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Lake Surveys and Biological Potential for Natural Lacustrine Rearing of Juvenile Atlantic Salmon (*Salmo salar*) in Newfoundland

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August 1984

LAKE SURVEYS AND BIOLOGICAL POTENTIAL FOR NATURAL LACUSTRINE REARING OF JUVENILE ATLANTIC SALMON (*SALMO SALAR*) IN NEWFOUNDLAND

by

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CONTENTS

Page

Abstract/Résumé iv
Introduction 1
  Lake survey objectives 1
  Atlantic salmon production potential 2
  Lake stocking experiment, site selection 2
  Indian Brook development project 3
Study area 3
  Lake study sites 3
  Geology of Indian Brook study area 3
  Soils and vegetation 4
  Aquatic vegetation 4
  Physical character of ponds 4
    Traverse Pond and Gull Brook 4
    Lower Micmac Pond 5
    Upper Micmac 5
    Micmac Lake 6
Methods 6
  Water chemistry and physical attributes 6
  Bathymetry 7
  Biological community 7
  Stream fish sampling 8
  Lake sampling 8
  Laboratory analysis 9
  Winter sampling 10
Results 10
  Traverse Pond 10
    Physical parameters 13
  Gull Brook 13
  Lower Micmac 14
  Upper Micmac 15
  Brook trout population comparisons 16
Discussion 17
  Physical and chemical characteristics 17
  Lake and stream zooplankton 18
  Brook trout populations 19
  Population estimates 20
  Growth 21
  Significance of results 21
  Enhancement considerations 22
  Juvenile salmon production potential 23
  Lacustrine stocking 25
Summary 29
Acknowledgments 30
References 30
Appendix 1: Mounting medium for parr, smolt, and brook trout scales ... 42

ABSTRACT

Pepper, V.A., N.P. Oliver, and R. Blundon. 1984. Lake surveys and biological potential for natural lacustrine rearing of juvenile Atlantic salmon (Salmo salar) in Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1295: iv + 72 p.

This report describes a biobaseline study designed to evaluate the technical desirability of implementing an Atlantic salmon enhancement project to increase production through use of natural lakes for rearing juveniles. Based on a brook trout lacustrine standing stock of 16 kg/ha, calculated from mark and recapture surveys undertaken in the absence of competing fish species, a rationale is developed in support of lacustrine fry stocking using 1000 swim up Atlantic salmon fry/ha. The responsibility of the salmon enhancement project planner, for maintaining salmonid communities while endeavoring to secure production benefits from economically desirable species, is also discussed.

RÉSUMÉ

Pepper, V.A., N.P. Oliver, and R. Blundon. 1984. Lake surveys and biological potential for natural lacustrine rearing of juvenile Atlantic salmon (Salmo salar) in Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1295: iv + 72 p.

Le présent rapport décrit une étude biologique fondamentale visant à évaluer les avantages techniques d'un projet de mise en valeur du saumon de l'Atlantique: des lacs naturels seraient utilisés pour élever des juvéniles dans le but d'augmenter la production. A partir d'une valeur de 16 kg/ha du stock actuel d'omble de fontaine en milieu lacustre, valeur calculée à l'aide de résultats obtenus au cours d'études de marquage et de recapture menées en l'absence d'espèces compétitives de poissons, on justifie une valeur de 1 000 alevins nageants de saumon de l'Atlantique/ha pour l'alevinage en milieu lacustre. Le rapport traite aussi de la responsabilité du planificateur du projet de mise en valeur qui devra maintenir les populations salmonicoles en plus de s'appliquer à garantir des avantages de production des espèces économiquement désirables.

INTRODUCTION

Department of Fisheries and Oceans policy for Canada's fisheries is to maximize net social and economic benefits derived from the fishery resource. In this context, enhancement of Canada's common property salmonid resources attempts to define projects that assure net benefits (i.e. that project benefits will exceed project costs). This requires that costs, necessary to support enhancement projects, and project benefits, be defined on a long-term basis (i.e. 20-25 years).

While identification of general cost flows for enhancement projects can often draw on experience gathered from similar types of projects in other parts of North America, prediction of salmonid production benefits, from natural and semi-natural enhancement opportunities, requires site specific biobaseline information. These biobaseline requirements include:

1) watershed characteristics of distribution and abundance of salmonid habitat (river spawning habitat, river rearing habitat, lake area, average lake depth);

2) water chemistry;

3) resident fish species (predators and/or competitors); and,

4) competitive water users (industry, agriculture, municipal).

Although these types of data will require considerable biological interpretation to define technical selection criteria for any given enhancement proposal, this information base is necessary to determine potential viability of enhancement projects. Provision of biological insight, prerequisite to identification of potential project costs and benefits for a new Atlantic salmon enhancement strategy, is the object of this report.

Previous investigations into lake ecology of pre-smoltification stages of Atlantic salmon (Pepper 1976) have documented significant numbers of salmon parr in lentic environments and established parr growth rates comparable to those of parr found in stream habitats. In view of these findings, and the abundance of unpolluted freshwater lakes in Newfoundland (Cox 1977), research is being directed towards experimental evaluation of lake stocking with unfed Atlantic salmon fry.

LAKE SURVEY OBJECTIVES

The purpose of the present study was to identify lakes that might be suitable for rearing juvenile Atlantic salmon in an experimental situation where such parameters as growth, mortality, predation and general species interactions could be monitored. The main objective of this study was to choose three lakes and evaluate their potential to produce salmon smolt for sea ranching (Thorpe 1980). Ultimately this study was intended to provide biobaseline information on which to design fry stocking experiments for evaluating fry rearing potential of natural standing waters.

ATLANTIC SALMON PRODUCTION POTENTIAL

Historically, estimates of Atlantic salmon production potential in Newfoundland have been based on aerial surveys of streams using criteria of Riche (1972). According to this method, salmon spawning areas are those stream sections with gravel substrate (2.5-7.6 cm diameter) while rearing areas have been defined as having cobble/rubble stream substrate (cobble over 30.5 cm, rubble from 7.5 cm to 30.5 cm; Lagler 1956). Unproductive areas for salmon are regarded as those stream sections having bedrock, sand or mud bottoms. Pond (1968) has provided evidence of the validity of this scheme. Deep pools and long still water sections also have been considered as undesirable for salmon parr (Elson 1957, 1975).

Salmon standing stock and production potential in freshwater habitat is expressed as smolts per unit (1 unit = 100 m^2 of accessible cobble/rubble stream substrate), these data being derived from electrofishing population estimates and smolt enumeration at various weirs. Recorded smolt production per unit of river area in Newfoundland has ranged from 1.5 to 2.0 (Riche 1972). In view of documented utilization of lakes by salmon parr (Harris 1973; Hewetson 1963; Jones and Evans 1962; Munro 1965), present estimates of salmon production potential, based entirely on stream habitat, may significantly underestimate the total potential for rearing juvenile Atlantic salmon in some river systems.

LAKE STOCKING EXPERIMENT, SITE SELECTION

Commencement of this lacustrine stocking biobaseline study depended on fulfilling several basic requirements, the most important one being accessibility to an adequate supply of Atlantic salmon fry. Salmon fry can be acquired from rivers at the time of emergence from their redds or from hatchery incubators. Fry trapping in rivers is usually inadequate where large numbers of fry are required while hatchery propagation has often proven costly. Popular during the 1950's and 60's as a means of producing good quality salmon fry, the artificial spawning channel was the preferred fry production option at the time of initial salmon enhancement activities in Newfoundland in the early 1960's. Such production facilities, one at Indian Brook and one at Noel Paul's Brook (Fig. 1), were used to supply fry stocking projects for insular Newfoundland over a 20 yr period.

In addition to proximity to an adequate supply of salmon fry, the lakes to be studied had to be accessible by road, small enough to monitor effectively, and contain no resident (landlock) salmon population to confuse assessments of results of anadromous fry stocking. Also, lake site selection criteria specified that potential study sites:

- have ample aquatic insect and benthic invertebrate production (Clemens 1928; Allen 1941, 1962, 1969; Larkin et al. 1957; Lillehammer 1973; Arnemo et al. 1980) to support a significant salmonid population;
- not support extensive public recreation; and,

- have controllable intake and outlet streams to allow monitoring of movements of stocked fry between lake and stream environments.

The present survey focused on lakes in the vicinity of the Indian Brook spawning channel since this area met the study requirements as described above. This study was undertaken in 1976.

INDIAN BROOK DEVELOPMENT PROJECT

The Indian Brook spawning channel was constructed in 1962 to compensate for the loss of 36 hectares of headwater spawning area following diversion of Indian Brook headwaters (Fig. 2) into the Humber River for hydro-electric generation. Spawning channel egg capacities, fry survivals, fry distributions and evaluations, have been described previously (Pratt and Sturge 1965; Pratt 1968; Rietveld 1970; Pratt et al. 1974; Davis and Farwell 1975).

The initial objective, for the Indian Brook swim-up fry production facility, was fry stocking within mainstem habitat to maintain salmon production in the river subsequent to headwater diversion for industrial purposes. This stocking plan was expanded in 1974 to include river areas above an impassable obstruction on Black Brook. Increasing river escapements suggest that the spawning channel was successful (Fig. 3) in fulfilling its mandate. However, due to budget restrictions, the Indian Brook project was abandoned in 1975.

STUDY AREA

LAKE STUDY SITES

Lacustrine habitats described in this report are morphometrically characteristic of ponds (Hutchinson 1957), generally having extensive littoral areas and virtually no 'profundal' habitat.

Figure 4 includes names of gazetteered ponds of the study area. For purposes of reference simplicity, for the remainder of this report, the pond northwest of Micmac Lake will be referred to as Upper Micmac while that south of Micmac Lake will be referred to as Lower Micmac though neither of these ponds are referenced in the gazatteer.

GEOLOGY OF INDIAN BROOK STUDY AREA

Watersheds of the main study area are shown in Fig. 4. Geological formations have been mapped by Hibbard (1982).

Geological surveys of the area (Hibbard op cit) indicate that the present study area is diverse in its geological composition. The area around Traverse Pond is composed of a narrow band of rhyolite and silicic volcanic rocks. This band extends southwest to include Lower Micmac, and borders the eastern shore of Micmac Lake. Extending eastward from Traverse Pond, past Gull Pond, rhyolite and granitic rocks predominate. A band of matic volcanic rocks, interspersed with sandstone deposits, borders the north shore of Micmac Lake. This lake is bounded on the south shore by the same sort of rhyolite and silicic volcanic rock that bounds Traverse Pond. West of Micmac Lake is a narrow band of ultramatic rocks that extends northward past Upper Micmac on the western side of the lake. The northern and eastern parts of the Upper Micmac watershed are comprised of highly metamorphosed (gneisses) rocks.

SOILS AND VEGETATION

Soils in the main study area are derived predominantly from medium grained granites with significant amounts of granodioite and diorite and some volcanic rocks. These soils are predominately orthic humo-ferric podzols, gleyed humo-ferric podzol and orthic gleysol. They are deposited mainly by glaciation and classified as hummocky moraine.

Some of this area is bog, comprised of a layer of grass peat with significant amounts of sphagnum peat containing mosses, sod grass, scattered black spruce and occasional heath shrubs over hummocky fens. Forested areas are predominantly black spruce interspersed with paper birch, aspen, larch, pin cherry and alder.

The area south of the junction of Black Brook and Micmac Brook is predominantly orthic humo-ferric podzol with a small amount of gleyed humo-ferric podzol and ortstein humo-ferric podzol. These soils are deposited as inclined, hummocky or ridged morainal sediment over a bedrock base. Forest cover is similar to that described above. Bogs are predominantly sphagnum peat with less grass and cover a more sandy fen. Bedrock exposure and general rockiness make tillage for agriculture unfeasible for all sites within the present study area.

AQUATIC VEGETATION

The same assemblage of aquatic plant species was found in each of the three study lakes though their relative abundance (subjective interpretation) varied. Species of the genus *Potamogeton* were most numerous (*P. praelongus*, *P. perfoliatus*, *P. amplifolius* and *P. natans*), while watermilfoil (*Myriophyllum tenellum* and *M. alterniflorum*) were also common. Other plants found in these lakes were: quillworts (*Isoetes* sp.) spikerush (*Eriocaulon septangulare*) and spatterdock (*Nuphar luteum*). Of the three lakes, Upper Micmac had the greatest abundance of aquatic plant material. *N. luteum* was the predominant species and often formed large emergent floral displays, especially along the northeast and southeast shores in mid to late summer.

PHYSICAL CHARACTER OF PONDS

Traverse Pond and Gull Brook

Traverse Pond is typical of many of the smaller bodies of standing water in the area. Physical data for the three study ponds are presented in Table 1.

Traverse Pond bathymetry is presented in Fig. 5. Total water volume, at elevation 194 m, amounts to approximately 734000 m^3. The watershed above Traverse Pond contains several lakes, the largest of which (Gull Pond, Fig. 4) has a surface area of 980 hectares at elevation 225.6 m. The entire Gull Brook watershed has an area of 34000 hectares.

Water discharge in Gull Brook above Traverse Pond, varied throughout the ice free period, from 0.26 to 0.31 m^3 per second. The boulder-rubble stream substrate, together with a mean stream slope of -1.1% (i.e. a drop of 1.1 m per 100 m stream length) results in little scouring from water flow. The mean volume of water entering Traverse Pond during the ice free period was calculated to be 0.28 m^3 per second. This indicates a total exchange of lake water mass once every 14 to 15 days.

From the outlet of Traverse Pond, Gull Brook flows into Micmac Brook (Fig. 4). This latter brook then flows to Black Brook and then on to Indian Pond on Indian Brook, a distance of 10.5 km. A 7 m high water fall, situated 1.3 km upstream from Indian Pond, prevents movement of fish upstream from this point on Black Brook.

Most of the substrate of Traverse Pond is gravel though the southeast arm is virtually all boulder/rubble. Only the deepest parts of this lake, plus parts of the southwest arm, have significant areas of fine clay-like material. Most of this softer bottom type is compacted by the roots of leafless watermilfoil (*M. tenellum*).

Lower Micmac Pond

Situated only 0.9 km south of Micmac Lake, this pond differs from Micmac Lake mainly in size.

The mean slope of Micmac Brook, from Micmac Lake to Lower Micmac, is -2%. Water velocity in Micmac Brook, below Micmac Lake, was not measured but appeared comparable to the flow in Gull Brook.

Substrate in Lower Micmac was very similar to that of Traverse Pond. The incidence of rubble/boulder material is low and generally confined to the outlet area of the lake and a small area on the northwest shore. Areas of clay and mud bottom are more common but again, the fine material is maintained in the sediment by the roots of leafless watermilfoil. This plant is more abundant (subjective) in Lower Micmac Pond than in Traverse Pond.

Stream substrate again consisted of boulders and smaller rubble sized smooth rocks. Much of the length of this section of Micmac Brook is riffle.

Upper Micmac

This lake drains the northwest region of the Micmac watershed (Fig. 4) and flows into Micmac Lake. Although this lake has less than one half the surface area of Traverse Pond, its total water volume (7.2×10^5 m^3) represents 98% of the volume of Traverse Pond. Upper Micmac bathymetry is presented in Fig. 6.

The inlet to Upper Micmac is short (1.5 km). It is a narrow brook flowing through a grassy marsh. This brook often becomes intermittant during dry summer periods. The outlet from Upper Micmac flows 2 km to its entrance into Micmac Lake. This brook has a mean slope of 1.5% and flows over mixed boulder, rubble and gravel substrate. It is also subject to summer droughts, occasionally having no apparent water flow during these periods. Once again flow was not measured in this brook. In consideration of the small size of this brook, its intermittant flow during the summer and the water volume of Upper Micmac Pond (being comparable to Traverse Pond) it is assumed this pond had the lowest turnover rate of the three study sites.

Micmac Lake

Though not an integral part of the present study, Micmac Lake is located between Upper Micmac and Lower Micmac Ponds and receives water from the former while discharging to the latter. As such, this 785 ha lake (at elevation 210 m) has potential significance to movement of fish species within this watershed. Being generally shallow with very little water area of > 6 m depth, and a considerable amount of rocky littoral area, this lake also represents significant rearing potential for juvenile salmonids.

METHODS

Three lakes were identified for study after aerial and ground surveys. Surveys of the three sites concentrated on collection of data on:

1. water chemistry;
2. bathymetry;
3. population magnitude and age structure of predator/competitor species;
4. predator/competitor movements and degree of interaction between resident stream and lake dwelling salmonids;
5. potential food resources for salmonids;
6. potential for parasitism; and,
7. lake bottom type and spatial distribution.

