the river.

The presence of sizeable numbers of 1+ and 2+ parr at electrofishing station 15 on Twenty-three Mile Brook and station 16 on Little Black Brook suggests an upstream migration of parr in these streams. No underyearlings were found during electrofishing studies at either of these stations in 1966 or 1967. Salmon redds were observed in the lower half mile of Twenty-three Mile Brook in the autumn of 1966 but none were seen in Little Black Brook. The presence of 1+ and older parr at electrofishing stations 15 and 16, then, indicates that there is an upstream migration of parr either from the lower reaches of these brooks or from the main part of Upper Indian River. The presence of 3+ parr at station 10 in 1966 and 1967 suggests that there is a movement of older parr into this area. The presence of almost no 1+ parr at station 10 in 1967 suggests that there is limited migration of young parr into this area, since the channel is only half a mile below this. 1+ parr at station 10 in 1966 were probably survivors from fry introduced near there in 1965. At stations 8 and 9, on North Brook, 1+ parr were found in 1966 but none were observed in 1967. It is probable that 1+ parr found at these stations in 1966 were survivors from fry introduced near station 8 in 1965. The presence of 2+ parr there in 1966 indicates that these parr moved into the area from elsewhere, since any 2+ parr found in 1966 were offspring from adults which spawned in 1963, and no adults moved above the channel after 1962. Also, 2+ parr found at stations 6 and 7 in 1966, must have migrated from other areas of the river. In North Brook, in 1967, the number of 2+ parr caught was greater than the number of 1+ parr caught in 1966. This, too, is indicative of parr migration. The high number of 3+ parr caught in North Brook in 1967 also suggests that parr moved into this area from other sections of river. These observations indicate that there is some migration of parr from one area of stream to another.

The information collected at Indian River suggests a general pattern of migration for young salmon. It appears that underyearlings tend to remain in or near the area where they were hatched, or distributed. Sometime between the underyearling and yearling stages, parr undertake limited migrations. The presence of 1+ parr in Twenty-three Mile and Little Black Brooks, and Indian Pond, which adjoin section one, and the absence of 1+ parr in North Brook, which is located a considerable distance away from any area where fry are living, is suggestive of this.

As parr become older, they appear to undertake more extensive migrations. The presence of sizeable numbers of 2+ and older parr in North Brook in 1967 is suggestive of this point.

The question of utmost importance to workers engaged in management of Atlantic salmon in Indian River is whether or not maximum parr production is being realized in those areas of Indian River which depend, for stocking, on parr migration. (i.e. Is it good management procedure to release large numbers of fry into any one section of river and hope that these fry will distribute themselves as older parr throughout the river to occupy, fully, areas which are now understocked?). Based on the evidence collected from this survey, the answer must be a qualified 'no'. This is best seen by referring to Figure 16. (Although upstream migrating adults are prevented from moving into that section of river between the channel and Bowater's Diversion Dam by a diversion fence located near the channel exit, parr can move freely through this fence and should experience little or no difficulty in migrating upstream from the channel). In 1966, at stations six and seven, there were less than two 2+ parr per unit. Any 2+ parr found at these two stations in 1966 had to come from some other part of Indian River, since no adults moved into this area (i.e. the river area between the channel and Bowater's Diversion) after the autumn of 1962 and no fry were distributed there until the summer of 1965. Offspring from adults, which moved into this area prior to 1963, would be at least 3+ parr and survivors from fry introduced there in 1965 would only be 1+ parr. That this area can support more than two 2+ parr per unit is shown by the substantial increase in 2+ parr indices at stations six and seven in 1967.

The 2+ parr found at stations six and seven in 1967 were, undoubtedly, survivors from fry introduced there in 1965. Figure 19 shows that in 1967 there were no 1+ parr living at stations eight and nine. In 1966, a fair number of 1+ parr lived in these areas. These are believed to be survivors from 3,000 fry which were introduced near station eight in 1965. Also, from Figure 21, it can be noted that while there were almost no 1+ parr at station 10 in 1967, when this station depended on parr migration for its stocking, there were almost twenty 1+ parr per unit there in 1966, after fry had been introduced near this station in 1965. Similarly, the almost complete lack of younger parr at stations 23 and 24 which have depended entirely on parr migration for stocking since 1962, can be seen from Figure 21. These observations indicate that stocking of a section of river is incomplete when that section has to depend on natural migration of parr as its stocking source, and that parr indices in such areas increase substantially after fry are introduced.

C. NATURE OF BOTTOM COMPOSITION

Kalleberg (1958) found that, at moderate population density and normal current velocity, all juvenile salmon in an aquarium occupied territories and he suggested that the reason why territories were finally abandoned might be increasing competition within the population because the individual had outgrown its environment. Mills (1964) concluded that availability of territory is an important limiting factor in parr production. Kalleberg (1958) has shown that in streams with large stones there are more but smaller territories available to fish owing to fish being out of sight of each other, while in streams with only a few stones on a substratum of gravel, territories were necessarily large due to the antagonistic behavior of neighbouring fish. This suggestion is further corroborated by Gilson's statement (1961). Referring to young trout, he states that there was evidence from the study of stream populations and their behavior.... that the capacity of a river to produce trout depends not only on the food supply, but often to a greater extent on the number of nooks and crannies where fish can lie. Murray (1967), referring to parr production in Little Codroy River, states that areas of stream with moderate flow over rubble (stones three to twelve inches in diameter) had the best parr populations. These, he suggested, were ideal habitats because the rubble provided excellent shelter not only for parr but for aquatic insects. Saunders and Gee (1964) concluded that pools are suitable habitats for young salmon. The writer has watched salmon living in pools at Indian River, and feeding on surface-dwelling insects.

Figure 22 shows the variation in parr indices for different substratum types in Indian River. This figure clearly indicates that areas where the predominant bottom type is rubble or boulder, are the best areas for parr production. Statistical comparison of mean parr indices for the bottom types listed in Figure 22 is presented in Tables III and IV of the appendix. It can be seen (Table IV of the appendix) that there is a significant difference in means, at the 0.05 level, between areas which have predominantly gravel type bottom and areas which have predominantly rubble type bottom. No significant difference in means exists between areas which are predominantly rubble and those which are predominantly boulder. The difference in means between gravel and boulder areas is highly significant, as is the difference in means between gravel areas and areas of rubble and boulder combined.

It is realized that the sample size, used in these calculations, especially for areas of gravel bottom type, is probably too small to make comparisons very meaningful. Nevertheless, Figure 22 does indicate that those areas of Indian River which have a predominantly gravel bottom type do not support as many parr as do those areas whose bottom composition is predominantly rubble and boulder. Thus it seems that the statement made by Gilson (1961), regarding the relationship between bottom composition and trout production, is as true for young salmon as it is for trout.

D. COMPETITION FOR FOOD

In Indian River there are three fish species which might compete with young Atlantic salmon for the available food organisms, these being brook trout, eels and sticklebacks. Sticklebacks, undoubtedly, offer no serious competition because of their scarcity and relative size. It has already been pointed out (page 67) that eels and sticklebacks are minor contributors to total standing crop of fish in Indian River, and that trout are a major contributor to standing crop in the smaller tributary streams but contribute relatively little in the main river. Since, however, the smaller tributary streams are, in general, the best salmon producing areas (per unit area), it may be considered significant that young salmon living in these smaller streams must compete with relatively large populations of trout.

