STUDIES ON THE BIOLOGY OF SEXUALLY MATURE MALE SALMON PARR, SALMO SALAR (LINNAEUS) 1758, IN INSULAR NEWFOUNDLAND

EDGAR L. DALLEY

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STUDIES ON THE BIOLOGY OF SEXUALLY MATURE MALE SALMON PARR, SALMO SALAR (LINNAEUS) 1758, IN INSULAR NEWFOUNDLAND

by

Edgar L. Dalley, B.Sc.(Hons.)

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science

Department of Biology
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St. John's Newfoundland

ABSTRACT

Precocious male Atlantic salmon (Salmo salar) parr were investigated in eastern, central and western areas of insular Newfoundland. The percent precocity varied in different areas, but Placentia Bay samples generally had a higher incidence. The proportions of male parr maturing increased beyond age 1+. Limited evidence indicated that precocity at age 0+ is rare.

Maturing males were larger than immature males at 1+ in all samples and significantly larger in one sample. Older precocious males were not larger than immature males of the same age indicating that maturity begins earlier in fast growing fish but that growth consequently slows down. Faster growth appeared to be related to precocity within a particular system but this relationship was not especially apparent in comparisons between systems. Overlap of 95% confidence intervals placed around eviscerated weights (calculated from regression equations) at corresponding lengths indicated no difference between weights for mature and immature parr. However the length-weight relationship was lower for precocious (spent) smolt than for immature smolt in larger length classes.

Sex ratios of each age group of the samples were often found to differ significantly from 1:1. Possible causes for these deviations are discussed in terms of sex-related distribution patterns and mortality of precocious parr. Evidence is presented

from certain sex ratios and from a tagging program that precocious males move upstream to spawn and circumstantial evidence indicates that they spawn with adult females.

Sex ratios in freshwater following the smolt run and of the smolt run indicates that most precocious parr do not migrate as smolts. The younger parr (1+ and 2+) may mature again while it appears most 3+ and older parr have a high mortality.

Existing data indicate that rivers with a high percentage of sexually precocious males have a corresponding high percentage of adult females, most likely as a result of few male smolt.

ACKNOWLEDGEMENTS

The author is grateful to his supervisor, the late Dr. C.W. Andrews, who acted as an inspiration throughout, for guidance and support. To his memory this thesis is respectfully dedicated.

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INTRODUCTION

In 1974 the Faculty of Science of Memorial University undertook an environmental study of Placentia Bay in which the author was involved in studies of aspects of the freshwater systems flowing into the bay. One of the preliminary results of the study was the discovery of an extremely high incidence of precocious male salmon parr, Salmo salar (Linnaeus) 1758. In view of limited information available on precocious S. salar males in Newfoundland the present study was undertaken.

The study attempts to describe the distribution and extent of precocity in different areas of Newfoundland, the sex ratios of parr, age and size at maturity and to compare the growth of precocious and non-precocious parr. Certain characteristics of precocious parr (eg. movement and spawning) and their fate following maturation and/or spawning have been studied. The literature on precocity in S. salar has been extensively reviewed to reveal aspects of precocity elsewhere and to compare with the local situation.

Precocity, used in describing Atlantic salmon males, means unusually early development or maturity of the gonads. The term is used to describe maturity of male parr of anadromous populations in which female parr have totally undeveloped ovaries. The fact that no mature female parr are found in these populations prevents the possibility of confusion with landlocked or ouananiche populations.

'Dwarf' is a term which is often used interchangeably with 'precocious' in describing male parr and is more commonly used in Europe (Leyzerovich 1973, Osterdahl 1969, Danil'chenko 1938), although more recently is also being used in North America (Saunders and Sreedharan 1977). The term 'dwarf', as used, refers to the small size of the fish. Berg (1937) points out that dwarf male salmon are able to produce reproductive products at a length of only 10 cm. Salmon males of normal size migrate to sea, greatly increasing their size by the time of maturity while dwarf males mature in the river, without going to sea.

As will be considered, precocious males may not migrate as smolts and in some cases may reach an age of 4 or 5 years in the river. It may be questioned whether or not these fish are precocious since adults may be no older than this. In such a case 'dwarf' might be a more suitable term. It is believed that if these older males, that are part of an anadromous population, had not been precocious at an earlier age they would have smoltified and gone to sea. In this report the terms 'dwarf' and 'precocious' are used synonomously and in considering the literature on precocity generally the terminology of the original author is employed.

The occurrence of precocious males that mature in freshwater is a characteristic of a number of species of the genera Salvelinus, Oncorhynchus and Salmo of the Family Salmonidae. In the genus

Salvelinus Savvaitova (1960) described dwarf males of *S. malma* (Walbaum) from Kamchatka, U.S.S.R., and Gritsenko (1969) described dwarf males of the Siberian char, *S. leucomaenis* (Pall.) from Sakhalen, U.S.S.R.

In the genus *Oncorhynchus* precocious males occur in *O. tshawytscha* (Walbaum) from California (Robertson 1957), Washington (Thomas et al. 1969), Idaho (Gebhards 1960) and New Zealand (Flain 1970). Utoh (1976) described precocious masu salmon *O. masou* (Brevoort) from Japan and Krokhin (1967) and Chernenko (1968) investigated precocious male sockeye, *O. nerka* (Walbaum) from Kamchatka, U.S.S.R.

More commonly, reports of precocious salmonids involve the genus *Salmo* particularly *S. salar*. Shevtsova (1968) mentioned that parr of the Black Sea salmon, *Salmo fario* (Pallas) mature in the river. Askerov (1964) described experiments in which eggs of Kura salmon *Salmo trutta caspius* (Kessler) were fertilized with sperm of dwarf males and Nikolsky and Koshin (1958) described precocious males for both *S. salar* and *S. trutta* (Linnaeus) in the U.S.S.R.

Sexually mature male Atlantic salmon (*Salmo salar*) parr have been reported from the entire geographic range of the species. Reports of precocious parr appear in the literature for nearly all areas of Europe in which the species is present, from southern France (Olivereau 1976) to northern Norway (Power 1973). Extensive research has been done in England (Jones and Orton 1940, King et al. 1939), and precocious parr are reported from Ireland (Frost and Went 1940, Frost 1950, Southern 1933) and Scotland (Thorpe 1975). Osterdahl (1968) has written on precocious parr and smolt in Sweden. Extensive work has been done in the U.S.S.R. on precocious S. salar from the Baltic (Mitans 1972, Khalturina and Khalturin 1969) and the White Sea (Mel'nikova 1970). Leyzerovich (1973) studied many aspects of dwarf males S. salar in hatcheries in the U.S.S.R., and Berg (1962) mentioned dwarf males in Czechoslovakian hatcheries.

In North America precocious male Atlantic salmon parr have been reported from Maine (A.L. Meister, pers. comm. in Schaffer and Elson, 1975) to the northern limits of the species in Ungava Bay, Quebec (Power 1969, Lee and Power 1976). Their presence has been noted in Nova Scotia (White 1934), New Brunswick (White and Huntsman 1938, Saunders 1976), Prince Edward Island (Saunders 1960) and Quebec. Schiefer (1972) and Shooner (1967) extensively studied precocious male S. salar on the North Shore Gulf of St. Lawrence, Quebec and they discussed their possible importance in the overall ecology of the species.

Despite the fact that the Atlantic salmon continues to flourish in Newfoundland with approximately one-sixth of the world's commercial salmon catch, 90% of Canada's commercial catch and 50% of the Canadian recreational catch coming from Newfoundland and Labrador (Chadwick et al. 1978a), the phenomenon of sexual precocity in

Newfoundland Atlantic salmon has been little studied. Belding (1937) reported that 3+ parr consisted mostly of males in some west coast Newfoundland rivers but did not mention their state of maturation. More recently Pepper (1976) noted that 85% of the male parr on the lower Gander River were mature. No further reports exist in the literature on precocity in Newfoundland salmon.

Figure 1. Location of systems in insular Newfoundland where samples were collected.

A. Salmonier River
B. North Harbour River, St. Mary's Bay
C. Southeast River
D. Northeast River
E. Come by Chance River
F. North Harbour River, Placentia Bay
G. Bay de l'eau River
H. Rushoon River
I. Gander River
J. Great Rattling Brook, Exploits System
K. Rocky Brook, Humber System
L. Lomond River
M. Western Arm Brook

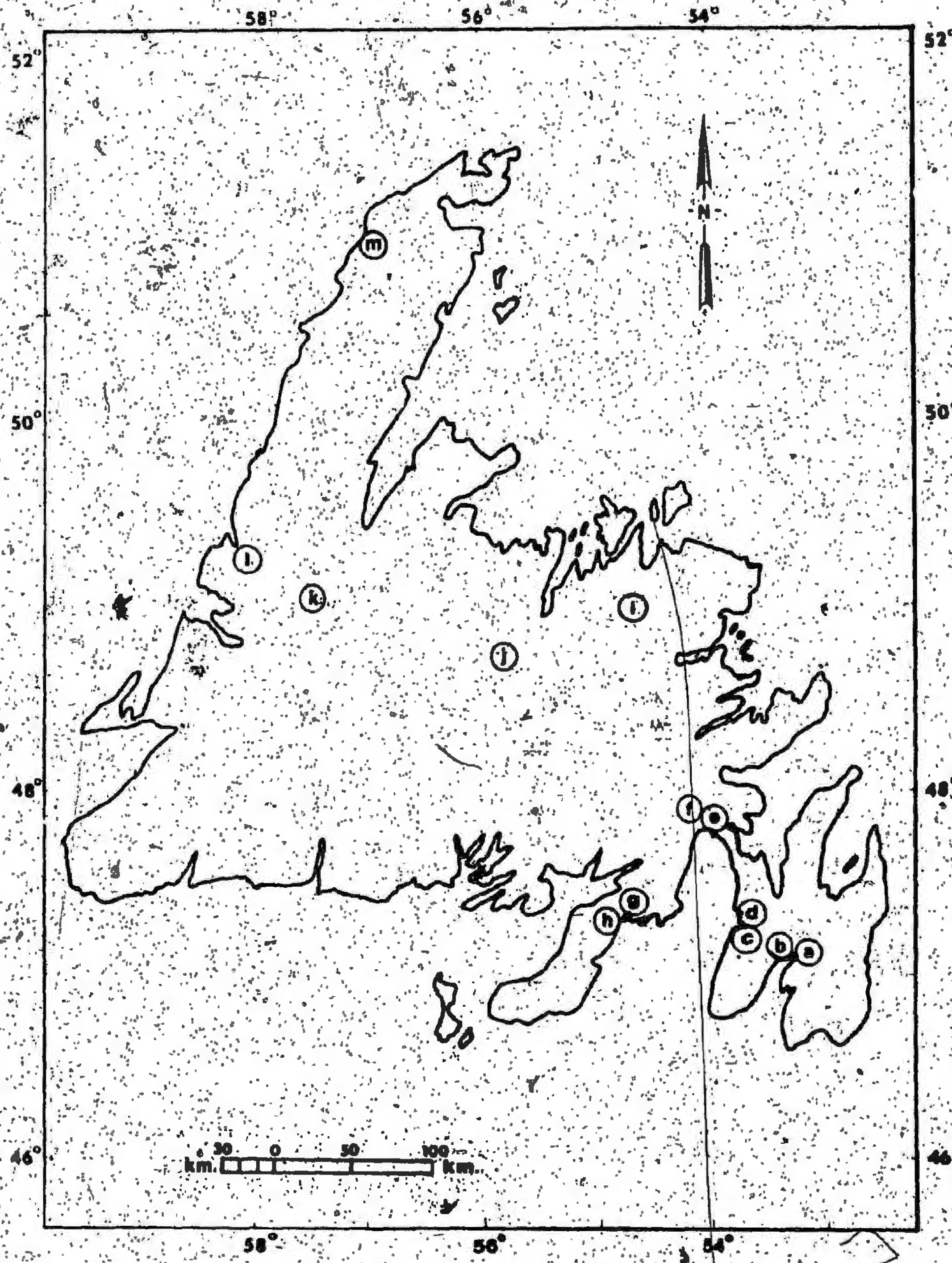

58°
56°
54°
52°
50°
48°
46°
N
m
l
k
j
i
h
g
f
e
d
c
b
a
30
0
50
100
km.
km.

Figure 2. Location within each river system where samples were collected.

2A Salmonier River

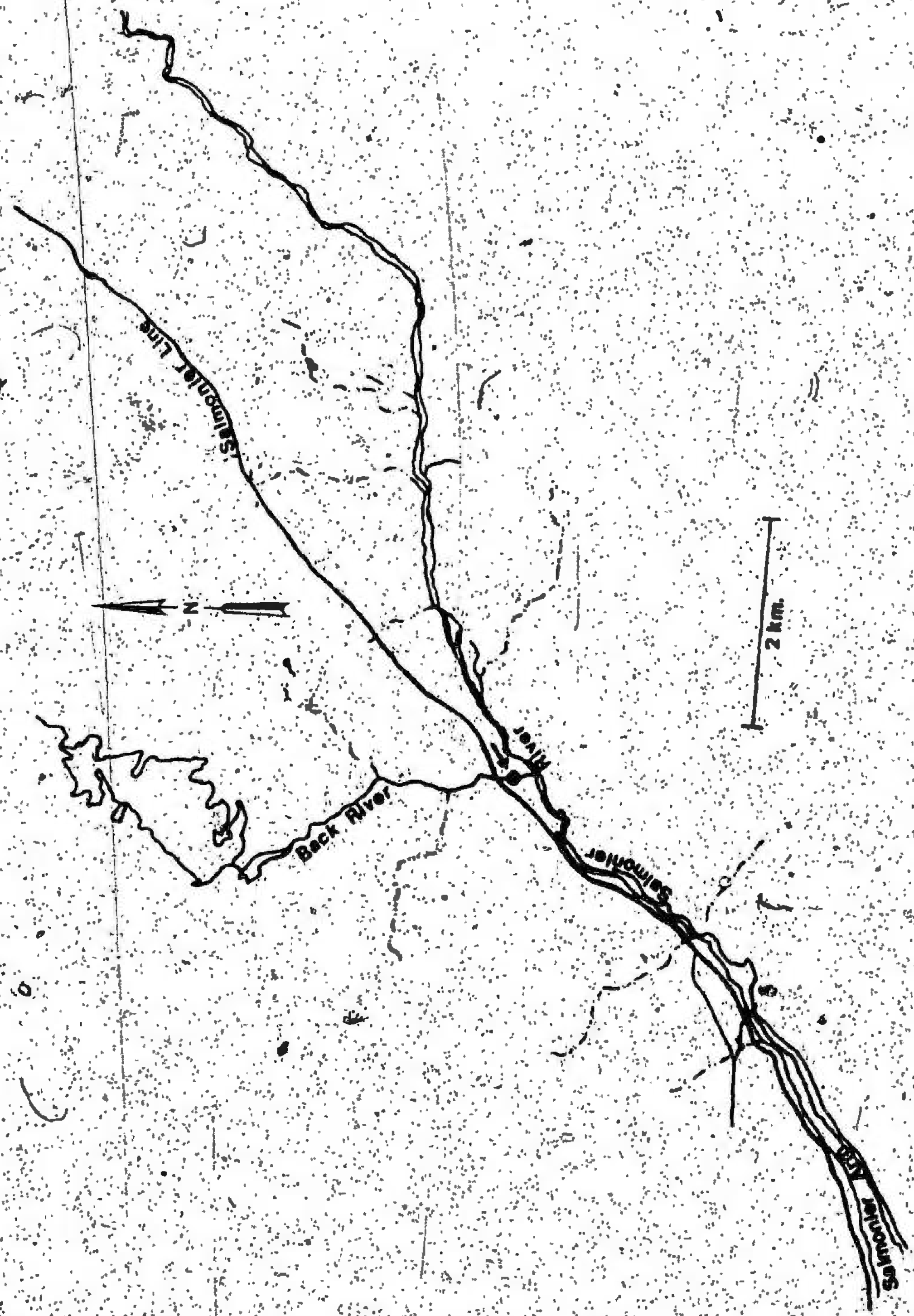

Salmonier Line
N
2 km.
River
Back River
Salmonier
Bay
Salmonier

Figure 2B. Northeast River

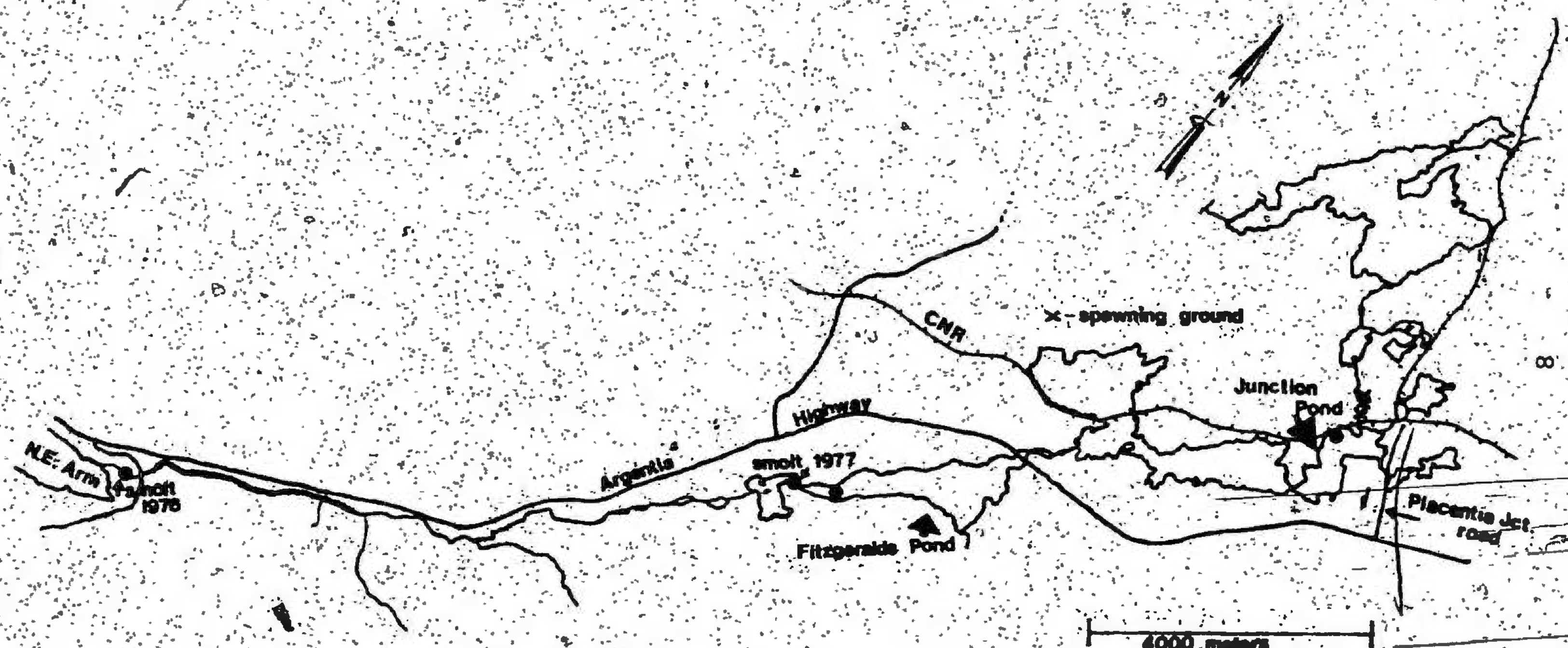

N
x - spawning ground
CNR
Junction
Pond
Highway
Argentia
smolt 1977
Fitzgeralds Pond
Placentia Jct.
road
4000 meters
N.E. Arm
smolt
1976