WATER CHEMISTRY AND PHYSICAL ATTRIBUTES

Water samples, for the purpose of chemical analysis, were collected periodically from each lake (30 cm depth, unfiltered, frozen) and transferred to the Water Chemistry Analysis Facility of Memorial University of Newfoundland. Samples were analysed for nitrate, total phosphorous, ortho-phosphate, specific conductance, calcium, iron and chloride according to the methods of Strickland and Parsons (1968). In addition to water chemistry, routine determinations of temperature, oxygen and radiant energy were made on each lake. Temperature and oxygen were measured with a YSI (Yellow Springs

Instrument) 51B oxygen meter and YSI 5739 temperature/oxygen probe. Data were obtained at 1 m intervals from surface to bottom. Radiant energy was measured, during July and August, with an IL700 (International Light) Research Radiometer and SEA010 number 125 detector, number 78 diffuser and CF61 number 122 filter (463 nm). Light was measured in this manner to facilitate in situ evaluations of water clarity. Secchi disk readings were not feasible due to the shallowness of the ponds. Light readings were taken 10 cm below the surface and on the bottom. Depth of water was also recorded to facilitate calculation of extinction coefficient (Vollenweider, 1969). These calculations were performed as:

$$K = \frac{Io_e - Id_e}{d}$$

where,

K = extinction coefficient at 463 nm

Io = surface radiant energy reading ($gcal/cm^2/sec$)

Id = bottom radiant energy reading

d = depth in m

e = base Napierian logarithm (natural)

Irregularity in periodicity of these measurements resulted from adverse weather conditions and equipment malfunctions. Measurements of conductivity were made with a YSI 33, S-C-T meter and a 3000 series conductivity/temperature probe.

BATHYMETRY

Depth soundings were made using either a Furuno, Mark III, 200A or an Apelco AE 725 echosounder. Bathymetric maps were produced from sounding traces according to procedures outlined by Welch (1948). Lake areas were calculated by use of a Keuffel and Esser 4236 compensating polar planimeter.

BIOLOGICAL COMMUNITY

Aquatic plants were collected by snorkel diving in the three lakes. Plant samples were dried, pressed, and later identified using Hotchkiss (1972).

Zooplankton were collected by ten minute surface plankton tows with a Wisconsin plankton net (80 micron mesh). Tows were made at a constant speed such that the plankton net remained at a position immediately below the surface. Plankton samples were preserved in 10% formalin. These samples were later examined for species composition with both compound and dissecting microscopes. Estimates of species abundance were made by subsampling with a Hensen-Stempel pipette.

Invertebrate drift was sampled in Micmac and Gull Brooks, with a Surber sampler. Samples were of 24 hr duration and were again preserved in 10% formalin. All samples were examined in the laboratory with a dissecting microscope and classified to the level of order.

STREAM FISH SAMPLING

Quantitative stream fish population estimates were pursued by electrofishing according to the techniques described by LeDrew (1972) and Pepper (1976). A Derigo, Series 500A electrofisher was used throughout this investigation. In addition to specimens collected by electrofishing, several specimens were taken by angling. Fish specimens of greater than 15 cm were frozen while fish smaller than 15 cm were preserved in 10% formalin. Preserved specimens were later (greater than 30 d) washed in running water and stored in 40% isopropyl alcohol prior to laboratory examination.

LAKE SAMPLING

Lake trap nets were used for fish sampling in all study lakes. These traps consisted of a 30.5 x 1.8 m leader, two 7.6 x 1.2 m wings and a 5.5 m tapered funnel supported by five square aluminum frames (1.9 cm tubing). The 1.2 m cod end was fitted with a drawstring to enable fish to be easily removed from the trap. Netting used on the trap body was 18 kg test, 0.6 cm (square measure) King bonded knotless nylon. The leader and wings were of a similar material but larger mesh (0.95 cm square measure). Trap design is illustrated in Fig. 7.

Nets were set with the leaders perpendicular to shore and wings at 45 degrees relative to the leader. Leaders were tied on shore with the trap stretched and anchored from the cod end. Wings were also anchored. Traps were allowed to fish throughout the night, the actual set duration varying from 22 to 26 hours.

During the first summer of this study (1976), preliminary population estimates of brook trout were arrived at through mark-recapture studies by finclipping (adipose). These somewhat crude estimates were then used to formulate more rigorous tagging programs (DeLury 1951) for implementation the following year. Initially, population estimates were made using the Schumacher-Eschmeyer (1943) calculation described by Ricker (1975). Final population estimation proceeded according to the Schnabel method as modified by Overton (1965). Estimates of brook trout population abundance in stream habitats were undertaken by electrofishing using catch vs. cumulative catch regression of Leslie (in Ricker 1975). Confidence limits were calculated according to the procedure of DeLury (1951).

Additional information, collected from trapped specimens, included fork length (for length frequency analysis) and degree of ectoparasitism. Small subsamples of brook trout were sacrificed once per month for detailed evaluations of age, growth, internal parasites, and feeding intensity. During the second and final summer of this study (1977), Traverse Pond brook trout were tagged with white Floy fingerling tags (Floy Tag and Manufacturing) using techniques described by Pepper (1976). These tags were numbered sequentially such that individual fish could be recognized. This facilitated studies of trout movement within the lake. Trapping was undertaken at four locations per week in Traverse Pond (Fig. 5), two sites near the inlet and two towards the outlet. This design allowed analysis of size distribution of trout within the lake. Trap locations were nested within pond area in a factorial analysis of mean trout fork length at each end of the pond over the seven time periods (weeks). These analyses were performed on an IBM 370 computer, using an analysis of variance program (Clyde 1969).

Trap locations in Lower Micmac Lake were also chosen with respect to inlet and outlet (Fig. 8). However, due to human resource limitations, this lake was sampled only once per month. No attempts were made at rigorous population estimation, abundance being determined by both C/E (for comparison with Traverse Pond catch results) and fin clipping (adipose) mark-recapture studies.

Upper Micmac Lake was also sampled only once per month. As with Lower Micmac, only two traps were set, one at each end of the lake. Fish were fin clipped and their fork lengths recorded. Subsamples were again sacrificed for laboratory investigations as described above.

LABORATORY ANALYSES

Applied to all specimens sacrificed for laboratory examination were determinations of: sex, condition, stomach contents, and year class.

Growth rate was also investigated for each population. Fish age was determined from projections of mounted scales (Acacia medium, Appendix 1). Images were projected by a Bausch and Lomb, Tri Simplex projector, onto millimeter graph paper and the focus, annuli and edge positions marked on the grid. For the present study, growth functions were calculated as a linear relation of observed fork length regressed on age. Growth rate comparison (slopes of regression equations) was performed as per Steel and Torrie (1960), page 320.

Weight-fork length regressions for both males and females of the various samples, were calculated and compared using ANOVA techniques described by Steel and Torrie (op. cit.). This facilitated both calculation of biomass elaboration and identification of potential sexual dimorphism pertaining to condition. Individual condition factors were also calculated as

$$W \times 10^2/L^3$$

where: W is weight in grams and
L is fork length in cm.

but were not subjected to quantitative analyses due to current arguments about the use of ratio estimators (Atchley et al. 1976; Atchley 1978; Atchley and Anderson 1978; Hills 1978; Dodson 1978; Albrecht 1978).

Stomach contents were examined with a Nikon dissecting microscope. Organisms were identified to the level of order. No attempt was made to partition these data further in statistical comparisons.

Mark-recapture data tabulations were performed on an IBM 370 computer. Days at large were calculated by the function:

$$\text{Julian day number} = \text{INT}(365.25y^1) + \text{INT}(30.6001m^1) + d + 1720982$$

where

y^1 = (year-1) if $m = 1$ or 2
or year^1 if $m>2$

m^1 = month +13 if $m = 1$ or 2
or month + 1 if $m>2$

INT denotes truncation of decimals to the next lowest whole number. Elapsed days = days(2) - days(1).

WINTER SAMPLING

Temperature and oxygen data were obtained by drilling holes through the ice with an ice auger (Swedish model, 20 cm bore) and recording temperature with a YSI model 51B and YSI 5739 temperature-oxygen probe.

Implemented only as a means of ascertaining whether or not these three lake environments support overwintering populations of brook trout, winter sampling was minimal and was limited to Traverse and Upper Micmac Ponds. During winter sampling, measurements of ice thickness and snow cover were also recorded.

RESULTS

TRAVERSE POND

Although salmon fry were introduced to Black Brook as recently as 1975 (from previous Indian Brook salmon enhancement activities) no fry stocking has taken place on Gull Brook. During the two summers of investigations in Traverse Pond, eight salmon parr were captured. These specimens were not sacrificed for laboratory studies of growth and morphometrics but their fork length range (14.1-18.0 cm) suggests they were stocked as fry in Black Brook in 1974 (i.e. 2+ when captured in 1976).

Within the entire study area, brook trout (Salvelinus fontinalis) was the most abundant fish species. The 1976 mark-recapture survey of Traverse Pond indicated a trout population of from 6000 to 50000 (1001 marked, 31 recovered). The 1977 population survey was undertaken to provide a narrower confidence interval. According to criteria of DeLury (1951), the 1977 survey was designed to tag 1300 trout.

During seven weeks of sampling in Traverse Pond, from July until September of 1977, 1440 post yearling trout were captured, of which 1060 received Floy fingerling tags. A total of 42 recaptures were recorded, 14 of which were taken at the site of previous release. Only two specimens were recaptured more than once. Maximum days-at-large between capture and release was 36 (Table 2). Underyearling trout were rare among trap net captures in Traverse Pond. Among yearling parr captured, those of less than 10 cm fork length were excluded from tagging due to suspected increased predation on small fish marked with white tags.

Throughout the course of the 1976 and 1977 mark/recapture surveys, mean fork length of recaptured brook trout was consistently greater than that of the initial capture sample. In 1976, the recapture sample averaged 16.3 cm fork length ($N = 31$, $S_{\bar{x}} = 0.63$) as contrasted with an average fork length of an initial capture subsample of 15.7 cm ($N = 245$, $S_{\bar{x}} = 0.21$). The 1977 recapture sample averaged 17.2 cm ($N = 42$, $S_{\bar{x}} = 0.49$) as contrasted with an average initial capture sample mean of 16.2 cm ($N = 1047$, $S_{\bar{x}} = 0.11$). A t-test of these latter two means indicated that mean fork lengths of the initial capture and recapture samples were not significantly different ($t = 1.7440$, $P = 0.0814$). Variances of the two groups were equal ($F = 1.31$, $P = 0.3027$).

C/E averaged 1.79 trout (0.2 - 7.8) per trap net hour. Highest catches were observed during the first trapping period. Trapping activities in August produced the lowest captures, ranging from 0.2 to 3.4 trout per trap hour. This trend of decreasing C/E with time from spring through summer is consistent with other trapping studies (Pepper 1976; Ryan 1984). Temperature readings taken during trapping activities indicated near shore surface temperatures of 8-12°C during June. Temperature readings taken in the central area of the lake revealed generally isothermal conditions that were usually about one degree less than near shore temperatures. A maximum temperature of 23°C was recorded at the near shore trap sites in mid-August.

Population estimation was undertaken by year class. Capture data and pertinent accumulations for 2+ and 3+ brook trout are presented in Tables 3 and 4 respectively. Estimates for the two year classes, plus their 95% confidence intervals, are 11380 (7249-16788) and 4278 (1905-8349) respectively. In spite of the overlap of confidence intervals, a Z-score for the two estimators (Chapman 1948) of 2.35 ($p = 0.004$) confirms the uniqueness of magnitude of the two parameters. During the sampling program, 15-4+ and 2-5+ trout were tagged. Lack of recaptures of either of these two components of the trout population prevented their estimation by conventional techniques.

Examination of trout fork lengths by trap location over the seven weeks of trapping (Table 5) revealed a significant change in mean fork length with time ($F = 4.467$, $P<0.001$) and difference between traps within each of the lake areas (i.e. intake and outlet; $F = 37.801$, $P<0.001$). There was no statistical difference between mean fork length of trout captured at opposite ends of the lake ($F = 0.058$, $P = 0.810$). Of the 28 tagged trout that were captured at locations other than their initial release sites, 19 had moved a considerable distance relative to the size of the lake. While analyses indicate an increase in mean trout size throughout the lake over the seven weeks of study, >50% of trout recaptured with tags did not grow between tagging and recovery.

During the two years of study, 102 brook trout were sacrificed from the Traverse Pond fyke net catches. These specimens were used to provide biological data to facilitate comparisons of populations between lakes.

Weight-fork length regressions established the following function:

$$\mathrm{Log}_{10}W = -1.8725 + 2.9628\ \mathrm{Log}_{10}L \quad (r = 0.98,\ Sb = 0.06,\ N = 101)$$

where

W = weight in g
L = fork length in cm

Sex specific regressions revealed homogeneity of regression coefficients between males and females (t = 0.95, P = 0.349).

Parasitism of Traverse Pond brook trout by Apophallus brevis was noted in at least 50% of the trout examined. Infestation ranged from mild, with scattered spots confined to the ventral region, to severe cases where the entire epidermal area had a 'sandpaper' texture. This parasitism had no obvious effect on trout behaviour. Both nematodes and acanthocephala were found loose in trout stomachs though the latter (spiny-headed worms) were most often attached to gut walls.

Examination of brook trout scales indicated a size at age distribution as per Table 6, from which a fork length at age key was interpolated as:

1+	8.0 - 12.99 cm
2+	13.0 - 17.99 cm
3+	18.0 - 23.99 cm
4+	24.0 - 28.99 cm
5+>	= 29.0 cm

These limits formed the base for age specific population estimates of Tables 3 and 4. Relative abundance of each length class is illustrated by length frequency histograms (Fig. 9). By applying the weight-fork length regression equation to all fork length data collected during the mark-recapture study and organizing fork lengths into age categories by the above scheme, it is possible to estimate biomass per age class. The 4+ and 5+ components of the trout population, being too small to estimate by mark-recapture techniques, were estimated by proportionate comparison as follows (the 1+ component was also estimated in this manner).

Of the sample of 1174 trout, for which weights have been calculated, age frequencies are: 1+ = 32, 2+ = 827, 3+ = 298, 4+ = 15 and 5+ = 2. By setting population estimates for the 2+ and 3+ components to the mid-point of confidence intervals (12019 and 5127), these two year classes total to 17146 representing 95.8% of the sample. Application of this percentage composition to the population results in a figure of 17898 trout (i.e. (100/95.8) x 17146) in Traverse Pond. This estimate of total population is used to derive age class magnitudes of Table 7. With these figures, trout biomass of Traverse Pond is estimated at approximately 16 kg per hectare.

Growth of Traverse Pond brook trout, calculated by observed length at age data, is represented by the linear function:

$$\text{Fork length} = 5.55 + 4.63\text{Age}$$
$$(r = 0.88,\ Sb = 0.28,\ N = 88).$$

Unidentifiable insect remains comprised most of the mass of trout stomach contents. Of those taxa that could be identified, Odonata and Diptera predominated (Table 8). Nineteen (20.7%) of the stomachs examined were empty. Amphipods were also common among trout stomach contents.

Ten minute surface plankton tows in Traverse Pond collected several species of zooplankton. Table 9 indicates species identified and their calculated abundance in the samples (Stempel pipette, 0.5% sample). Although too rare to be included in Table 9, several other species were identified. These include: *Epischura lacustris*, *Holopedium gibberum*, *Sida crystallina* and *Diaptomus spatulocrenatus*. Of particular interest is the tentative identification of *Acroperus elongatas* (Sars).

PHYSICAL PARAMETERS

After several attempts at light energy measurement in Traverse Pond, the aspired calculation of an extinction coefficient was abandoned. Most often, surface and bottom energy readings were so similar that there was more variation among successive readings at the surface (i.e. 10 cm depth) and on the bottom than there was between surface and bottom readings. Extinction coefficients ranged from 1.1 to 1.3 for Lower Micmac and 2.9-3.4 in Upper Micmac. Light energy received at the lake surface usually varied around values of 0.008 gcal/cm^2 (measured at 463 nm). Water chemistry data for all lakes is presented in Table 10.

Winter conditions on Traverse Pond saw snow cover ranging from slight to a maximum depth of 40 cm. Ice generally formed on this lake in mid-November and, by late December, had reached a thickness of 20 cm. Ice cover reached its greatest thickness in March (60-90 cm), after which it began to subside. Winter temperatures recorded were uniform throughout the water column, at 0.5°C from mid-December through early February, rising to 2.2°C by mid-February. Temperatures rose to 3°C in March and to 5°C in May. Oxygen levels remained constant at 14 ppm. By virtue of supporting periodic successful ice fishing activity (brook trout) throughout the winter months, Traverse Pond winter conditions can be deduced to be conducive to overwintering brook trout. Ice cover was observed to break up in late May.

GULL BROOK

Of 28 brook trout angled in Gull Brook in 1976, nine were 1+, eight were 2+ and 11 were 3+. Although no underyearling trout were angled, they were collected during electrofishing studies. The weight-length regression for the Gull Brook sample was:

$$\text{Log}_{10}W = -1.8581 + 2.9535\ \text{Log}_{10}L$$
$$(r = 0.99,\ Sb = 0.31,\ N = 28)$$

There was no significant difference between weight-length regressions of males and females ($t = 0.59$, $P = 0.56$).