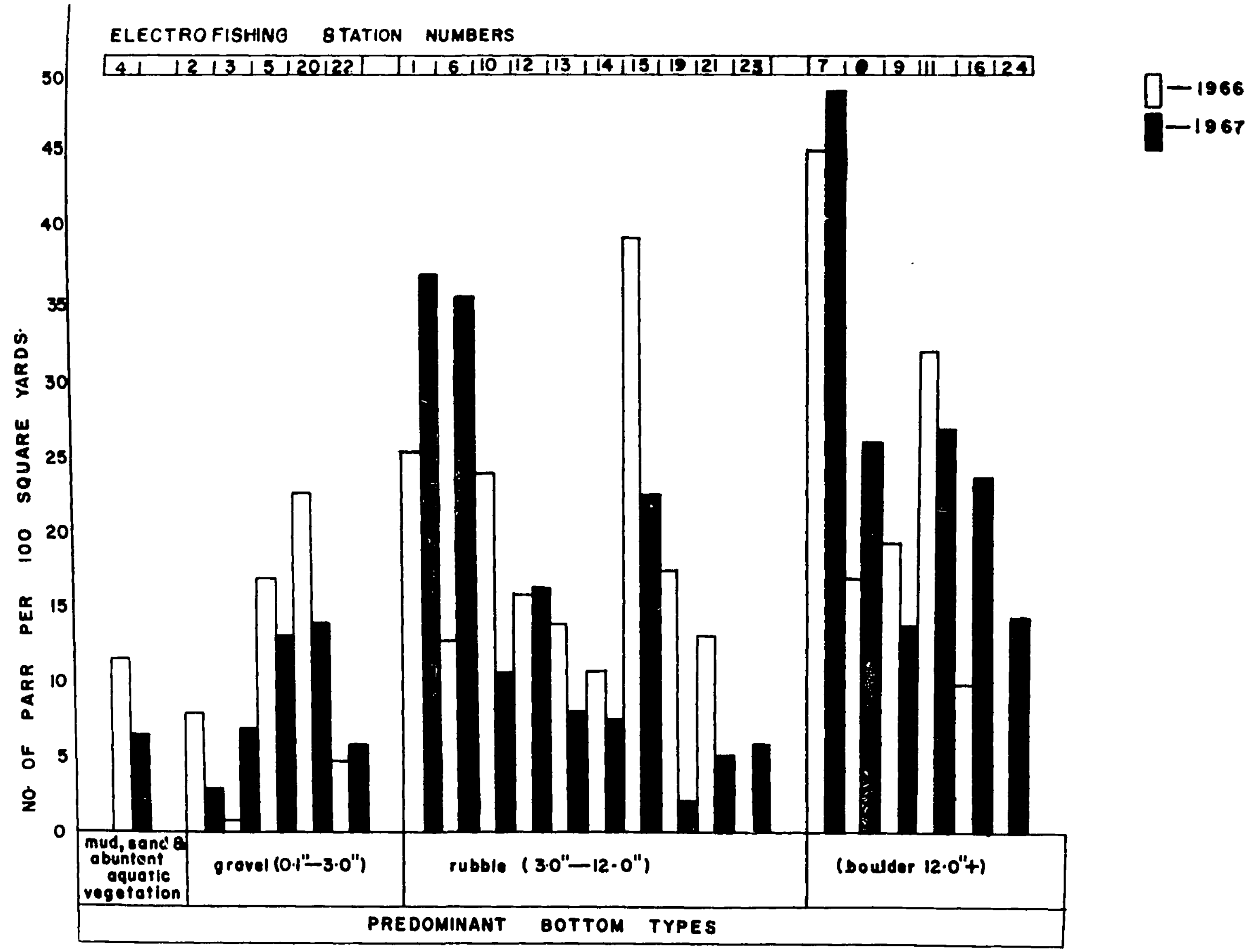

Fig. 22. Relation of parr density in Indian River; 1966, 1967, to predominant bottom type. (Each vertical bar represents one electrofishing station).

It has been shown by Frost (1950), Piggings (1962), and Thomas (1962) that brown trout compete with salmon for food. Mills (1964) has shown that with few exceptions brown trout, in the River Bran, compete with salmon for the available food.

The food of various fish species, collected in Indian River during electrofishing studies in 1967, is presented in Table VII of the appendix and in Figure 23. The chief food organisms of all species were Ephemeroptera and Plecoptera nymphs, Trichoptera and Neuroptera larvae, and adult Coleoptera. Adult mosquitoes were eaten extensively by salmon parr and brook trout. Brook trout and salmon parr ate some adult Hemiptera, but these were not found in the stomachs of eels and sticklebacks. Eels and young salmon ate some Amphipods but none were found in the stomachs of brook trout or sticklebacks. Eels ate more Odonata nymphs than did the other species. Larval Chironomidae were more prevalent in the stomachs of salmon fry than in any of the other species, or in salmon parr. Sticklebacks also feed heavily on larval Chironomidae.

As a general conclusion, then, it appears that some degree of competition existed between all fish species for the available food organisms. Because of the large number of trout living in the smaller tributaries, it may be that competition is serious, in these smaller streams, between trout and salmon parr.

E. PREDATION

The importance of predation as a factor affecting the production of young salmon has been discussed by McCrimmon (1954) who concluded that

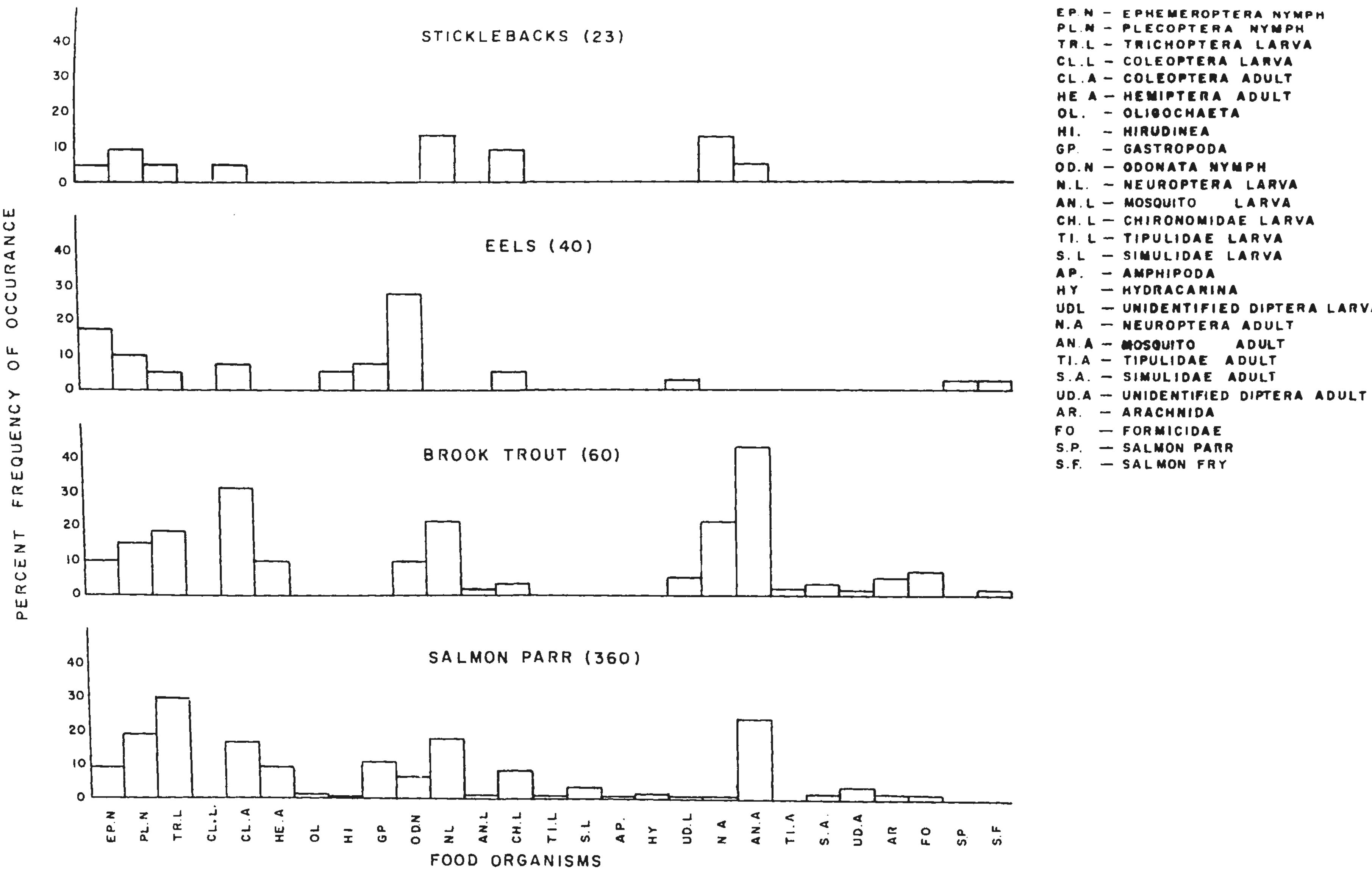

Fig. 23. Food of fish species in Indian River during July and August, 1967. Numbers in parentheses indicate number of stomachs sampled. Percent frequency of occurance = number of stomachs containing each food organism expressed as a percentage of the total stomachs examined.

the Eastern brook trout (among other species of fish) preyed heavily on fry and underyearling parr when the opportunity arose. Burnet (1959) found that the survival of young brown trout in the streams running into Lake Ellesmere, New Zealand, was seriously affected by the number of older fish present and concluded that fry should only be added at intervals of three or four years. Mills (1964) stated that while stocking densities are, without doubt, an important factor governing survival of fry, the density of older fish already in the stream will also have an important effect on fry survival. He concluded that brown trout ate considerable numbers of fry in the River Bran, Scotland, with the largest numbers of fry being found in trout stomachs shortly after liberation of the fry. He concluded also that predation on fry by trout, as well as salmon parr and smolts, in the first few days after stocking, is likely to be high. Elson (1962-a) states that limits of effective post-planting dispersal of underyearling salmon was frequently associated with pools containing numbers of brook trout of a size large enough to eat the newly planted salmon. Elson (1962-a) showed that more young salmon could be produced in Pollett River, Nova Scotia, when mergansers (Merganser americanus) and kingfishers (Megaceryle alcyon) were effectively controlled.

In Indian River predation is considered to be from two sources, namely, avian predators and fish predators.