Figure 2C. Come by Chance River

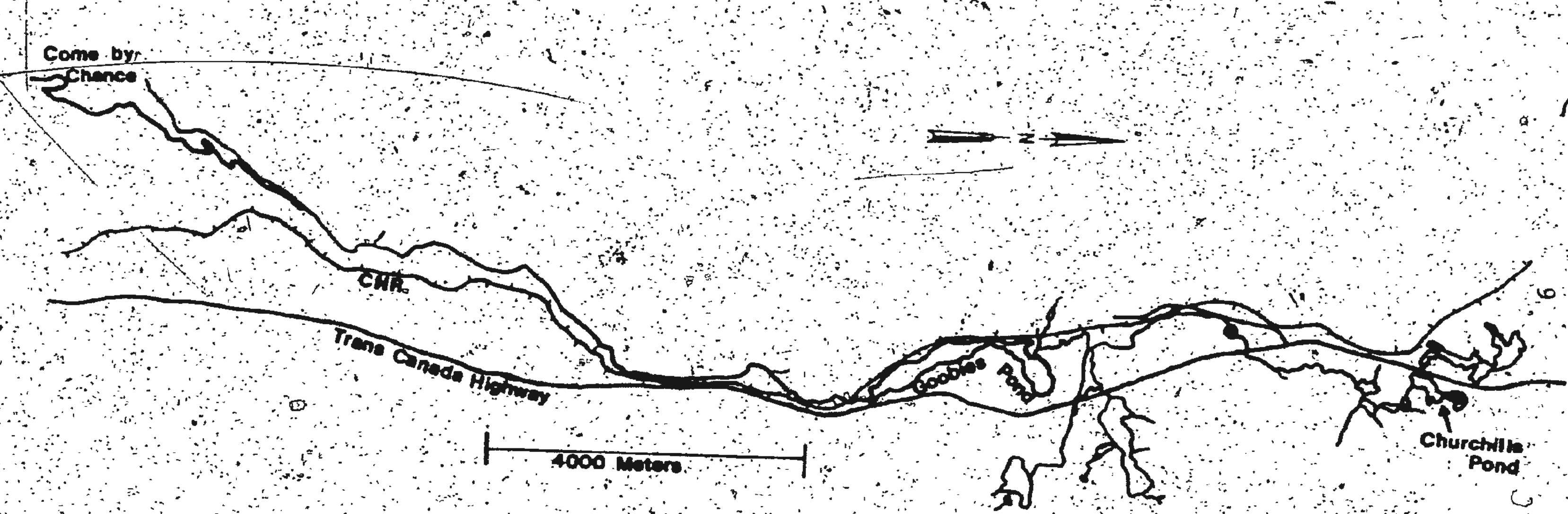

Come by
Chance
CNR.
Trans Canada Highway
N
4000 Meters
Goobies Pond
Churchills Pond
9

Figure 2D. North Harbour River

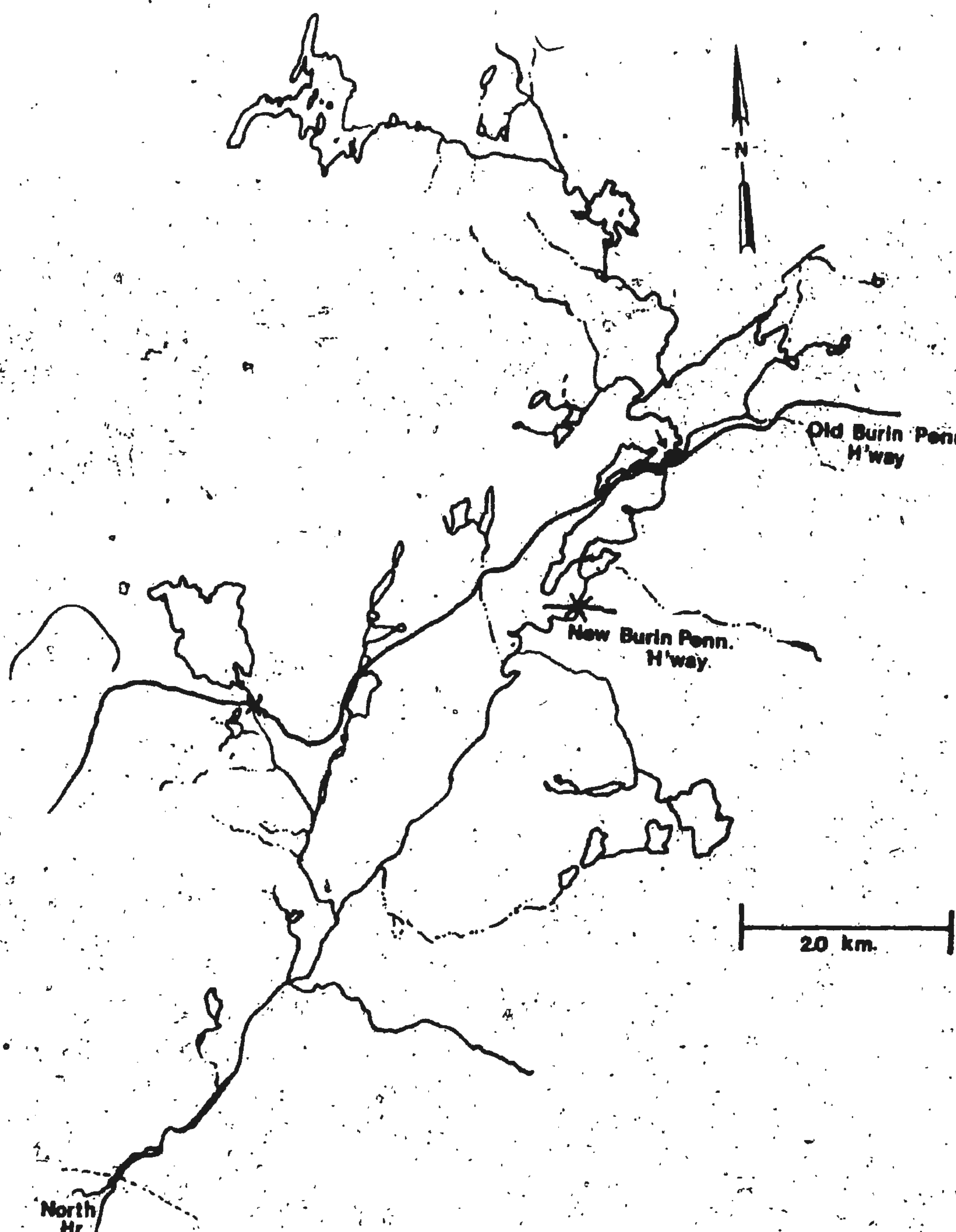

N
Old Burin Penn.
H'way
New Burin Penn.
H'way.
20 km.
North
Hr.

Figure 2E. Bay de L'eau River

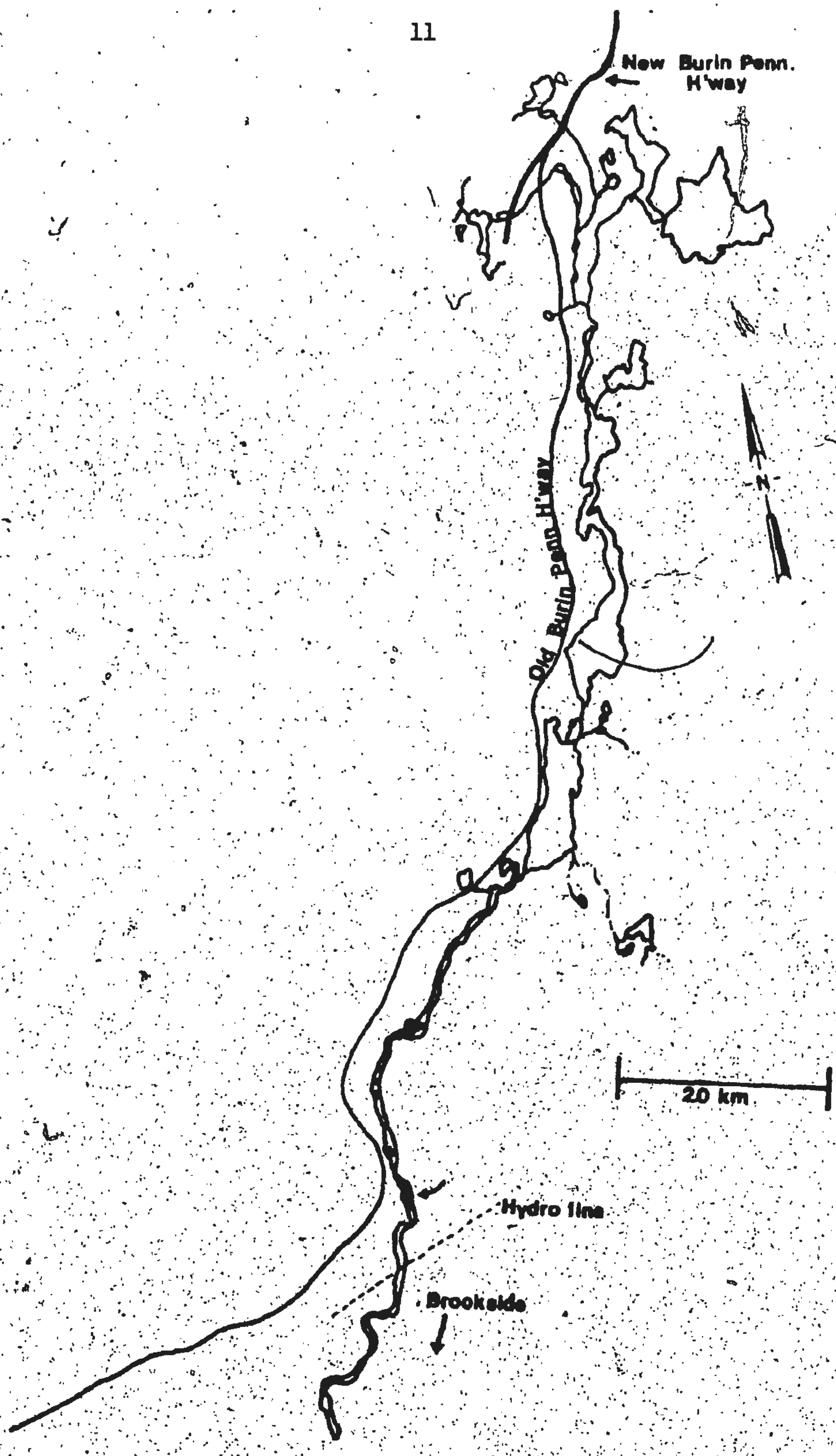
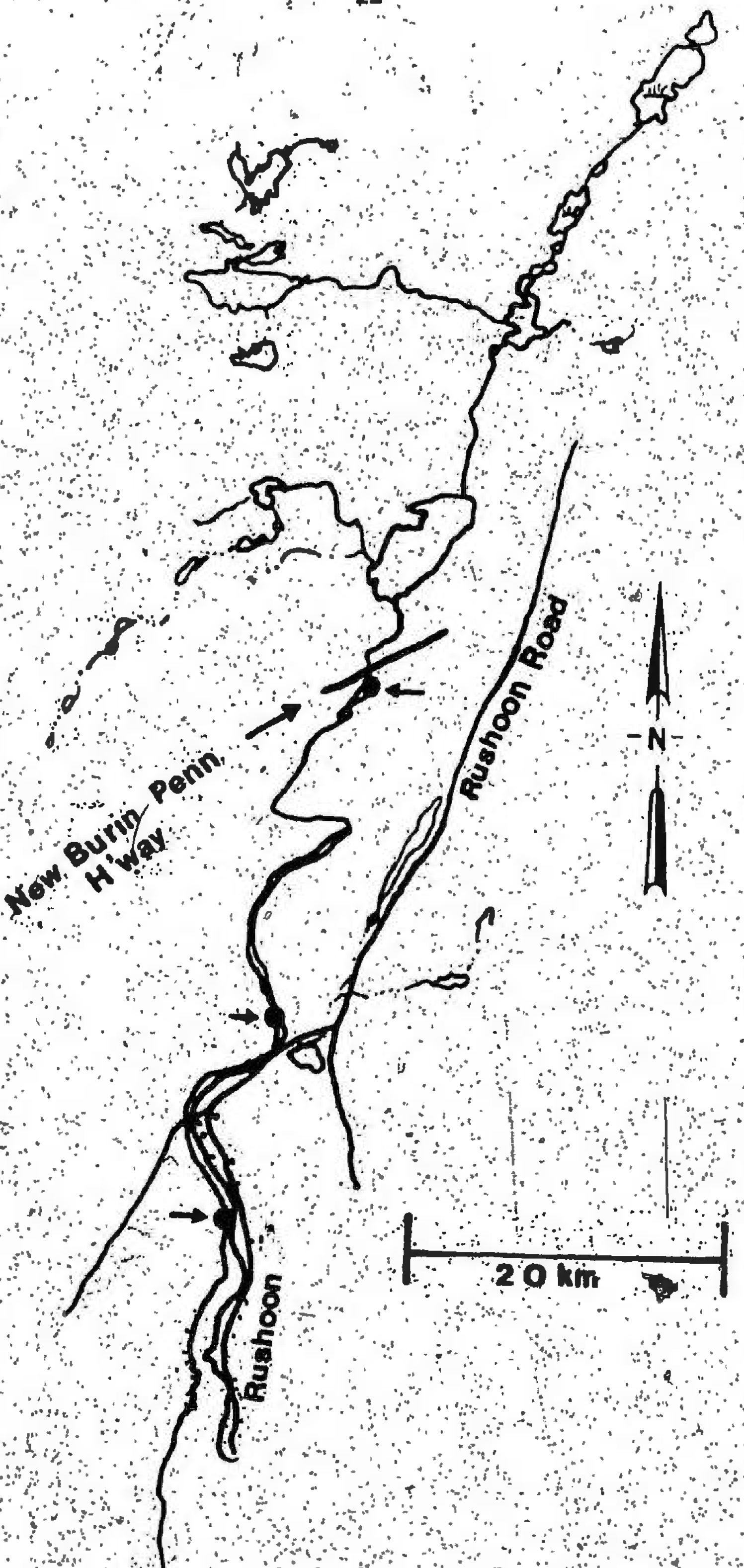

New Burin Penn.
H'way
Old Burin Penn H'way
N
20 km
Hydro line
Brookside

Figure 2F. Rushoon River

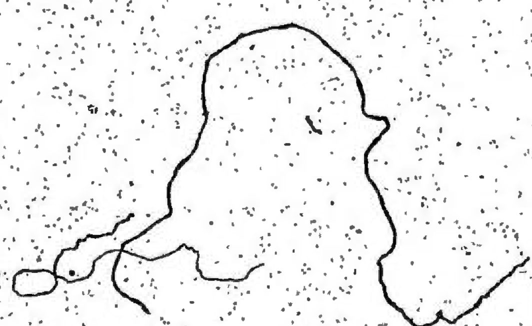


New Burin Penn. H'way
Rushoon Road
N
20 km
Rushoon

Figure 2G. Gander River


N
Salmon Pond
Gander River
Salmon R.
Glenwood
Trans Canada H'way
Gander Lake
2km

Figure 2H. Great Rattling Brook



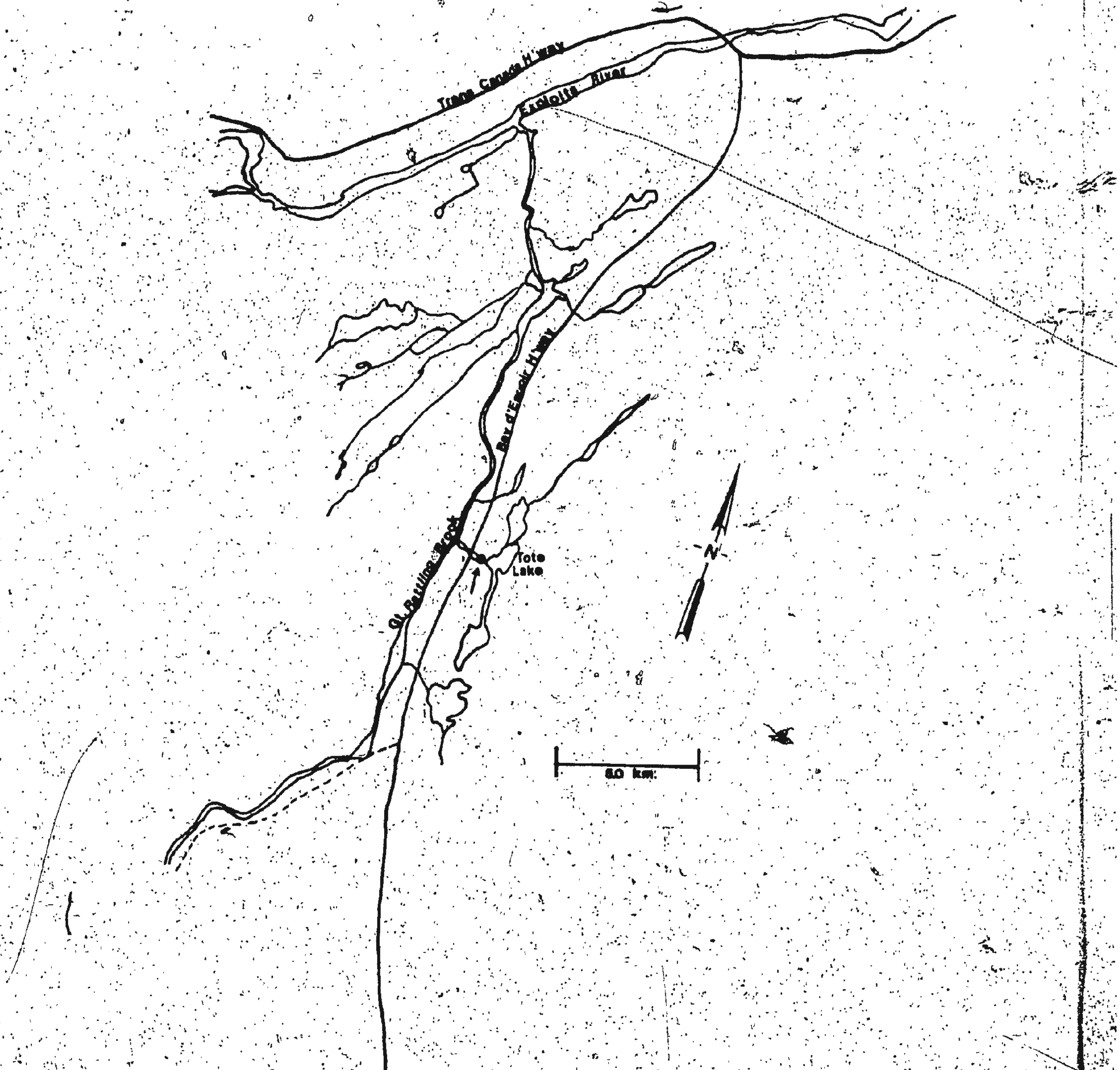

Trans Canada H'way
Exploits River
Bay d'Espoir H'way
Gt. Rattling Brook
Tote Lake
N