Attempts to estimate the underyearling brook trout population in stream habitat from electrofishing data failed due to insignificant regression in the catch vs. cumulative catch model. This is attributed to the underyearling habit of hiding under rocks and therefore becoming lodged in the substrate when subjected to the electric field. Length-frequency histograms of the Gull Brook trout sample are presented in Fig. 10.

Samples of the invertebrate population of Gull Brook, collected by Surber sampler, are identified in Table 11.

LOWER MICMAC

Atlantic salmon fry stocking projects on Black Brook, below Lower Micmac Pond during 1974 and 1975, introduced approximately 357000 fry to this system. Sampling in Lower Micmac captured 65 salmon parr in 1976 and 33 in 1977. Examination of scales from 12 parr, preserved for laboratory analysis in 1976, revealed 1+ and 2+ parr. Of the 98 juvenile salmon captured in the two years of this study, all appeared to be in excellent physical condition. Due to the small size of the sample sacrificed for laboratory examination, data are too few to expand to discussions of growth of salmon parr in this lake.

Of the 12 salmon parr sacrificed, only four stomachs contained food remains. These remains were unidentifiable.

Resident brook trout in Lower Micmac were both numerous and, although highly variable, of relatively robust condition. Individual trap net catches (22-26 hour sets) ranged as high as 93 trout. C/E ranged from 0.1 to 3.6 (mean of 2.11) trout per trap net hour. As with Traverse Pond, catches were highest during the first sampling period. August sampling efforts resulted in low catches. Water temperature for Lower Micmac was virtually identical to that for Traverse Pond though near shore temperature was recorded as high as 26°C. Maximum temperature was again recorded in August.

Progression of length modes within the Lower Micmac sample (Fig. 9) suggests the presence of four age classes. The sample contained 14 underyearling trout (5.7% of sample). The largest specimen captured in Lower Micmac (31 cm) was four years old. This was the only 4+ specimen taken in the Lower Micmac sample. The empirical growth function calculated for Lower Micmac brook trout was (including this single 4+ specimen):

$$\text{Fork Length} = 3.22 + 5.68\ \text{Age}$$
$$(r = 0.94,\ S_b = 0.31,\ N = 45)$$

Exclusion of the 4+ specimen from the calculations results in the following:

$$\text{Fork Length} = 3.63 + 5.37\ \text{Age}$$
$$(r = 0.93,\ S_b = 0.32,\ N = 44)$$

Weight and fork length data for Lower Micmac trout produced the regression:

$$\mathrm{Log}_{10}W = -1.8670 + 2.9321\ \mathrm{Log}_{10}L$$
$$(r = 0.99,\ Sb = 0.075,\ N = 53)$$

Individual condition factors varied from 0.94 to 1.34.

Quantitative electrofishing was undertaken in Micmac Brook between Micmac Lake and Lower Micmac in mid-June. This resulted in estimates of 44 brook trout per 100 m^2 (95% confidence = 34 - 55). By age, estimates were: 42 - 0+; one - 1+; and one - 2+. No older trout were captured. A repeat assessment of this electrofishing station in October resulted in an estimate of 28 brook trout per 100 m^2 (27 - 41). Age distribution was: 20 - 0+ and eight - 1+. No 2+ parr were captured. During this repeat survey, adult brook trout were so numerous in the vicinity of the electrofishing station that no attempt was made at actual counts. These fish were not yet reproductively active but were approaching maturity. Subjective interpretation among three observers concluded that several hundred (greater than 400) trout were visible within a 50 m length of stream (mean width about 10 m).

UPPER MICMAC

This lake has four characteristics that make it unique with respect to other lakes of the immediate vicinity. These are:

1) A large percentage of surface area with depths greater than two meters (Fig. 6);

2) Very low rate of water mass turnover during much of the summer period when intake and outlet streams tend to dry up;

3) Heavily stained water; and,

4) A resident population of landlocked Arctic charr, _Salvelinus alpinus_.

Landlocked charr were not abundant in the Upper Micmac samples (N = 63). All but two of the specimens captured were greater than 15 cm fork length and apparently belonged to the same year class. Of six specimens preserved (15.6 - 17.0 cm fork length) all were in their fifth year (i.e. 4+). Maximum charr fork length was 20.6 cm (age 4+).

The incidence of charr in trap nets was incidental relative to that of brook trout. Whereas the greatest single catch of charr was 28, catches of greater than 100 trout were common (24 - 26 hour sets). Of six charr stomachs examined, three contained only cladocerans while the other three were empty.

Trap net catches of brook trout suggest a large population in Upper Micmac. Trout C/E data ranged from 1.5 to 14.5 (mean of 4.24) per trap net hour. Subsequent to the first sampling period, the largest C/E figure was 2.5. The fork length distribution of the sample was markedly skew (Fig. 9). Length frequency modes at 14 and 17 cm correspond with ages 2+ and 3+ respectively.

According to this distribution, 2+ trout comprised 55% of the sample while age 3+ accounted for 23%. The calculated growth function for Upper Micmac brook trout was:

$$\text{Fork Length} = 3.81 + 4.45 \text{ Age}$$
$$(r = 0.91,\ Sb = 0.27,\ N = 56)$$

Regression of weight on fork length resulted in the equation:

$$\text{Log}_{10}W = -1.8476 + 2.9329 \text{ Log}_{10}L$$
$$(r = 0.997,\ Sb = 0.04,\ N = 34).$$

There was no significant difference between males and females regarding their weight-length regression coefficients (t = 0.61, P = 0.54). Individual condition factors ranged from 1.14 to 1.44. Mean values of length, weight, and condition factor are presented in Table 12. Dipterans were the most common food organisms found in the 34 brook trout stomachs examined. Cladocerans were found among stomach contents of only three specimens but were the dominant food items taken in these three instances. One 4+ trout stomach contained two yearling trout parr.

In the absence of a mark-recapture population estimate for Upper Micmac trout, estimates of age specific biomass are based on mean observed length per age and calculated mean weight (from weight-length regression). Using these data, age specific biomass accounted for the following sample percentages: 1+ = 0.11%, 2+ = 7.71%, 3+ = 48.85% and 4+ = 43.34%.

Ten minute surface plankton tows captured considerable amounts of zooplankton. Species and relative abundance is presented in Table 13. Plankton samples also contained large numbers of colonial rotifers. Sponge spicules were also identified but were rare.

Winter conditions on Upper Micmac were similar to those for Traverse Pond. Snow cover was generally greater while maximum ice thickness was recorded in March, 1977, at 99 cm. Ice formation and break up was similar to that for Traverse Pond. Contrary to Traverse Pond, winter temperature varied with location in Upper Micmac. Temperature at 1 m was observed to range from 0.5 to 1.5°C while dissolved O_2 ranged from 13.2 to 14 ppm at 1 m and dropped to 12.2 ppm at 2 m. Once again, ice fishing activity in this lake, and the incidence of successful anglers, suggests that winter conditions are amenable to the overwintering trout population. Summer water temperature records indicated surface temperatures of 21 to 23°C and, although there was no pronounced thermal stratification, temperatures below 3 m were 0.5 to 1.0 degree cooler than surface waters. Near shore temperatures were similar to those of surface waters of the central lake area.

BROOK TROUT POPULATION COMPARISONS

Comparison of growth functions for the study lakes (Table 14) indicated that all three populations had similar growth rates. Similar comparison of weight-fork length regressions (Table 15) indicate that these functions also are similar.

DISCUSSION

PHYSICAL AND CHEMICAL CHARACTERISTICS

Water chemistry data of Table 10 suggest a general progression in potential productivity from Traverse Pond, with the lowest, to Upper Micmac with the greatest (based largely on total phosphorous and ortho phosphate) of the three study lakes. This conforms with initial speculations based on water clarity. Considering the similarity of light energy recorded at the surface and on the bottom of Traverse Pond, and the variability among values described above, we do not place any confidence in resultant extinction coefficients. Rather, we prefer to state that our subjective interpretation, that Traverse Pond waters had the greatest clarity of the three lakes studied, is warrented. With such clarity, Traverse Pond is typical of many of Newfoundland's lakes that are generally oligotrophic. In contrast, Upper Micmac seems atypical of the usual pristine provincial waters and compares (subjectively) more with chthoniooligotrophic (Hutchinson 1957) waters. Regarding Lower Micmac, specific conductance and total dissolved solids conform more with what was expected from Upper Micmac. However, water clarity for Lower Micmac, being intermediate between the other two lakes, suggests that suspended solids and/or tannins and lignins from bog outwash (McNeely et al. 1979) are in greater concentration in Upper Micmac and that light penetration would be greatly reduced through these means (James and Birge 1938). Indeed, the brown discolouration of Upper Micmac water is known to filter out blue light and would therefore greatly increase the extinction coefficient of light at 463 nm as determined in this study. Considering these factors, together with Wetzel's (1975) statement that, 'Calculations of vertical extinction coefficient are not very reliable in the first meter below the surface because of surface agitation.', we conclude that light measurement is not an alternative to the secchi disk in very shallow ponds. We have therefore applied our light data only as substantiation to subjective interpretation of water clarity.

With shoreline development indices (Welch 1948, Table 1) quantifying the irregularity of Traverse Pond shoreline relative to that for Upper Micmac, the shoreline development lake morphometry index of relative productivity (Ryder et al. 1974; Wetzel 1975) is at odds with the interpretation of chemical parameters.

Shore and littoral zone characteristics among the study lakes suggest conditions in Lower Micmac and Traverse Pond would be better suited to young salmonids since bottom slope is very gradual as opposed to Upper Micmac that, for much of its circumference, slopes more rapidly downward. With mean depths of 1 m for Traverse and Lower Micmac ponds and 2.2 for Upper Micmac, it becomes evident that the former two lakes have larger proportions of shallow, rocky, littoral habitat than Upper Micmac. In contrast, the greater maximum depth for Upper Micmac (8 m), as opposed to Traverse and Lower Micmac ponds (3.6 and 2.5 m respectively), suggests the possibility for thermal gradients and a more desirable environment for larger (older) salmonids. This is hypothesized in consideration of the inverse relation between fish size and temperature tolerance (Huntsman 1942), temperature preferenda of salmonids (Fry 1948, 1951; Ferguson 1958; McCormick et al. 1972; Cherry et al. 1975; Hokanson et al. 1977) and substrate preferences among juvenile salmon (Lagler 1956). Relative to substrate preference, we suggest that deeper lake areas, generally having muddy bottoms, are not as attractive to juvenile salmonids as are the usual rocky substrates of littoral areas most often found among insular Newfoundland lakes and ponds.

At apparent odds with these physical variables is the greater relative abundance of emergent vegetation in Upper Micmac. We suggest this biotic variable conveys a considerable advantage to lacustrine salmonids in providing habitat for larger zooplankton, thereby serving as a valuable food reservoir for juvenile salmonids. Considering Allen's (1940) statement that young salmon begin active feeding at temperatures above 7°C, the growing season in these ponds extends from early June until late September, thus providing approximately 4 mo/yr in which to expect significant salmon growth.

LAKE AND STREAM ZOOPLANKTON

Examination of Tables 9 and 13 reveals a greater abundance of zooplankton in Upper Micmac than in Traverse Pond. This is possibly in response to higher nutrient levels in Upper Micmac water (total phosphorous and ortho phosphate, Table 10) but is likely mediated by water entrapment in Upper Micmac. With an estimated turnover rate of only a few times per year, most nutrients entering the lake are retained long enough to be incorporated into the biological community. Although selective absorption of blue light by brown water is likely the greatest single contributor to increased extinction coefficients, the great masses of zooplankton observed in Upper Micmac likely also contributed to decreased light penetration in this lake. Visibility while snorkle diving in this lake was greatly obstructed by the masses of swimming zooplankton. Although peripheral to development of this discussion, we note the identification of Acroperus elongatas (Sars) from among Traverse Pond zooplankton samples. Our only other reference to this species is Daggett and Davis (1975) who found this species in 6% of their samples. Perhaps of greater significance to the present study is the absence of cyclopoids from Traverse Pond zooplankton samples. Thus, not only are zooplankters less abundant in Traverse Pond than in Upper Micmac, the species community is also less diverse.

Stomach contents of brook trout from Traverse Pond suggested a preference for aquatic insects (Table 8) and amphipods. By virtue of the presence of both gastropods and ephemeropterans among stomach contents, brook trout appear to be following an opportunistic feeding behaviour. A similar appraisal is commonly found in brook trout literature (Frost 1940; Wiseman 1969; McFadden 1961; Momot 1965; Flick 1977). However, the large, virtually unused copepod population of both study lakes tempts speculation of a low level of intraspecific competition within the respective lakes. We suspect that the copepod food resource would be utilized by underyearling brook trout (White 1930; Ricker 1930; White 1967; Wurtsbaugh et al. 1975), if this age class were abundant in the study lakes but that the energy content of individual copepods is insufficient to offset the energy cost of the feeding act among larger trout (Kerr 1971). We hypothesize that under-yearlings are not common in the lacustrine environment due to a strong territorial behaviour among salmonid fry that greatly limits their movements (Bjornn and Mallet 1964; Gibson 1973, 1981; Edmundson et al. 1968) and the fact that brook trout normally spawn in rivers

(Greeley 1932; Vladykov 1942; Needham 1960) rather than in lakes. Johnson (1958) suggests that the distribution of young sockeye is more a reflection of adult spawner distribution than it is a preference on the part of fry.

The same general diet preference for aquatic insects prevailed in Upper Micmac, in spite of extremely abundant zooplankton populations. Identification of juvenile brook trout remains among the stomach contents of a single 4+ brook trout is significant in that it is the only documented incident of brook trout cannibalism in our field records. This isolated case may be a result of confinement within the trap net. We did not observe cannibalism in any of our other extensive trapping activities.

BROOK TROUT POPULATIONS

Length-frequency distributions for the three study lakes provide a comparison of brook trout population structure among ponds (Fig. 9). From these histograms, age modes can be seen for underyearling, 1+, 2+, and 3+ trout. Relative frequencies illustrate the magnitude of each age group in the lakes but also indicate either the inadequacy of the sampling gear for underyearlings or their absence from lake habitat. Length frequency histograms for Gull Brook (sampled by angling and electrofishing) could be interpreted either way (Fig. 10).

While the majority of the population sampled from Upper Micmac and Traverse Pond was composed of 2+ and 3+ individuals, Lower Micmac had its strongest representation within the 1+ mode. Since the same sampling gear was used in all sites, the adequacy of the gear for yearling trout is confirmed, lending support to the argument for minimal yearling populations in Traverse Pond and Upper Micmac Pond. With pronounced 2+ and 3+ trout populations and low incidence of yearling trout in Traverse Pond, speculation is that Gull Brook serves as the nursery area for the Traverse Pond trout population. This is corroborated by Alexander and Merrill (1976) and Flick (1977) and supported further by our observations of trout spawning activities in Gull Brook. However, it seems unlikely that the substantial post yearling trout abundance observed in Upper Micmac could be supported by either intake or outlet stream habitat due to its limited extent and intermittant stream flow. It is also interesting to note that 5+ individuals were found only in Traverse Pond. Though 4+ individuals were found in all three lakes, their presence was rare in Lower Micmac. We suspect these observations are partly related to the proximity to other lakes within the system. Where Traverse Pond is the largest and deepest body of standing water within several km of stream habitat, both Upper and Lower Micmac Ponds are close to Micmac Lake (Fig. 4) that, with greater maximum depths, may serve as a reservoir for older trout. It is also possible that, since cannibalism is rare among brook trout (Harkness and Ricker 1929; Ricker 1930; Frost 1940; Scott and Crossman 1964) and there are no other forage species available for larger trout that often exhibit a piscivorous habit (Clemens 1928; White 1942; Wiseman 1969), 4+ and 5+ trout emigrate down stream to Indian Pond where smelt (*Osmarus mordax*), stickleback (*Gasterosteus aculeatus*) and juvenile Atlantic salmon are abundant. This is consistent with the concept that the size attained by brook trout is positively correlated with the size of the water body in which it lives (Ricker 1932).

Regardless of origins of resident populations, it is evident that the 2+ and 3+ trout population components exert most of the feeding pressure on food resources of Upper Micmac and Traverse Pond while Lower Micmac has the potential for greater competition within the yearling class.

POPULATION ESTIMATES

Throughout this discussion it is important to recognize that we are evaluating relative standing stocks and not production (see discussion of production, standing crop and turnover by Petrusewicz and Macfadyen 1970). While standing stock is considered to be a poor index of productivity (Macfadyen 1964; Odum 1971; Petrides and Swank 1966), several authors have discussed carrying capacity based on standing crop biomass values (Petrides 1956; Dasmann 1962; Dasmann and Mossman 1962; Bourlière 1963; Talbot and Talbot 1963). In our present studies with trout, potential yield, in terms of the number of salmon smolt that could be produced each year from fry stocking, is the parameter we desire to estimate. However, it has been aptly stated (Donald 1961), '...the relative yield of genotypes without competition is no criterion of their capacity to yield...'. Hence, our appraisals of the potential of study sites for juvenile salmon production, developed on the basis of brook trout standing stock, represent only a rough approximation that will have to be be refined through stocking experiments.