1. Avian Predators

Whether or not avian predation is of any significance in controlling the production of young salmon in Indian River is difficult to say. It has been noted, however, that each year, late in the spring, groups of mergansers visit Indian River, but disappear in a matter of five to ten days. Apparently these birds are passing through to their nesting grounds farther North. Each year since Indian River channel has been in operation, the writer has noticed at least one pair of adult mergansers, accompanied by a brood of young, on Indian River in late summer. On one occasion, sixteen young mergansers were counted, accompanied by two adults. Also, it has been noted that at least one pair of kingfishers breed between the channel and Indian Pond each year. Kingfishers have also been sighted on Black Brook. Incidents of the greater yellow legs (Totanus melanoleucus) have also been noted. These birds are reported by Peters and Burleigh (1951) to feed on small minnows and it is conceivable that they may be responsible for some fry mortality. The writer has seen these birds feeding quite often near the shoreline of Indian River, immediately below the channel where large numbers of fry were concentrated. It has not, however, been definitely determined that they were feeding on fry.

Elson (1962-a) has shown that adult mergansers eat about 40 fish per day, young mergansers about 20 fish per day, and kingfishers about 20 fish per day. Since salmon are the dominant species in areas where mergansers and kingfishers have been sighted on Indian River, it is likely that salmon comprise most of the diet of these birds. On the basis of the figures listed by Elson (1962-a) and taking into consideration the length of time which the birds spend at Indian River, it is probable that mergansers and kingfishers consume in the order of twenty thousand young salmon per year.

2. Fish Predators

In Indian River, there are three fish species that may be considered as possibly dangerous predators on young salmon; these being, brook trout, eels, and larger salmon parr.

From Table VII of the appendix, and from Figure 23, it can be seen that once migrating fry have settled into the environment, predation is not extensive by either of the fish species mentioned above. There are two stages in the life cycle of salmon when predation is heaviest, these being;

(a) the egg stage, when the eggs are being deposited in the redds by the adult females,

(b) the fry stage, when fry, after having emerged from the gravel of the spawning riffle, are dispersing into the environment.

Elson (1957) describes eels feeding voraciously on newly planted underyearlings, but Jones and Evans (1960, 1962) found that in various Welsh rivers predation by eels on salmon eggs and young was negligible. They considered that eels are more important as competitors for the food of salmon and trout. Piggins (1962) found that on the Glenamong River in Ireland, eels were serious competitors of salmon and trout. Sinha and Jones (1967) found that eels in the River Dwyfach, Wales, competed with salmonids for available food, but fish formed a minor portion of the eel diet. They found that the most commonly eaten fish were elvers and younger eels. No salmonid eggs were found in any of the fish examined.

(a) Predation on Fry - Each year at Indian River, during the annual fry run, large numbers of brook trout, large parr and, to a lesser extent, eels, have been observed in concentrations immediately below the channel exit where large numbers of fry are released from the channel. Brook trout, in particular, have been observed in relatively large numbers. Fish caught at this location, in almost all instances, have been filled to capacity with fry. Eels, large parr and brook trout have been caught in the fry counting trap with their stomachs full of fry and with fry protruding from their mouths.

This type of predation appears to be of the type B predation described by Ricker (1954) and Elson (1962-a), i.e., a given number of predators take whatever they encounter and so get a fixed proportion of the prey animals present during a season, the number of prey animals taken being dependent on how often one of the predators encounters and captures one of the prey.

No attempt has been made at estimating the number of fry eaten each year by predatory fish species but it seems likely that the number is quite high.

(b) Predation on Eggs - Each year just prior to commencement of spawning, there has been a noticeable increase in the number of parr and brook trout present in the channel. Apparently a considerable number of parr move from the main river into the channel. Many of these parr are ripe males which take part in spawning. Jones and King (1948) observed that male parr moved upstream to areas where adults are spawning.

Prior to spawning in 1967, the channel was electrofished throughout its entire length, and the number of brook trout and parr noted. Only nine brook trout were captured in 1967, but in other years more than this number have resided in the channel although no attempt was made to determine exactly how many. It is estimated that about 500 parr were living in the channel during the 1967 spawning season (482 were actually captured). Each day during the spawning season, three parr were captured. Each parr was killed, measured, weighed and the number of eggs in its stomach was noted. Forty-two parr and seven brook trout were killed. 28.6 percent (2) of the trout and 33.3 percent (14) of the parr, which were examined, had no eggs in their stomachs. Fish were taken before or around noon, so it is assumed that the number of eggs counted in the stomach represented a minimum number eaten by the fish for that day. Since the number of brook trout captured by electrofishing was insignificant, no consideration is given to them in this discussion.

It was found that,as an average,parr ate a minimum of eleven eggs per day. This suggests that all the parr in the channel, during the spawning period, probably ate about 3,600 eggs per day. (It is assumed here that one-third of the parr were not eating eggs, as is suggested by the figures listed above). From the record of samples taken, it is known that this continued for at least twenty days. At this rate it appears that some 70,000 eggs were consumed by predators during the 1967 spawning season. Considering that the total egg deposition in the channel in 1967 was about 200,000 eggs, this represents a considerable mortality (35 percent) due to predation. These figures suggest that measures should be taken to reduce this predation by parr.

This subject is discussed further on page 106.

XI. MANAGEMENT IMPLICATIONS

A. SURVEY OF POTENTIAL PARR REARING AREAS

During the course of this study, it became apparent to the writer that large areas of Indian River were not being utilized as parr rearing grounds, and that better use might be made of channel produced fry if they were introduced manually to other areas of Indian River that are not presently being utilized. Surveys were undertaken, therefore, to determine which sections of Indian River would be best suited for the introduction of fry should this action be considered necessary.

The writer has walked all of the tributary streams between Indian Pond and Bowater's Diversion (Little Black Brook, Twenty-three Mile Brook, North Brook and Oxford's Brook), and has flown in helicopter over practically all of the remaining watershed of Indian River.

Table XIII is based on observations made during these surveys and during electrofishing studies. The number of fry considered necessary for stocking purposes is based on the assumption that fry would be distributed at a stocking density of 40 per unit. This would appear to be a reasonable stocking density considering that Elson (1962-a) found that nothing was gained, in terms of smolt production, when underyearlings (note underyearlings, not fry) were stocked at a rate greater than 20 - 30 per unit.

Table XIII. Summary of potential parr rearing area in some sections of Indian River, and the number of fry needed to stock these areas.

Section of river	Remarks on suitability of area as parr rearing grounds	Approximate rearing area (square yards) Utilized	Approximate rearing area (square yards) Not or partially utilized	No. of fry needed for stocking purposes
Tributary streams above Indian Pond (Little Black Brook, Twenty-three Mile Brook, North Brook, Oxford's Brook) and Whitehorn's Brook.	All streams are characterized by rubble and boulder bottom type and appear excellent for parr production. The smaller brooks like Oxford's and Little Black Brooks suffer severe drought in summer which could affect production.	40,000	80,000	32,000
Upper Indian River between the channel and Bowater's Diversion.	Characterized by gravel bottom type, like area between channel and Indian Pond. Moderately suitable as a parr rearing area.	-	120,000	48,000
Main River below Indian Pond.	Characterized by areas of rubble bottom type and gravel bottom type. Appears capable of supporting more parr than it now does.	1,000,000	-	400,000
Burnt Berry Brook and associated tributaries.	Characterized by same bottom type as main river below Indian Pond, with probably more rubble and boulder areas. Appears to have very good parr rearing area.	50,000	750,000	300,000
Black Brook between Black Brook Falls, Black Lake and Micmac Lake.	Characterized by extensive areas of rubble and boulder. Appears to be an excellent area for parr production.	-	1,000,000	400,000

B. DISCUSSION AND CONCLUSIONS

> Elson (1962-a) states, "Salmon do not become a useful commodity until they have spent one or more years at sea after having transformed to smolts, so there is no advantage in increasing the younger stages unless the increase is carried over first to migratory smolts, then to usable salmon. The relationship between the number of smolts descending to sea and the return of mature salmon to fisheries may vary over a considerable range from place to place and from time to time. It still required more precise definition. Increasing the supply of smolts, by one means or another, seems to be the chief method by which management of inland rearing grounds can be expected to yield increase in stocks of salmon. Huntsman (1941) examined the commercial catches from the Margaree area resulting from the smolt runs studied by White (1939). He concluded that there was a positive relationship, in this instance, between increase in smolt output and increase in the resulting commercial fishery".

