FECUNDITY OF FOUR SPECIES OF SALMONID FISHES IN NEWFOUNDLAND WATERS

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by

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ABSTRACT

A total of 530 female rainbow trout, brown trout, landlocked Atlantic salmon and brook trout collected from seven ponds on the Avalon Peninsula, Newfoundland, in 1969 are included in this investigation. Except for brook trout which ahd a predominance of males, the sex ratios of these species were not significantly different from a 1:1 ratio.

Females of the four species generally mature one year later than males. Landlocked salmon from Forest Pond had a higher percentage at first maturity than Ocean Pond fish of the same age. There was no marked difference in age at first maturity between Long Pond and Middle Pond brown trout. Female brook trout matured one year earlier (2+) than the other three species. While both sexes of brown trout and landlocked salmon differed in age at first maturity, they varied little in size at first maturity.

The rates of development of the ovary in early and mid-summer are nearly constant for the four species, each decreasing one month before spawning. Landlocked salmon from both Forest Pond and Ocean Pond had the largest eggs of all fish examined. Egg size could not be consistantly correlated with size and age of fish in all species. Egg numbers were significantly correlated with size and age of fish (at the 1% level) and the relationships between the variables were linear. Fecundity and weight were more closely correlated than fecundity and length. Brown trout from Middle Pond had a higher percentage of atresia than Long Pond fish. Atresia in landlocked Atlantic salmon from Forest Pond and Ocean Pond were nearly the same. Within each species the K factor of the fish was inversely correlated with atresia and positively correlated with fecundity. Fecundities of the four species in descending order are, rainbow trout, brown trout, brook trout, and landlocked salmon.

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INTRODUCTION

In the present study, four species of salmonids were studied, namely the rainbow trout, *Salmo gairdneri* Richardson, 1836; the brown trout, *Salmo trutta* Linnaeus,1758; the landlocked Atlantic salmon, *Salmo salar* Linnaeus, 1758; and the brook trout, *Salvelinus fontinalis* Mitchill, 1815. The rainbow trout and brown trout were introduced into Newfoundland from New York State[1] and Scotland respectively in the latter part of the 19th century (Andrews, 1965). Rainbow trout were planted in Murray's Pond and other waters of the upper Avalon Peninsula, and for the past eight decades have only spread in a small area from where they were planted. Brown trout were more successful in naturalizing themselves and are widely distributed on the Avalon Peninsula, the north shore of Trinity Bay and the eastern side of the Burin Peninsula (Andrews, 1965). The brown trout is apparently replacing the brook trout where they occur sympatrically. Since brook trout are highly regarded as a food fish by anglers, there has been a re-evaluation of the wisdom of further natural spread of the brown trout in Newfoundland. Landlocked salmon are widely distributed throughout the Island and in other parts of North America. Surprisingly, no work has been done on the fecundity of this species.

1. The New York State rainbow trout were originally from California.

Fecundity is one of the fundamental factors which determines population density and constitutes one of the regulating mechanisms which maintains stocks at certain levels. The principal aim of this study is to examine the sexual maturity and fecundity of the four species and to compare them with other stocks in California, Europe and other areas. Such information is of academic importance to the ecologists as well as being of importance to the fishery biologists. It is hope that, with increased knowledge of the species concerned, better management programs can be developed in the future.

PONDS STUDIED

Seven ponds were selected for study: Murray's Pond, Long Pond, Middle Pond, Kelly's Pond, Island Pond, Forest Pond and Ocean Pond. Except for Ocean Pond which is about 80 Km west of St. John's, the others are located either in or near the city (Fig. 1).

Various physico-chemical characteristics were measured. Dissolved O_2 was measured by YSI Oxygen Meter (Model 51). Hydrogen concentration was measured by Radiometer (Model 22). Total hardness was determined by DS Meter. Temperature was recorded both by the ordinary mercury thermometer and a Ryan thermograph. The results of these measurements are summarized in Table 1.