Actual mark-recapture estimation of trout population magnitude was limited to Traverse Pond. Populations of Upper and Lower Micmac have been approximated by linear interpolation. Johnson (1958) suggests that estimates of population based on C/E are sound. This is substantiated by Ryan (1984). Based on average catch per unit of trapping effort for each lake (trout captured per trap net hour for Traverse Pond = 1.79; Upper Micmac = 4.24 and Lower Micmac = 2.11) it appears that Traverse Pond may have the lowest brook trout population of the three study ponds. It is questionable whether these mark recapture estimates were biased by adverse effects of marking on the smaller brook trout. By virtue of the fact that the average fork length of the recapture sample was not significantly different from the initial capture sample, and by similar variances between the two groups, it is unlikely that the smaller marked trout suffered higher mortality. Therefore, C/E should not have been depressed in Traverse Pond due to marking. However, since it is possible that C/E in Upper and Lower Micmac was biased by the smaller area of these ponds relative to Traverse Pond, thereby resulting in a greater catchability factor, we do not advocate population magnitude proportionate to C/E data. However, we suggest that brook trout population density in Upper and Lower Micmac was at least as high as in Traverse Pond and therefore speculate that the Traverse Pond trout biomass figure of 16 kg/ha is representative of all three of our study lakes. We suspect this figure is conservative since evidence has been presented (Havey et al. 1981) that multiple-census methods (i.e. Schnabel, Schumacher) result in lower estimates than the single-census Petersen method.

It is possible to deduce the relative feeding pressures exerted by the respective age classes due to the similarity of growth rates and weight-length relations, and the speculation of similar trout biomass for each of the study lakes. Age specific biomass calculations for Traverse Pond (Table 7) indicate that, although the 2+ component of the trout population has the greatest abundance, its biomass is less than that of the 3+ component. Hence, the 3+

component of the Traverse Pond trout population is likely to exert the greatest energy drain on Traverse Pond food resources. Without age specific population estimates for Upper and Lower Micmac, we cannot be certain about age class feeding pressure in these lakes. However, just as for Traverse Pond, where the 3+ age class is numerically only 36% of the 2+ component (i.e. 25%/70%) and yet accounts for 50% of trout biomass due to a more than 2X increase in mean individual weight (i.e. 88 g/39 g) we suggest the Upper Micmac 4+ trout population component places a drain on pond food resources at least equivalent to that for the 2+ and 3+ components. This suggestion is consistent with the observation of cannibalism in this lake. In the literature, cannibalism has been suggested to occur when other suitable food is scarce (Harkness and Ricker 1929; Ricker 1930; Frost 1940; Scott and Crossman 1964). With 41% of the trout sample from Lower Micmac belonging to the 3+ age group (highest of the three study lakes), it is safe to conclude that this group exerts the greatest pressure on food resources in Lower Micmac.

GROWTH

While the linear growth models presented in this report may oversimplify length at age relations within the respective study sites, it is informative in comparing habitat characteristics. Since average length at age has been shown above to be similar among study lakes, we conclude that trout populations have approximately equal growth opportunities among study sites irrespective of other physical and biological differences among these environments. Comparison of mean length at age data, for brook trout of the present study, with data of Wiseman's (1969) extensive study of brook trout from several insular Newfoundland watersheds, and with data from Whelan and Wiseman (1977), indicates that growth rates calculated in the present study are average for this area although they are certainly low relative to some of Wiseman's observations (i.e. Terra Nova River, Indian Bay Big Pond). Comparison with other literature again suggests that trout populations of the present study had growth rates that were average for the species (Table 16). Together with consideration of standing crop estimates of 14.7 - 17.9 lb per acre (16.6 - 20.1 kg/ha) recorded by Cooper et al. (1962) in Pennsylvania and 6 - 12 lb per acre (6.7 - 13.5 kg/ha) recorded by Hatch and Webster (1961) in New York, we conclude that the lakes studied in this report represent average lacustrine habitat conditions.

SIGNIFICANCE OF RESULTS

Having examined some of the specific characteristics of the Indian Brook study area, it is now necessary to regain perspective on the long-term objective of this research, namely evaluation of lacustrine stocking potential for juvenile Atlantic salmon. This requires consideration of characteristics of the Indian Brook salmon population (as a source of brood), the population's distribution within the system, the production potential of the system, stock reproductive potential, and the expected role of a renewed salmon enhancement initiative in this watershed. Such considerations are essential to decisions as to whether the river system should be regarded as a salmon management responsibility (wherein harvest allocations and spawning escapements are controlled to permit optimum natural utilization of river habitat) or a viable enhancement opportunity (wherein artificial salmon propagation is the desirable means to secure salmon production potential). These decisions are based on the economics of project operation (Anderson 1977) that in turn are defined by the salmon production potential of the water system in question and by logistic costs involved in securing this production potential by artificial means. In this respect we assume there is considerable variability in salmonid production potential among the three ponds of our study and that this range in potential may well span an economic analysis gamut from desirable to undesirable. In other words, not all lacustrine habitats will meet production requirements for positive economic benefits. From our studies of the three ponds surveyed, we conclude that Upper Micmac represents the most productive of the three ponds for Atlantic salmon. However, outlet characteristics, being not always conducive to smolt migrations, may well negate the growth advantage of presmoltification stages through increased smolt mortality. On the other hand, Traverse Pond, with its extremely clear water, lower zooplankton diversity and abundance, and a greater incidence of 4+ trout, may not support high enough fry to smolt survival to recover fry stocking costs (in terms of adults returning to the project). In the event that both of these concerns are justified, stream remedial activities might be considered for Upper Micmac and water fertilization could be applied to Traverse Pond. Such considerations must await the results of experimental fry stocking.

With conditions apparently well suited to experimental evaluation of fry stocking, and the absence of agriculture and industrial activity (competitive water users) in the area, we now concentrate on development of a stocking strategy, the results of which are intended to provide empirical evidence of the development potential for lacustrine rearing of Atlantic salmon fry.

ENHANCEMENT CONSIDERATIONS

The main stem of Indian Brook is generally deficient in rearing habitat (Sturge 1968), being composed mainly of gravel and small rubble material. With several of the tributaries of Indian Brook being virtually all rearing habitat, with little suitable spawning area, Indian Brook is an ideal salmon enhancement opportunity due to the inappropriate distribution of habitat types necessary to support juvenile stages of Atlantic salmon. Growth rates of juvenile salmon from the main stem of Indian Brook are well within the range of those documented for insular Newfoundland (Table 17).

As a result of initial enhancement efforts on the main stem of Indian Brook, from 1962 to 1975, salmon escapement to the river is now in excess of 3000 grilse. This is adequate to support main stem spawning requirements and provide surplus brood stock for tributary enhancement. Recognizing that this escapement is approximately 15 - 20% of the annual salmon production of Indian Brook (65% commercial fishery harvest and 15 - 20% recreational harvest), annual present production in the river is close to its estimated stream habitat production potential of 15000 adults. Thus, salmon enhancement of accessible stream habitat is not justifiable for Indian Brook and salmon populations would therefore normally be considered as a resource management responsibility. However, with considerable stream habitat currently inaccessible to adult salmon due to natural obstructions on tributaries, and large areas of standing waters within these tributaries that conform with Pepper's (1976) criteria for lacustrine nursery areas for Atlantic salmon, additional enhancement potential may yet exist for the Indian Brook watershed.

With a heavy dependency on the fishing industry as one of the major employers in the Halls Bay area and the presence of a modern fish plant, located within 80 km by paved highway from the mouth of Indian Brook, there is considerable justification for assessment of the potential viability of further enhancement activities. As a first step in assessing the potential merits of further investment in Indian Brook salmon enhancement, additional production benefits, together with the costs necessary to support enhancement activities, must be identified. This requires consideration of the amount of salmon habitat available and the production that can be expected per unit of this habitat area. Although stream habitat in Newfoundland has been estimated to produce two smolt per 100 square meters (Riche 1972), potential production capacity of standing waters (i.e. lakes, ponds and steadies) has not yet been identified. Therein lies the challenge of interpretation of the present study results.

JUVENILE SALMON PRODUCTION POTENTIAL

During the last two years of operation of the Indian Brook spawning channel, salmon fry were distributed to stream habitat of Black Brook, upstream of the impassable obstruction. During these two years, approximately 357000 fry were distributed. Though the present study was implemented too late to document fully the fate of these fry, the few parr sampled from these plantings suggest this tributary represents prime rearing habitat. Of interest is the fact that, though no fry were distributed to Gull Brook, eight salmon parr were captured in Traverse Pond. This indicates that these juvenile salmon had strayed at least 12 km from their release sites on Black Brook. Their apparent robust condition suggests that Traverse Pond represented an acceptable rearing habitat though, without a clear indication of rearing history, it is possible that these juvenile salmon were only transient visitors to the pond or that they were in the process of smoltification and were just passing through the pond on their way downstream. By virtue of having to originate from either the 1974 or 1975 fry stocking in Black Brook (since Black Brook is inaccessible to migrating adult salmon), it is unlikely that the specimens captured could have been residual smolt reverting to a resident population component. The absence of salmon parr from trap net samples taken subsequent to 1977 suggests residualism (or landlocking) due to lake residence was not a significant negative factor in smolt production from the 1974 and 1975 year classes. Clearly, the well established brook trout population of Traverse Pond did not preclude these salmon parr from utilizing lacustrine space though the extent of this utilization remains unknown.

Although it appears that the lake environment was able to support the few juvenile salmon that were introduced into the system, the consequences of intensive experimental stocking with salmon fry, in the presence of a well established trout population, have yet to be addressed. There exists considerable literature to indicate that cohabitation of Atlantic salmon and brook trout is a common occurrence in many rivers of North America, and that behavioural mechanisms between the two species determine the dynamics of their distribution and abundance among habitat types under varying environmental conditions.

Due largely to stream spawning of both Atlantic salmon and brook trout, fry of both species either coexist or segregate in stream habitat, depending on stream characteristics of substrate type, cover, current, temperature, and food availability (Gibson 1966, 1973, 1978; Peterson et al. 1977; Dickson 1980). Gibson (1973, 1981) indicates that brook trout are more tolerant of the presence of other species than are Atlantic salmon. He found that, while larger brook trout were dominant over smaller salmon parr, juvenile salmon were generally more aggressive and dominated behavioural interactions between individuals of similar size. In this respect, an established brook trout population may have an advantage over salmon fry in natural stream conditions. White (1940) indicated that brook trout fry emerge a month earlier than Atlantic salmon and that this gives them a size advantage. This has also been suggested to provide a competitive advantage for brown trout in interactions with Atlantic salmon fry (Egglishaw and Shackley 1980). From our own experience in artificial incubation of Atlantic salmon and brook trout eggs, such a head start for brook trout, being approximately half the size of Atlantic salmon fry on emergence from the incubation medium, may convey little more than a chance for survival of the brook trout population by allowing the smaller brook trout fry to establish their feeding behaviour before having to face competition from salmon fry. The report of brook trout alevins ingesting food while still retaining their yolk sacs (Bridges 1958) may indicate a further adaptation to competition with young of other species. Clearly, the sizes of fry of both species usually encountered under natural growth conditions (trout larger than salmon by mid to late summer), indicate that brook trout have a greater growth rate. We suspect however, that this size advantage is a more complicated function of genetics rather than a simple extension of the growing period by earlier emergence of brook trout fry.

While aggressiveness has been shown to be generally greater for Atlantic salmon than for brook trout, it has also been documented (Elson 1959; Keenleyside 1962; Gibson 1978) that these two species demonstrate reduced aggressiveness when found in still water. Since salmon parr have been shown to be highly mobile in some lakes (Pepper 1976), we suspect aggressive interactions between juvenile salmon and trout may be of less significance in lentic environments. Taken together with low incidence of underyearling trout in lakes of the present study, and the absence of underyearling salmon in lacustrine environments (Pepper 1976; deGraaf 1981) the question of how to best utilize lake habitat for Atlantic salmon must address the question of where fry should be stocked or if stocking with a fall fingerling (i.e. 90 day fed parr) would be more effective than fry stocking. By virtue of Atlantic salmon fry not commonly utilizing lacustrine habitat, the obvious question of potential negative influences of lacustrine conditions on fry growth and survival requires consideration.

Experiments with salmon fry in still water (White 1930) indicated that, once fry had time to regulate their swim bladders (one to three days) they were more amenable to lentic conditions but that initial planting was accompanied by frantic upward swimming movements. This is among the possibilities suggested to account for the poor results of a lake stocking experiment in New Brunswick (Matthews et al. 1974; Rimmer 1975) where the fry recipient waters were deep. Rimmer and Power (1978) found that salmon fry in still water were successful in their feeding activities and readily consumed lake zooplankton. They found that prey movement was important in initiating a feeding response and that, under lacustrine conditions, fry consumed greater total amounts of food material than fry in the stream environment. Although Nilsson and Pejler (1973) indicate that zooplankton are not eaten by members of the genus Salmo unless the zooplankters are very abundant, Lillehammer (1973) records amphipods (that are mainly littoral) as being commonly ingested by 1- to 4-month-old salmon fry in West Norway. deGraaf (1981) found that cladocerans were consumed by juvenile anadromous Atlantic salmon in his lacustrine study area. Taken together with considerable literature on landlocked salmon, and their feeding habits in still water (Havey and Warner 1970), there is little reason to suspect obstruction of feeding behaviour among juvenile anadromous Atlantic salmon in lake environments.

The question remains as to why underyearling Atlantic salmon are not normally found in lakes. Juvenile salmon apparently are not deterred from the lake environment by any behavioural trait relative to their own feeding requirements. Salmon fry may in fact be entering lakes naturally, only to be eliminated through predation. Mills (1964) indicates that fry migrate downstream under conditions of extreme crowding. Downstream displacement of salmon at times of flooding has also been documented (Mills 1964; Bulleid 1972; Egglishaw and Shackley 1980). With heavy predation on salmon fry by brook trout described by Sturge (1968) and Symons (1974), and documented cannibalism by older salmon parr (Mills 1964; Symons and Heland 1978), fry may not be able to withstand predator pressure within lentic habitats. Such mortality may limit the effectiveness of standing water habitats in contributing to salmon production in lakes with resident salmonid populations. However, we suspect that fry distribution and abundance in stream habitat is more a result of adult spawning distribution than of habitat preference among fry (Johnson 1958) or of predation restricting fry distribution and that it is limited fry movement (Sosiak 1978; Egglishaw and Shackley 1980) that serves to confine fry to stream habitat close to where parents have spawned. In this context, territoriality (or perhaps more generally, a high substrate affinity) is more likely responsible for correlations between habitat type and fry abundance. We base these hypotheses on the work of Kalleberg (1958), Keenleyside (1962), and Keenleyside and Yamamoto (1962) and the fact that underyearling brook trout are not commonly found in lakes and yet have been recorded in lacustrine habitat in situations where lake spawning of adult trout occurs (Wurtsbaugh et al. 1975). Present literature does not provide any further insight into potential predatory extinction of lacustrine salmon populations. This leaves evaluation of predation pressure on fry in lake habitat for experimental evaluation. This question is important to Newfoundland enhancement activities where lacustrine habitats are extensive and, if proven to be productive for juvenile salmon, could greatly increase appraisals of watershed production potential for this species.

LACUSTRINE STOCKING

To derive an experimental design for fry stocking in the study lakes, we use the resident brook trout population of Traverse Pond as representative of a general base case and apply a trial and error approach to evaluations of juvenile salmon biomass that might be supported in this pond. Although annual survival rates through the freshwater residence period are important to development of a fry stocking plan for standing waters of Newfoundland, current literature does not provide these parameters as annual values for 3+ smolt of Newfoundland. Knowing that fry-to-smolt survival under natural conditions has been documented (Elson 1962) as ranging from 2.1 to 12.9%, and that Symons (1979) calculated annual survival ranging from a low of 28% for underyearlings, to a high of 65% annual survival for 2+ and older juveniles, we arbitrarily partition anticipated mortality as: 0+ - 1+ = 75%, 1+ - 2+ = 40% and 2+ - 3+ = 20% in general conformance with a type C survivorship curve (Odum 1971). Additional support for this type of mortality distribution is found in Ricker (1941), Latta (1969) and Slaney et al. (1980). These proposed mortality rates correspond to survivals of 25, 60 and 80% respectively and give an overall fry to smolt survival of 12%. To gain perspective on how successive fry stockings would assault lake carrying capacity, a hypothetical three year stocking program of 100000 fry per year is presented in Table 18. From this exercise it is evident that juvenile salmon population within the lake would be at its greatest abundance during the final year of a three year stocking program. Using a survival regime as presented above, the lake population, on completion of the third year of fry stocking, would be composed of approximately 71% underyearlings, 18% yearlings and 11% 2+ parr (Table 18).