To have value as a salmon management facility, then, Indian River spawning channel must demonstrate that it can produce a significant increase in smolt production. What happens to these fish from the time they leave our rivers as smolts to their appearance in the commercial fishery and as adults returning to the river, is at present beyond our control. To increase salmon stocks it is necessary to concentrate on producing more smolts and hope that this action results in an increase in mature adults. Indian River spawning channel was a step in this direction. It has already been stated (page 17) that the channel was constructed to compensate for the loss of spawning ground that occurred with the diversion of part of Upper Indian River into Birchy Lake. The writer, at this point, feels compelled to point out certain errors in this line of reasoning:

(1) The amount of so-called spawning ground cut off by Bowater's Diversion is negligible since immediately above the diversion the bottom type changes from the loose gravel which is so prominent below the diversion, to a bottom type characterized by rubble and

boulder, in which salmon would, conceivably, have difficulty spawning;

(2) There is ample spawning area between Bowater's Diversion and the channel to meet the needs of any salmon which presently move into this section of river;

(3) The situation (which the channel at present fails to provide for) is this - the diversion of Upper Indian River into Birchy Lake has caused a severe restriction in the amount of parr rearing area below the Bowater's Diversion Dam which is particularly evident during low water periods (The parr rearing area above the diversion has also been lost). The channel and its associated structures, instead of correcting this situation, merely act as a barrier to salmon that might move into the available river area between the channel and the diversion as well as North Brook. It has already been noted that North Brook is an excellent parr rearing area. Apart from rearing facilities, there is ample spawning area on this brook to serve a sizable number of salmon (any that might be expected to move into this area judging from the magnitude of the run that now spawns above Indian Pond).

The contention by Department of Fisheries personnel that egg-fry survival under natural conditions does not exceed 10 percent (Trade News, August - September, 1965, pp. 13) may be "much ado about nothing". This writer, for one, finds it difficult to accept the supposition that egg to fry survival rate does not exceed 10 percent under natural conditions. Stuart (1953) obtained 95 percent survival to the fry stage, for eggs placed in cages in a natural spawning area. Table XI shows that in 1966 - 1967, egg to midsummer young-of-the-year was about 14 percent in section one of Indian River. It is quite likely, therefore, that survival from egg to newly hatched fry was more than this, indeed 20 percent does not at all seem like an unreasonable figure. Elson (1962-b) has listed 6 percent as the average survival from egg to underyearlings, and Meister (1962) listed 9 percent and 11 percent egg to midsummer young-of-the-year survival rates for Cove Brook (note the reference to underyearlings and midsummer young-of-the-year, not newly emerged fry). Electrofishing studies at Indian River in 1966 indicated that (with channel productions included) egg to midsummer young-of-the-year survival (1965 - 1966) was not more than 11 percent. It seems possible, then, that egg-fry survival in the channel since it became operative (which has averaged 43 percent) may not be more than 20 percent greater than that experienced under purely natural conditions.

Be that as it may, the fact is the channel is now in operation, and the Department of Fisheries should try to make the best possible use of it as a management tool. The question of how to do this is, of course, a matter of opinion. The following discussion summarizes this writer's opinion, based on the results of studies described throughout this thesis.

The practice of releasing large numbers of channel-produced fry into section one of Indian River has probably resulted in a complete waste of a large number of fry each year, since parr production is lower in this section than for most other parts of the river. All evidence points to the fact that there is a high mortality on fry released from the channel into section one. Electrofishing studies have shown that this is a poor area for parr rearing. This is, undoubtedly, related to the bottom composition. The bottom in this section of river is composed almost entirely of loose gravel, sand and mud. Figure 24 shows characteristic views of section one. It has been shown (Fig. 22) that many more parr can be produced in areas where the bottom consists of coarse rubble and boulders and where adjacent banks are overhung by thick vegetation growth, such as the river sections shown in Figure 25. It has also been shown that very few fry move more than two miles from the channel during their first summer (Fig. 13, Table VI). Also, there is every indication that enough fry are produced naturally between the channel and Indian Pond to stock this area.

In summary, the following conclusions are drawn from the results of the work described in this thesis:

(1) When fry are allowed to move directly out of the channel into section one of Indian River, they remain in the area as underyearlings, at a relatively high density;

(2) A lower than average population of one and two year old parr is supported (per unit area) in the same section of river;

(3) There is no extensive migration of underyearlings out of this area;

(4) Unless there is an extensive movement of parr from this area, sometime between the underyearling and 1+ stage, excessive mortality occurs;

(5) If parr do, indeed, move out of this area sometime between

the underyearling and 1+ parr stage, full utilization of the river area above Indian Pond is still not being realized;

(6) There is, in all probability, enough natural spawning each year in section one to sufficiently stock this area. (This point will have to await the results of the 1968 electrofishing program before a definite conclusion can be made).

In view of the above conclusions, it seems reasonable to suggest that better use can be made of the salmon management facilities at Indian River. The best use to be made of these facilities depends on what the defined purpose of the channel is. If the channel is to remain as a tool for maintaining, or possibly increasing, the Atlantic salmon population of Indian River, the Department of Fisheries must concentrate, not on providing sufficient spawning ground for the salmon (there is plenty already), but on first producing as many fry as the channel is capable and, secondly, finding sufficient rearing area for these fry so that maximum smolt production can be achieved. Egg-fry survival is certainly greater in the channel than under purely natural conditions, although the difference is not as great as was originally supposed. Maximum fry production in the channel can be realized as follows:

(1) Supplement the natural entry of adults into the channel by transferring adults from the counting fence, on lower Indian River, to the channel. (Care should be taken, however, not to remove too many fish that would spawn naturally in other areas of the river);

(2) All females held in the channel should be stripped of their eggs when they become ripe and the eggs planted, after fertilization,

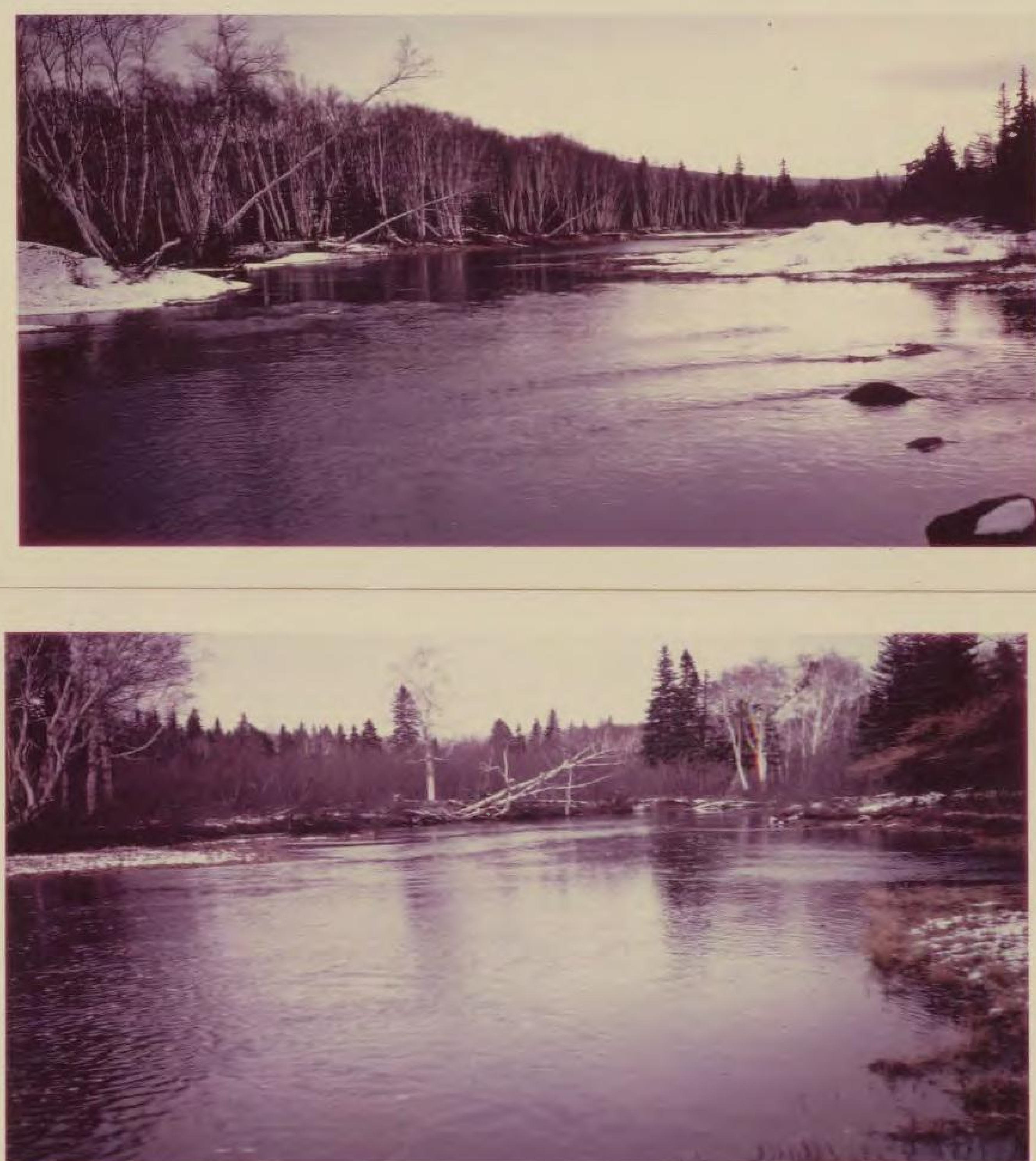

Fig. 24. Typical views of Indian River between the channel and Indian Pond, showing poor parr rearing area.