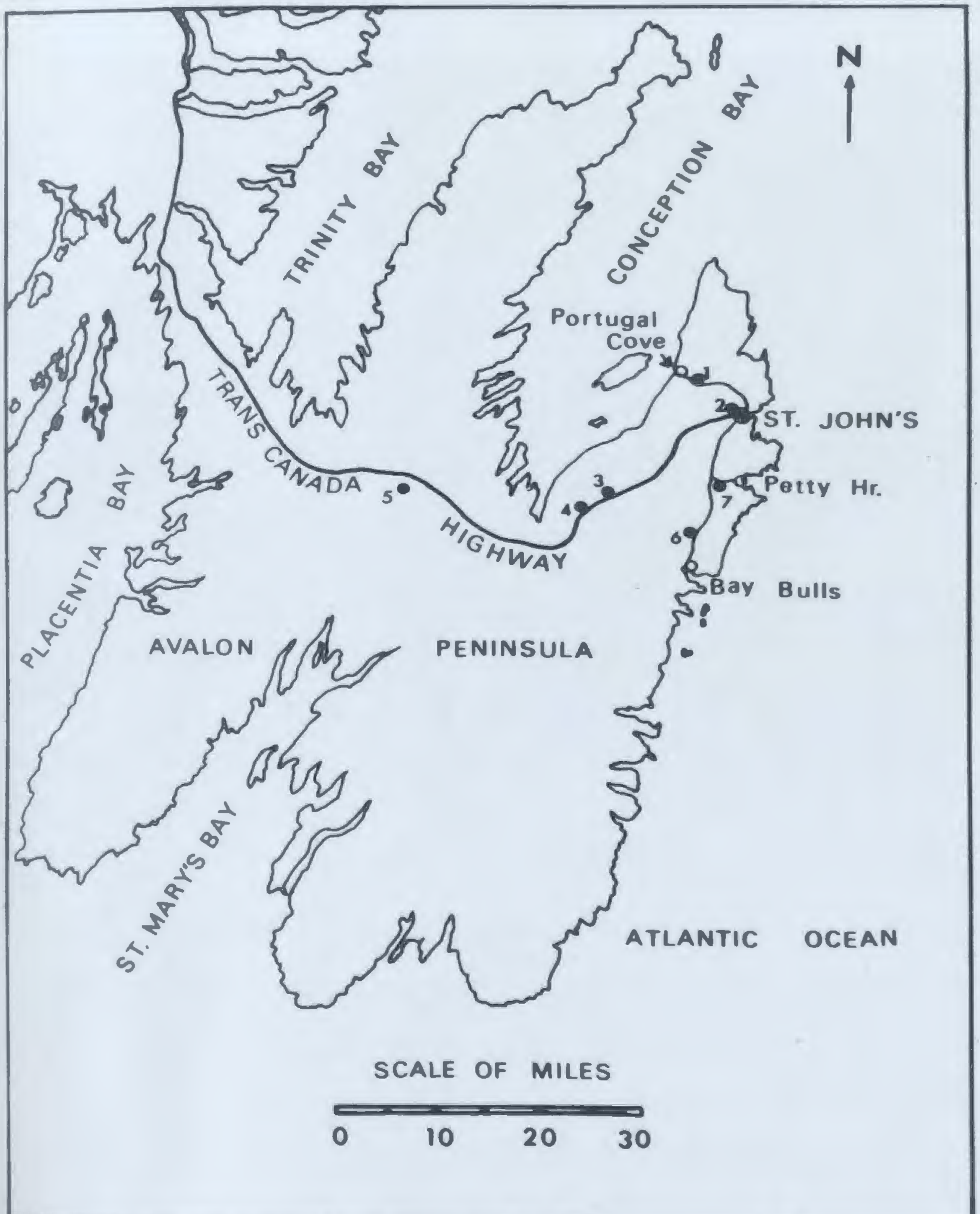
Table 1. Areas and average physical and chemical characteristics of the seven study areas. Samples were taken in the fall, 1969, except for Murray's Pond where data were collected in the spring, 1969.