Although our experience with respect to cohabiting populations of juvenile Atlantic salmon and brook trout indicates that relative abundance of salmon tends to greatly outpace that of trout (by factors of as much as 8:1, Pepper, unpublished data) we prefer to take a more conservative approach in anticipating the dynamics of salmon:trout population equilibria. Mills (1964) found that sympatric populations of Atlantic salmon and brown trout occurred at a frequency of 3:1 in stream habitat. A similar situation (2.5:1) was found for ouananiche (landlock salmon) and brook trout in Newfoundland (Beak Consultants 1980). With an estimated brook trout biomass of 16.55 kg/ha for Traverse Pond (271 trout), and a 3:1 salmon to trout ratio (based on numbers rather than biomass) Traverse Pond should support a salmon population of about 800 salmon parr per ha. Using the partitioning defined for the above hypothetical fry stocking example, Traverse Pond, during the third year of fry stocking, would have a juvenile salmon population composed of 577 underyearlings, 146 yearlings and 90 2+ parr/ha. Equating this standing stock to biomass requires an appraisal of potential growth rates.

Literature on freshwater growth of juvenile salmon in insular Newfoundland indicates considerable variability among studies (Table 17). For the present exercise we propose a median growth rate as described by Beak Consultants (1980). By applying these weight at age data to the standing stock calculations presented above, a Traverse Pond salmon population, if present at a ratio of three salmon for each trout, would have a biomass of 1.7 kg/ha. If the presence of salmon had no negative effect on the resident trout population, Traverse Pond would then support a salmonid biomass slightly in excess of 18 kg/ha. By virtue of the fact that the present estimators for the 2+ and 3+ components of the brook trout population have upper limits of 16788 and 8349 respectively, equating to 23.4 kg/ha (i.e. 16788 x 39.13 + 8349 x 106.46 ÷ 66 ha), we expect that a potential combined salmonid biomass of 18 kg/ha is conservative, and suggest that a fry stocking rate of 1000 per ha is justified. Relative to other studies of fry stocking densities, 1000 fry/ha (0.1 fry/m^2) is a very conservative figure. Sinha and Evans (1969) state that 7000 unfed fry was an optimal stocking density for their 0.4 ha pond (17500/ha or 1.75 m^2). Pedley and Jones (1978) summarized studies using 0.06 - 1.5 fry/m^2 (600 - 15000/ha) and Egglishaw and Shackley (1980) stocked fry at 3.6 - 29.3/m^2 (36000 - 293000/ha). Though the latter study documented increased mortality at stocking densities greater than 11/m^2 (110000/ha) they record survival rates to the end of the first growing season of 9.4 - 31%. Recognizing that Egglishaw and Shackley (1980) conducted their experiments in apparently productive stream habitat (conductivity of 150 μmhos/cm), we suspect that their stocking densities would be excessive for the Indian Brook study area. What is most interesting about fry stocking densities from the literature is the wide range of values (600 to 293000 fry/ha). This range of stocking density, representing approximately 2.7 orders of magnitude from lowest to highest, indicates that causative agents in juvenile salmon mortality are not well understood. In view of the work of Dumas (1980), wherein drainable ponds in Sweden produced 2900 - 8300 yearlings/ha, we feel justified in stating that our proposed stocking density of 1000 unfed fry/ha is conservative and that stocking of up to 10000 fry/ha could be supported by the lake habitats of the present study area. Even considering the conclusion of Egglishaw and Shackley (1980) that densities in excess of 110000 fry/ha were detrimental to survival, we still have two orders of magnitude from our proposed starting density to the 110000 limit. While advocating a conservative approach to experimental stocking of lakes with swim-up fry (necessitated by limited artificial incubation capacity of the Indian Brook spawning channel), we recognize that the potential exists for excessive depensatory mortality from the established brook trout population and from larger salmon parr in the second and third years of fry stocking. Should this prove to be the case, alternatives to the present proposed fry stocking include increasing fry stocking density (after building an incubation facility with greater capacity) or distribution of fall fingerlings. By virtue of a larger size, and release at a time of year when salmonid predator feeding is not so intense (Allen 1940), it is likely that fall fingerlings will have a greater chance of survival. We expect to evaluate these possibilities over the next several years.

Remaining conservative until such time as experiments provide further evidence of the viability of this approach in Newfoundland, lake stocking experiments will be designed to accommodate 1000 fry/ha. Such a stocking program for Traverse Pond would result in annual distribution of 66000 fry to Traverse Pond. Under the survival regime proposed above, this would result in a juvenile salmon population as presented in Table 19. Annual smolt production would amount to roughly 8000 specimens.

Having provided a numerical rationale for the contention that Traverse Pond should accommodate a combined salmonid biomass of at least 18 kg/ha, the question remains as to whether this contention is compatible with biological theory. Central to development of biological substantiation for introduction of salmon into the present watersheds are the concepts of ecological niche and of interspecific competition (see discussion by Weatherley 1963 and Odum 1971). It is well known in plant ecology that polycultures are more stable and generally have greater standing stocks of organic mass than do monocultures

(Macfadyen 1964; MacArthur and Connell 1967; Wagner 1969). While monocultures require regular inputs of exogenous energy (Odum's (1971) energy subsidies), to maintain their productivity, polycultures tend to be self sustaining by efficient partitioning of community energy budgets through niche diversification. A similar phenomenon has been documented in fish literature by Carlander (1955), Nilsson (1956), Yashouv (1963), Hartman (1965), Fraser (1969) and Bjornn (1978). Carlander (1955) and Bjornn (1978) found that standing stock increased as the number of species increased but the average standing crop of selected species was lower in the presence of other species.

The introduction of salmon fry into the brook trout dominated community of the study area cannot be thought of as contributing to community stability in the sense of Swingle (1950), since juvenile Atlantic salmon and brook trout occupy the same trophic level. Rather, the resulting competitive regime established by such an introduction is likely to make more effective use of food resources available to the resident brook trout population by niche restriction in sympatry. This is supported by Kennedy and Strange (1980) who found that the total biomass of salmon and trout together was 45% greater than that for trout alone.

In proposing more efficient utilization of food resources, through interspecific competition, and considering potentially increased overall salmonid biomass proportionate to that found by Kennedy and Strange (1980), it may be possible that Traverse Pond could support in excess of 24 kg/ha. Assuming that the standing stock of trout observed in the present study (16.55 kg/ha) will drop in the face of competition with juvenile salmon (Carlander 1955), salmon biomass could exceed 7.5 kg/ha. Such a standing stock is approximately 4.5 times that likely to develop from stocking with the proposed 1000 fry/ha. Concurrent with this reasoning, a deeper concern becomes evident; namely the potential outcomes of competition (Elton 1958). In the present situation, this concern may be viewed as three possible alternatives:

1. coexistence with brook trout predominating;
2. coexistence with salmon predominating; and,
3. competitive exclusion.

Considering literature presented above, coexistence of the two species is common throughout North America. Also, the success of introductions of salmon into areas of previous brook trout dominance (Farwell and Porter 1979) indicates that juvenile salmon are successful in establishing themselves in the presence of resident salmonid communities. What has not been documented is the long term dynamics of such Atlantic salmon colonization projects. Thus, it is important to weigh the inference of the various circumstantial evidence with respect to management connotations. Through the process of substantial energy subsidies, brought about through continued artificial stocking of salmon fry, and the energy advantage conveyed to anadromous salmonids in the marine environment, salmonid community equilibrium may be displaced in favour of salmon and unless carefully balanced by energy subsidy restrictions, may result in eventual exclusion of brook trout populations. In the context of salmon enhancement technical selection criteria (specifically technical desirability), energy subsidy restrictions may be imposed by economics. Successive stockings of salmon fry in lotic habitat, dominated by brook trout, have resulted in establishment of salmon populations, thereby demonstrating the salmon's advantage in this habitat. However, if the enhancement effort required to achieve the same goal in lentic habitat is significantly greater, the economics of lacustrine fry stocking may be prohibitive, thereby leaving ponds as a refugium for brook trout in watersheds subjected to intensive salmon enhancement.

To those charged with responsibility for management of salmonid resources, it is most desirable to aim for coexistence of salmon and trout populations. Competitive exclusion of trout is undesirable both ecologically and to local anglers. However, salmon have a greater economic value. The manager of salmonid resources must be alert for signs of shifts in equilibria between populations and be able to predict the biological and economic consequences of these shifts. Provision of such resource management tools, together with cost effective mechanisms to maintain and increase salmon production, should be the object of initial experimental fry stocking in lakes of Newfoundland.

To return to the present study, perhaps of greater significance than the juvenile salmon production capacity of Traverse Pond, is consideration of standing water production potential for the general study area. Summation of individual lake areas results in a figure of approximately 2000 hectares of lake habitat that appears to have characteristics conducive to production of salmon smolt. Assuming annual fry stocking density of 1000 fry per hectare, lacustrine rearing of juvenile salmon could accommodate an annual production of two million fry. Adding to this amount another 0.5 million fry for stocking river habitat of other Indian Brook tributaries, sufficient brood stock would have to be made available to produce approximately 2.5 million fry for full realization of potential production benefits of the area defined in Fig. 4. Under a juvenile mortality schedule as hypothesized in this report, 2.5 million fry would require an adult brood of 1789 (i.e. 1342 females) and could result in the production figures of Table 20. Since the fry stocking rate proposed here is the lower limit of a range of stocking densities, and the desired density might in fact be several times the proposed value, a production facility, built to accommodate stocking experiments for the present study area, should have considerable expansion potential.

It is through such considerations that salmon resource managers design enhancement strategies that are compatible with economic criteria and with watershed production potential. In the case of the Indian Brook study site, potential production from lake areas is attractive if it can be achieved with financial investments that do not outpace production benefits. Further appraisal of such considerations will be pursued in a separate publication dealing with the results of standing water fry stocking experiments that are designed according to criteria defined in this report.

SUMMARY

Biobaseline surveys were conducted in three small Newfoundland ponds over a two year period. The largest of the three ponds (66 ha) had water chemistry characteristic of oligotrophic waters and was considered to be the least productive of the three study sites. Species diversity in all ponds was low, with brook trout predominating. The study areas, being located upstream of a river obstruction that did not permit access to upstream areas by migrating salmon, did not support anadromous salmon.

Growth and standing stock estimates for resident brook trout, when compared with literature values, indicated that the least productive of the three study ponds had a trout population that was average for Newfoundland (standing stock of 16 kg/ha; weight length regression - $\log_{10} W = -1.8725 + 2.9628 \log_{10} FL$; growth - Fork length = 5.55 + 4.63 Age; oldest fish caught = 5 yr).

Based on the ecological concepts of niche and interspecific competition and on the principles of production in monocultures and in polycultures, observed brook trout standing stock and growth characteristics were used to develop a rationale in support of an Atlantic salmon fry stocking project. An Atlantic salmon fry stocking density of 1000 ha^{-1} is advocated and is shown to be conservative relative to the range of salmon stocking densities used in other parts of the world.

The responsibility of the biologist, in assuring salmonid community stability rather than simply maximizing returns on economically desirable species, is highlighted.

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APPENDIX 1: MOUNTING MEDIUM FOR PARR, SMOLT, AND BROOK TROUT SCALES

Preparation of medium

1. Dissolve 200 g gum arabic in 340 cc distilled water.
2. Let stand until gum arabic is in suspension (about 2 hours).
3. Centrifuge. DFO uses 40 ml centrifuge tubes, at 3,000 rpm for 15 min.
4. Add 80 cc glycerol and 40 cc 40% formalin.

Method of mounting scales

1. Select scales to be mounted.
2. Dip them one at a time in a wetting agent solution (i.e. alcohol).
3. Set them momentarily on blotting paper to absorb excess moisture.
4. Place scales on a glass microscope slide.
5. Place one drop of gum arabic medium on the slide so as to cover the scales.
6. Apply cover slip. Do not place the edge of the cover slip in the medium before dropping because this causes the scales to run out under the edge of the slip.
7. Gently tap the cover slip into position and to remove any large air bubbles trapped.
8. Label.
9. Leave scales flat for 24 hr. They are then dry enough to be stored.
10. Cover slips can be removed at any time by soaking slides in warm water.
11. Slides can be kept several years in perfect condition.
12. With practice, 80-100 samples may be mounted per day.

Table 1. Physical characteristics of study ponds

	Traverse Pond	Upper Micmac	Lower Micmac
Area (ha)	66	32	27
Maximum Depth (m)	3.6	7.5	2
Mean Depth (m)	1.0	2.2	<1
Shoreline Index	2.56	1.52	2.24

Table 2. Traverse Pond brook trout recapture data, 1977.

Tag Number	Mark Station	Mark Date	Recapture Station	Recapture Date	Days at Large
1364	3	14 07	1	25 07	11
1386	3	14 07	4	25 07	11
1586	2	15 07	1	25 07	8
1370	3	14 07	3	26 07	12
1718	1	25 07	3	26 07	1*
1775	4	26 07	3	10 08	15
1495	1	15 07	4	26 07	11
1711	1	25 07	4	02 08	8
1941	4	02 08	1	03 08	1*
1819	4	26 07	3	03 08	8
1892	3	02 08	1	03 08	1*
1584	2	15 07	2	03 08	19
1738	2	25 07	2	03 08	9
1915	3	02 08	2	03 08	1*
1891	3	02 08	2	03 08	1*
1907	3	02 08	4	11 08	9
1917	3	02 08	2	03 08	1*
1592	2	15 07	2	10 08	26
1691	1	25 07	3	11 08	17
337	2	10 08	4	11 08	1*
316	2	10 08	1	19 08	9
1679	1	25 07	1	19 08	35
1358	3	14 07	1	19 08	36
1827	4	26 07	4	11 08	16
289	2	10 08	4	11 08	1*
1963	4	02 08	3	18 08	16
1983	4	02 08	4	11 08	9
			4	18 08	16
386	4	11 08	4	18 08	7
1936	4	02 08	4	18 08	16
444	4	02 08	1	24 08	6
			3	25 08	7
1693	1	25 07	1	24 08	31
273	1	10 08	1	24 08	14
214	1	03 08	1	24 08	21
1555	2	15 07	2	19 08	35
1853	3	26 07	2	19 08	24
1623	2	15 07	2	19 08	35
597	3	25 08	1	31 08	6
513	2	19 08	3	30 08	11
380	4	11 08	3	30 08	19
551	1	24 08	4	25 08	1*

* Only those specimens recaptured after greater than 5 days at large are included in population estimation calculations. Specimens with less than 5 days at large are included in this table to illustrate movement among capture stations.

Table 3. Mark-recapture data for Traverse Pond 2+ brook trout sampled during 1977.

Sample	Fish Caught	Newly Marked Fish Released	Fish Killed	Marked Fish Caught	N(I)M(I)*	A(I)*
1	412	219	15	0	0	0
2	223	200	0	5	48837	732555
3	121	107	0	4	50699	760485
4	138	124	6	6	72588	1088820
5	72	64	0	5	46800	982800
6	59	53	0	2	42126	884646
7	30	0	6	3	23010	483210
Totals	1055	767	27	25	284060	4932516

*Notation of Overton (1965).

Table 4. Mark-recapture data for Traverse Pond 3+ brook trout sampled during 1977.

Sample	Fish Caught	Newly Marked Fish Released	Fish Killed	Marked Fish Caught	N(·I)M(I)*	A(I)*
1	113	60	0	0	0	0
2	53	48	0	0	3180	0
3	74	66	0	0	7992	0
4	56	50	6	2	9744	0
5	36	32	0	5	8064	48384
6	22	20	0	2	5632	33792
7	14	0	0	0	3864	23184
Totals	368	276	6	9	38476	105360

*Notation of Overton (1965).

Table 5. Observed mean size (fork length in cm) of brook trout captured at trap locations in Traverse Pond (1977).

Sampling Period	Inlet End		Outlet End	
	West Shore	East Shore	West Shore	East Shore
1	14.4	16.2	16.7	14.7
2	14.5	16.8	15.9	15.2
3	15.1	18.5	16.9	16.4
4	14.7	16.9	18.1	16.4
5	16.9	18.1	17.4	15.6
6	14.7	16.2	17.0	17.3

Table 6. Traverse Pond brook trout age-length key.

Fork Length (mm)	0+	1+	2+	3+	4+	5+
50 - 59	2					
60 - 69	5					
70 - 79	3					
80 - 89		2				
90 - 99		4				
100 -109		4				
110 -119		6				
120 -129		7				
130 -139			2			
140 -149			3			
150 -159			2			
160 -169			7			
170 -179			2			
180 -189						
190 -199			2	4		
200 -209				3		
210 -219						
220 -229				2		
230 -239				3		
240 -249				1	2	
250 -259						
260 -269					1	
270 -279						
280 -289					1	
290 -299						
300 -309						
310 -319						1
.						
.						
.						
370 -379						1
N	10	23	18	13	4	2
Mean Length (mm)	64.5	109.1	160.2	215.2	260.0	342.0
Standard Deviation	0.78	1.38	1.67	1.98	2.08	NA
Standard Error	0.25	0.29	0.39	0.55	1.04	NA

NA = not applicable. N too small.