Fig. 25. Typical views of North Brook, showing good parr rearing area.

in the gravel of the spawning channel. This would almost certainly eliminate most, if not all, of the predation caused by fish predators. The writer feels that this action would add much to fry production in the channel.

The question of finding sufficient rearing area for the fry produced in the channel, must in this writer's opinion, involve the transfer of fry to areas of Indian River which are not now being utilized, or areas which are at present being underutilized for parr production. Concern over mortality which might result from handling fry can be dismissed. Fry are hardy little creatures and can readily stand manipulation. (Samples of fry which have been handled considerably at the Wolfe trap, have shown very little mortality when retained in holding boxes for several days after handling). There are three areas of Indian River which should receive consideration in a fry transfer program. Table XIII presents a summary of potential parr rearing areas on Indian River and the number of fry needed to stock each area.

The possibilities which the Department of Fisheries should consider for proper utilization of fry produced at the channel are:

(1) Stock the area between the channel and Bowater's Diversion with fry from the channel so that this area, which must have once figured prominently in parr production, may do so again. Although tributary streams are the best parr producing areas, no fry should be introduced into these streams since they tend to dry up severely during the summer. A possible exception to this is North Brook where good parr populations exist in spite of drought. The writer

believes that, if fry are distributed into that section of river between the channel and Bowater's Diversion, enough parr will be available to the tributaries through natural migration. Table XIII shows that some 50,000 fry would be needed to stock this area.

In the average year, when stocking of the area between the channel and Bowater's Diversion is complete, an additional 100,000 fry (or thereabouts) would be available for stocking elsewhere. These could be released in the area below Indian Pond, on the main river. In view of the large amount of rearing area in this section and the low parr densities there, coupled with the fact that this section has a considerable amount of rubble and boulder bottom type, it seems reasonable to assume that it is not producing parr at its full capacity. It should be noted that if parr production in this area could be raised by two to four per unit, as much would be accomplished as if the entire area between the channel and Bowater's Diversion were to produce 20 parr per unit. It is vital to remember, however, that this area is already accessible to spawners and may now be supporting as many parr as it can. Researchers, trying to increase parr production in areas which already contained natural populations by the introduction of additional fish, have usually met with discouraging results.

(2) The other possibility for utilization of channel produced fry is the one preferred by this writer. It involves the transfer of all fry, produced at the channel, into areas which are presently inaccessible to migratory salmon, namely; Black Brook above Black

Brook Falls and Burnt Berry Brook above Burnt Berry Falls, and to make these areas available to returning adults by fishway construction.

Black Brook is excellent for this kind of development because of the proximity of the channel and because the falls can be rendered surpassable at very little cost. Opening up Burnt Berry Brook can be done only at considerable expenditure, and it would certainly be wise to carry out experiments on Black Brook first.

If the Department of Fisheries wishes to attack this problem on a long term basis, the following plan is suggested. Distribute into each of the areas mentioned above for a minimum of four successive years, starting with the area below Indian Pond and the area between the channel and diversion, followed by the inaccessible areas on Burnt Berry Brook and Black Brook. Evaluate the success of each series of transfers on the basis of parr production, as determined by electrofishing, and the total number of smolts counted at the main counting fence on lower Indian River (Fig. 2).

Whichever series of transfers shows the greatest mean production of smolts should be accepted as the most suitable. Such a program will take a minimum of ten years to complete and evaluate, but would make a very valuable contribution to determining proper use of controlled flow spawning channels as a tool for Atlantic salmon management.

If the Department is anxious to forego long term studies in the interest of producing immediate results, a program of distribution should still be started with distribution sites being picked from those listed above. It is recommended that the idea of distributing fry into the inaccessible area above Black Brook Falls be considered first. The writer believes that this area can be expected to contribute immensely to salmon production on Indian River if management procedures are followed, as outlined above.

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APPENDICES

Table I. Calculation of abundance indices of all species, electr

STATION NUMBER		1	2	3	4	5	6	7	8	9	10
AREA FISHED (sq. yd.)	1966...	880	(1) 2,230	1,040	960	660	350	450	230	550	650
	1967...	350	790	800	1,090	630	90	270	50(2)	320	290
TOTAL CATCH											
Fry	1966...	-	666	447	499	143	73	151	0	0	0
	1967...	244	475	8	31	8	11	124	102	0	0
Parr	1966...	164	153	14	87	86	35	188	39	106	154
	1967...	114	23	47	66	76	32	125	13	44	31
Trout	1966...	13	68	2	8	9	2	7	20	19	2
	1967...	7	10	1	8	4	2	3	13	51	0
Eels	1966...	2	1	1	7	5	27	1	0	0	3
	1967...	3	0	0	11	2	10	2	0	1	0
Sticklebacks	1966...	-	37	10	19	6	10	7	0	0	11
	1967...	3	29	13	31	2	1	2	0	0	1
TOTAL ESTIMATE											
Fry	1966...	-	842	708	626	184	80	191	0	0	0
	1967...	262	503	8	37	10	11	131	112	0	0
Parr	1966...	224	180	15	111	112	45	203	39	106	155
	1967...	129	23	56	72	84	32	132	13	44	31
Trout	1966...	15	75	2	12	20	2	9	21	21	2
	1967...	7	10	1	9	4	2	3	13	51	0
Eels	1966...	2	1	1	7	5	30	1	0	0	3
	1967...	3	0	0	11	2	10	2	0	1	0
Sticklebacks	1966...	-	45	12	20	6	11	10	0	0	11
	1967...	3	29	13	38	2	1	2	0	0	1
ESTIMATED INDEX (No. per 100 sq. yd.)											
Fry	1966...	-	144.8	68.1	65.1	28.0	22.9	42.4	0	0	0
	1967...	74.9	63.8	1.0	3.4	1.6	12.2	48.5	448.0	0	0
Parr	1966...	25.4	8.1	1.4	11.5	17.0	12.9	45.1	17.0	19.3	23.9
	1967...	36.9	2.9	7.0	6.6	13.4	35.5	48.8	26.0	13.8	10.7
Trout	1966...	1.7	3.4	0.2	1.2	3.0	0.6	2.0	9.1	3.8	0.3
	1967...	2.0	1.3	0.1	0.8	0.6	2.2	1.1	26.0	16.0	0
Eels	1966...	0.2	0.1	0.1	0.7	0.8	8.6	0.2	0	0	0.5
	1967...	0.9	0	0	1.0	0.3	11.1	0.7	0	0.3	0
Sticklebacks	1966...	-	2.0	1.2	2.1	0.9	3.1	2.2	0	0	1.7
	1967...	0.9	3.7	1.6	3.5	0.3	1.1	0.7	0	0	0.3

(1) Only 580 sq. yd. fished quantitatively for fry.
(2) Only 25 sq. yd. fished quantitatively for fry.
(3) No barrier nets used.
\- Not fished.

, electrofishing stations, Indian River; 1966, 1967

10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
650	680	550	900	670	150	150	530	150	240	300	2,000	1,860(3)	-	-
290	690	1,760	950	1,370	120	80	450	90	180	200	2,840	1,410(3)	290	630
0	42	54	59	62	0	0	0	0	0	8	45	237	-	-
0	140	228	40	214	0	0	0	0	0	46	88	20	0	0
154	210	86	111	59	39	15	0	0	25	53	228	83	-	-
31	182	249	78	73	27	19	0	0	4	27	139	70	17	90
2	7	4	14	0	53	72	46	104	57	48	7	1	-	-
0	0	3	0	0	81	62	61	134	45	4	1	0	0	0
3	2	5	9	4	0	0	0	0	0	0	1	1	-	-
0	0	20	5	7	0	0	0	0	4	2	10	5	4	21
11	0	0	2	11	0	0	0	0	0	20	21	5	-	-
1	0	2	4	5	0	0	0	0	0	15	4	6	0	0
0	44	53	87	81	0	0	0	0	0	10	53	257	-	-
0	153	301	43	236	0	0	0	0	0	70	94	20	0	0
155	216	87	126	73	59	15	0	0	42	68	267	90	-	-
31	185	289	78	104	27	19	0	0	4	28	149	84	17	90
2	7	4	17	0	56	79	70	113	63	56	8	1	-	-
0	0	3	0	0	82	62	63	146	45	4	1	0	0	0
3	2	5	9	4	0	0	0	0	0	0	1	1	-	-
0	0	20	5	7	0	0	0	0	4	2	10	5	4	21
11	0	0	2	13	0	0	0	0	0	21	24	100	-	-
1	0	2	4	5	0	0	0	0	0	17	4	6	0	0
0	6.5	9.6	9.7	12.1	0	0	0	0	0	3.3	2.7	13.8	-	-
0	22.2	17.1	4.5	17.2	0	0	0	0	0	35.0	3.3	1.4	0	0
23.9	31.8	15.8	14.0	10.9	39.4	10.0	0	0	17.5	22.7	13.4	4.8	-	-
10.7	26.8	16.4	8.2	7.6	22.5	23.8	0	0	2.2	14.0	5.2	6.0	5.9	14.3
0.3	1.0	0.7	1.9	0	37.4	52.7	13.2	75.4	26.3	18.7	0.4	0.1	-	-
0	0	0.2	0	0	68.3	75.5	14.0	162.2	25.0	2.0	0.1	0	0	0
0.5	0.3	0.9	1.0	0.6	0	0	0	0	0	0	0.1	0.1	-	-
0	0	1.7	0.5	0.5	0	0	0	0	2.2	1.0	0.4	0.4	1.4	3.3
1.7	0	0	0.2	1.9	0	0	0	0	0	7.0	1.2	5.4	-	-
0.3	0	0.1	0.4	0.4	0	0	0	0	0	8.5	0.2	0.4	0	0