Figure 21. Rocky Brook, Upper Humber


20 km
N
Upper Humber River
Trans Canada Hway
Rocky Brook
Gt. Northern Penn Hway
Deer Lake

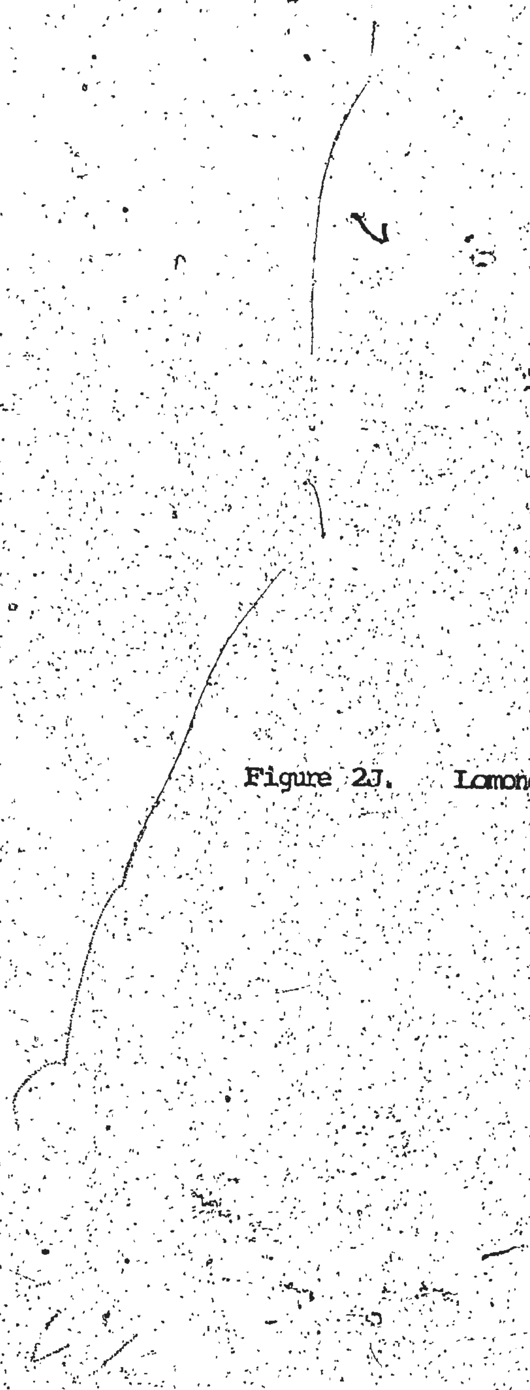
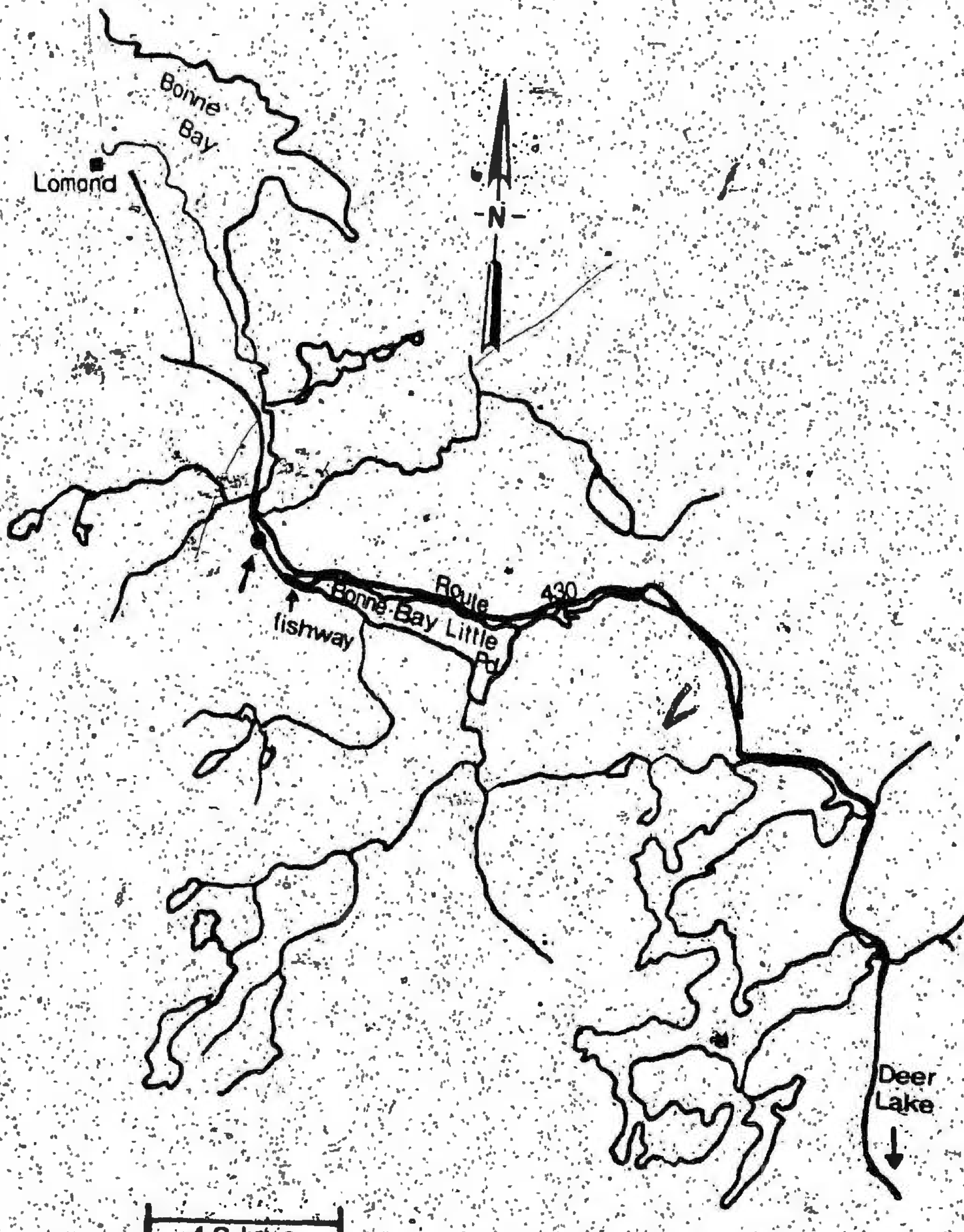


Figure 2J. Lomond River



Bonne Bay
Lomond
N
Route 430
Bonne Bay Little Pd
fishway
Deer Lake
4.0 km

METHODS AND MATERIALS

Collection of samples

Table 1 gives the locations, dates, type of gear used, and number of specimens collected. Figure 1 shows locations of the systems from which the samples were collected and Figure 2 (A-J) shows the locations, within each system, from which the samples were collected.

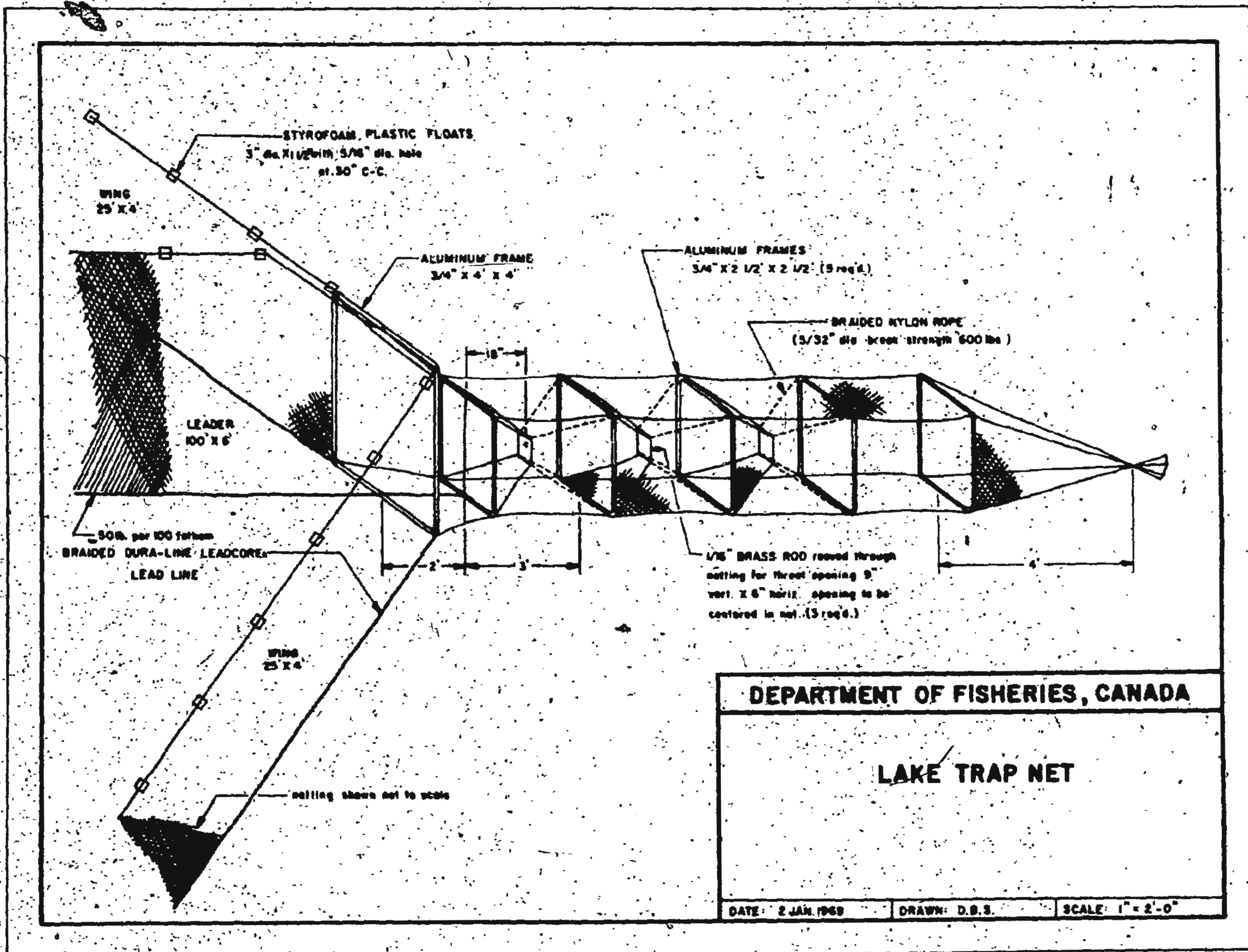
All samples of parr from rivers (except Western Arm Brook) were electrofished using a Smith Root Type V electrofisher. Those from ponds were caught in lake traps (Figure 3) set from shore, except for part of the September 1974 sample from Fitzgerald's Pond which was caught in a monofilament gillnet stretched from shore. The net consisted of three fifty yard panels, the one closest to shore of ½-inch (12.7 mm) square mesh, one of 3/4-inch (19.05 mm) square mesh and the panel furthest from shore of 1½-inch (38.1 mm) square mesh. Smolts were collected in modified lake traps with the leader and one wing tied to one side and used as barriers to ensure capture of all migrants (Figure 4). The river was blocked from shore to shore with the wings and leader forming a v-shaped barrier leading to the open mouth of the trap. The base of the barrier was rocked down to prevent passage of fish below the net, as was the main frame of the trap to prevent its movement in the current.

Table 1.

Summary of samples used in study

Location	Date	Gear	Number in sample parr	smolt
Placentia Bay				
Northeast River System, Placentia				
Fitzgerald's Pond	Sept. 10-19/74	Gillnet/Fyke Trap	201	
Fitzgerald's Pond	July 24/75	Fyke Trap	77	
Spawning ground	Nov. 6/75	Electrofisher	109	
River	May 18/76	Fyke Trap		69
Spawning ground	Nov. 13/76	Electrofisher	76	
Fitzgerald's Pond (Outlet)	May-June/77	Fyke Trap		159
Junction Pond	June 15/77	Fyke Trap	134	
Southeast River	May 11-29/77	Fyke Trap		97
Come by Chance River System				
Churchill's Pond	July 8/75	Fyke Trap	81	
Come by Chance River	October 22/75	Electrofisher	82	
North Harbour River	October 22/75	Electrofisher	66	
Rushoon River	Sept. 23-24/75	Electrofisher	105	
Bay de l'eau River	Sept. 30-Oct. 1/75	Electrofisher	74	
St. Mary's Bay				
North Harbour River	May 11-13/76	Fyke Trap		100
Salmonier River	July 1/76	Electrofisher	33	
Central				
Tote Brook	August 19/76	Electrofisher	106	
Salmon Brook	August 24/76	Electrofisher	113	
Western				
Rocky Brook	August 10/76	Electrofisher	119	
Lomond River	Aug. 11-12/76	Electrofisher	84	
Western Arm Brook	Aug. 22-24/77	Rod	54	

Figure 3. Model of lake trap nets used to capture parr.



STYROFOAM, PLASTIC FLOATS
3" dia. X 1 1/2" with 5/16" dia. hole
at 30" C-C.
WING
25' X 4'
ALUMINUM FRAME
3/4" X 4' X 4'
ALUMINUM FRAMES
3/4" X 2 1/2' X 2 1/2' (5 req'd.)
BRAIDED NYLON ROPE
(5/32" dia. break strength 600 lbs.)
18"
LEADER
100' X 6'
50lb. per 100 fathom
BRAIDED DURA-LINE LEADCORE
LEAD LINE
2'
3'
1/16" BRASS ROD reeved through netting for throat opening 9" vert. X 6" horiz. opening to be centered in net. (3 req'd.)
4'
WING
25' X 4'
netting shown not to scale
DEPARTMENT OF FISHERIES, CANADA
LAKE TRAP NET
DATE: 2 JAN. 1969
DRAWN: D.B.S.
SCALE: 1" = 2'-0"

Figure 4. Lake traps set in Northeast River, May-June, 1977 to capture migrating smolt.

Processing of samples

Samples were generally frozen (10 specimens per plastic bag) within several hours of capture and examined at a later date. Samples of smolt from Northeast River, 1977 and Southeast River were examined fresh in the field shortly after capture.

Measurements

Measurements of length from the tip of the snout to the fork of the tail were taken to the nearest millimeter. Weights in the laboratory were measured to the nearest 0.01 gram using a Mettler 1200 balance and in the field to the nearest 0.1 gram using a Model 700 Ohaus Triple Beam balance. As gutted weights were to be used in the length-weight relationships, the gonads and the gut (from the esophagus, just anterior to the liver, to the cloaca) was removed and a gutted weight was recorded. In the case of parr from the spawning ground, presence of eggs in the stomach was noted.

Determination of sex and maturity

Sex of the fish was determined by visual examination. In most cases immature females could be noted by the presence of immature ova, and immature males by having a long thin gonad with no evidence of spermatogenesis. In the case of smaller fish (< 70 mm) sex was determined by presence or absence of ova which could only be determined by examination under a stereo microscope.

Any males which had maturing gonads were considered to be precocious and maturation could be determined by enlargement of the gonad as spermatogenesis progressed. The precocity of males in the samples taken in July was not easily determined. In the July 1975 samples from Fitzgerald's Pond and Churchill's Pond, males were all placed in the immature category due to inexperience in distinguishing the earlier stages of gonadal development. However, the precocious males in the July 1976 sample from Salmonier River could be distinguished visually by a definite widening anteriorly as described by Jones (1940) which he classified as a 1+ stage of maturity. Most samples were taken later in the maturity cycle so that maturity and hence precocity could easily be judged by the size of the gonad (Figure 5). Fish were placed (except for July samples from Fitzgerald's Pond and Churchill's Pond, when all males were considered immature) into one of the following categories: 1) precocious male, 2) immature female or 3) immature male.

Two groups of gonads could be distinguished (especially in the fresh condition) in the male smolts. One type was immature while the other was spent. The spent gonads were thicker and often darker in color than the immature and usually contained remnants of sperm from the previous maturation (Figure 6). Pentelow et al. (1933), Jones and Orton (1940) and Osterdahl (1967) all described these 2 types of gonads for Atlantic salmon male smolts. Robertson (1957) described the two types as 'expressed' and 'non-expressed' for precocious male king salmon, *Oncorhynchus tshawytscha*.

Figure 5. Precocious male parr captured in September, showing development of gonads.

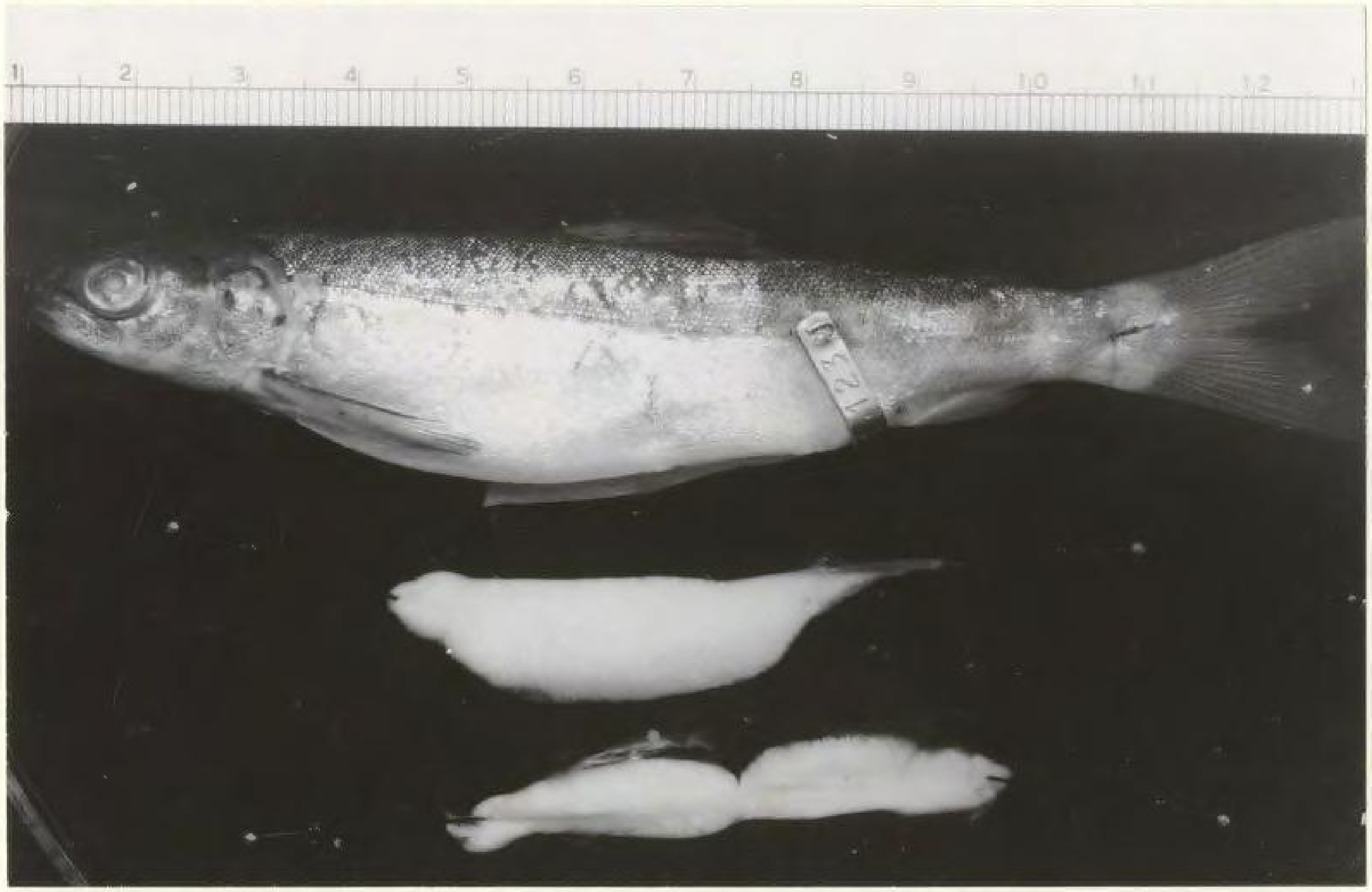

1 2 3 4 5 6 7 8 9 10 11 12

Figure 6. Gonads of spent male smolt (left) and immature male smolt (right).