Pond	Areas (ha.)	Dissolved O_2* (ppm)	Total hardness* (ppm)	Temperature* (°C)	Ph*
Murray's P.	8.5	11.7	35.0	5.0	6.8
Long P.	6.5	10.5	38.0	8.6	6.8
Middle P.	153.0	10.4	24.5	8.2	6.1
Kelly's P.	14.6	9.0	18.0	12.0	6.9
Island P.	8.1	9.5	23.0	10.0	5.7
Forest P.	10.1	10.7	32.0	8.5	6.7
Ocean P.	403.9	10.8	19.0	9.4	6.5

* Data were taken from the surface (0.6 - 3.0 m).

Fig. 1. Map showing the seven study areas on the Avalon Peninsula.

1. Murray's Pond
2. Long Pond
3. Island Pond
4. Kelly's Pond
5. Ocean Pond
6. Middle Pond
7. Forest Pond


N
TRINITY BAY
CONCEPTION BAY
Portugal Cove
1
2
ST. JOHN'S
TRANS CANADA HIGHWAY
3
4
5
6
7
Petty Hr.
Bay Bulls
PLACENTIA BAY
AVALON
PENINSULA
ST. MARY'S BAY
ATLANTIC OCEAN
SCALE OF MILES
0
10
20
30

METHODS AND MATERIALS

Sampling

Rainbow trout were first collected from Murray's Pond during spring, 1969, while the pond was covered by ice. Angling through the ice was tried, but was unsuccessful. Alternatively, a gang of nylon gill nets, 2" and 2½" mesh size, was set under the ice with an ice jigger. This method was successful and 49 fish were taken. Thirty-two fish were caught with the same nets after the ice melted.

The remaining three species were collected between May and November, 1969. Nylon nets of the same mesh size as above were set at random across the pond or along the shore. Prior to and during the spawning period, nets were set either at the outlet or inlet of the pond.

Mwasurements

All specimens were examined fresh. Fork length and total weight were measured to the nearest tenth of a centimeter, and gram respectively. The right and left ovaries were weighed separately to the nearest hundredth of a gram. Cheese cloth was used to wipe off the excess body fluid adhering to the ovaries prior to weighing.

Aging and Sexing

Scales for aging were taken from between the dorsal and adipose fin slightly above the lateral line. A micro-projector with a magnification of about 50 times was used to facilitate determination of age as described by Lagler (1966). Determination of sex was based mainly on macroscopic examination. Immature gonads were examined under a low power dissecting microscope.

Handling of Eggs

Ovaries were preserved either in 5% formalin or in modified Gilson's fluid (Simpson, 1960) for a period of a few weeks to about 10 months. Right and left ovaries of fish which had reached development stage 4 and above (Vladykov, 1956) were kept separately for the study of differential egg counts.

The diameter of eggs was determined using a wooden measuring trough similar to the one described by von Bayer (1910). Twenty eggs from each of the ovaries were measured to the nearest hundredth of a mm, then the average of the combined diameter of the 40 eggs was taken.

Enumeration of eggs were done by direct count and egg counters. The counter consists of a metal trough with a cork stopper at one end and a rectangular plastic plate with five hundred drilled holes (Fig. 2). Three plates were used for different egg sizes and are as follows:

Plate	Size (cm)	Thickness (mm)	Diam. of holes (mm)	Egg size (mm)
1	42 × 9	3.50	3	2 - 3
2	"	5.00	4	3 - 4
3	"	6.00	5	4 - 5

When in operation, the plate was slightly immersed in water. Eggs of known size were placed at one end of the plate, a plastic blade was used to sweep the eggs over the plate forcing 2 eggs into each hole. In this way, a count of 1,000 eggs could be made in about one minute.

It was found that the counter was not accurate in enumerating eggs smaller than 3 mm in diameter. Only eggs between 3 mm and 5 mm in diameter were enumerated by the counter. Eggs which were not in the size range (3 - 5 mm) were counted directly.