Table 7. Population and biomass estimates for brook trout of Traverse Pond, 1977.

Age Group	Number	Mean Weight (g)	Biomass (kg)	Density (kg/ha)
1	483	7.53	3.64	0.06
2	12019	39.13	470.30	7.13
3	5127	106.46	545.82	8.27
4	233	238.06	55.47	0.84
5	36	479.98	17.28	0.26
Total	17898		1092.51	16.56

Table 8. Stomach contents of Traverse Pond brook trout

Order	Number of Specimens	Number of stomachs Containing Specimens	% of Stomachs Containing Specimens
Odonata	41	17	18.5
Coleoptera	5	4	4.4
Diptera	76	17	18.5
Hymenoptera	7	6	6.5
Ephemeroptera	6	5	5.4
Trichoptera	22	10	10.9
Malacostraca	6	3	3.3
Gastropoda	48	5	5.4
Bivalvia	6	1	1.1
Cladocera	>100	2	2.2
Amphipoda	>3000	11	12.0

Table 9. Zooplankton forms identified from Traverse Pond (10 minute surface tow, August 1976).

Identification	Number in Subsample	Calculated Number per 10 min tow
Cladocera		
Daphnia catawba	5	1000
Eubosmina longispina	1	200
Copepoda		
Diaptomus minutus	71	14200

Table 10. Water chemistry of study lakes.

Area	Site	Parameter* Nitrate	Total Phosphorous	Ortho Phosphate	Specific Conductance µmhos/cm	Total Dissolved Solids	Calcium	Iron	Chloride
Traverse Pond	1	0.096	0.042	0.014	21.41	22.44	1.432	0.013	7.44
	2	0.048	0.026	0.008	22.06	22.90	1.453	0.031	9.22
	3	0.215	0.046	0.005	21.01	22.15	1.205	0.047	7.80
	4	0.044	0.064	0.009	21.21	22.29	1.313	0.023	8.50
	Centre	0.026	0.044	0.002	20.44	21.74	1.326	0.043	7.09
	Mean	0.086	0.044	0.008	21.19	22.28	1.346	0.031	8.01
Gull Brook		0.022	3.339	0.196	21.20	22.28	1.9;61	0.077	7.44
Upper Micmac Pond	1		0.275	0.233	29.49	28.25	1.978	0.250	12.05
	2		0.053	0.028	26.69	26.24	1.890	0.245	13.83
	3	0.013	0.063	0.032	28.16	27.30	1.931	0.250	15.24
	4		0.248	0.163	28.16	27.30	1.975	0.232	13.12
	Centre	0.038	1.387	1.316	35.78	32.78	2.052	0.269	10.64
	Mean	0.025	0.405	0.354	29.66	28.37	1.97	0.249	12.98
Lower Micmac Pond	1		0.051	0.013	63.06	52.42	1.582	0.098	10.64
	2		0.049	0.013	29.16	28.02	1.509	0.048	10.64
	3	0.025	0.041	0.012	27.67	26.94	1.544	0.048	10.64
	4		0.046	0.012	28.32	27.41	1.841	0.058	9.92
	Centre		0.046	0.012	29.88	28.53	1.499	0.041	10.28
	Mean		0.047	0.012	35.62	32.66	1.595	0.059	10.42

*Except for Specific Conductance, all parameters recorded as mg/l.

Table 11. Stream invertebrate drift samples from Gull Brook (total number/24 hr).

Order	Month		
	July	August	September
Diptera	377	110	68
Ephemeroptera	34	38	12
Plecoptera	72	10	1
Trichoptera	32	10	7
Hymenoptera	25	2	2
Amphipoda	15	1	0

Table 12. Mean condition factor by age for Upper Micmac brook trout.

	Age			
Parameter	1	2	3	4
Mean fork length	6.14	11.52	15.10	19.43
Mean weight (g)	3.08	17.50	40.17	89.63
Mean condition factor	1.33	1.14	1.17	1.22
Sample size	6	15	7	4

Table 13. Calculated number of zooplankton for Upper Micmac Pond (10 min surface tow, August 1976).

Identification	Sample Number 1	2	3
Cladocera			
Holopedium gibberum	1000	1700	0
Daphnia catawba	500	300	200
Calanoida			
Epischura lacustris	500	>10000	0
Diaptomus minutus	>10000	>10000	>10000
Diaptomus spatulocrenatus	500	670	200
Copepoda	>10000	>10000	>10000

Table 14. Comparison of slopes of linear growth functions of brook trout populations from the three study sites.

Sample	Total Degrees of Freedom	Sum Squares X	Sum of Cross Products	Sum Squares Y	Residual Degrees of Freedom	Reduction Sum Squares
Upper Micmac	54	55.71	247.89	1325.18	53	1102.91
Lower Micmac	42	31.89	171.35	1056.00	41	920.74
Traverse Pond	86	70.00	324.35	1960.48	85	1502.90
Residuals from Individual Regression					179	815.11
Totals for Single Regression	182	157.60	743.58	4341.66	181	833.33
Difference for Homogeneity of Regression					2	18.22

F = 2.007, P = 0.14

Table 15. Comparison of slopes of linear weight-length regressions (log-log, base 10) for brook trout populations of the three study sites.

Sample	Total Degrees of Freedom	Sum Squares X	Sum of Cross Products	Sum Squares Y	Residual Degrees of Freedom	Reduction Sum Squares
Upper Micmac	32	1.19	3.48	10.27	31	10.22
Lower Micmac	51	1.64	4.80	14.49	50	14.07
Traverse Pond	97	2.68	7.94	24.47	96	23.52
Residuals From Individual Regression					177	1.42
Totals For Single Regression	180	5.5	16.22	49.23	179	1.42
Difference For Homogeneity of Regression					2	0.00

F = 0.0772, P = 0.93

Table 16. Literature survey of brook trout growth. Fork length recorded in cm and weight (in parentheses) in g.

Reference	Population	Age 0	1	2	3	4	5	6
Wiseman 1969								
	Terra Nova Lake		11.8	17.3	22.6	28.3	34.8	
	Thomas' Pond		14.2	19.5	22.1			
	Big Bear Cove		14.6	17.3	25.4	31.7	34.9	
	Indian Brook		8.1	12.9	16.2	21.7		
	Berry Hill Pond		10.3	14.8	18.4	23.5		
	Gander River		11.5	14.6	19.4	22.5		
	Indian Bay		18.9	22.3	27.3	34.1	40.1	
	Stephens' Pond		12.0	16.6	19.4	23.8	29.0	
	Angle Pond		12.0	19.2	22.7	30.0	32.5	
Whelan and Wiseman 1977								
	Avalon Average* (44 locations)	5.5	10.8	16.1	21.3	26.5	31.4	35.0
Bruce 1979								
	Jacopie Lake		8.0	16.1	24.1	32.1	40.1	48.1
	Churchill River		7.7	15.8	23.4	30.8	35.3	39.3
	Churchill River		9.3	16.5	23.1	29.3	35.3	41.0
	Valley River		6.2	10.6	14.5	18.1	20.4	
Beak 1980								
	Crooked Lake		10.1	15.7	18.1	22.4	28.0	
			(5.0)	(47.0)	(69.2)	(126.3)	(263.5)	
	Great Burnt Lake			15.8	17.7	20.6		34.9
				(41.7)	(58.3)	(91.7)		(600.0)
	Cold Spring P.			15.8	17.8	18.9	31.0	35.9
				(37.5)	(52.7)	(62.5)	(285.0)	(415.0)
	Round Pond		12.0	15.3	18.7	25.7	33.5	38.6
			(20.0)	(41.0)	(68.9)	(190.4)	(377.9)	(695.0)
deGraaf 1981								
	Top Pond		13.5	24.2	25.3	29.8	37.9	40.2
	Stephenson's P.			22.2	24.2	24.9	25.5	
	Dry Pond		16.9	19.9	23.3			
	Dry Pond Bk.	6.2	10.5	15.5				

*Back calculated fork lengths.

Table 17. Fork length and weight at age data for populations of Atlantic salmon in insular Newfoundland. Fork length recorded in cm. Weight (in parentheses) in g.

Reference	Population	Race	Age			
			0	1	2	3
Belding 1936						
	Middle Barachois	anadromous		5.0	9.0	12.8
	Fishell's	''		5.0	8.7	12.4
	Crabb's River	''		4.9	8.2	11.5
	Grand Bay	''		4.7	8.0	11.3
	Robinson's	''		4.5	7.6	10.7
	Codroy	''		4.4	7.4	10.3
Scott and Crossman 1964						
	Terra Nova River	ouananiche		12.3	15.3	20.8
Andrews 1965						
	Gander River	anadromous		7.1	9.8	11.3
	Lower Gander	''		6.9	9.3	11.2
Andrews 1966						
	Terra Nova River	ouananiche		9.9	11.3	17.6
Leggett and Power 1969						
	Flatwater Pond	''		8.7	14.5	18.7
				(7.1)	(38.3)	(72.3)
	Gambo Pond	''	5.0	8.0	15.7	20.5
			(1.7)	(6.6)	(49.9)	(107.1)
Wiseman 1971						
	Thomas Pond	''		4.7	10.0	15.4
	Avalon Mean	''		5.0	9.1	13.6
Pepper 1976						
	Lower Gander	anadromous		4.3	6.7	9.0
Pepper (unpublished)						
	Indian Brook			6.7	9.1	12.2
				(3.1)	(8.2)	(19.4)
Beak 1980						
	Upper Salmon	ouananiche		6.7	9.7	11.9
				(3.3)	(10.2)	(18.0)
deGraaf 1981						
	Top Pond Brook	anadromous		5.5	8.8	12.2
Ryan et al. 1981						
	Spruce Pond	''		5.7	9.1	12.8
	Headwater Pond	''		6.4	10.3	14.1
	Little Gull Lake	''		5.2	8.2	11.7
Chadwick 1982						
	Western Arm Brook	''		7.0	9.8	13.7
				(4.8)	(12.3)	(31.4)

Table 18. Potential juvenile Atlantic salmon fry stocking results from standing water habitat, using 100000 unfed fry.

Year	Age of Juvenile Salmon (yr) 0	1	2	3*	Total Parr Population
1	100000				100000
2	100000	25000			125000
3	100000	25000	15000		140000
4		25000	15000	12000	40000
5			15000	12000	15000
6				12000	0

* 3 yr juveniles (smolt) not included in totals due to their migration from fresh water just prior to the time of fry stocking.

Table 19. Potential juvenile salmon production from Traverse Pond using fry stocking density of 1000 fry per hectare.

Year	Age 0	1	2	3*	Total* Population
1	66000				66000
2	66000	16500			82500
3	66000	16500	9900		92400
4		16500	9900	7920	26400
5			9900	7920	9900
6				7920	0

* 3 yr juveniles (smolt) excluded from totals due to migration from freshwater habitat at beginning of growing season (May-June).

Table 20. Proposed Atlantic salmon production schedule for lacustrine nursery area project, Black Brook, Newfoundland.

Year	[1]Required broodstock	[2]Approximate egg production x 10^6	Expected juvenile production x 10^6				[5]Adult production x 10^5	[1]Potential harvest x 10^3		
			0[3]	1[4]	2[4]	3[4]		Recreational (number)	[6]Commercial (kg)	Total (number)
1	895	1.47								
2	895	1.47	1.25							
3	895	1.47	1.25	0.31						
4	895	1.47	1.25	0.31	0.19					
5	895	1.47	1.25	0.31	0.19	0.15				
6	1790	2.94	1.25	0.31	0.19	0.15	0.15	2.6	36.6	14.1
7	1790	2.94	2.50	0.31	0.19	0.15	0.15	2.6	36.6	14.1
8	1790	2.94	2.50	0.62	0.19	0.15	0.15	2.6	36.6	14.1
9	1790	2.94	2.50	0.62	0.38	0.15	0.15	2.6	36.6	14.1
10	1790	2.94	2.50	0.62	0.38	0.30	0.15	2.6	36.6	14.1
11	1790	2.94	2.50	0.62	0.38	0.30	0.30	5.3	73.3	28.2
12	1790	2.94	2.50	0.62	0.38	0.30	0.30	5.3	73.3	28.2

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continued to end of project

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[1] Artificial propagation activities must assure adequate spawning escapement to the river to maintain natural production potential.

[2] The Indian Brook salmon stock has a mean spawner weight of 1.42 kg, a sex ratio of 3 females per male and a fecundity of 1543 eggs/kg of female weight.

[3] Artificial incubation techniques should be able to maintain an egg to fry survival of at least 85%.

[4] Mortality factors described in text.

[5] Marine survival estimated at 10%

[6] Average weight of salmon in commercial fishery in Newfoundland Statistical Area B is 3.2 kg.

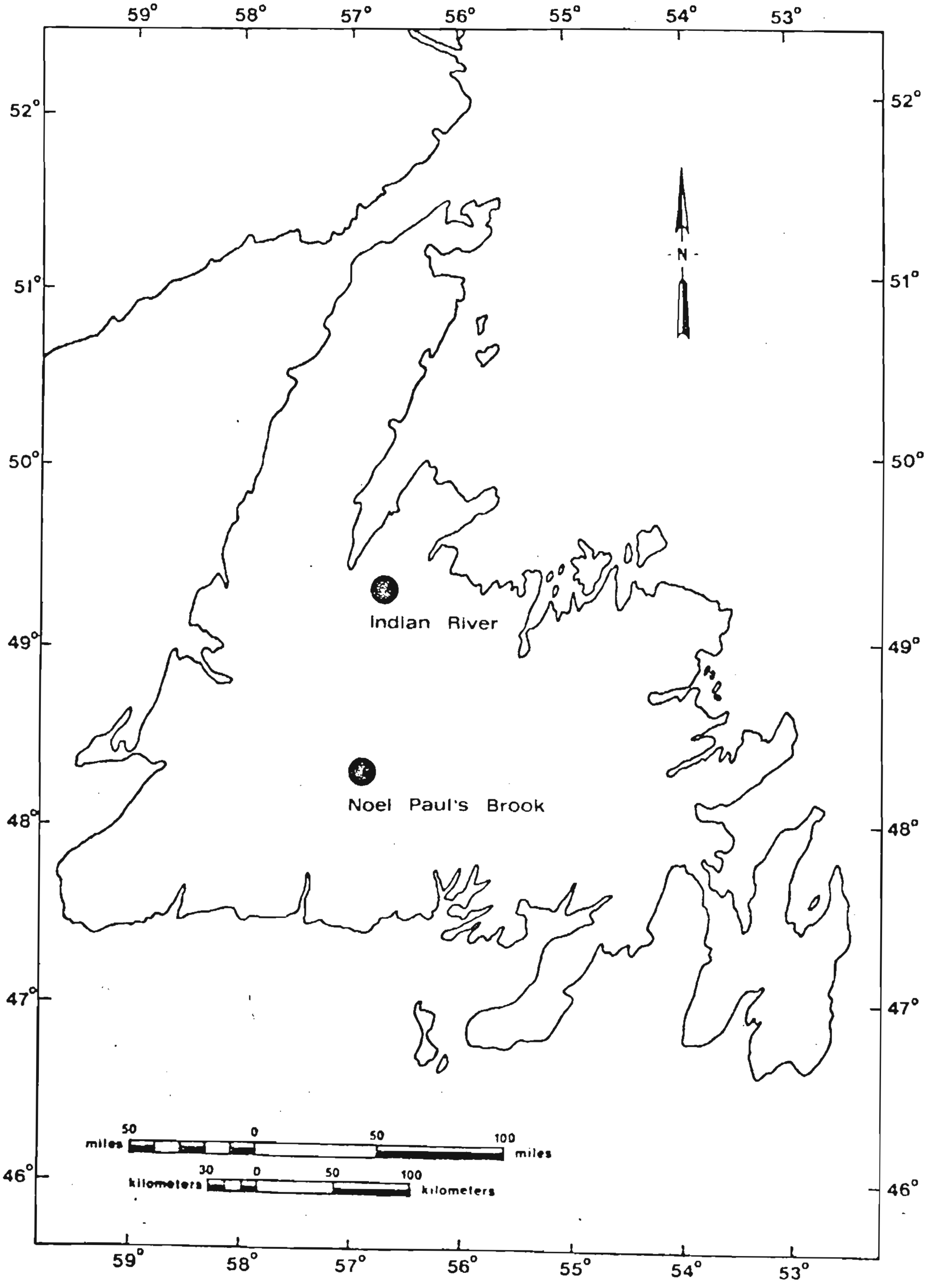

Fig. 1. Location of artificial spawning channels for Atlantic salmon in Newfoundland.