Ageing

A scale sample was taken from the left side of each fish, posterior to the dorsal fin and above the lateral line. Scales were later examined under a stereo microscope and 12 to 20 of the clearest, non-regenerated scales were dry mounted between two microscope slides. Ageing was done using a Bausch and Lomb microprojector according to the annulus method validated by Havey (1959.

Scales from precocious male parr from the spawning ground were examined for the presence of spawning marks, as were the spent or resting males that were captured during the smolt run. This was done to ascertain whether precocious parr mature more than once.

Sex ratios

Sex ratios for the whole sample and for each age group in the sample were recorded and Chi-square tests were used to determine if they differed significantly from a one to one ratio.

Comparison of size (length)

In samples with sufficient numbers per group (immature female, immature male or precocious male) in one or more age groups, length comparisons were made. Where only two groups were available a Students T-Test was applied. A one-way analysis of variance was used where three groups were present and when a significant difference was found between groups, a Student Newman Keuls multiple range test (Steel and Torrie, 1960) was used to isolate the differences. T-tests and analysis of variance were done using an Olivetti-Programma 101 Desk Top Computer.

Length-weight relationships

Length-weight relationships were investigated using eviscerated weights to eliminate the effects of undigested food and enlarged gonads on the relationship. A Log-Log Regression was done using SPSS (Statistical Package for the Social Sciences) on a S/370-158 IBM computer. In the regressions Log_{10} (Length) was used as the independent variable (X) and Log_{10} (Weight) as the dependent variable (Y).

After the regression coefficients (a and b) were determined and regression formula calculated (LogW = a LogL + b), weights for each centimeter length class for each of the three groups were calculated. It is generally an unsafe procedure to predict from regression equations values of Y outside the observed ranges of X (Zar 1974). For this reason calculated weights were found only for length classes that fell within the range of actual observed lengths. This accounts for the differences in the range of lengths between groups found for some of the samples.

For each sample a 95% confidence interval was placed around each weight calculated from each regression equation. In this way the confidence limits for all the points on the regression line result in a confidence belt for the line as described by Zar (1974).

The confidence intervals of calculated weights at a given length were examined for the three groups to see if any differences existed in the calculated weights for that given length.

Marking and tagging

Some marking and tagging experiments were carried out to study the movement of precocious parr prior to spawning and their fate following it. These were undertaken in the Northeast River System in Placentia Bay. On August 5-6, 1976, 219 unsexed parr were tagged at Fitzgerald's Pond. The tags and their method of attachment were similar to the Carlin type described by Saunders (1968) except that the legend consisted of color coded ceramic beads rather than a plastic label. Electrofishing was done later, during the spawning season, to investigate movements to the spawning ground.

An investigation into the fate of precocious parr following the spawning season was done by marking 475 precocious parr on the spawning ground. These fish were electrofished and were marked by removal of the adipose fin. White and Huntsman (1938) found that when the adipose fin is shaved off close to the body there is no regeneration and a clean scar is left. The fin was severed close to the body using a pair of sharp bone cutters. The river system was checked at several places the following spring, including examination of the total smolt run at the outlet to Fitzgerald's Pond, for presence of these marked fish.

Examination of smolt run

As much as possible of the smolt run of Northeast River, Placentia was captured during the spring of 1977 in an attempt to recapture males marked on the spawning ground. This afforded an opportunity to examine the migrants and check sex ratios and differences between immature and spent males. The age structure of the spent male smolt was examined and compared with that of the typical immature smolt. Sex ratios were examined as was percentage of immature and spent male smolt, in relation to other smolt samples that were collected.

RESULTS

Distribution and extent of precocity

Precocious male parr are prevalent in the areas of Newfoundland studied (Table 2). The percent precocity of total male parr and percent precocity per age group does, however, vary from one area to another.

The overall percent precocity varied from a low of 12.3% of all male parr in Rocky Brook of the Upper Humber System to a high of 100% in Salmonier River, St. Mary's Bay and Rushoon River, Placentia Bay. The overall average percentage of precocious males among males from all samples was 72.7%. Table 2 summarizes the percent precocity in the different samples as well as within each age group.

There was also considerable variation within the same age class between areas. The percent precocity in the 1+ age group varied from 16.0% in Rocky Brook to 100% in Salmonier and Rushoon River. The next lowest to Rocky Brook was Salmon Brook with 24% of 25 males precocious. The average percentage of 1+ precocious males from all samples was 59.7%. Percent of precocious 2+ males ranged from 9.4% in Rocky Brook to 100% in Salmonier and Rushoon Rivers, with an overall average of 75.5%. In all samples except two where there were males in the 3+ age group, 100% of the males were precocious. The two exceptions were Tote Brook (72%) and Western Arm Brook (88.9%). All samples which had males in the 4+ age group exhibited 100%

Table 2

Percentage of male parr in each age group and for the whole sample that are precocious (Number in brackets are number of parr in sample).

Sample	1+	2+	3+	4+	Combined age groups
Salmonier River	100 (8)	100 (14)	100 (1)	100 (1)	100 (24)
Fitzgerald's Pond	93.8 (48)	87.5 (16)	100 (4)	-	92.6 (68)
Come by Chance River	85.7 (42)	85.7 (7)	100 (4)	-	86.8 (53)
North Harbour River (P.B.)	53.1 (32)	85.7 (7)	100 (4)	100 (1)	63.6 (44)
Bay de l'eau River	69.2 (26)	90.9 (11)	100 (3)	-	78.9 (40)
Rushoon River	100 (26)	100 (21)	100 (4)	100 (1)	100 (52)
Salmon Brook	24.0 (25)	95.7 (46)	100 (9)	100 (1)	74.1 (81)
Tote Brook	0.0 (1)	40.0 (25)	72.0 (25)	100 (3)	57.0 (54)
Rocky Brook	16.0 (25)	9.4 (32)	-	-	12.3 (57)
Lomond River	54.8 (42)	75.0 (4)	-	-	56.5 (46)
Western Arm Brook	-	62.5 (16)	88.9 (18)	100 (2)	77.8 (36)
x of all samples	59.7	75.7	95.7	100	72.7

precocity.

Sex ratios

Table 3 shows the overall sex ratios of each of the samples as well as the sex ratios of the age classes constituting the sample. While one sample (Fitzgerald's Pond, September 1974) shows a sex ratio significantly in favor of females, the other samples that have a ratio differing significantly from a one to one ratio exhibit it in favor of males. These include Junction Pond, Churchill's Pond, Come by Chance River, North Harbour River (P.B.), Salmonier River, Salmon Brook and Western Arm Brook.

The samples from Churchill's Pond, Come by Chance River and North Harbour River are represented mainly by the 1+ age group while Salmonier River and Salmon Brook have a large proportion of 2+ representatives. Junction Pond exhibited no difference in 1+ age group, but showed male dominance in the 2+, 3+ and 4+ age groups, which was highly significant in the 3+ and overall.

On October 6, 1976 a sample of 18 females and 5 mature male parr were caught in fyke traps in Fitzgerald's Pond, while fishing for other species. This confirms the sex ratio in favor of females for that time of year.

Age and size at maturity

Since the youngest age group represented in the samples was 1+, it is difficult to make any definite statement concerning maturity

Table 3

Age class and overall sex ratios of samples

Fitzgerald's Pond, September 1974

	Male	Female	x^2	Sign Diff.
1+	48	51	.09	None
2+	16	68	32.2	.001
3+	4	14	5.56	.02
TOTAL	68	133	10.51	.01

*Junction Pond, June, 1977

	Male	Female	x^2	Sign Diff.
1+	20	20	.000	None
2+	35	22	2.96	None
3+	31	3	23.06	.001
4+	3	0	3.00	None
TOTAL	89	45	14.44	.001

Come by Chance, October 1975

	Male	Female	x^2	Sign Diff.
1+	42	28	2.80	None
2+	7	0	7.00	0.01
3+	4	1	1.80	None
TOTAL	53	29	7.02	0.01

Bay de l'eau River, Sept.-Oct./75

	Male	Female	x^2	Sign Diff.
1+	26	29	0.16	None
2+	11	5	2.25	None
3+	3	0	3.00	None
TOTAL	40	34	0.49	None

Salmonier River, July 1976

	Male	Female	x^2	Sign Diff.
1+	8	1	5.44	0.02
2+	14	8	1.[illegible]4	None
3+	1	0	1.00	None
4+	1	0	1.00	None
TOTAL	24	9	6.82	0.01

Tote Brook, August 1976

	Male	Female	x^2	Sign Diff.
1+	1	5	2.67	None
2+	25	24	0.02	None
3+	25	20	0.56	None
4+	3	3	0.00	None
TOTAL	54	52	0.04	None

Lomond River, August 1976

	Male	Female	x^2	Sign Diff.
1+	42	37	0.32	None
2+	4	1	1.80	None
TOTAL	46	38	0.76	None

Fitzgerald's Pond, July 1975

	Male	Female	X^2	Sign Diff.
1+	36	35	.014	None
2+	2	2	.00	None
3+	2	-	1.0	None
TOTAL	40	37	.012	None

Churchill's Pond, July 1975

	Male	Female	X^2	Sign Diff.
1+	42	24	4.90	0.05
2+	7	3	1.60	None
3+	5	0	5.00	0.05
TOTAL	54	27	9.00	0.01

North Harbour River, October 1975

	Male	Female	X^2	Sign Diff.
1+	32	17	4.59	0.05
2+	7	5	0.33	None
3+	4	0	4.00	0.05
4+	1	0	0.50	None
TOTAL	44	22	7.33	0.01

Rushoon River, September 1975

	Male	Female	X^2	Sign Diff.
1+	26	18	1.45	None
2+	21	33	2.67	None
3+	4	2	0.67	None
4+	1	0	1.00	None
TOTAL	52	53	0.01	None

Salmon Brook, August 1976

	Male	Female	X^2	Sign Diff.
1+	25	12	4.57	0.05
2+	46	18	12.25	0.001
3+	9	2	4.45	0.05
4+	1	-	1.0	None
TOTAL	81	32	21.25	0.001

Rocky Brook, August 1976

	Male	Female	X^2	Sign Diff.
1+	25	20	0.56	None
2+	32	39	0.69	None
3+	0	3	3.00	None
TOTAL	57	62	0.21	None

Western Arm Brook, August 1976

	Male	Female	X^2	Sign Diff.
2+	16	8	2.67	None
3+	18	10	2.29	None
4+	2	0	1.00	None
TOTAL	36	18	6.00	0.02

in the first year (0+). Maturity in the second summer (1+) is a common occurrence and in certain areas (eg. Rushoon River), 100% of the 1+ males may mature. There is, however, one indication from the present study suggesting that maturation does not occur in the first year or is at least quite rare. This evidence is found in the 1+ males caught at Junction Pond in June, 1977. Of the 20 fish in this group, none had gonads which showed evidence of having matured the previous year (0+). All twenty fish had immature gonads. This is in a system (Northeast River system) where in excess of 90% of the 1+ males mature.

The average length of the males that matured at 1+ years ranged from 72.6 mm in Bay de L'eau River to 116.1 mm in Fitzgerald's Pond. The smallest precocious parr in any of the samples was 60 mm long and was taken from Come by Chance River.

Comparison of size (length)

Table 4 shows the average length of each group (immature male, immature female, or precocious male) within each of the age classes of the samples. Also shown is the value of the F-ratio, where three sex groups were compared, or the T-statistic, where only two sex groups were compared. While no definite trends are obvious, one point of note is that in all samples that had both immature and precocious males in the 1+ age class, the precocious males were, without exception, longer than the immature males. In Come by Chance River this was statistically significant ($p = 0.001$). Further

TABLE 4

Comparison of Average Lengths of the Groups for each Age Class in the Samples

Age	Immature Males	Immature Females	Precocious Males	F or T	Level of Significance
Fitzgerald's Pond, September, 1974					
1+	113.3 (3)	116.9 (51)	116.1 (45)	F = 0.1583	0.50
2+	148.5 (2)	154.0 (68)	147.1 (14)	F = 1.3879	0.50
3+	-	172.3 (14)	172.0 (4)	T = 0.0236	0.50
North East River (Smolt) May - June, 1977					
2+	-	165.0 (8)	154.0 (3)	T = 1.1838	0.50
3+	181.0 (5)	180.0 (77)	178.4 (54)	F = 0.1449	0.50
4+	-	194.0 (6)	190.4 (5)	T = 0.6254	0.50
Junction Pond, June, 1977					
1+	91.3 (20)	91.2 (20)	-	T = 0.0253	.50
2+	128.0 (4)	129.0 (22)	124.1 (31)	F = 1.7813	.50
3+	134.0 (1)	142.0 (3)	142.5 (31)	T = 0.1254	.50
4+	-	-	161.3 (3)	-	-
Come by Chance River, October, 1975					
1+	60.7 (6)	72.0 (28)	74.2 (36)	F = 8.7226	0.001
2+	106.0 (1)	-	109.2 (6)	-	-
3+	-	120.0 (1)	138.3 (4)	-	-
***Churchill's Pond, July, 1975**					
1+	79.9 (42)	80.8 (24)	-	T = 0.4563	.50
2+	116.3 (8)	112.3 (3)	-	T = 0.5891	.50
3+	146.0 (5)	-	-	-	-
North Harbour River (P.B.), October, 1975					
1+	80.9 (15)	84.2 (17)	87.4 (17)	F = 1.5919	.50
2+	125.0 (1)	105.8 (5)	110.8 (6)	T = .5488	.50
3+	-	-	147.0 (4)	-	-
4+	-	-	162.0 (1)	-	-
Bay de L'eau River, October, 1975					
1+	70.6 (7)	74.0 (28)	72.6 (17)	F = 1.2437	0.50
2+	99.0 (1)	87.6 (5)	102.3 (10)	T = 1.5211	0.20
3+	-	-	125 (03)	-	-

continued on next page ....

TABLE 4 - continued

Age	Immature Males	Immature Females	Precocious Males	F or T	Level of Significance
Rushoon River, September, 1975					
1+	-	100.2 (18)	95.2 (26)	T = 2.9632	0.01
2+	-	107.2 (33)	109.3 (21)	T = 0.5895	0.50
3+	-	152.5 (2)	148.5 (4)	T = .7604	0.50
4+	-	-	163 (1)	-	-
Salmon Brook, August, 1976					
1+	72.8 (19)	73.2 (12)	76.8 (6)	F = 1.7012	0.50
2+	104.5 (2)	102.6 (18)	99.9 (44)	F = 1.3751	0.50
3+	-	130.0 (2)	126.1 (9)	T = 1.0839	0.50
4+	-	-	158.0 (1)	-	-
Tote Brook, August, 1976					
1+	63.0 (1)	62.5 (5)	-	-	-
2+	84.3 (15)	81.2 (24)	84.5 (10)	F = 0.9214	0.50
3+	109.4 (7)	114.3 (20)	109.8 (18)	F = 0.4840	0.50
4+	-	137.7 (3)	137.7 (3)	T = 0.0000	0.50
Rocky Brook, August, 1976					
1+	87.8 (21)	81.7 (20)	91.3 (4)	F = 2.2622	0.50
2+	103.4 (29)	104.5 (39)	112.3 (3)	F = 0.6820	0.50
3+	-	117.5 (3)	-	-	-
Lomond River, August, 1976					
1+	70.9 (19)	72.9 (37)	73.9 (23)	F = 1.1731	0.50
2+	118.0 (1)	117.0 (1)	101.7 (3)	-	-
Western Arm Brook, August, 1977					
2+	104.2 (6)	122.6 (8)	113.8 (10)	F = 2.4168	0.50
3+	149.0 (2)	151.6 (10)	139.2 (16)	F = 1.5655	0.50
4+	-	-	197.0 (2)	-	-

examination with the Student Newman Keuls test showed that the precocious males and the immature females were both significantly longer ($p = 0.001$) than the immature males. There was no significant difference between the precocious males and the immature females. The mean length of all males combined was 72.3 mm as compared with 72.0 mm for the females.

It can also be seen by the 2+ age class that this difference no longer exists and in the majority of cases the immature males are now longer than the precocious males. Sample sizes in the 3+ age groups are generally too small and inconsistent to discern any trends. Tote Brook was the only sample with sufficient numbers in the 3 groups to compare lengths at 3+. Here there was no significant difference between any of the groups.

The only other test that showed a significant difference between groups was that for 1+ immature females and precocious males from Rushoon River. Here the females were significantly longer ($p = 0.01$) than the precocious males. By age 2+ this difference does not exist and the precocious males are slightly, although not significantly, longer than females.

Length-weight relationships

Table 5 summarizes the results of the linear regression analysis of Log_{10}(Gutted weight, W(gm.)) on Log_{10}(Length, L(cm)) for the three groups in the different samples. Shown for each regression are the slope a, intercept b, correlation coefficient R, and the standard

TABLE 5

Results of Linear Regression Analysis
of Log_{10} (Gutted Weight) on
Log_{10} (Length) for the
Sexes in the
Samples

Sex	Number	Slope (a)	Intercept (b)	R	S.E.
Fitzgerald's Pond, September, 1974					
M (P)	63	3.190	- 2.205	0.980	.0465
F (Imm)	133	3.190	- 2.211	0.987	.0404
M (Imm)	5	3.517	- 2.568	0.982	.0691
Fitzgerald's Pond, July, 1975					
M	40	3.179	- 2.182	0.961	0.0548
F	37	3.432	- 2.430	0.980	0.0363
North East River (Smolt), May - June, 1977					
M (P)	63	2.746	- 1.812	0.940	0.0460
F (Imm)	91	3.056	- 2.172	0.979	0.0282
M (Imm)	5	2.396	- 1.343	0.993	0.0147
Junction Pond, June, 1977					
M (P)	64	3.102	- 2.130	0.952	0.0434
F (Imm)	45	2.919	- 1.923	0.994	0.0263
M (Imm)	25	2.798	- 1.803	0.990	0.0283
Come by Chance River, October, 1975					
M (P)	46	3.195	- 2.244	0.993	0.0385
F (Imm)	29	3.453	- 2.462	0.958	0.0584
M (Imm)	7	3.306	- 2.320	0.995	0.0400
North Harbour River, October, 1975					
M (P)	28	2.985	- 2.035	0.989	0.0455
F (Imm)	22	3.178	- 2.211	0.983	0.0441
M (Imm)	16	2.979	- 2.002	0.984	0.0501
Bay de L'eau River, September - October, 1975					
M (P)	31	2.725	- 1.759	0.995	0.0270
F (Imm)	34	2.954	- 1.964	0.931	0.0549
M (Imm)	9	2.998	- 2.009	0.996	0.0199

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TABLE 5 - continued

Sex	Number	Slope (a)	Intercept (b)	R	S.E.
Rushoon River, September, 1975					
M (P)	52	2.883	- 1.826	0.984	0.0383
F (Imm)	53	2.709	- 1.658	0.931	0.0551
Salmon Brook, August, 1976					
M (P)	60	3.020	- 1.971	0.989	0.0287
F (Imm)	32	3.092	- 2.061	0.995	0.0252
M (Imm)	21	3.122	- 2.077	0.990	0.0239
Tote Brook, August, 1976					
M (P)	31	3.221	- 2.157	0.994	0.0286
F (Imm)	52	3.140	- 2.091	0.990	0.0483
M (Imm)	23	3.214	- 2.156	0.995	0.0279
Rocky Brook, Upper Humber, August, 1976					
M (P)	7	2.990	- 1.922	0.986	0.0329
F (Imm)	62	2.819	- 1.782	0.964	0.0581
M (Imm)	50	2.842	- 1.796	0.959	0.0551
Lomond River, August, 1976					
M (P)	26	3.130	- 2.079	0.992	0.0231
F (Imm)	38	3.153	- 2.103	0.990	0.0214
M (Imm)	20	3.273	- 2.205	0.993	0.0253

error of estimate S.E. for the prediction equation. Examination of the slopes of the different groups indicate that neither group has a consistently higher or lower slope than the others. The same is true of the intercept values.