Maturation

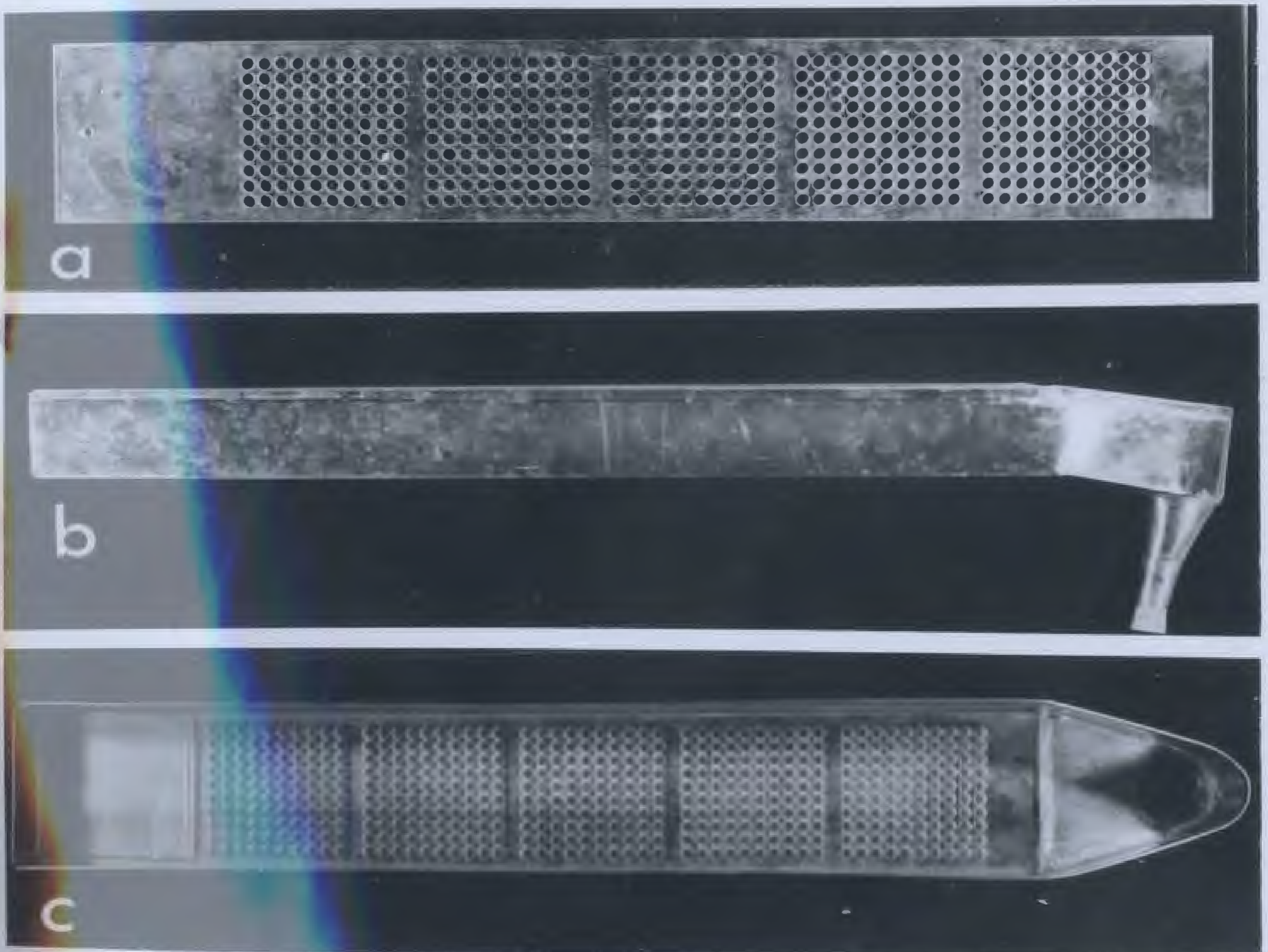
Age and Size at First Maturity

Maturity in trout is readily apparent during the spawning season, however, some difficulties are enountered

Fig. 2. (a) Top view of the plastic egg counter.

(b) Lateral view of the metal trough.

(c) Top view of the metal trough with egg counter inserted.


a
b
c

in distinguishing fish maturing for the first time from mature resting fish. The appearance of the gonads, the size and compactness of the maturing eggs and those retained from the previous spawning were used as criteria for the distinction. Samples collected from August to October were used to determine the age and size at first maturity.