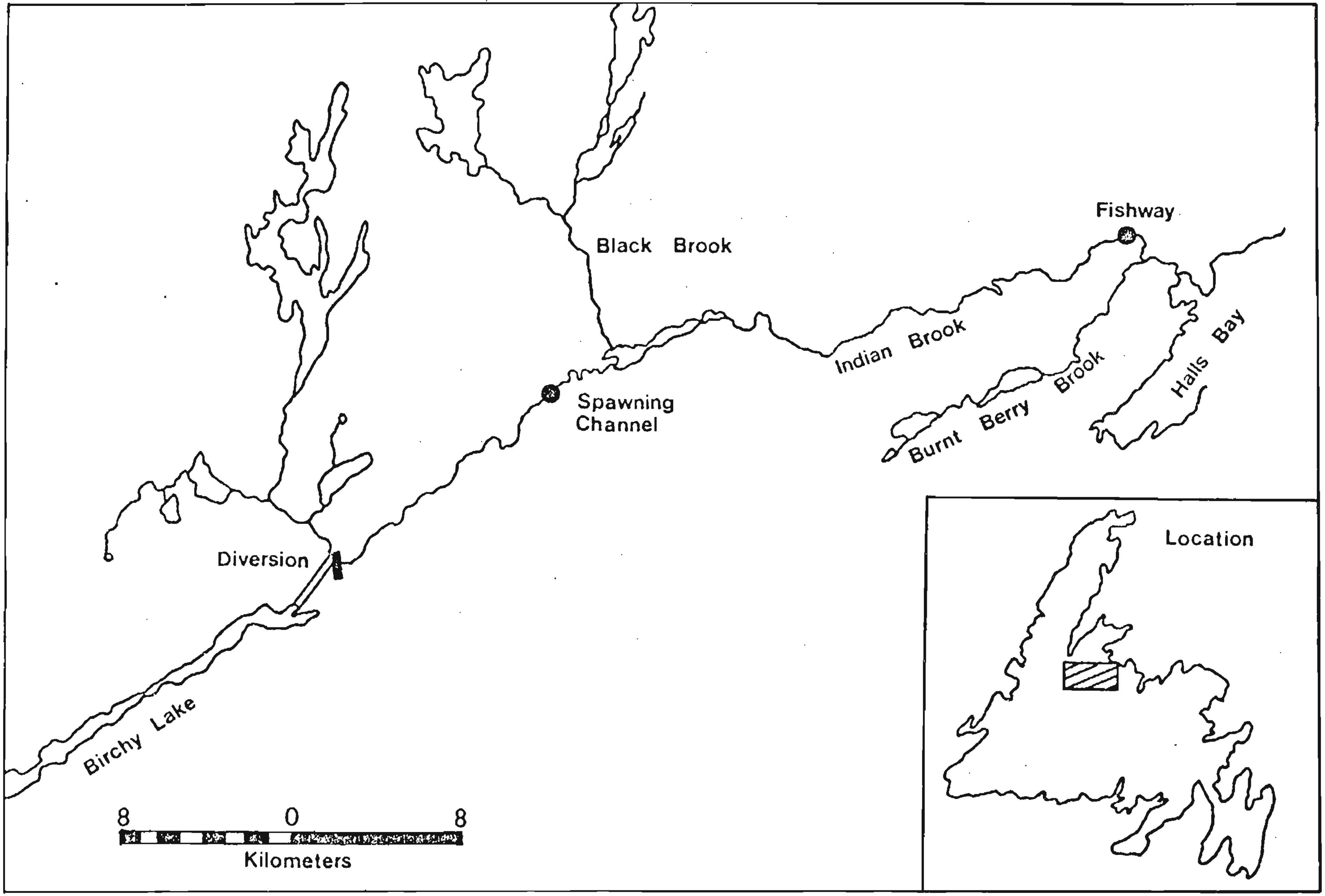

Fig. 2. Indian Brook and headwater diversion.

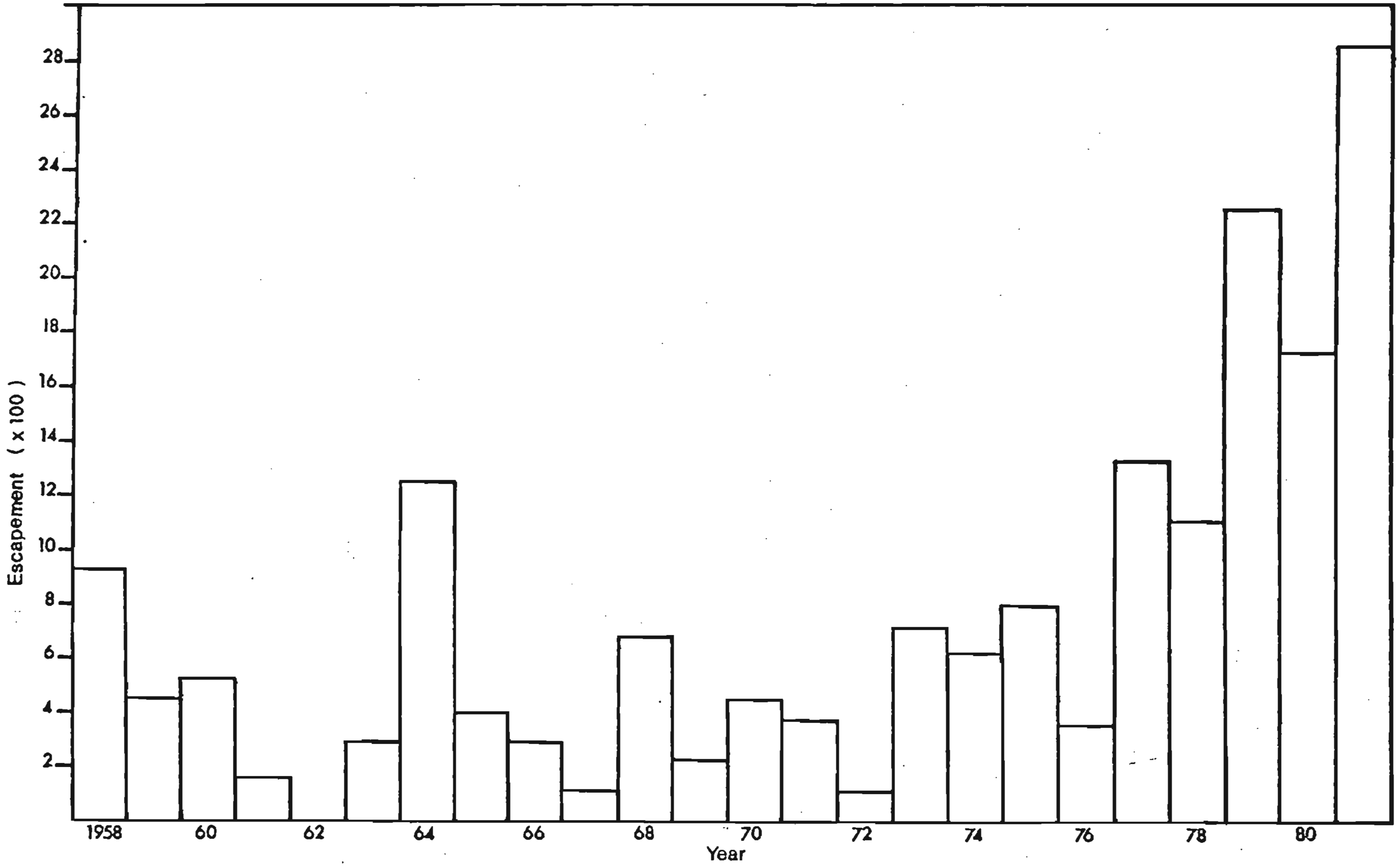

Fig. 3. Indian Brook Fishway Escapement 1958 – 81

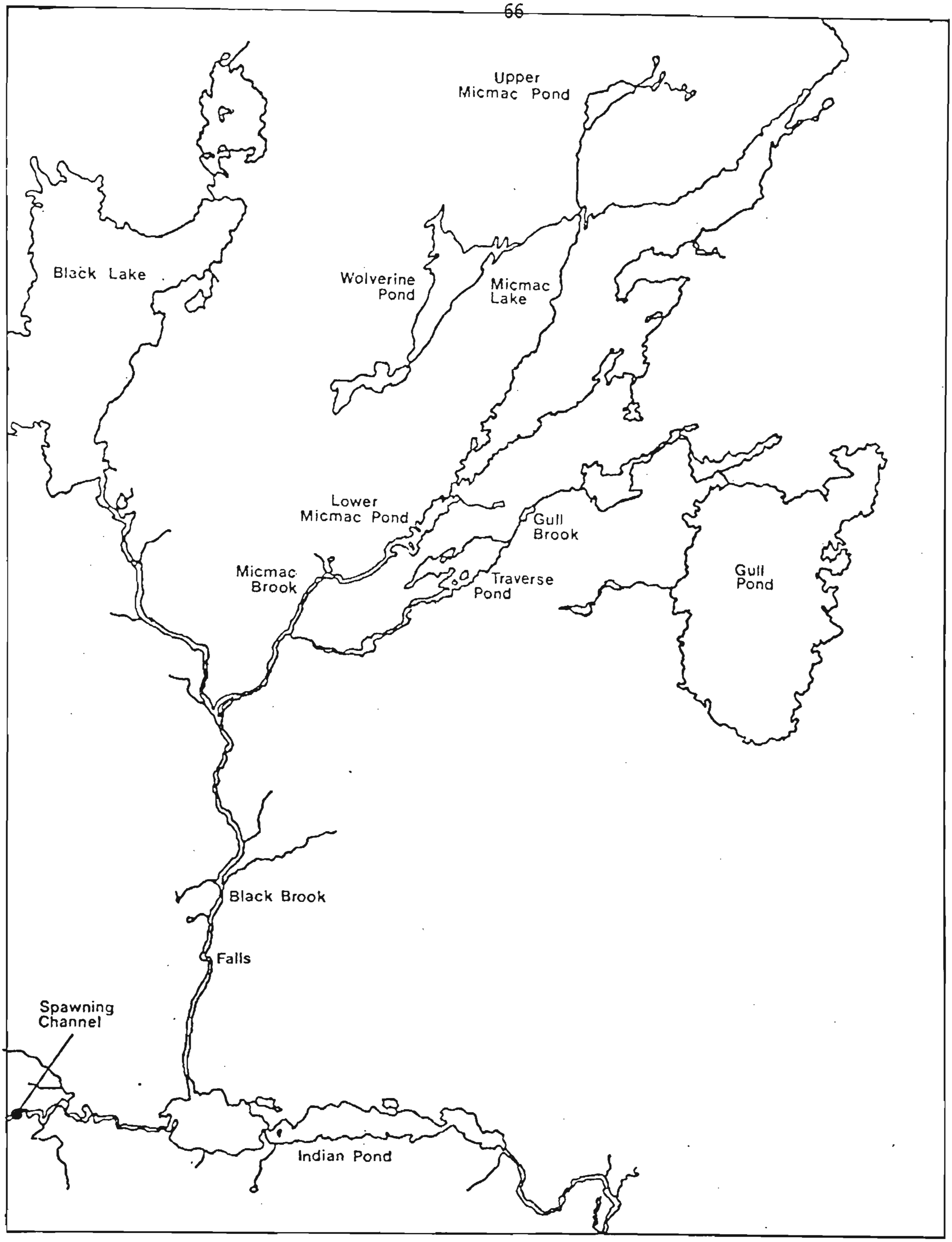

Fig. 4. Biobaseline study area location references.

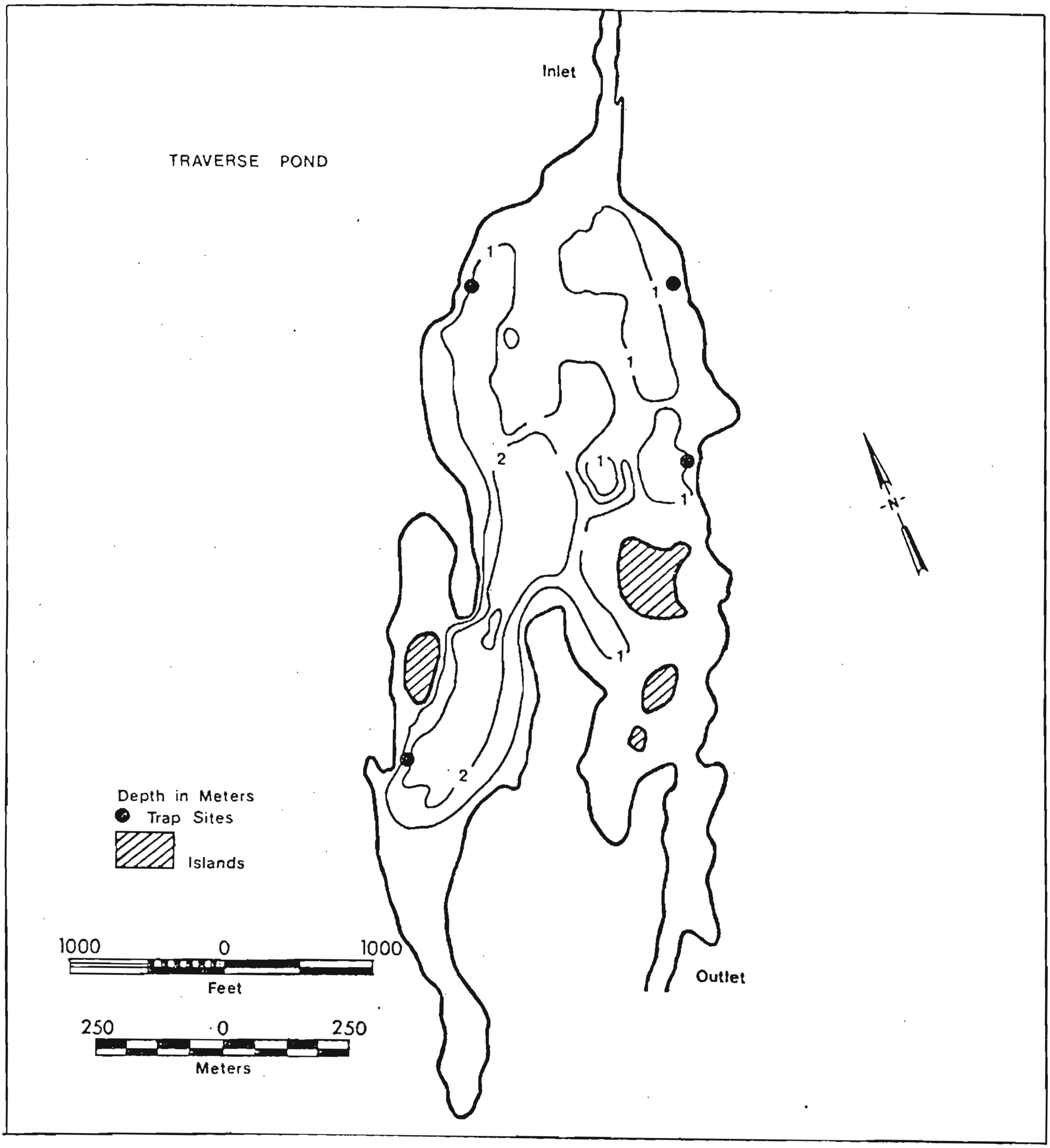

Fig. 5. Traverse Pond bathymetry and trap locations.