Table II. Calculation of abundance indices, by age class, of parr o

STATION NUMBER		1	2	3	4	5	6	7	8	9	10	11
AREA FISHED (sq. yd.)	1966...	880	2,230	1,040	960	660	350	450	230	550	650	68[illegible]
	1967...	350	790	800	1,090	630	90	270	50	320	290	69[illegible]
AGE COMPOSITION OF SAMPLE												
1+	1966...	129	131	13	73	72	25	168	6	40	121	[illegible]
	1967...	58	11	30	48	44	21	65	0	0	1	[illegible]
2+	1966...	29	17	0	13	13	5	5	11	18	7	[illegible]
	1967...	49	12	15	16	28	8	58	7	25	24	[illegible]
3+	1966...	6	4	1	1	1	5	13	22	45	24	
	1967...	7	0	2	2	4	3	2	6	12	6	
Over 3+	1966...	0	1	0	0	0	0	2	0	3	2	
	1967...	0	0	0	0	0	0	0	0	8	0	
NO. IN SAMPLE	1966...	164	153	14	87	86	35	188	39	106	154	[illegible]
	1967...	114	23	47	66	76	32	125	13	45	31	[illegible]
PERCENT AGE COMPOSITION OF SAMPLE												
1+	1966...	78.6	85.6	92.9	83.9	83.7	71.4	89.3	15.4	37.8	78.6	[illegible]
	1967...	50.9	47.8	63.8	72.7	57.9	65.7	52.0	0	0	3.2	[illegible]
2+	1966...	17.7	11.1	0	14.9	15.1	14.3	2.7	28.2	17.0	4.5	[illegible]
	1967...	42.9	52.2	31.9	24.3	36.8	24.9	46.4	53.8	55.5	77.4	[illegible]
3+	1966...	3.7	2.6	7.1	1.2	1.2	14.3	6.9	56.4	42.4	15.6	[illegible]
	1967...	6.2	0	4.3	3.0	5.3	9.4	1.6	46.2	26.7	19.4	[illegible]
Over 3+	1966...	0	0.7	0	0	0	0	1.1	0	2.8	1.3	
	1967...	0	0	0	0	0	0	0	0	17.8	0	
ESTIMATED INDEX	1966...	25.4	8.1	1.4	11.6	17.0	12.8	45.0	17.0	19.3	23.9	[illegible]
	1967...	36.9	2.9	7.0	6.6	13.3	35.5	43.9	26.0	13.8	10.7	[illegible]
AGE COMPOSITION OF INDEX												
1+	1966...	20.0	6.9	1.3	9.8	14.9	9.2	40.2	2.6	7.3	18.8	[illegible]
	1967...	18.8	1.4	4.5	4.8	7.7	23.3	25.4	0	0	0.3	[illegible]
2+	1966...	4.5	0.9	0	1.7	2.6	1.8	1.3	4.8	3.3	1.1	
	1967...	15.8	1.5	2.2	1.6	4.9	8.9	22.7	14.0	7.7	8.3	
3+	1966...	0.9	0.2	0.1	0.1	0.2	1.8	3.1	9.6	8.2	3.7	
	1967...	2.3	0	0.3	0.2	0.7	3.3	0.8	12.0	3.7	2.1	
Over 3+	1966...	0	0.1	0	0	0	0	0.4	0	0.5	0.3	
	1967...	0	0	0	0	0	0	0	0	2.4	0	

\- Not fished.

older than underyearlings, Indian River; 1966 - 1967.

11	12	13	14	15	16	17	18	19	20	21	22	23	24
680	550	900	670	150	150	530	150	240	300	2,000	1,860	-	-
690	1,760	950	1,370	120	80	450	90	180	200	2,840	1,410	290	630
171	77	102	49	26	7	0	0	0	38	112	21	-	-
134	143	53	36	6	7	0	0	0	5	86	35	4	0
31	9	9	7	8	7	0	0	21	13	8	1	-	-
46	103	25	28	15	11	0	0	0	18	52	29	12	22
6	1	0	3	5	1	0	0	4	2	1	0	-	-
2	3	0	9	6	1	0	0	4	4	1	6	1	8
2	0	0	0	0	0	0	0	0	0	0	0	-	-
0	0	0	0	0	0	0	0	0	0	0	0	0	19
210	87	111	59	39	15	0	0	25	53	121	22	-	-
182	249	78	73	27	19	0	0	4	27	139	70	17	49
81.3	88.4	91.9	83.0	66.7	46.7	0	0	0	71.7	92.6	95.5	-	-
73.7	57.4	67.9	49.3	22.2	36.8	0	0	0	18.5	61.9	50.0	23.5	0
14.8	10.4	8.1	11.9	20.5	46.7	0	0	84.0	24.5	6.6	4.5	-	-
25.2	41.4	32.1	38.4	55.6	57.9	0	0	0	66.7	37.4	41.4	70.6	44.9
2.9	1.2	0	5.1	12.8	6.6	0	0	16.0	3.8	0.8	0	-	-
1.1	1.2	0	12.3	22.2	5.3	0	0	100.0	14.8	0.7	8.6	5.9	16.3
1.0	0	0	0	0	0	0	0	0	0	0	0	-	-
0	0	0	0	0	0	0	0	0	0	0	0	0	38.8
31.8	15.8	14.0	10.9	39.3	10.0	0	0	17.5	22.6	13.3	4.8	-	-
26.8	16.4	8.2	7.6	22.5	23.7	0	0	2.2	14.0	5.2	6.0	5.9	14.3
25.9	14.0	12.9	9.0	26.0	4.7	0	0	0	16.3	12.3	4.6	-	-
19.7	9.4	5.6	3.8	5.0	8.7	0	0	0	2.6	3.2	3.0	1.4	0
4.7	1.6	1.1	1.3	8.0	4.7	0	0	14.6	5.3	0.9	0.2	-	-
6.8	6.8	2.6	2.9	12.5	13.7	0	0	0	9.3	1.9	2.5	4.2	6.4
0.9	0.2	0	0.6	5.3	0.6	0	0	2.9	1.0	0.1	0	-	-
0.3	0.2	0	0.9	5.0	1.3	0	0	2.2	2.1	0.1	0.5	0.3	2.3
0.3	0	0	0	0	0	0	0	0	0	0	0	-	-
0	0	0	0	0	0	0	0	0	0	0	0	0	5.6

Table III. Calculation of Arithmetic mean ($\bar{X}$) and Standard Deviation (s) of parr indices for various "Bottom Types" in Indian River. Data for 1966 and 1967 combined. X = parr index per station. N = Number of Samples.

(a) Gravel Bottom Type.

Station no.	X	$x = (X - \bar{X})$	x^2
2	8.1	- 1.61	2.59
	2.9	- 6.81	46.38
3	1.4	- 8.31	69.06
	7.0	- 2.71	7.34
5	17.0	7.29	53.14
	13.3	3.59	12.89
20	22.6	12.89	166.15
	14.0	4.29	18.40
22	4.8	- 4.91	24.11
	6.0	- 3.71	13.76
	97.1		413.83

$$\bar{X} = \frac{\text{Sum of X}}{N} = \frac{97.1}{10} = 9.71$$

$$S = \text{Square root of} \left(\frac{\text{Sum of } x^2}{N}\right) = 6.43$$

Table III (Continued)

(b) Rubble bottom type

Station no.	X	$x = (X - \bar{X})$	x^2
1	25.4	8.35	69.72
	36.9	19.85	394.02
6	12.8	- 4.25	18.06
	35.4	18.35	336.72
10	23.9	6.85	46.92
	10.7	- 6.35	40.32
19	17.5	- 0.45	0.20
	2.2	- 14.85	220.52
12	15.8	- 1.25	1.56
	16.4	- 0.65	0.42
13	14.0	- 3.05	9.30
	8.2	- 8.85	78.32
14	10.9	- 6.15	37.82
	7.6	- 9.45	89.30
15	39.3	22.25	495.06
	22.5	5.45	29.70
21	13.3	- 3.75	14.06
	5.2	- 11.85	140.42
23	5.9	- 11.15	124.32
	323.9		2146.81

$$\bar{X} = \frac{\text{Sum of } X}{N} = \frac{323.9}{19} = 17.05$$

$$S = \text{Square root of} \left(\frac{\text{Sum of } x^2}{N}\right) = 10.60$$

Table III (Continued)

(c) Boulder bottom type.