In immature female trout, the ovary is one quarter or less the length of the body cavity and is hidden by the liver and stomach when viewed from below. The eggs are 1 mm or less in diameter, tightly packed together and of uniform size. The ovary of a resting female is about half the length of the body cavity, usually wider and darker in colour than the immature one. Retained eggs are often found either in the ovary tissue or free in the body cavity.

In an immature male, the testes are white narrow strings of almost constant width except for the posterior ends which are very thin. They become pink and swollen, particularly in the anterior and middle portion by about early June and creamy coloured as maturity progresses. Testes of a spent fish look shrunken, blood-shot.

Maturity Index-Seasonal Variation

The maturity index (O/F) was calculated as the gonad weight times 100, divided by the total body weight (Vladykov, 1956). The mean O/F for all age groups for each month was calculated to show the seasonal development of gonads.

Egg Size vs Maturity Index

Based on the egg size, mature females can be distinguished from immature ones at all times of the year (also refer to p. 9). The mean diameter of eggs of the same size group was compared with the mean maturity index.

Fecundity

Two types of fecundity (total and relative) have been recognised by Määr (1949), Toots (1951), and Vladykov(1956) for char (Salvelinus alpinus), whitefish (Coregonus) and brook trout (Salvelinus fontinalis) respectively. The same methods have been adopted here.

Total fecundity is the total number of mature ova present in both ovaries. The relationship between total number of eggs and fish size is a positive one and each population has its own typical regression line.

Relative fecundity is expressed as the number of mature ova per 100 g of fish weight or per 100 mm of fork length.

Statistical Analysis

As some of the maturing ova degenerate during the development (Vladykov, 1956; Henderson, 1963; Wydoski and Cooper, 1966), the number of mature ova present in the ovary prior to spawning is smaller than the number of maturing eggs in the fish earlier in the season. Only those females with less than 20 free eggs in the body cavity were accepted for fecundity determination.

The samples used in regression analysis were restricted to those collected nearest to the spawning season (April & May for rainbow trout; September & October for brown trout, brook trout and landlocked salmon). This restriction is necessary because of atresia of eggs during development.

Data relating the size and age of fish to the size of mature ova were restricted to those samples collected either in a single day or within a period of not more than a week. The same criterion was applied in determining the relationships between gonad weight and number of mature ova and gonad weight and size of fish.

RESULTS

Length Composition

Brown Trout

Fish from Long Pond and Middle Pond were grouped in 2 cm intervals and are shown in Fig. 3a and Appendix 4a, 4b. Long Pond fish, which grew to a greater length, ranged from 18 to 44 cm, with a mode of 27 cm. In Middle Pond, specimens ranged from 15 to 37 cm with a modal length of 29 cm. As shown in Fig. 3a, a high percentage of Middle Pond fish belong in the 28 to 34 cm groups.