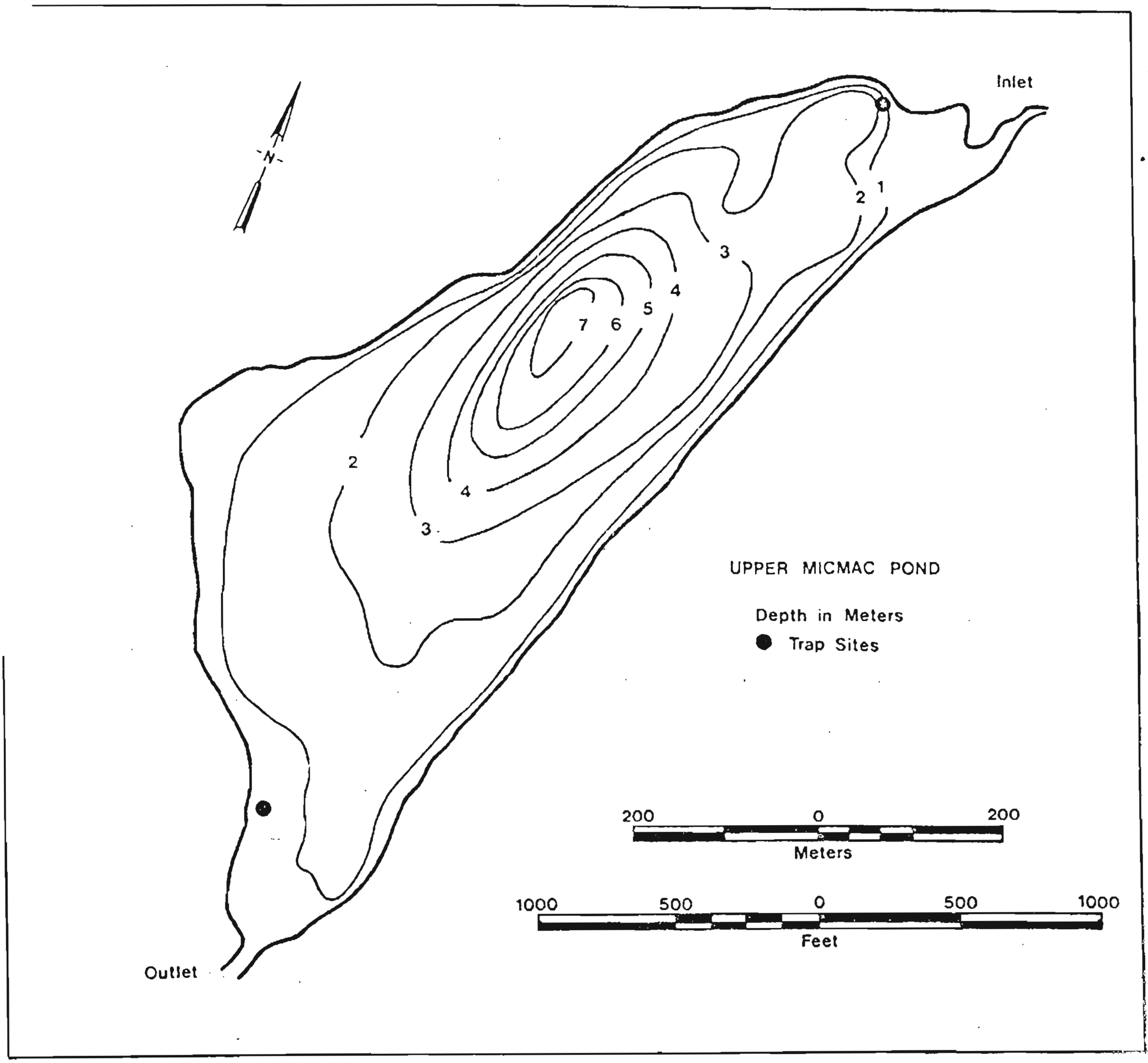

Fig. 6. Upper Micmac bathymetry and trap locations.

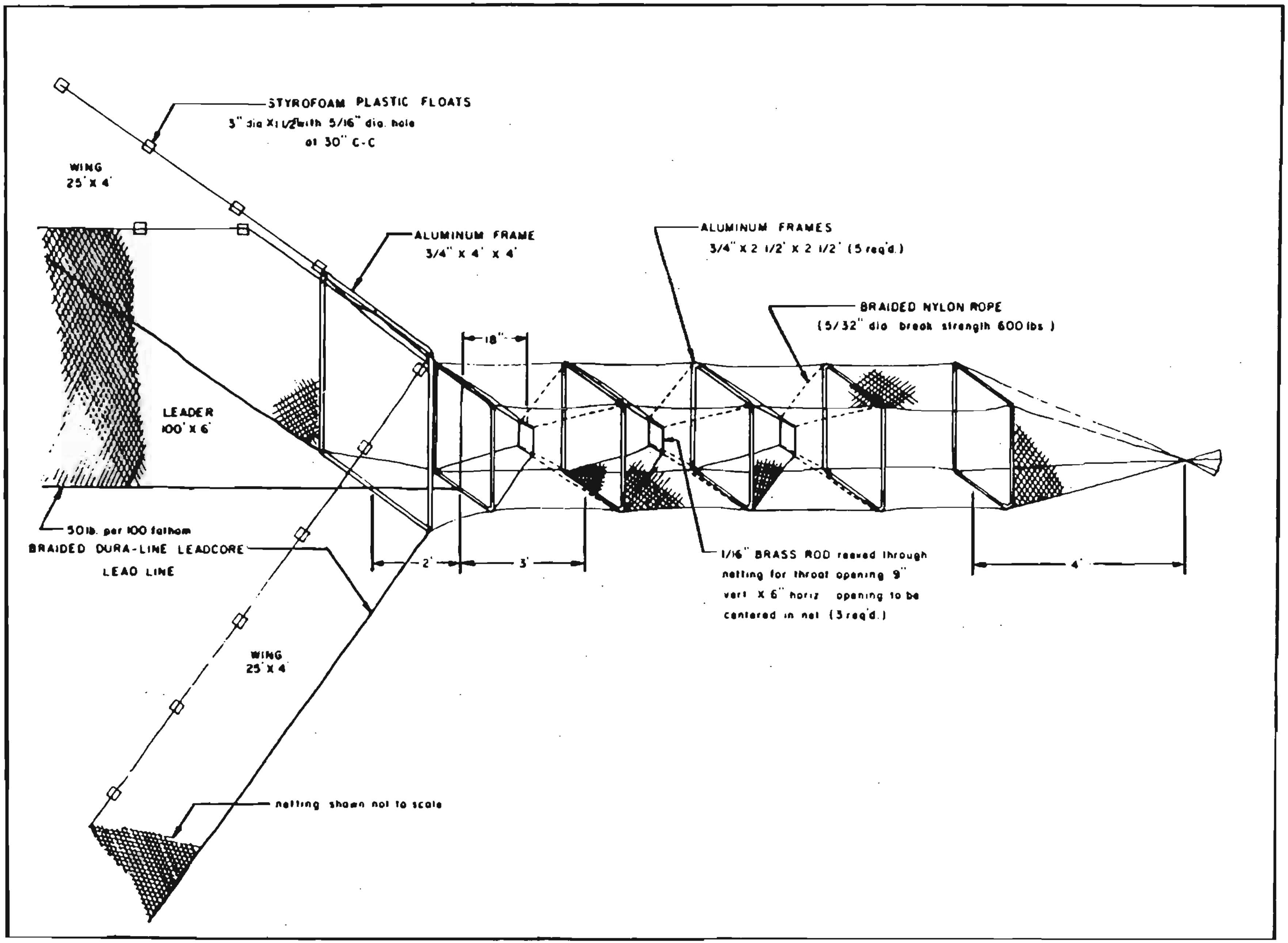

Fig. 7. Lake trap net.

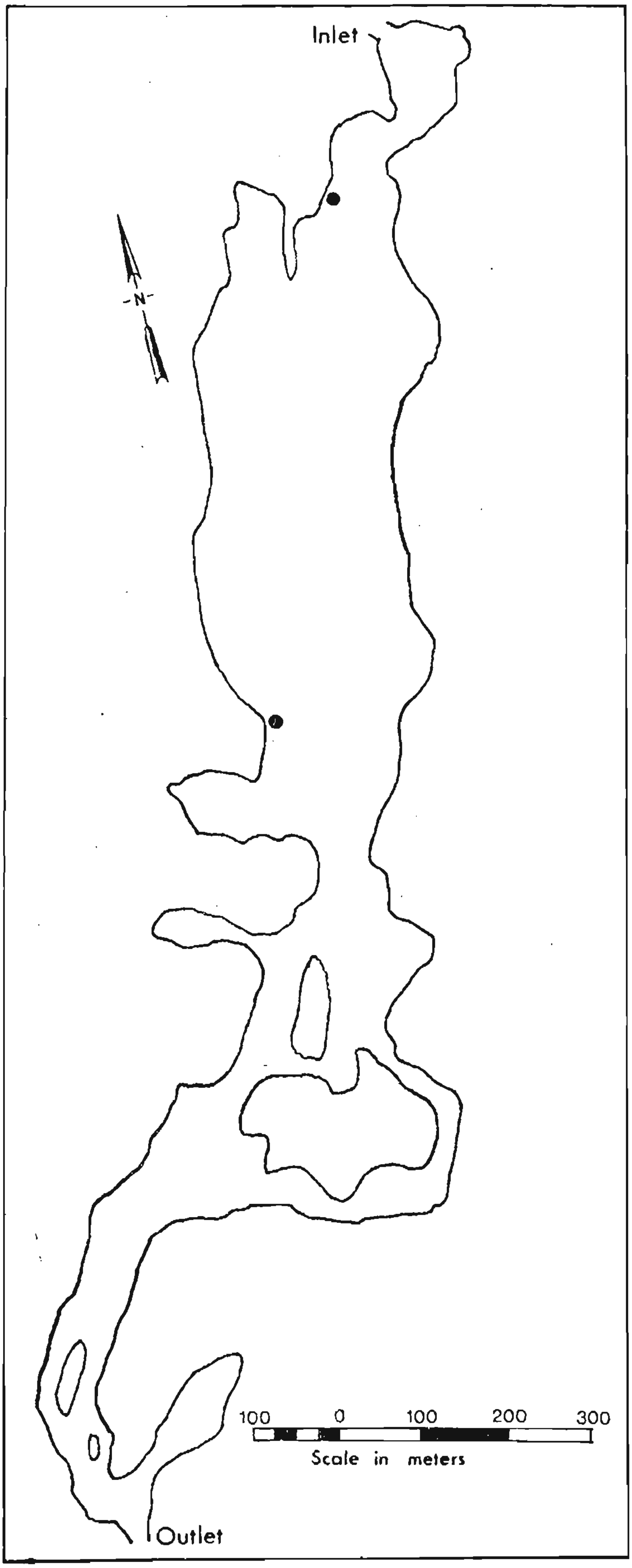

Fig. 8. Lower Micmac trap locations.

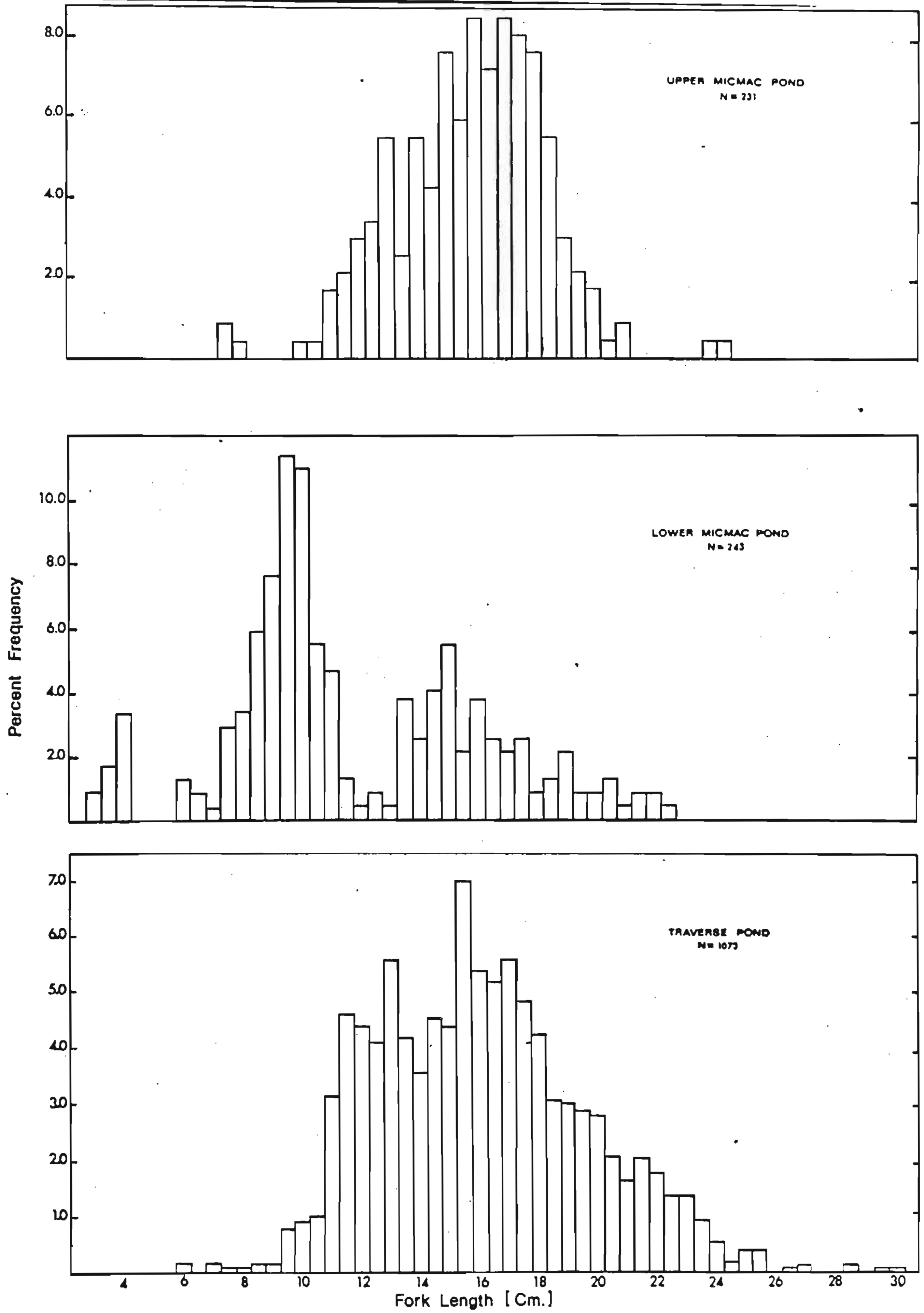

Fig. 9. Brook trout fork length-frequency distributions for study ponds.

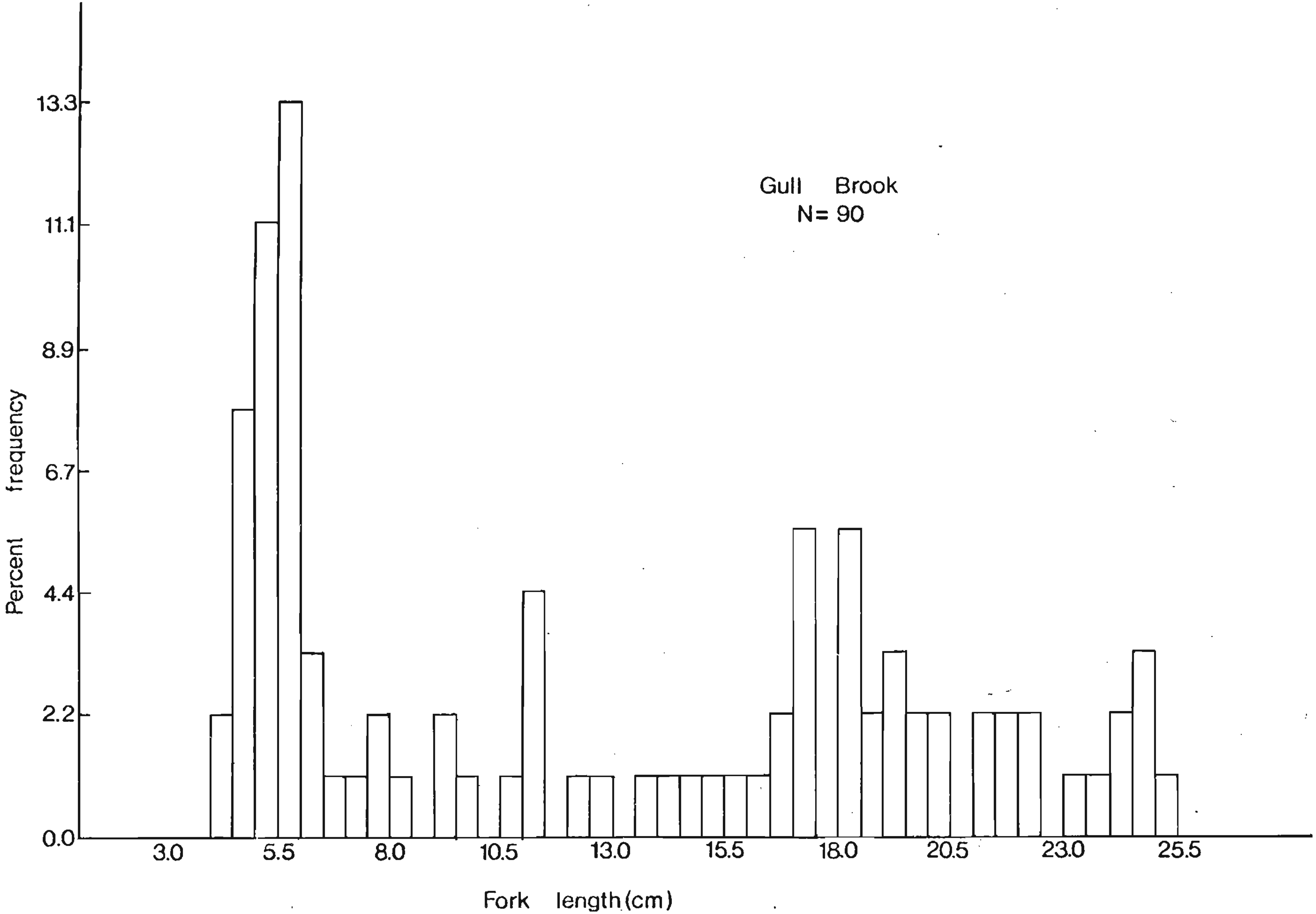

Fig. 10. Brook trout fork length distribution for Gull Brook sample.