Station no.	X	$x = (X - \bar{X})$	x^2
7	45.0	19.85	394.02
	48.9	23.75	564.06
8	17.0	- 8.15	66.42
	26.0	0.85	0.72
9	19.3	- 5.85	34.22
	13.8	- 11.35	128.82
11	31.8	6.65	44.22
	26.8	1.65	2.72
16	10.0	- 15.15	229.52
	23.7	- 1.45	2.10
24	14.3	- 10.85	117.72
	276.6		1584.57

$$\bar{X} = \frac{\text{Sum of } X}{N} = \frac{276.6}{11} = 25.15$$

$$S = \text{Square root of } \left(\frac{\text{Sum of } x^2}{N}\right) = 12.0$$

Table III (Continued)

(d) Combined rubble and boulder bottom type.

Station no.	X	$x = (X - \bar{X})$	x^2
1	25.4 36.9	5.38 16.88	28.94 284.93
6	12.8 35.4	- 7.22 15.38	52.13 336.72
10	23.9 10.7	3.88 - 9.32	15.05 86.86
19	17.5 2.2	- 2.52 - 17.82	6.35 317.55
12	15.8 16.4	- 4.22 - 3.62	17.81 13.10
13	14.0 8.2	- 6.02 - 11.82	36.24 139.71
14	10.9 7.6	- 9.12 - 12.42	83.17 154.26
15	39.3 22.5	19.28 2.48	371.72 6.15
21	13.3 5.2	- 6.72 - 14.82	45.16 219.63
23	5.9	- 14.12	199.37
7	45.0 48.9	24.98 28.88	624.00 834.05
8	17.0 26.0	- 3.02 5.98	9.12 35.76
9	19.3 13.8	- 0.72 - 6.22	0.52 38.69
11	31.8 26.8	11.78 6.78	138.77 45.97
16	10.0 23.7	- 10.02 3.68	100.40 13.54
24	14.3	- 5.72	32.72
	600.5		4188.24

$$\bar{X} = \frac{\text{Sum of } X}{N} = \frac{600.5}{30} = 20.02$$

$$S = \text{Square root of} \left(\frac{\text{Sum of } x^2}{N}\right) = 11.82$$

Table IV. t-test of significance between mean parr indices for various bottom types in Indian River (1966 and 1967 data combined). N = number of stations sampled, $\bar{X}$ = arithmetic mean parr index for (N) stations, S = Standard deviation, n = number of degrees of freedom, P = level of significance.

(a) Between gravel bottom type and rubble bottom type.

Sample	N	$\bar{X}$	S	S^2
1	10	9.71	6.43	41.34
2	19	17.05	10.60	112.36

$$S_{(\bar{X}_1 - \bar{X}_2)} = \text{Square root of} \left(\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2} \right) = 3.17$$

$$|\bar{X}_1 - \bar{X}_2| = 7.34$$

$$t = \frac{|\bar{X}_1 - \bar{X}_2|}{S_{(\bar{X}_1 - \bar{X}_2)}} = \frac{7.34}{3.17} = 2.32$$

$$n = 27$$

P is between 0.05 and 0.025, therefore, the difference between means is significant at the 0.05 level of significance.

Table IV (Continued)

(b) Between rubble bottom type and boulder bottom type.

Sample	N	$\bar{X}$	S	S^2
1	19	17.05	10.60	112.36
2	11	25.15	12.00	144.00

$$S_{(\bar{X}_1 - \bar{X}_2)} = \text{Square root of} \left(\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2} \right) = 4.36$$

$$|\bar{X}_1 - \bar{X}_2| = 8.10$$

$$t = \frac{|\bar{X}_1 - \bar{X}_2|}{S_{(\bar{X}_1 - \bar{X}_2)}} = \frac{8.10}{4.36} = 1.86$$

$$n = 28$$

P is between 0.10 and 0.05, therefore, the difference between means is not significant at the 0.05 level of significance.

Table IV (Continued)

(c) Between gravel bottom type and boulder bottom type.

Sample	N	$\bar{X}$	S	S^2
1	10	9.71	6.43	41.34
2	11	25.15	12.00	144.00

$$S_{(\bar{X}_1 - \bar{X}_2)} = \text{Square root of} \left(\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2} \right) = 4.15$$

$$\left| \bar{X}_1 - \bar{X}_2 \right| = 15.44$$

$$t = \frac{\left| \bar{X}_1 - \bar{X}_2 \right|}{S_{(\bar{X}_1 - \bar{X}_2)}} = \frac{15.44}{4.15} = 3.72$$

$$n = 19$$

P is less than 0.01, therefore, the difference between means is highly significant.

Table IV (Continued)

(d) Between combined boulder and rubble bottom types and gravel bottom type.

Sample	N	$\bar{X}$	S	S^2
1	30	20.02	11.82	139.71
2	10	9.71	6.43	41.34

$$S_{(\bar{X}_1 - \bar{X}_2)} = \text{Square root of} \left(\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2} \right) = 2.97$$

$$\left| \bar{X}_1 - \bar{X}_2 \right| = 10.31$$

$$t = \frac{\left| \bar{X}_1 - \bar{X}_2 \right|}{S_{(\bar{X}_1 - \bar{X}_2)}} = \frac{10.31}{2.97} = 3.47$$

$$n = 38$$

P is less than 0.01, therefore, the difference between means is highly significant.

Table V. t-test of significance between arithmetic mean parr indices (older than underyearlings) in section one, Indian River, 1966 and 1967. ($\bar{X}$ = arithmetic mean, N = number of samples, S = Standard deviation, P = level of significance, n = degrees of freedom).

Sample	N	$\bar{X}$	S	S^2
1	5	12.7	8.12	65.97
2	5	13.3	3.87	14.99

$$S_{(\bar{X}_1 - \bar{X}_2)} = \text{Square root of} \left(\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2} \right) = 4.03$$

$$|\bar{X}_1 - \bar{X}_2| = 0.6$$

$$t = 0.6/4.03 = 0.15$$

$$n = 8$$

P is greater than 0.90, therefore, the difference between means is not significant at the 0.05 level.

Table VI. Arithmetic mean weight of fish sampled during electrofishing studies, Indian River; 1966 and 1967.

Species	No. sampled		Mean weight (gm.)		Mean weight (lb.)	
	1966	1967	1966	1967	1966	1967
Salmon (parr)	302	254	4.15	8.24	0.0091	0.0181
Salmon (fry)	0	330	0.42	0.54	0.0009	0.0012
Trout	110	67	6.36	10.72	0.0140	0.0236
Eels	46	47	51.30	80.16	0.1130	0.1765
Sticklebacks	94	28	1.63	1.41	0.0036	0.0031

Table VII. Food of salmon parr, salmon fry, brook trout, eels and sticklebacks in Indian River, July and August, 1967: (TO. = actual number counted, NO. = number of each food organism expressed as percentage of total number of organisms, F. = number of stomachs containing each food organism expressed as percentage of total stomachs examined, N. = nymph, L = larva, A = adult).

Fish species	Salmon parr			Salmon fry			Brook trout			Eels			Sticklebacks		
No. sampled	360			310			60			40			23		
	TO.	NO.	F.	TO.	NO.	F.	TO.	NO.	F.	TO.	NO.	F.	TO.	NO.	F.
Food composition															
Salmon parr	0	0	0	0	0	0	0	0	0	1	0.6	2.5	0	0	0
Salmon fry	0	0	0	0	0	0	1	0.1	1.7	1	0.6	2.5	0	0	0
Ephemeroptera..N	76	2.1	8.9	17	2.7	-	14	1.6	10.0	86	50.9	17.5	4	10.0	4.4
Plecoptera..N	216	5.8	18.9	94	15.1	-	52	6.1	15.0	37	21.9	10.0	10	25.0	8.7
Trichoptera..L	324	8.7	29.5	42	6.8	-	18	2.1	18.4	3	1.8	5.0	3	7.5	4.4
Coleoptera..L	2	0.1	0.6	0	0	-	1	0.1	0	0	0	2.5	0	0	0
Coleoptera..A	1421	38.4	16.4	110	17.7	-	509	59.6	31.7	8	4.7	7.5	7	17.5	4.4
Hemiptera..A	66	1.8	9.2	5	0.8	-	17	2.0	10.0	0	0	0	0	0	0
Oligochaeta	58	1.6	0.8	0	0	-	0	0	0	0	0	0	0	0	0
Hirudinea	4	0.1	0.3	0	0	-	0	0	0	1	0.6	5.0	0	0	0
Gastropoda	667	18.0	10.3	7	1.1	-	0	0	0	11	6.5	7.5	0	0	0
Odonata..N	27	0.7	6.1	3	0.5	-	6	0.7	10.0	20	11.8	27.5	0	0	0
Neuroptera..L	306	8.3	17.8	191	30.8	-	72	8.4	21.7	0	0	0	10	25.0	13.1
Mosquito...L	6	0.2	0.8	0	0	-	33	3.9	1.7	0	0	0	0	0	0
Chironomidae..L	123	3.3	8.1	97	15.6	-	6	0.7	3.3	1	0.6	5.0	4	10.0	8.7
Tipulidae..L	1	0.03	0.3	0	0	-	0	0	0	0	0	0	0	0	0
[illegible]	40	1.1	3.1	12	1.9	-	0	0	0	0	0	0	0	0	0