The relationship between length and weight can be more meaningfully compared by finding the calculated weights for each of the length classes in each of the sexes (using the formula Log W = a Log L + b). To examine more thoroughly any differences in weight at a given length, 95% confidence limits are placed around each of the calculated weights so that a 95% confidence belt was formed for each length-weight regression line. By considering the confidence belts, any differences that occur as a result of small sample size (eg. Fitzgerald's Pond, September 1974) will be accounted for. Also taken into account are the standard errors of the prediction equations under consideration, since the confidence interval is dependent on both the sample size and the standard error of the prediction equation. By examination of the confidence intervals, comparisons become more meaningful and differences in weights at given lengths that have no overlap of intervals take on more significance.

Table 6(A-L) shows the weight(gm.) of the length classes(cm.) in each group for the samples, calculated using the formula obtained from the regression analysis. Also shown in the table are the 95% confidence limits around each calculated weight. L_1 indicates the lower limit, L_2 the upper limit. It can be seen from the tables that in most of the samples there is a considerable overlap of confidence

TABLE 6A

Calculated Gutted Weights with 95% Confidence Limits for

Fitzgerald's Pond, September, 1974

Length	♂ P L1	♂ P Weight	♂ P L2	♀ imm L1	♀ imm Weight	♀ imm L2	♂ imm L1	♂ imm Weight	♂ imm L2
8.5				5.41	5.67	5.95			
9.5	7.78	8.20	8.65	7.79	8.09	8.40	4.89	7.42	11.26
10.5	10.85	11.29	11.74	10.80	11.14	11.48	7.68	10.55	14.51
11.5	14.64	15.09	15.55	14.53	14.88	15.24	11.31	14.54	18.69
12.5	19.16	19.68	20.23	19.05	19.41	19.77	15.54	19.49	24.44
13.5	24.42	25.16	25.92	24.41	24.81	25.22	20.00	25.55	32.63
14.5	30.47	31.61	32.80	30.68	31.18	31.70	24.56	32.86	43.94
15.5	37.37	39.09	40.90	37.84	38.56	39.28	29.25	41.53	58.94
16.5	45.23	47.73	50.37	46.06	47.08	48.12			
17.5	54.08	57.57	61.29	55.32	56.78	58.28			
18.5	64.06	68.77	73.82	65.81	67.82	69.90			
19.5	75.11	81.30	88.00						
20.5	87.46	95.41	104.09						

TABLE 6B

Calculated Gutted Weights with 95% Confidence Limits for

Fitzgerald's Pond, July, 1975

	♂			♀		
Length	L1	Weight	L2	L1	Weight	L2
7.5	3.59	3.98	4.42	3.48	3.74	4.03
8.5	5.52	5.92	6.34	5.49	5.75	6.02
9.5	8.04	8.44	8.85	8.18	8.42	8.68
10.5	11.14	11.60	12.08	11.51	11.88	12.26
11.5	14.71	15.49	16.30	15.51	16.23	16.99
12.5	18.83	20.18	21.64	20.30	21.61	23.00
13.5	23.58	25.78	28.18			
14.5	29.03	32.37	36.08			
15.5	35.21	39.99	45.43			

TABLE 6C

Calculated Gutted Weights with 95% Confidence Limits for

North East River Smolt, May - June, 1977

		♂ p			♀ imm			♂ imm	
Length	L1	Weight	L2	L1	Weight	L2	L1	Weight	L2
13.5	18.13	19.58	21.13						
14.5	22.46	23.83	25.29	23.09	23.83	24.60			
15.5	27.35	28.62	29.94	28.53	29.21	29.92	29.40	32.28	35.46
16.5	32.86	33.99	35.15	34.76	35.38	36.00	35.06	37.51	40.12
17.5	38.84	39.93	41.05	41.74	42.33	42.91	41.04	43.17	45.42
18.5	45.20	46.53	47.90	49.48	50.19	50.91	46.95	49.34	51.86
19.5	51.84	53.74	55.71	57.88	58.91	59.97	52.49	55.95	59.63
20.5	58.94	61.69	64.57	67.14	68.69	70.27			
21.5	66.47	70.28	74.30	77.18	79.40	81.68			
22.5	74.52	79.64	85.09	88.17	91.26	94.45			
23.5	83.10	89.74	96.92	100.18	104.3	108.49			

TABLE 6D

Calculated Gutted Weights with 95% Confidence Limits for

Junction Pond, June, 1977

Length	L1	♂p Weight	L2	L1	♀ imm Weight	L2	L1	♂ imm Weight	L2
7.5							4.19	4.42	4.67
8.5				5.98	6.17	6.36	6.05	6.27	6.50
9.5				8.33	8.53	8.73	8.33	8.56	8.80
10.5	10.22	10.91	11.64	11.22	11.42	11.64	11.00	11.33	11.67
11.5	13.83	14.46	15.13	14.63	14.90	15.18	14.05	14.62	15.20
12.5	18.19	18.74	19.29	18.60	19.01	19.42	17.55	18.45	19.41
13.5	23.18	23.78	24.39	23.16	23.79	24.42	21.50	22.89	24.36
14.5	28.74	29.70	30.68	28.41	29.32	30.26			
15.5	34.87	36.51	38.20	34.31	35.60	36.95			
16.5	41.77	44.33	47.04						

TABLE 6E

Calculated Gutted Weights with 95% Confidence Limits for

Come by Chance River, October, 1975

		♂ p			♀ imm			♂ imm	
Length	L1	Weight	L2	L1	Weight	L2	L1	Weight	L2
5.5							1.20	1.34	1.47
6.5	2.17	2.26	2.34	2.06	2.21	2.37	2.13	2.33	2.55
7.5	3.46	3.56	3.67	3.44	3.63	3.82	3.37	3.74	4.15
8.5	5.17	5.31	5.46	5.15	5.59	6.05	4.94	5.66	6.48
9.5	7.35	7.58	7.83	7.29	8.20	9.24	6.89	8.17	9.69
10.5	10.04	10.44	10.85	9.92	11.59	13.55	9.28	11.38	[illegible].95
11.5	13.32	13.96	14.63	13.11	15.87	19.22			
12.5	17.24	18.22	19.26	16.92	21.16	26.48			
13.5	21.87	23.30	24.81						
14.5	27.30	29.29	31.43						
15.5	33.50	36.22	39.17						

TABLE 6F

Calculated Gutted Weights with 95% Confidence Limits for

North Harbour River (P.B.), October, 1975

		♂ P			♀ imm			♂ imm	
Length	L1	Weight	L2	L1	Weight	L2	L1	Weight	L2
5.5				1.21	1.39	1.60	1.39	1.60	1.83
6.5				2.14	2.36	2.60	2.38	2.62	2.89
7.5	3.53	3.78	4.04	3.48	3.72	3.96	3.75	4.02	4.30
8.5	5.21	5.49	5.78	5.28	5.53	5.79	5.48	5.83	6.21
9.5	7.33	7.65	7.97	7.49	7.87	8.27	7.52	8.12	8.77
10.5	9.89	10.31	10.74	10.13	10.82	11.57	9.91	10.94	12.08
11.5	12.90	13.53	14.18	13.25	14.45	15.77	12.69	14.35	16.22
12.5	16.39	17.35	18.35	16.91	18.83	20.97	15.90	18.39	21.28
13.5	20.40	21.82	23.34						
14.5	25.01	27.03	29.21						
15.5	30.17	32.96	36.01						

TABLE 6G

Calculated Gutted Weights with 95% Confidence Limits for

Bay de L'eau River, September, 1975

	♂P			♀ imm			♂ imm		
Length	L1	Weight	L2	L1	Weight	L2	L1	Weight	L2
5.5							1.51	1.62	1.75
6.5	2.76	2.86	2.97	2.54	2.74	2.95	2.56	2.68	2.80
7.5	4.11	4.22	4.34	4.00	4.18	4.37	3.97	4.12	4.27
8.5	5.80	5.94	6.07	5.66	6.05	6.46	5.70	5.99	6.30
9.5	7.84	8.04	8.25	7.56	8.40	9.33	7.79	8.36	8.97
10.5	10.23	10.56	10.91	9.78	11.29	13.03	10.31	11.29	12.36
11.5	13.01	13.53	14.08	12.33	14.77	17.68			
12.5	16.20	16.99	17.81	15.25	18.89	23.39			
13.5	19.84	20.95	22.11						

TABLE 6H

Calculated Gutted Weights with 95% Confidence Limits for

Rushoon River, September - October, 1975

		♂ ρ			♀ imm	
Length	L1	Weight	L2	L1	Weight	L2
8.5	6.86	7.14	7.43	6.72	7.24	7.79
9.5	9.55	9.83	10.12	9.33	9.79	10.26
10.5	12.81	13.13	13.45	12.39	12.84	13.30
11.5	16.58	17.06	17.55	15.73	16.42	17.16
12.5	20.93	21.70	22.50	19.36	20.58	21.88
13.5	25.89	27.08	28.33	23.38	25.35	27.49
14.5	31.53	33.29	35.14	27.84	30.78	34.03
15.5	37.85	40.33	42.96	32.71	36.86	41.52

TABLE 61

Calculated Gutted Weights with 95% Confidence Limits for

Salmon Brook, Gander River, August, 1976

		♂ P			♀ imm			♂ imm	
Length	L1	Cal. Wgt.	L2	L1	Cal. Wgt.	L2	L1	Cal. Wgt.	L2
6.5	2.89	3.05	3.21	2.72	2.83	2.96	2.78	2.89	3.01
7.5	4.52	4.70	4.88	4.28	4.41	4.55	4.41	4.52	4.63
8.5	6.67	6.85	7.03	6.35	6.50	6.65	6.44	6.68	6.92
9.5	9.41	9.59	9.77	8.97	9.16	9.36	8.94	9.45	9.98
10.5	12.75	12.97	13.20	12.18	12.49	12.81	11.99	12.92	13.91
11.5	16.70	17.07	17.45	16.02	16.55	17.09	15.65	17.16	18.81
12.5	21.32	21.96	22.62	20.58	21.41	22.27			
13.5	26.70	27.70	28.74	25.92	27.16	28.45			

TABLE 6J

Calculated Gutted Weights with 95% Confidence Limits for

Tote Brook, Great Rattling Brook, August, 1976

	♂ p			♀ imm			♂ imm		
Length	L1	Weight	L2	L1	Weight	L2	L1	Weight	L2
5.5				1.59	1.71	1.84			
6.5				2.74	2.89	3.06	2.71	2.86	3.02
7.5				4.35	4.54	4.73	4.37	4.54	4.71
8.5	6.63	6.86	7.11	6.50	6.72	6.94	6.59	6.78	6.98
9.5	9.57	9.82	10.08	9.24	9.53	9.83	9.41	9.69	9.98
10.5	13.23	13.56	13.90	12.60	13.05	13.52	12.89	13.37	13.87
11.5	17.66	18.19	18.71	16.65	17.36	18.10	17.10	17.91	18.76
12.5	22.93	23.77	24.65	21.47	22.56	23.70	22.11	23.41	24.79
13.5	29.14	30.46	31.83	27.11	28.71	30.41			
14.5	36.39	38.36	40.44	33.67	35.96	38.40			
15.5				41.19	44.31	47.67			

TABLE 6K

Calculated Gutted Weights with 95% Confidence Limits for

Rocky Brook, Upper Humber, August, 1976

	♂ p			♀ imm			♂ imm		
Length	L1	Weight	L2	L1	Weight	L2	L1	Weight	L2
6.5				2.97	3.23	3.52	2.96	3.27	3.61
7.5				4.56	4.84	5.14	4.58	4.91	5.26
8.5	6.41	7.19	8.07	6.60	6.89	7.18	6.69	7.00	7.34
9.5	9.28	10.03	10.84	9.11	9.42	9.75	9.27	9.61	9.96
10.5	12.49	13.53	14.66	12.03	12.50	12.98	12.24	12.77	13.33
11.5	15.91	17.76	19.83	15.37	16.15	16.96	15.62	16.54	17.51
12.5	19.65	22.79	26.42	19.20	20.43	21.74	19.47	20.96	22.56
13.5				23.52	25.37	27.36			

TABLE 6L

Calculated Gutted Weights with 95% Confidence Limits for

Lomond River, August, 1976

		♂P			♀ imm			♂ imm	
Length	L1	Weight	L2	L1	Weight	L2	L1	Weight	L2
6.5	2.82	2.92	3.02	2.82	2.88	2.95	2.76	2.85	2.95
7.5	4.47	4.57	4.67	4.46	4.53	4.61	4.44	4.56	4.69
8.5	6.57	6.76	6.95	6.55	6.72	6.90	6.59	6.87	7.16
9.5	9.07	9.58	10.14	9.17	9.54	9.93	9.32	9.89	10.48
10.5	12.20	13.10	14.07	12.40	13.09	13.80	12.72	13.72	14.80
11.5				16.31	17.43	18.63	16.85	18.48	20.27

intervals, indicating that the small differences in the weights are not really clear-cut or significant. One sample, however, which does not show overlap of the confidence belts was that of the smolt from Northeast River, 1977 (Figure 7). While the sample of immature males was small, had a limited length range and exhibited much overlap of confidence limits with the other two groups, the precocious males and the immature females showed overlap of confidence belts only in the shorter length classes. Except for the 145 mm length class (the shortest) in which the weights were equal, the immature females were always heavier for a given length class than the precocious males. In the length classes from 175 mm to 235 mm, there was no overlap in the confidence limits placed on the weights, with the females always heavier or of better condition relative to that of the precocious or spent male smolt. The average condition factor ($W \times 10^5/L^3$) for all the length groups represented by the female smolt was 0.79 while that for the precocious males was 0.74. The average condition factor for the immature males was 0.81 but the sample consisted only of five specimens.

Although a difference in weights was evident in the higher length classes of the precocious male smolt and immature female smolt, there was no significant difference in the weights at any lengths for any of the groups that remained in freshwater of the same system (Junction Pond) just following the smolt run in June (Figure 8). Figures 8 and 9 are indicative of how graphical representation of the confidence belts for the other parr samples would appear. The average

Figure 7. 95% confidence belts for length-weight regression lines of smolt from Northeast River.

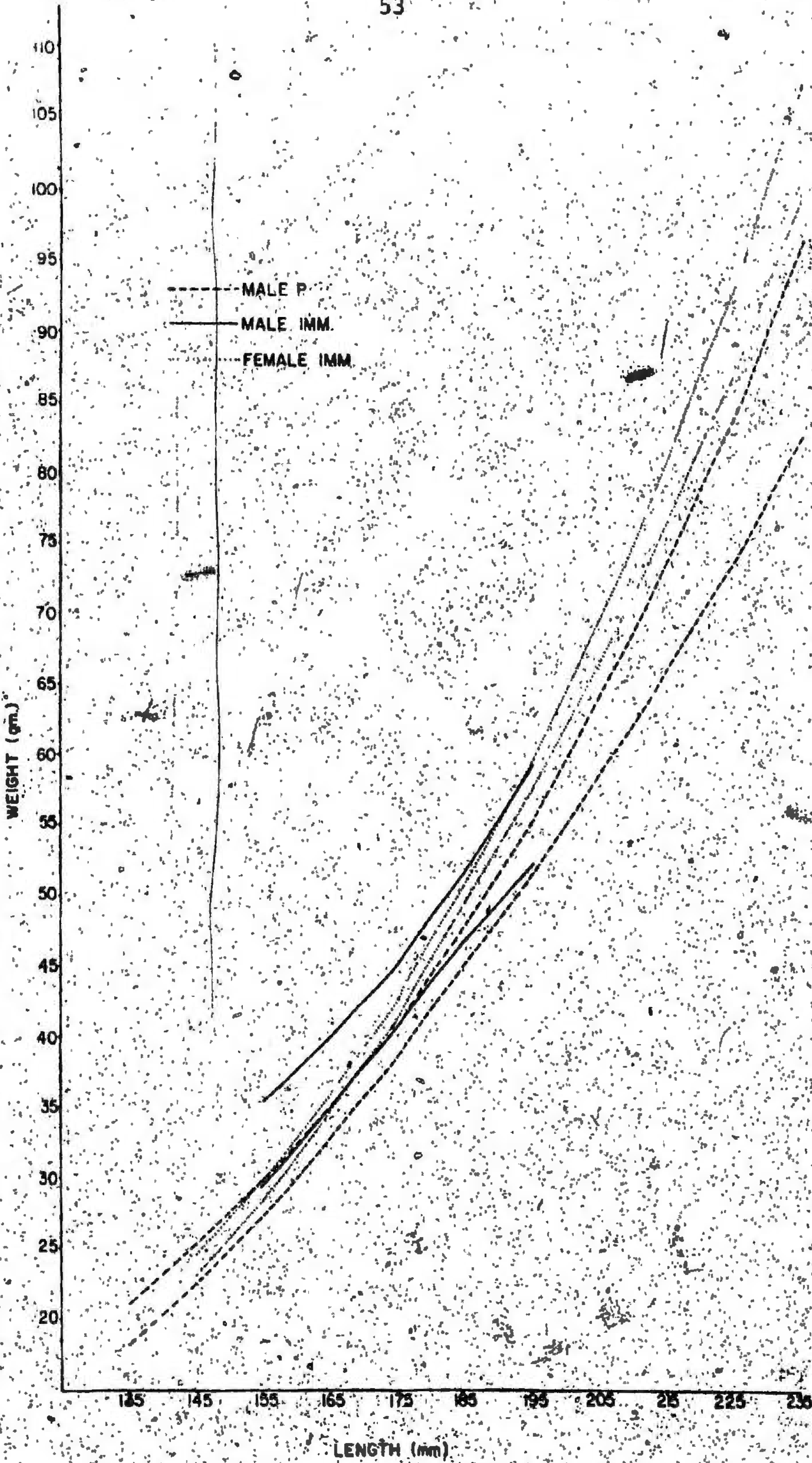

MALE P
MALE IMM.
FEMALE IMM.
WEIGHT (gm.)
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
135
145
155
165
175
185
195
205
215
225
235
LENGTH (mm)

Figure 8. 95% confidence belts for length-weight regression lines of parr, Junction Pond, Northeast River System.

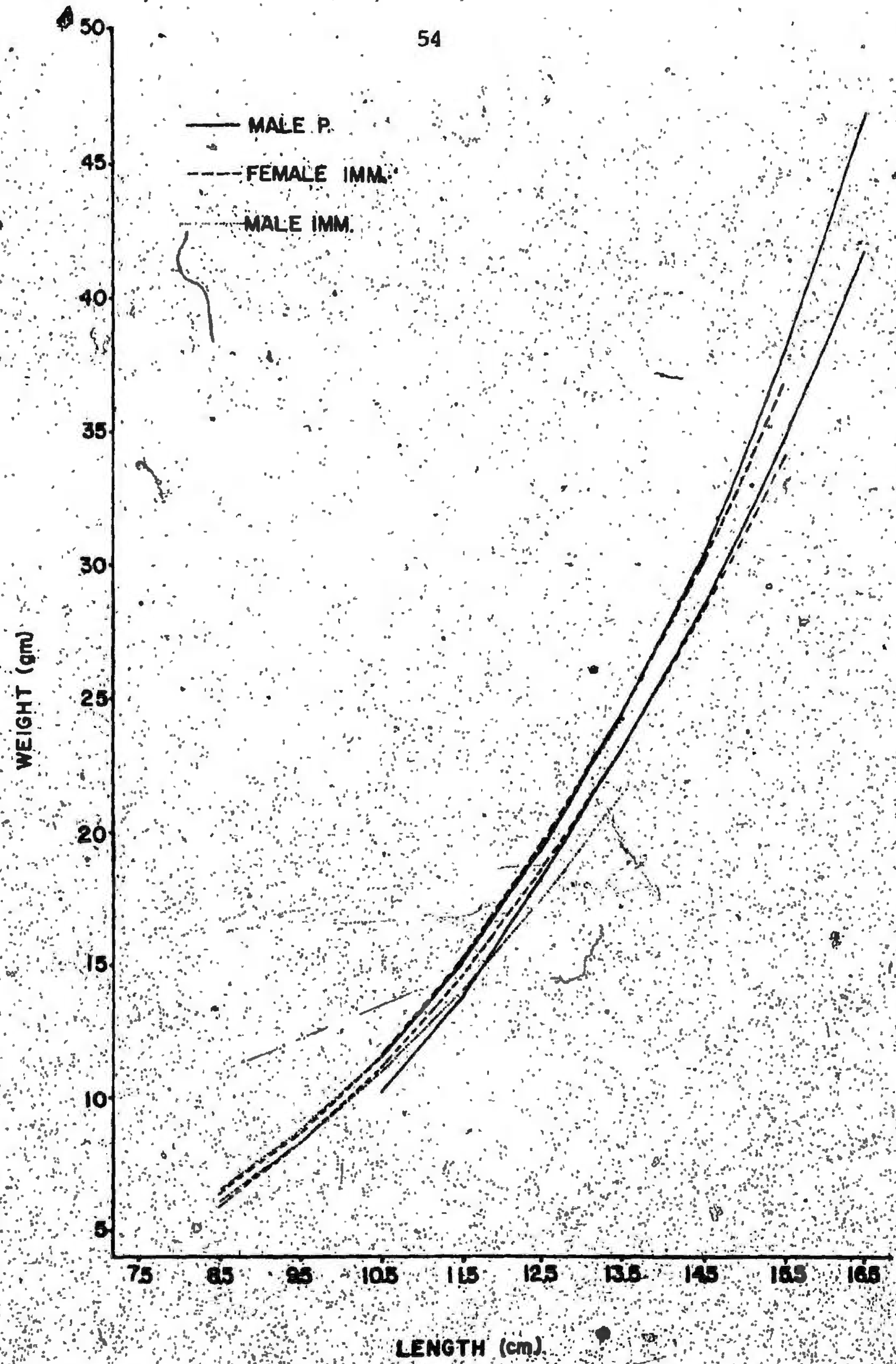
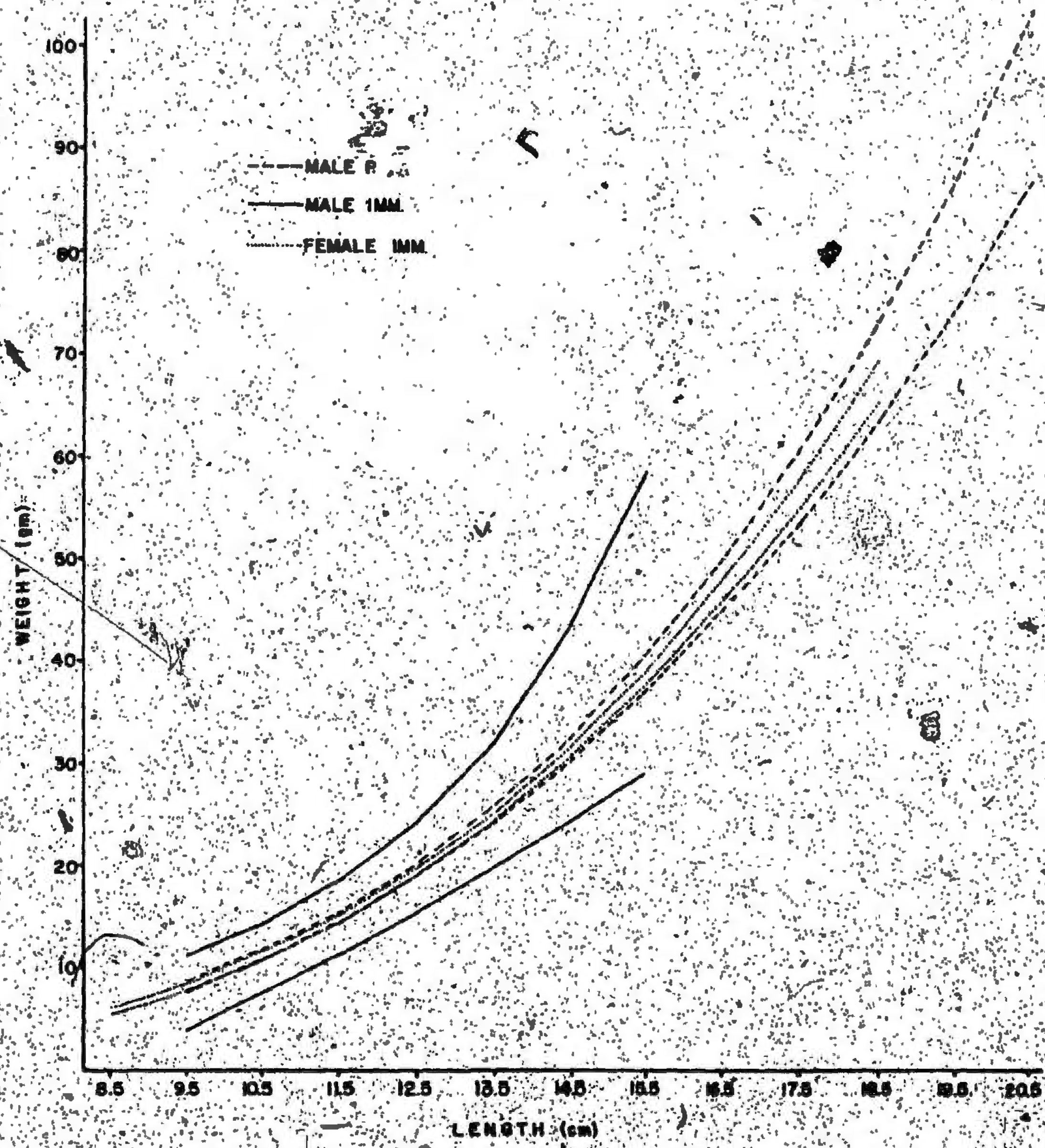

MALE P.
FEMALE IMM.
MALE IMM.
WEIGHT (gm)
50
45
40
35
30
25
20
15
10
5
7.5
8.5
9.5
10.5
11.5
12.5
13.5
14.5
15.5
16.5
LENGTH (cm)

Figure 9. 95% confidence belts for length-weight regression lines of parr, Fitzgerald's Pond, Northeast River System.


MALE R
MALE IMM.
FEMALE IMM.
WEIGHT (gm)
100
90
80
70
60
50
40
30
20
10
8.5
9.5
10.5
11.5
12.5
13.5
14.5
15.5
16.5
17.5
18.5
19.5
20.5
LENGTH (cm)

condition factors for the groups in Junction Pond were precocious (spent) males 0.97, immature males 0.99 and immature females 0.98. The difference in the range of lengths used for the smolt and for the parr that remained in freshwater should be noted in this regard. Smolt length classes ranged from 135 mm to 235 mm while the parr ranged from 85 mm to 165 mm. The only length groups represented in both samples are from 135 mm to 165 mm; these show less difference in the weights of the spent male and immature female smolts than do the longer length groups. This does not, however, take away from the fact that of all the samples compared it was only the smolt sample in which the confidence interval did not overlap. It does implicate larger size, as well as smoltfication, in the difference.

The September, 1974 sample from Fitzgerald's Pond adds evidence to this. In this sample the lengths of both precocious males and females ranged up to 185 mm. As Figure 9 illustrates, up to these lengths, in Fitzgerald's Pond, there is no difference in the weights of the two sexes for corresponding lengths. The confidence limits of the precocious males almost entirely enclose those of the females. In the smolt sample there was no overlap in the confidence intervals above the 165 mm length class. The sample of immature male parr from Fitzgerald's Pond was also small so that no meaningful comparisons could be made with this group.

Tagging and marking

The tagging program yielded limited results on the movement of precocious parr to the spawning ground. Several fish were captured near the place of marking later the same summer and were again released. Three of the 219 tagged fish were recaptured outside Fitzgerald's Pond. Two (1 immature female and 1 immature male) were recaptured in the smolt run the following spring and one was recaptured at Junction Pond just below the spawning ground the following spring. This specimen was a spent male which had moved approximately 8 km upstream from the place of tagging.

Seventeen of the 475 mature parr marked by adipose fin clipping on the spawning ground were recaptured the following spring. Twelve were caught as smolts in fyke traps below Fitzgerald's Pond during May 1977; four were recaptured in Junction Pond from June 15-17, 1977 following the smolt run. The other was electrofished on June 16 on the spawning ground where it had originally been marked. This was the only fish of any sex that was electrofished from the spawning ground at this time.

Observations on the spawning ground, Northeast River

Observations were made prior to and during the spawning season of 1976. The same section of river was electrofished at fairly regular intervals from October 13 to November 17 using approximately the same amount of fishing effort each time. In this way the relative number of fish in the area could be judged by the frequency with which they were encountered by the electric field. Although male parr were frequently encountered on October 13 there was an increase in numbers up to November 10, which appeared to be the peak of spawning activity. On November 13 there were fewer parr encountered than on the tenth and on November 17 there were even fewer. The greatest concentration of parr on the spawning ground was from approximately October 23 to November 13. No adults or redds were observed on October 23 but by November 3 many redds were present and on this date three female adult salmon were encountered while electrofishing. November 10 appeared to be near the peak of spawning activity and 14 adult salmon were encountered (12 females, 2 males). On November 13 only two adult females were encountered. Around each of the adult females that were encountered were numerous precocious males (15-25). The relative frequency of parr near the adult males was not noted.

A sample of precocious males was collected from the spawning ground during the fall of 1975 and 1976. The age structure of these samples is shown in Table 7.

Table 7

Age structure of precocious males taken from the spawning ground

Age	Year 1975	Year 1976	Mean
1+	30.3 (33)*	7.9 (6)	19.1
2+	45.9 (50)	64.5 (49)	55.2
3+	21.1 (23)	21.1 (16)	21.1
4+	2.8 (3)	3.9 (3)	3.4
5+		2.6 (2)	1.3

*Numbers in brackets signify actual number in sample.

It can be seen that over 75% of the males on the spawning ground are 2+ or 3+ years with the 1+ being the next most frequent age group. The average of the two years indicates that less than 5% of the males on the spawning ground are older than 3+.

Of 111[1] parr taken randomly from the spawning ground in 1975, only two were females and in the sample of 76 taken in 1976, none was female. The 1976 sample taken on November 13 indicates that no immature female parr were in the area. However, earlier, on October 20, when parr were being electrofished and marked, 7 out of 100 parr caught were females. There were no indications of female parr on the spawning ground on November 17 nor was there on June 17 the following spring, 1977.

From examination of the stomachs of the parr from the spawning ground, it was determined that 24.3% of the precocious males in the 1975 sample contained salmon eggs, while eggs were found in 44.7% of the stomachs during 1976.

Spawning marks

Scales of males captured on the spawning ground were examined for spawning marks, evidence of spawning in previous years. Figure 10 shows a probable spawning mark while Figure 11 shows one which is quite well

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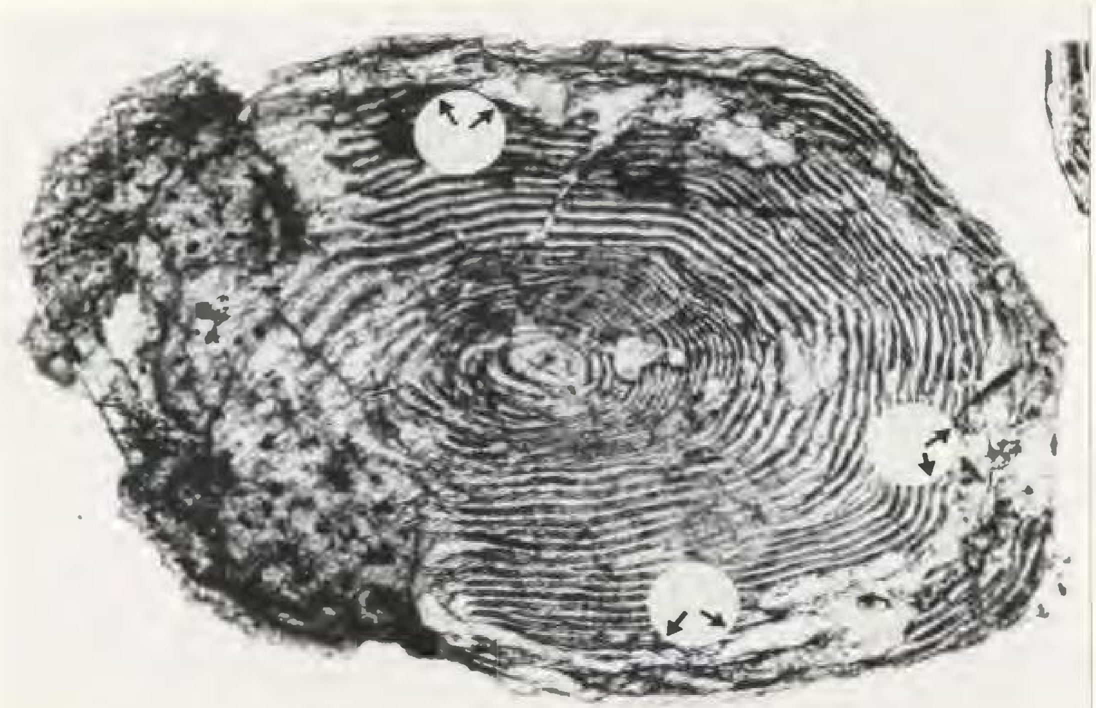
[1] This total differs slightly from that shown in Table 1 since when these fish were processed, females were selected out, so as to examine a sample of precocious males only.

Figure 10. Probable spawning mark on scale of precocious parr from spawning ground.

Figure 11. Well pronounced spawning mark on scale of precocious parr from spawning ground.

Figure 12. Erosion along the edge of a scale from a parr on the spawning ground.



pronounced around nearly all of the scale. Figure 12 shows erosion along the edge of a scale from a parr on the spawning ground. This indicates that some male parr do lay down spawning marks and that in fact some do mature more than once. By examination of spent male smolt scales from Northeast River, all of which had matured the previous season (determined by the condition of the gonad), it was discovered that a very low proportion indeed actually laid down definite spawning marks. Approximately 15% of the specimens had what was classified as a good 'possible' spawning mark. While definite spawning marks were difficult to ascertain, it was noted that many scales from spent smolt did not exhibit the consistencies of circulus formation as did the female smolt. Spacing of circuli and formation of the annulus on the scales of female smolt was generally quite regular. Spacing of circuli on scales of spent male smolt was often less regular, with more incomplete circuli and crossing over, so that the annulus was less clearly perceived. This is especially true in trying to ascertain where an annulus actually begins.

Examination of smolt

The two samples of smolt captured in the spring of 1976 exhibited a sex ratio highly in favour of females. The sample from North Harbour River in St. Mary's Bay consisted of 81% females and 19% males. Of the males, 21% were immature and had not matured the previous season, while 79% were precocious males that did mature the previous summer. The gonads were larger and contained traces of white sperm, whereas those of the immature males were thin filaments (Figure 6).

The 1976 sample from Northeast River, Placentia consisted of 19% males, 46% of which had matured the previous year. The sample of smolts from Northeast River, 1977, provided additional information on sex ratio and reproductive performance of male migrants. Similar information was obtained from a sample of 97 smolt from the neighbouring Southeast River during the same period. Only 8.2% of this sample was male (91.8% female), 25% of which had matured the previous season.

The fyke traps set at the outflow of Fitzgerald's Pond, Northeast River System (Figure 2) caught a total of 10,651 smolt from May 2 to June 8. Appendix A shows the timing of the smolt run. Table 8 shows the sex composition of the fish in each of the four smolt runs sampled.

After several days of observation of the smolt run and recapture of precocious males that were marked on the spawning ground the previous fall, it was discovered that spent males could be distinguished externally from the immature fish. The sides of the fish were not as silvery as typical smolts. The sides and undersides were a greyish-brown with a copper color tinge which was also prominant on the opercular cover and the maxillary bone. Although parr marks were not visable, some of the red spots typical of parr were on the sides but were mottled. While the pelvic and anal fins

Table 8

Sex composition of the smolt runs sampled

River	Sex		
	% Immature Female	% Precocious Male	% Immature Male
North Harbour River (S.M.B.)	81	15	4
Northeast River 1976	81	8.7	10.3
Northeast River 1977	90	5	5
Southeast River	91.8	2.1	6.1

of a typical smolt are light, almost white with some charcoal coloring, those of a precocious or spent male smolt are predominantly a greyish brown color. The caudal fin also is brownish whereas that of a typical smolt is grey to a charcoal color. This description was recorded comparing the two types of smolt in fresh condition. Figure 13 shows the differences in coloration of the two types of smolt. While this was the usual condition, there were gradients from this to a nearly typical smolt condition. Many precocious (spent) male smolt were fairly silvery. These could often be distinguished by scales missing from their sides.

Forty-six chosen selectively, 5 that were part of the random sample of the run, plus the 12 that were marked on the spawning ground the previous autumn composed a sample of 63 spent male smolt. The age distribution of this sample is shown in Table 9 with that of typical

Figure 13. Difference in coloration of typical (top and bottom) and spent smolt (middle) from Northeast River.

smolt (91 female + 5 immature male).

Table 9

Age composition of typical and precocious male smolt

Age	Typical	Precocious (Spent) Male
2+	8.3 (8)*	4.8 (3)
3+	85.4 (82)	85.7 (54)
4+	6.3 (6)	7.9 (5)
5+		1.6 (1)

*Numbers in brackets signify actual numbers in sample.