Mosquito...L	6	0.2	0.8	0	0	-	33	3.9	1.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chironomidae..L	123	3.3	8.1	97	15.6	-	6	0.7	3.3	1	0.6	5.0	4	10.0	8.7
Tipulidae..L	1	0.03	0.3	0	0	-	0	0	0	0	0	0	0	0	0
Simulidae..L	40	1.1	3.1	12	1.9	-	0	0	0	0	0	0	0	0	0
Amphipoda	1	0.03	0.3	0	0	-	0	0	0	0	0	0	0	0	0
Hydracarina	6	0.2	1.1	0	0	-	0	0	0	0	0	0	0	0	0
Unidentified Diptera..L	1	0.03	0.6	21	3.4	-	1	0.1	5.0	0	0	2.5	0	0	0
<u>Surface organisms</u>															
Neuroptera..A	10	0.3	0.6	0	0	-	72	8.4	21.7	0	0	0	10	25.0	13.1
Mosquito... A	306	8.3	23.9	18	2.9	-	93	10.9	43.4	0	0	0	2	5.0	4.4
Tipulidae..A	0	0	0	0	0	-	1	0.1	1.7	0	0	0	0	0	0
Simulidae..A	5	0.1	1.4	0	0	-	3	0.4	3.3	0	0	0	0	0	0
Unidentified Diptera..A	23	0.6	3.6	3	0.5	-	15	1.8	1.7	0	0	0	0	0	0
<u>Terrestrial organisms</u>															
Arachnida	11	0.3	1.9	1	0.2	-	5	0.6	5.0	0	0	0	0	0	0
Coleoptera..A	1	0.03	0.3	0	0	-	0	0	0	0	0	0	0	0	0
Formicidae..A	6	0.2	1.9	1	0.2	-	7	0.8	6.7	0	0	0	0	0	0
Empty	21	-	5.8	-	-	-	5	-	8.4	11	-	27.5	8	-	34.8
Digested bolus	10	-	2.8	-	-	-	1	-	1.7	2	-	5.0	0	0	0
Totals	3707	100.1	175.3	622	100.2	-	854	100.2	200.4	169	100.0	123.0	40	100.0	82.9

Table VIII. Weekly count of salmon at Indian River Fishway; 1958 - 1966 (1962 excluded).

		June	July					August					September			Total
1958	Week ending	28	5	12	19	26	-	2	9	16	29	-	6	-	-	
	Number counted	24	53	80	163	133	-	180	101	139	33	-	11	-	-	923

		June	July					August					September			Total
1959	Week ending	-	-	-	11	18	25	1	8	15	22	29	5	-	-	
	Number counted	-	-	-	36	107	108	75	24	40	24	33	9	-	-	456

		June	July					August					September			Total
1960	Week ending	-	2	9	16	23	30	6	13	20	27	-	24	-	-	
	Number counted	-	13	49	93	105	92	75	40	21	7	-	24	-	-	519

		June	July					August					September			Total
1961	Week ending	-	1	8	15	22	29	5	12	19	26	-	2	9	-	
	Number counted	-	10	16	33	14	41	10	4	7	4	-	13	2	-	154

August September

1961	Week ending	June			July					August				September		Total
		-	1	8	15	22	29	5	12	19	26	-	2	9	-	
	Number counted	-	10	16	33	14	41	10	4	7	4	-	13	2	-	154

1963	Week ending	June			July					August				September		Total
		29	6	13	20	27	-	3	10	17	24	31	7	14	-	
	Number counted	4	7	38	83	44	-	50	51	9	3	0	0	0	-	289

1964	Week ending	June			July					August				September		Total
		-	4	11	18	25	-	1	8	15	22	29	5	12	-	
	Number counted	-	7	6	68	313	-	527	131	94	63	23	12	-	-	1,244

1965	Week ending	June			July					August				September		Total
		-	3	10	17	24	31	7	14	21	28	-	4	-	-	
	Number counted	-	16	29	54	90	66	48	34	27	18	-	12	-	-	394

1966	Week ending	June			July					August				September		Total
		-	-	9	16	23	30	6	13	20	27	-	3	-	-	
	Number counted	-	-	25	24	78	40	52	26	33	14	-	3	-	-	295

Table IX. Mean fork length and Standard deviation of salmon entering Indian River Spawning Channel; 1963 - 1967.

Year	1963	1964	1965	1966	1967
Mean length (cm.)	51.6	50.3	50.1	48.5	50.3
Standard deviation	4.7	2.2	4.2	4.2	3.0
Number sampled	73	248	110	160	152

SUMMARY

Indian River is a medium size stream (drainage area 500 square miles) flowing into Hall's Bay, Newfoundland. Prior to 1962, a run of Atlantic salmon, numbering about 1,500 to 2,000 fish, frequented Indian River. Many of these fish spawned in Upper Indian River, a tributary of Indian River.

During 1962, Bowater's Pulp and Paper Company constructed a hydro diversion dam on Upper Indian River which resulted in the diversion of most of the headwaters of this tributary into Birchy Lake. The Department of Fisheries of Canada, which is responsible for maintenance of Atlantic salmon stocks in Newfoundland rivers, reasoned that, with completion of the hydro-electric project, many of the salmon utilizing Upper Indian River would be deprived of suitable spawning grounds. As an effort to compensate for the expected loss of spawning grounds, the Department of Fisheries constructed, on Upper Indian River, a controlled flow spawning channel at a point 2.8 miles above Indian Pond during 1962-63. The channel is basically a man-made spawning area which provides nearly ideal conditions for the deposition and subsequent development of eggs.

Prior to the beginning of this study, it was the policy of the Department of Fisheries to allow fry, which were produced in the channel, to move directly out of the channel into the 2.8 mile section of river between the channel and Indian Pond. It was known that a sizable number of salmon continued to spawn naturally in this area. Gradually it became apparent that it might not be sound management policy to release large numbers of fry from the channel into this section of river, where they

would necessarily enter into competition, for food and living space, with naturally produced fry. During the summer of 1966, therefore, a survey was undertaken to provide information on;

(a) the fate of fry after they left the channel,

(b) the contribution of channel produced fry to salmon parr populations in Indian River,

(c) the best way to utilize channel produced fry, if it were established that the policy, being followed at that time, was not suitable.

To study fry migration, specially constructed traps, consisting of a diagonal screen fence and holding box, were utilized. In addition, electrofishing gear was used to determine underyearling densities upstream and downstream from areas where fry were released. The electrofishing gear was also used to determine parr densities throughout Indian River, so that parr production in the area of direct channel influence could be compared with that in areas where the channel was not likely to have any effect. Twenty-two representative stations were fished in 1966 and twenty-four in 1967. Each station was secured at both ends by fine mesh netting before fishing began. A catch per unit of effort method, described by DeLury (1947) was used to estimate fish populations at each station.

Comparison of fry production in the channel with that in the river, under natural conditions, indicated that egg-fry survival in the channel is, at least, double what it is under natural conditions. Results showed that fry tended to remain near the area where they were hatched. The degree of post-hatching dispersal of fry appears to be directly related to the stocking density. Underyearling production is greater in the area of direct channel influence than in any other area of Indian River. Production of 1^{+} and older parr is lower in this area than in any other area of Indian River except in the main river below Indian Pond. Parr density in the area of direct channel influence averaged 13 per 100 square yards compared with 19 per 100 square yards for the river as a whole. The total standing crop of Indian River averaged 34.9 pounds per acre. The standing crop of juvenile Atlantic salmon averaged 12.0 pounds per acre. Compared to other streams, described by other authors, Indian River can be described as being moderately productive. As a producer of Atlantic salmon it rates favourably with most rivers described in the literature.

Underyearling to yearling survival, in the area of direct channel influence, was compared with survival rate in three other areas of Indian River. Survival in the area of direct channel influence was 9.7 percent compared to an average of over 70 percent for the other three areas studied.

Based on the results obtained from this study, it was concluded that most of the fry, which have been released from the channel into the 2.8 mile section of river between the channel and Indian Pond, have either died or moved to some other part of the river. No evidence was obtained to show that extensive emigration occurred. It seems likely, therefore, that mortality was high. Consequently, it has been recommended that fry, produced in the channel, be distributed to areas of the river which are presently understocked or inaccessible to spawning adults.

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