The mean age of the typical smolt was 2.98 while that for spent males was 3.06.

DISCUSSION

Contribution of precocious males on the spawning ground

It appears that a large number of people were either unaware, overlooked or were unprepared to accept the reality and significance of mature male parr in salmon, S. salar, biology in Canada. Neither Scott (1967), Leim and Scott (1966) nor Scott and Crossman (1973) considered precocious male parr significant enough to warrant mentioning in relation to the general biology of the Atlantic salmon.

As to the question of the potency of precocious males, Robertson (1957) used precocious males of king salmon (O. tshawytscha) to fertilize adult female eggs and found that the eggs hatched and that the young salmon developed normally. Askerov (1964) used dwarf males of Salmo trutta for fertilization and Koshin and Protasov (1958) found that progeny of dwarf males and females did not differ from progeny of "winter" form of anadromous S. trutta at the stage of migration to the sea.

For Atlantic salmon, S. salar, Jones and King (1949) cite Shaw (1839) in Scotland and Alm (1943) in Sweden as having successfully used male parr sperm for fertilization of adult salmon eggs. Orton et al. (1938) summarized an account of the sperm of male salmon parr used to fertilize eggs of adult salmon and Jones and King (1952 a) found that the percentage of eggs fertilized using parr compared favourably with that of adults. Jones and King (1950) found that progeny of male parr were as good as those of adults up to the smolt stage. Berg (1962) also mentioned that in Czechoslovakia the milt of dwarf males is successfully used for fertilization.

Circumstantial evidence has been collected in this study supporting the view that precocious males normally take part in spawning. The observation that the density of precocious male parr increased on the spawning ground as spawning time approached supports this idea as does the fact that many parr were observed around each adult on the spawning ground. If the parr's main purpose on the spawning ground was to prey on eggs, there would be no reason not to expect immature males and females to also be present. Gebhards (1960) found similar behavior in precocious chinook O. tshawytscha where 4-30 yearling males formed a compact school in the redd. The fact that a large majority of male parr taken from the spawning ground were spent or partially spent after the redds were made is a strong indication that they spawn. Jones and Orton (1938) stated that the gradual disappearence of ripe male parr during the spawning season and the correlated appearence and increase of spent males was almost conclusive evidence that the ripe male parr spawn on the redds. Much work has been done in Great Britain to prove that male parr actually take part in spawning. Earlier observations on the spawning activity of adult salmon failed to prove that male parr shed milt although they were near the female at the time of adult female and male spawning (Jones and King, 1949, 1950). Further experiments using sterilized adult males finally led to observations of male parr spawning with adult salmon

(Jones and King, 1952 a). Jones and King (1952 b) concluded,

> "Since it has already been shown that sperm from stripped parr is as effective in the fertilization of salmon eggs as is the sperm stripped from adults, there is no longer doubt that male parr, in natural conditions are responsible for the fertilization of a considerable fraction of the total eggs which develop."

Berg (1962) also stated that evidence in the U.S.S.R. indicates that mature male parr normally participate in spawning. It would also be reasonable to conclude that in Northeast River and other areas where field observations are similar to those of Jones and King that parr normally participate in spawning.

Another indication of the actual participation is the sex ratio of the adults on the spawning ground. While it is known that milt of one adult male is capable of fertilizing more than one female it seems unlikely that each adult male could fertilize the eggs of 8-9 females. Several authors indicate that this situation is not unusual. Nikolsky and Koshin (1958) and Makeeva and Nikol'skii (1965) explain that in the upper parts of many rivers the precocious male parr take up an important role in fertilizing the eggs of anadromous females. Mitans (1973) stated that the lack of adult males on the spawning ground was compensated for by dwarf males. An implied lack of males on the spawning ground is then inaccurate, since it refers only to anadromous males.

The observation that many male parr had eaten salmon eggs suggests that egg predation could reduce the reproductive potential of the population. This observation is not unique to Newfoundland. Gebhards (1960) found that 5% of precocious chinook males had eaten eggs. Reports of eggs in stomachs of male S. salar parr include Vladimirskoya (1950), Jones(1949), Jones and King (1950, 1952). On the other hand, Jones and King (1949) stated that no parr was seen to definitely eat any eggs while spawning and Jones and King (1952) again found that although eggs were present in the stomach of spent parr, at no time during any of the spawnings were parr seen to eat eggs. They suggested that the eggs eaten by parr were stray ones. If this were so the parr would not have a deleterious effect on the spawning potential since such eggs are destined to die anyway. Although no evidence was provided by this study, it was assumed that eggs eaten by the parr were lost ones. If from fifteen to twenty-five parr were actively preying on the eggs of each female the number of eggs eaten would be quite high, and damage to salmon productivity would be more apparent than it now is.

Distribution, percent precocity, age and size at first maturity

Precocious male parr of Atlantic salmon have been reported throughout the range of the species and the present study being the first to survey their occurrence in Newfoundland, found the island to be no exception. Even though all the rivers sampled during the study had precocious parr there was variation in the percent precocity in different rivers. While most rivers, particularly those of the eastern part of the island had a high incidence of precocity, Rocky Brook, a tributary of the Humber on the West Coast had an incidence of only 12.3%. Several hypotheses have been proposed to explain variations in the percentage of precocious parr in different areas. This will be elaborated in appropriate sections of the discussion which follow. Naevdal (1975) stated that the ratio of precocious parr varied in salmon of different river origin and Saunders and Sreedharan (1977) found differences in the incidence of sexually mature (dwarf) males among purebred and hybrid strains of hatchery reared Atlantic salmon.

The literature on precocity indicates that it is generally much less frequent (2–3%) in the genus Oncorhynchus than Salmo (Gebhards 1960, Robertson 1957). Many authors report that approximately 50% of the male parr of Atlantic salmon mature (Berg 1962, Orton et al. 1938, Osterdahl 1968). Incidences of less than 50% have been reported by Power (1969, 1973) in far northern populations of both Europe and North America. Thorpe (1975) also reported low incidences of precocity (<50%) in several groups of Atlantic salmon in Scottish hatcheries. Frequently more than 50% of the male parr are reported to be precocious: King (1943) found 80% of 2+ male parr to be mature, Frost and Went (1940) and Frost (1950) found approximately 70% precocity in two rivers of Scotland, and Mitans (1973) found a 75% incidence in 1+ and an 86% incidence in 2+ parr in the U.S.S.R. Evropeytseva (1960) also found during the cultivation of Atlantic salmon in ponds that 83–90% (100% in some cases) of the male parr matured in their second year. King et al. (1939) found 100% of 48 male parr near adult spawning salmon to be mature, although as will be pointed out later the location probably biased the sample.

While there is much variation in the percent precocity of Atlantic salmon over the extent of its geographic range, local areas can also show wide variation. For example, Schiefer (1971) found that on the North Shore of the Gulf of St. Lawrence the percent precocity varied from 0% in all age classes in the St. Jean River to 100% of the 3+ and 4+ parr in the smaller rivers. The level of variation found in Newfoundland is therefore not unique for a region of such size. Schiefer found that within any age class there was an increase in numbers of precocious male parr as river size decreased and lake influence increased. In the present study the same general type of relationship was identified. The Placentia Bay rivers, which on the whole showed a higher percent precocity than those further west ($\bar{x}$ = 84.5%), have an average axial length[1)] of less than 20 km, while the four western rivers (excepting Western Arm Brook), with a mean percent precocity of only 50% have a mean axial length of approximately 120 km. Lomond River with an axial length of 14 km and a percent precocity of only 56.5% is an anomaly to this general rule. It is also questionable if the Exploits could be included in this analysis since much of the river above Grand Falls (approximately

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1) Porter et al. (1974) defined axial length as the length of the long axis of the basin measured from the mouth to the most distant point on the perimeter.

25 km from the mouth) is ordinarily inaccessible to returning adult salmon. The data from Western Arm Brook were not included in this analysis since the method of capture (angling) probably biased the ages of the fish in the sample such that no 1+ fish were captured.

Schiefer (1971) also found that for a given river, the Moisie, the further upstream the sample was taken the greater the proportion of precocious male parr of each age. This particular question was not examined in the present study, but the sample from Rushoon River was taken from three different areas varying in distance upstream. While the percent precocity did not vary (100% in all three stations) the sex ratio did. At the furthest upstream station males outnumbered females 33 to 25. At the station which was intermediate in distance there were 14 males to 9 females. At the station which was just above the estuary there were only 5 males to 19 females indicating that there were fewer precocious males in relation to females near the estuary than further upstream.

The sample collected by King et al. (1939) in which only mature male parr (48) were captured just below where adult spawners were being held is probably comparable to these samples, taken during the present study, on the spawning ground. In both 1975 and 1976, 100% of the male parr taken on the spawning ground were mature. As indicated by King et al. this cannot be taken as an indication of percent precocity in the system since mature parr are attracted chemotactically to mature females and they would therefore tend to accumulate near them.

The percent precocity of Newfoundland Atlantic salmon parr appears to be directly related to age (Table 2) in most samples, with a higher proportion of the males maturing with increased age. The same relationship has been reported by numerous authors (Shooner 1967, Schiefer 1972, Mitans 1973 and others). The only samples which deviated from this were Fitzgerald's Pond and Rocky Brook, Upper Humber System, both of which had a slightly higher incidence at 1+ than at 2+.

The youngest fish in any of the samples that was mature was 1+, but no 0+ fish were ever captured. The only indication of the state of maturation in the 0+ age class was a sample of 20 1+ male parr captured in the spring at Junction Pond, Northeast River System. The gonads of these fish showed no signs of having matured during the previous year (0+). There are reports in the literature, however, of maturation occurring in the first year (White 1934, Saunders and Henderson 1965, White and Huntsman 1938, Jones 1950, Saunders and Sreedharan 1977), although it is more common for fish to mature in their second year (1+) or older (Vladimirskaya 1958, Melnikova 1970, Mitans 1973, Saunders 1960, Orton et al. 1938).

Size also appears to be important in the first maturation of parr and White (1934) reported that parr which had matured at 0+ had reached a length of 70 mm, the same critical size Utoh (1976) found for maturation of parr of <u>Oncorhynchus masou</u>. The smallest size of any fish maturing in this study, 60 mm, was small by these records but was of age 1+. Both Berg (1962) and Nikolsky (1961) mention 10 cm as the length at which parr become mature and King.

(1947) found mature males varying from 11.4 cm up to 20 cm.

Thus precocious males appear to be distributed throughout Newfoundland. The percent precocity varies from one region to another with the rivers of eastern Newfoundland having the higher values. Precocity starting at 1+ agrees with values found elsewhere, although there are many reports of maturation starting at 0+. While the minimum size of any precocious male was smaller than that reported elsewhere, generally the size range of precocious parr from this study agrees with other figures.

Sex ratios of parr and smolt with possible explanations

There is often deviation from a 1:1 sex ratio in the various life history stages of the Atlantic salmon, but most students of salmon believe that there is a basic 1:1 ratio at hatching. Osterdahl (1968), for example, believed that the primary sex ratio was 1:1 since a 1:1 ratio is found among unsorted hatchery parr. Mitans (1973) and Vladimirskaya (1958), who found the youngest age of smoltification to be 1+, found that males and females were in equal numbers as underyearlings but that males were more frequently encountered as yearlings and were in considerably larger numbers than females as 2+ parr. Similar evidence of a basic 1:1 ratio is that 1+ parr in Junction Pond were in equal numbers in the spring. Power (1969) found that male and female parr in Ungava Bay, where precocity was low, were equally abundant and concluded that the basic sex ratio was 1:1. Power (1969) also referred to detailed work by Shooner (unpublished) in the Nabisipi River and in a Quebec hatchery which also indicated that the basic sex ratio was 1:1.

As can be seen in Table 3, there is often deviation from the 1:1 ratio in the samples collected in this study. In most cases where this difference is significant it is in favour of males. The only parr sample that had significantly more females was the September Fitzgerald's Pond sample. There are several possible reasons that account for the inequality in numbers of the sexes. These will be briefly mentioned and then discussed in more detail incorporating the sex ratios and other evidence found in this study, as well as evidence from elsewhere.

The possible reasons that many samples collected do not indicate a basic 1:1 ratio are:

1) a difference in distribution pattern as a result of
   a) sex-related movement within the stream
   b) movement of females from the stream as smolt while the males remain
2) sex-related mortality (this particular aspect will be discussed in more detail in the section on length-weight relationships and energy expenditure).

Many other authors have documented that males outnumber females in the older age classes of parr (Belding 1937) and they attributed it to the fact that males mature precociously and stay longer in the rivers, i.e. they do not smoltify (Berg 1962, Mitans 1973, Power 1973, Vladimirskaya 1958). There are, however, samples in this study (Churchill's Pond, Come by Chance River, North Harbour River, P.B., Salmonier River) that show a significant difference in favour of males in the 1+ age group. This can not be accounted for by the above mechanism since the earliest age of smoltification in these rivers is 2+ (mostly 3+) and no fish would have yet migrated from the system.

Aside from the dispersal factor associated with parr movement (Huntsman 1945), there is evidence suggesting that juvenile salmon occupy different wintering and feeding areas, (Vladimirskaya 1958, Mitans 1966, Saunders and Gee 1964) and furthermore that immature parr move into winter areas before mature parr. Mitans (1973) discussed the difficulty of obtaining data on the structure of the entire parr population in the autumn since sexually immature young move into winter refuges before the precocious young. Aside from the earlier movement of immature parr to the wintering areas, it has been shown that precocious males are generally even more active than immatures prior to and during spawning (Mel'nikova 1970, Vladimirskaya 1958). Vladimirskaya (1958) also stated that by the end of summer the study of sex ratios of parr in the River Petchora is complicated by the gradual increase in the number of small mature males encountered as one moves toward the spawning ground. King (1947) found that parr caught below a spawning station were all mature males and suggested that they were attracted by the female salmon and moved upstream to this location. Aside from upstream movement of precocious parr in autumn, Saunders (1960) and Elson et al. (1972) have recorded a downstream movement of small numbers of precocious parr in autumn. Thus the mature males segregate from immature parr in late summer to early winter by moving to spawning areas, and by then remaining at these areas while others move to wintering areas.

Evidence for the movement of parr to the spawning ground has been obtained in this study. The sex ratio in favor of females in a non-spawning area (Fitzgerald's Pond) prior to the spawning season (September) was probably caused by the emmigration of precocious male parr. Also the sex ratios of the parr on the spawning ground near adult spawning salmon, with such a heavy preponderance of precocious males, can only be accounted for by movement to the area.

Also, the results of the tagging program supports the idea of an upstream migration to the spawning ground. The tagged parr that was captured at Junction Pond in June 1977 had moved upstream from the tagging site approximately 8 kilometers. Since the specimen was not caught until spring it is not known for sure that it spawned; however, the facts that (1) its gonads were spent, (2) that it was captured just below the major spawning ground and, (3) that several precocious (spent) males that were marked on the spawning ground during spawning were captured in the same fyke trap setting, all suggest that it spawned the previous fall.

It is necessary then to consider that any samples taken which intercept a significant number of these migrating parr cannot be used as an indication of the primary sex ratio of the species.

As an example, the samples from 3 different areas of Rushoon River show sex ratios of male to female of (1:3.8), (1:0.64), and (1:0.76) while the overall sex ratio of the combined sample was 1:1.

These differences in the distribution pattern of mature fish can probably explain the preponderance of males in many of the river samples particularly in age classes younger than the age of smoltification. Two samples, however, that have significantly more males than females at 1+ (Salmonier River and Churchill's Pond) cannot easily be explained by movement to spawning areas, since they were captured in July, probably before any movement began.

The second reason for differences from a 1:1 ratio is that following maturation male parr remain in the river, and do not smoltify with females of the same age. This would explain the preponderance of males in older age classes of most samples. That this occurs is indicated by the sample of 3+ parr from Junction Pond in June, 1977. The sample was highly in favor of males ($p = 0.001$) and was taken just following the smolt run when the vast majority of females had smoltified and migrated.

The sex ratios of the smolt runs examined in the study also suggests that males remain behind after the smolt run. Table 8 showed that precocious males constituted only 2% of 15% of the smolt in the samples examined, while females dominated the runs (between 81 and 92% of the smolt).

It is not unusual for females to outnumber males in smolt runs. Jones (1949) and Mel'nikova (1970) found that females usually predominate among downstream migrants, averaging approximately 60% of the runs. Similar proportions have been recorded from mainland Canada (Saunders 1976, Jessop 1975, Forsythe 1968) while Lee and Power (1976) found that females outnumbered males by 5:1 in smolt from Leaf River, Ungava Bay. Davis and Farwell (1975) found 77% of smolts in the Exploits to be female and Chadwick et al. (1978) found 79% of 80 smolts from Western Arm Brook to be female indicating that the percentage of female smolt on the island of Newfoundland is higher than most locations elsewhere. The percentages of female smolt from this study (81-92%) are even slightly higher than that reported previously from Newfoundland. However, the published reports are not from areas examined in this study (Placentia and St. Mary's Bays). Reid (1977) also found an extremely high incidence of females (86 of 90 smolt) captured from Crossing Place River, St. Mary's Bay.

Most authors attribute the lack of males in the smolt run to precocious sexual development, which results in a higher mortality or causes them to remain longer in the rivers. Whatever is the cause, it appears to be acting to a larger degree in Newfoundland salmon than salmon from other North American locations and Europe.

Males significantly outnumbered females in Junction Pond at the age (3+) at which the majority of females had just smoltified. These were the 2+ age group the previous fall, which accounted for 55.2% of the precocious males on the spawning ground. (Table 10 shows the relative precentage of each age class of the various groups of precocious males.)

Table 10

Age composition of various groups of precocious males from Northeast River Placentia Bay

Age	Spawning Ground	Smolt	Junction Pond
1+	19.1*	-	-
2+	55.2	4.8	47.7
3+	21.1	85.7	47.7
4+	3.4	7.9	4.6
5+	1.3	1.6	0
		0	0

*Lines indicate the same year classes.

The large majority of spent males (85.7%) that smoltified were also in this age class. Over 25% of the males on the spawning ground were 3+ or over, but less than 10% of the smolt were in this age category, as were less than 5% of the males remaining in Junction Pond. It appears then that most of the spent males that remain are 2+ and 3+, (1+ and 2+ the previous spawning season). Only a low percentage of the 3+

and older on the spawning ground appear in the smolt run or are found in freshwater following the smolt run. It is therefore suggested that a large number of older precocious parr not only do not smoltify but die over the winter. This is consistent with findings of Gebhards (1960) and Thomas et al. (1969) in Oncorhynchus tshawytscha. The ages of precocious males were lower, but the majority of younger fish (0+) survived to mature again while the yearlings apparently all died. The question of mortality will be considered again with length-weight relationships and energy expenditures.

Repeat spawning

Only limited evidence was found that parr mature more than once. Several fish caught on the spawning ground had what appeared to be a spawning mark on the last annulus of the scale, indicating that it had matured in two successive years. Examination of scales showed that spawning marks were rare. Only 15% of the scales of spent precocious males, that had spawned the previous season, bore what could be classified "possible spawning marks". The remaining 85% of the sample had no spawning mark even though they had previously matured, indicating that scales were largely unreliable as a means of determining past maturation in parr.

Several authors have attempted to identify spawning marks on the scales of precocious male salmon. One positive report is from parr and smolt of two rivers in Ireland (Southern 1933), although this particular evidence was later questioned by Frost and Went (1940). The only other indication of such marks is from Canada where White and Huntsman (1938) stated that the scales of precocious parr showed slight absorption on the sides. Attempts have been made without success to identify spawning marks in Oncorhynchus tshawytscha (Robertson 1957, Gebhards 1960). Authors that have searched and failed to identify spawning marks on precocious male S. salar include Frost and Went (1950) in Ireland, Jones (1949) in England, Osterdahl (1967) in Sweden and Mitans (1973) in Latvian S.S.R.

While it appears that spawning marks cannot be used to determine if a parr has matured more than once, other evidence in the literature does suggest that successive maturation occurs. Robertson (1957) found that testes secured from spent parr of O. tshawytscha 5 months after the loss of their sperm revealed a picture of renewed spermatogenesis. Jones and Orton (1940) in describing the seasonal condition of the testes of male parr (S. salar) found that the maturation cycle had begun again in some spent fish, that did not migrate, following the smolt run. Leyzerovich (1973) found that 55 of 56 dwarf males reared in tanks matured again at an age of 28 months. Evropeytseva (1963), from a histological study, found that 2 year old Baltic and Lake salmon that remained as parr had testes in which a renewed spermatogenesis was beginning, and suggested that the reason they did not migrate was that the gonads matured a second time. Mitans (1972) stated that apparently only few of the precocious males that survived the winter did not become smolts, and remained in the river where they could ripen repeatedly. Makeeva and Nikol'skii (1965) pointed out that migratory males of the Black Sea salmon usually died after spawning but the dwarf males survive to spawn several times. With so many reports of repeated maturation from elsewhere, there is no reason to suspect that a proportion of 2+ and especially 3+ precocious males in Newfoundland have not also matured previously.

Growth, length-weight relationships, energy expenditure

Numerous authors have investigated growth in relation to maturation of fish. Alm (1959) conducted experiments on several species in this regard at the Kalarne Fishery Research Station in Sweden. His experiments confirmed the hypothesis that it was mainly the larger specimens of a particular group that mature. He found that a more or less distinct relationship of this kind existed for all species examined and for nearly every individual experiment. Alm pointed out, however, that this did not imply that all mature specimens were larger than immature ones. He also investigated the frequently occurring statement in the literature that maturation causes a decrease in the growth rate. He stated that neither his experiments, nor the studies of natural populations have shown a very pronounced growth inhibiting effect.

It is appropriate then in considering the growth rates of immatures and matures to consider growth at two different stages, 1) the growth rate prior to or at the onset of maturation and, 2) during or subsequent to maturation.

Utoh (1976) found that maturing 0+ males of O. masou had a larger body length than immature 0+ males and Krokhin (1967) related an increase in the number of so-called residual form sockeye, O. nerka, (similar to Atlantic salmon dwarf males) to an improvement in food resources and a subsequent acceleration in growth rate. Evropeytseva (1960) also found that under conditions of intensive growth early maturation of the males occurs, and in her opinion the quantity of dwarf males obtained in pond-rearing of Baltic salmon is dependent on growth rate in the period preceding spermatogenesis. These authors then agree with Alm's statement that faster growing individuals mature earlier than more slowly growing ones.

The results of the present study support the idea that the larger individuals within a certain age group mature first. In all cases where 1+ (probably the earliest age for maturity) immature and precocious males were compared, the precocious parr were larger than the immature parr. In one sample, Come by Chance River, this difference was significant ($p = 0.001$). As Evropeytseva (1960) found, it would also be reasonable to assume that any acceleration of growth within a certain area would probably result in a higher percentage of mature males in that area.

While, within a particular population of parr, the faster growing individuals may mature earlier, it can be seen by comparing Table 2, (showing the percent precocity) and Table 4, (showing the lengths at each age) that factors other than fast growth are necessary for maturation. While Fitzgerald's Pond and Rushoon River, both of which had relatively fast growth rates, had a high precocity, Rocky Brook which also had a relatively fast growth rate, had a low precocity. Come by Chance River, which had a slower growth rate than neighbouring North Harbour River at 1+, had an incidence of 85.7% and North Harbour had only 53.1%. Salmon Brook also had a growth rate a little faster than Come by Chance but had only 24% mature in the first year. It is noteworthy, on the other hand, that Tote Brook, which had by far the slowest growth rate of all samples in the study, had a precocity of only 40% at 2+, the lowest incidence of any 2+ sample except for Rocky Brook. Thus while growth rate may effect the incidence of precocity, fast growth alone does not necessarily implicate high precocity nor slow growth low precocity. One should also consider the different times at which some of these samples were collected when comparing the growth.

Most literature on salmonids concerning precocious maturation and growth rate is not in agreement with Alm's second point, i.e. reports indicate for the most part that the growth rate of salmonids is reduced by maturation. The only support for Alm is Jones (1949), who counted rings on scales, and found that in maturing fish, scales grow normally and possibly a little more rapidly than those of immature fish. More often it has been found that the growth rate of male parr is decreased by maturation. Many authors have found that growth rate of mature males is slowed by the latter stages of maturation, (Orton 1949, Vladimirskaya 1958, Lee and Power 1976) or that the growth curve was flatter for ripening parr than for precocious parr (Osterdahl 1967, Saunders and Sreedharan 1977). Thorpe (1975) found that immature parr were 3-5 cm longer than mature ones in Scottish hatcheries and pointed out that one of the reasons precocious maturation is of concern to hatchery managers in Scotland is that the formation of reproductive tissue diverts energy away from conversion into muscle.

The results of the present study also indicate that growth is slowed down by maturation since after the first year precocious males are not consistently longer than immature males. In many cases, (Fitzgerald's Pond, Come by Chance River, North Harbour River, Salmon Brook, Lomond River) as can be seen in Table 4, the growth of 2+ immature fish nearly "caught up" with that of the mature fish and often surpassed it.

Even though the maturation process appears to slow growth the mature male smolt from Northeast River are not significantly smaller in length than the immature male or female smolt. This would be expected if it is the faster growing parr that becomes precocious as suggested earlier. Pentelow et al. (1933) also found that the average size of male smolt, 27.3% of which had enlarged gonads, was approximately the same as female smolt, and Larsson and Svensson (1974) found that the size distribution is equal for mature and immature male smolts.

Growth and development of the gonads make such high demands on the supply of nutrition that only a small part of the food can be used for increased growth of the body. The opinion is furthermore held that the general condition of the fish is weakened by the energy spent in spawning. Alm (1959) pointed out that these statements are often used to explain the view that maturity had a growth inhibiting effect, although as mentioned he did not find the influence to be particularly pronounced.

In view of this growth inhibiting factor generally associated with maturation, length-weight relationships of non-maturing and maturing parr were investigated to determine if a difference existed in the weights at corresponding lengths (condition) of the fish before the effect of maturation could be manifested in the growth rate. As previously mentioned weight used in the relationships were those of eviscerated fish, eliminating the effects of undigested food and of enlarged gonads in the males. By using eviscerated weights any fat deposits among the organs of the abdominal cavity were also removed. Several authors (Orton 1942, Leyzerovich 1973, Saunders and Sreedharan 1977) found that fat reserves are used up in precocious males during the maturation process. If this difference in fat reserves was detectable in the weight of the fish is unknown, but at any rate the factor was eliminated using gutted weights. Table 6 shows that by comparing the 95% confidence intervals of the weights at each 1-cm length interval no significant differences were detected, since there was overlap of the confidence intervals placed around the weight at each length interval. While maturation of the gonads may affect the amount of fat deposits in the body cavity, as reported in the literature, it did not affect the condition of the parr to the extent that somatic tissues of the body were emaciated in comparison to immature fish.

The foregoing was found to be true only for comparisons of length-weight relationships of the parr. In the smolt from Northeast River (Table 6C and Figure 7) it was found that above the 145 mm length class the calculated weight at each length interval (condition) of the females was higher than that of precocious (spent) males, with no overlap of confidence intervals above 165 mm. These relationships were also calculated using eviscerated fish, again excluding the effect of mesenterial fat, but in this case the somatic tissue of the body was also reduced. From these results then a difference in the length-weight relationships between groups occurs only after smoltification. Numerous authors (eg. Hoar 1953, Malikova 1957) have documented that smoltification involves increased energy consumption. Mitans (1973) and Osterdahl (1967) also found that dwarf males which have survived to the smolt stage characteristically have little fat on the viscera whereas juvenile males retain more fat throughout the time of overwintering and smoltification. It is suggested then that the energy cost of maturation is low enough to be undetectable by comparing the calculated weights from length-weight regressions of eviscerated mature and immature parr. However, with the added stress of energy expenditure during smoltification, the condition of the precocious male smolt is reduced more than that of immature smolt.

As seen from Figure 7 the difference in the condition of the female and spent male smolt is directly related to size of the fish. As the fish gets larger the condition of the spent male smolt gets less in comparison to the female. This is also presumably related to age with the condition of precocious males decreasing with increased length and age - those fish in which the probability of maturation occurring more than once is higher. This observation may be an indication of the fate of precocious parr following maturation and spawning. As discussed earlier evidence from Junction Pond, where there were large numbers of 3+ spent males compared to females, indicates that many spent parr, upon reaching smoltification age, remain within freshwater. The suggestion was also made that mortality is higher in precocious males.

Many authors have considered the question of whether the precocious parr die after spawning. Robertson (1957) found that spent males of O. tshawytsha had a mortality only slightly higher than of immature controls, while Gebhards (1960) and Thomas et al. (1969) found that precocious yearling males of this species all died. Jones and Orton (1940) suggested a 15% mortality of precocious male S. salar following spawning. Mitans (1972, 1973) found a survival of just over 50% of precocious Atlantic salmon males and Leyzerovich (1973) found that dwarf males reared in tanks are distinguished from immatures by reduced survival. He stated:

> "the tempestuous process of maturation of the gonads in dwarf males, which necessitates very large energy expenditure proceeds parallel to the process of growth in the course of the summer. During this period both processes are covered mainly by feeding

> and also by the use of inner reserves, for example, depot fat. At the end of the summer the growth rate is lowered since it is evidently no longer possible to cover both processes. Subsequently there is a gradual resorption of the sexual products which also requires certain additional expenditure of energy during overwintering. All this apparently explains the considerable weight loss and increased mortality of dwarf males."

Power (1969) stated that an increase in mortality of precocious males can be expected as a result of exposure to predators on the spawning ground and of utilization of body reserves for maturation. Also Elson et al. (1972) found that salmonids exposed to DDT suffered heavy mortalities in autumn. The salmon mortalities were largely confined to large sexually mature males. This observation is significant since the first fish which died when the population was put under a stress were the precocious parr. This suggests that any added stress on juvenile salmon will lead to the death of mature parr before immatures. In the case at hand the added stress is smoltification.

Leyzerovich (1973) found that maturation alone caused an increase in the mortality of precocious parr. He did not consider smoltification and its associated energy consumption. There are then the following demands on the energy resources of a precocious parr which spawns in the fall and migrates to sea the following spring: 1) growth, 2) maturation, 3) increased activity prior to and during spawning, 4) resorption of gonads as suggested by Leyzerovich (1973), (many of the parr in this study were only partly spent following spawning), and 5) smoltification. From the evidence collected in this study on the comparative condition of smolts and from evidence available in the literature it is suggested that after contributing energy to the first four processes, the energy cost of smoltification is more than the fish can manage. The fact that most spent males were of a dark color and retained some parr characteristics suggests that smoltification was incomplete. This is a further indication of the lack of energy reserves at the time of smoltification as energy was probably insufficient to complete the process.

While it appears that many of the younger precocious parr (1+ and 2+) may remain in the river to mature again and the older precocious parr (3+ and older) may have a heavy mortality, another possible fate of precocious parr is that they migrate to the ocean at a time other than the regular smolt run. As discussed several authors (Elson et al. 1972, Saunders 1976) have noted the downstream movement of small proportions of precocious parr in autumn. Saunders (1960) also found a downstream movement of precocious parr in November and December but again found that the proportion of the stream population was small. Calderwood (1906) and Meister (1962) have also recorded a small autumn migration of a small proportion of fish, and found that they would normally migrate the following spring. Gardner (1976) presented evidence indicating that a fall migration of salmon may be quantitatively important. The smolt run of Northeast River consisted of 10,650 fish of which only 5% were precocious males. If male smolt were as numerous as females, a total of nearly 10,000 would have to migrate at times other than the normal smolt run. It is felt that such an extensive run of smolt (nearly as large as the normal smolt run) would not go undetected. Since it has not been detected it is suggested that if males do migrate at other times the run must be small. It would be necessary though in order to clarify this to monitor fish movement year round, a proposition made difficult by varying water levels and ice. Also, if an equal proportion of males went to sea we would expect an equal proportion to return as adults, which from the sex ratio on the spawning ground, is not the case. If, however, smoltification is incomplete as suggested by the color of many precocious male smolt, it is probable that mortality of these in the sea is higher than of typical smolt that have undergone a complete smoltification. In view of the effect of smoltification on the condition of precocious parr it is questionable whether many could go through the process quickly enough following maturation for a fall migration. If some do migrate at other times then, it is probably at a time later than the normal smolt run.

The incidence of precocious parr in relation to adult salmon runs in Newfoundland

Two phenomena characterize the adult salmon runs returning to the majority of Newfoundland rivers. The first is that an extremely high proportion (sometimes up to 100%) of returning adult salmon are grilse (Moores et al. 1978). The second is the sex ratio of these grilse which is highly in favor of females. Chadwick et al. (1978 b) found that 76% of 224 adults sampled in Western Arm Brook were female. Davis and Farwell (1975) found that while 58.7% of 414 adults that returned to Adies Stream, of the Humber system, were females, 85.7% of 24 fish that returned to Grand Falls on the Exploits were female and 73.9% of 403 on Indian River were female.

Several authors have suggested that precocious male parr lead directly to a higher proportion of grilse. For example, Schiefer (1971) found that males which matured as parr later smoltified and themselves returned as grilse. He documented that the higher the incidence of precocious parr the more males that would return as grilse on the North shore of the Gulf of St. Lawrence. Schaffer and Elson (1975) questioned whether this relationship was applicable to all populations and gave examples where it was not. It is obvious that it does not apply to Newfoundland rivers considered in this study where only 10% of the seagoing smolts were males and the large majority of returning grilse (as indicated by adult sex ratios on the spawning ground) are females. It is obvious that males cannot return as grilse or large salmon in populations where so few go to sea to begin with. It seems then that in some populations many males may survive maturation to smoltify and return as grilse while in others the majority of males do not survive these processes. This might be a result of the resources available to the animal from its environment. Where resources are available to allow the animal to smoltify following maturation there will be a higher proportion of adult males, probably grilse.

As mentioned the sex ratio of salmon from Adies Stream of the Humber was 58.7% females. Angling records from the river (one of the few rivers where data on the sex of angled adult salmon in the river are available)* show that female to male is 90:84. These reports indicate that the proportion of males on the Humber is probably higher than that of other rivers. Interesting in this regard is the fact that the Humber had the lowest incidence of precocity of all rivers examined in this study (12.3%). This supports the view that precocious males in Newfoundland have a high mortality and thus cannot return as adults. In the Humber where the incidence of precocity was low the adult sex ratios were not as highly in favor of females.

The phenomenon of a high proportion of grilse in Newfoundland salmon is one which is more difficult to link to the high proportion of precocious males. Several authors (Schaffer and Elson 1975, Chadwick et al. 1978 b) suggest that larger salmon are selected for in the commercial fishery allowing a higher proportion of grilse than might actually exist in the population to return to the rivers. Other causes of grilse have been the subject of much research recently on both sides of the Atlantic and several extensive reviews have been written on the subject (Schaffer and Elson 1975, Gardner 1976). Genetic and environmental aspects are involved although no factors have been found to be overriding the range of the species, and no evidence has been presented that precocious males lead to a higher incidence of

*unpublished data, Freshwater and Anadromous Fishery Management Program, Fisheries and Marine Service, St. John's, Newfoundland.

grilse other than directly.

The obvious examination which would provide answers in the area, would be the crossing of precocious male parr with both grilse and large salmon parents. Large numbers of offspring from both lineages could be tagged and the nature of the returning adults would answer some questions on the possible genetic contribution of precocious parr on the sea age of the adults.

Jones and King (1950) stated that the progeny of parr are as good as those of adult males up to the smolt stage. Alm (1943) also reared progeny of parr parents to the smolt stage. No reports are available of a program where the progress of the progeny has been monitored past the smolt stage. Such a program could more easily be carried out today with use of hatcheries to control fertilization and rearing facilities where progeny could be kept separated until tagged and later released as smolts.

SUMMARY

1. Precocious male parr were present in all areas sampled. Precocity varied from 16% to 100% in the 1+ age group with an average of 59.7% of 1+ males in all samples mature. An average of 75.7% of 2+ parr, 95.7% of 3+ parr and 100% of 4+ parr were mature. Precocity appeared to be generally more prevalent in Placentia Bay Rivers than those further west. Rocky Brook of the Upper Humber had the lowest incidence (12.3%) of all the samples.

2. Sex ratios of parr samples were often found to deviate significantly from a 1:1 ratio. In most samples this was in favour of males although in one females significantly outnumbered males. These differences in sex ratios are discussed in terms of sex-related distribution patterns, migration and mortality.

3. The earliest observed age of maturation was 1+. The limited evidence available suggests that maturation at 0+ is rare in Newfoundland rivers. The smallest individual precocious male was 60 mm and the smallest average size of 1+ precocious males from a given system was 72.6 mm. While 60 mm is small by other records the age and size range of precocious parr from Newfoundland is comparable to that from elsewhere.

4. Precocious 1+ males were consistently longer than immature males in all samples, significantly ($p = 0.001$) in one. This is not

true of older age groups. This agrees with most literature on the subject that larger individuals mature first with growth consequently slowing. Increased incidence of maturity appeared to be related to faster growth within a particular system but was not especially apparent in comparisons between the systems.

5. No differences were observed in length-weight relationships by examining 95% confidence intervals of calculated weights at corresponding lengths for mature and immature parr. There was, however, no overlap of confidence intervals of calculated weights for immature female and precocious (spent) male smolt in the longer length classes. Females were always heavier, or of better condition than the precocious males.

6. Capture of marked precocious males in the smolt run of Northeast River indicated that some spent males do migrate. The examination of 4 samples of smolt indicated that the runs were dominated by females (81-91.8%). Spent males made up from 2.1 to 15% of the smolt samples.

7. The fate of precocious parr is discussed in relation to sex ratios, smolt runs, and length-weight relationships. The smolt run and sex ratios in freshwater following the smolt run indicate that few precocious males migrate. Limited evidence from spawning marks suggests that at least some precocious parr may mature more than once. While few spent males migrate, precocious parr older than 3+ are not

numerous in freshwater, suggesting a high mortality of the older males. Lowered condition of spent smolt compared to female smolt is discussed in connection with energy expenditure and it is suggested that older precocious parr may die of emaciation.

8. The number of precocious males increased on the spawning ground in Northeast River as spawning approached, and decreased shortly after. From 15 to 25 precocious males were observed around each adult on the spawning ground. Gonads of precocious parr were spent or partially spent after the redds were made, indicating that they had spawned. Seventeen adult females and only two males were encountered on the spawning ground.

9. It appears, from the evidence available, that rivers with a higher percentage of sexually precocious males have fewer male smolt and a corresponding high percentage of adult females.

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Appendix A. Number of smolt captured each day during the smolt run, Northeast River, 1977.