Landlocked Salmon

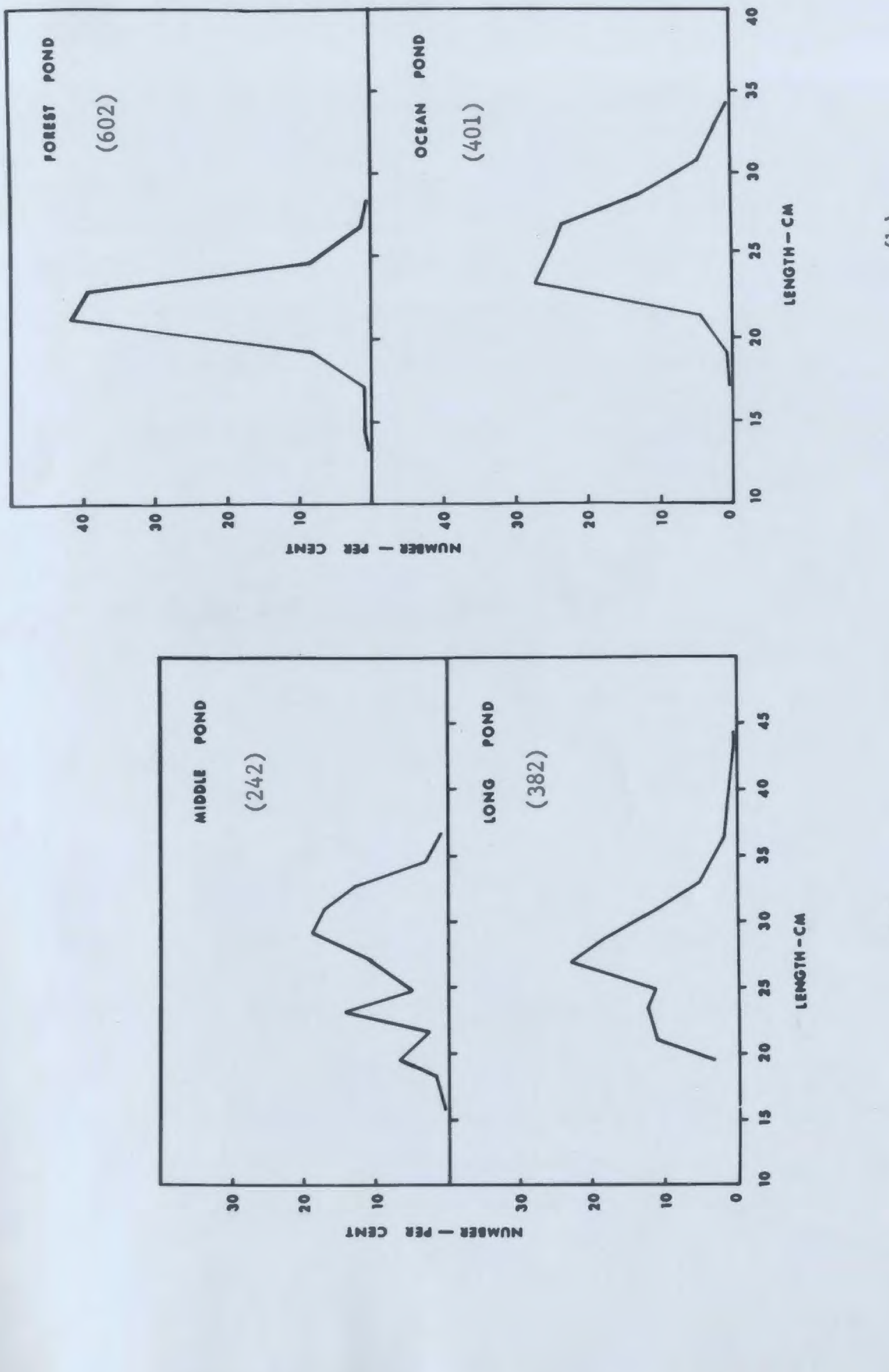
Fish from Forest Pond and Ocean Pond were arranged by the same method described above. Very similar frequency graphs were obtained for the two populations with both having almost equally high peaks (Fig. 3b). Forest Pond fish were smaller and varied from 13 to 27 cm. Ocean Pond fish were larger in size and ranged from 16 to 34 cm. The sample consisted mainly of the 22 to 27.9 cm length groups (74%).

Rainbow Trout

The length of rainbow trout ranged from 18 to 40 cm. The average size was larger than the other three species.

Fig. 3. Length composition of brown trout (a) and landlocked salmon (b) from the four study areas.

Bracketed values represent the number of fish.


FOREST POND
(602)
OCEAN POND
(401)
MIDDLE POND
(242)
LONG POND
(382)
NUMBER — PER CENT
LENGTH — CM

(a) (b)

The 30 to 41.9 cm length groups were 57.8% of the sample (Fig. 4b and Appendix 4e). Because of the small size, the data are probably not representative of the population.

Brook Trout

Most of the brook trout were small in size. They ranged from 12 to 32 cm with a mode of 19 cm (Fig. 4a and Appendix 4f). The largest fish were caught in Ocean Pond.

Age Composition

Brown Trout

Fig. 5a and Appendix 5a show the major age groups of Long Pond and Middle Pond samples. The 5+, 6+, 7+, 8+ and 9+ year classes were most abundant in Middle Pond (80.7%), while in Long Pond, the 3+, 4+, 5+ and 6+ year old fish were 87.6% of the sample.

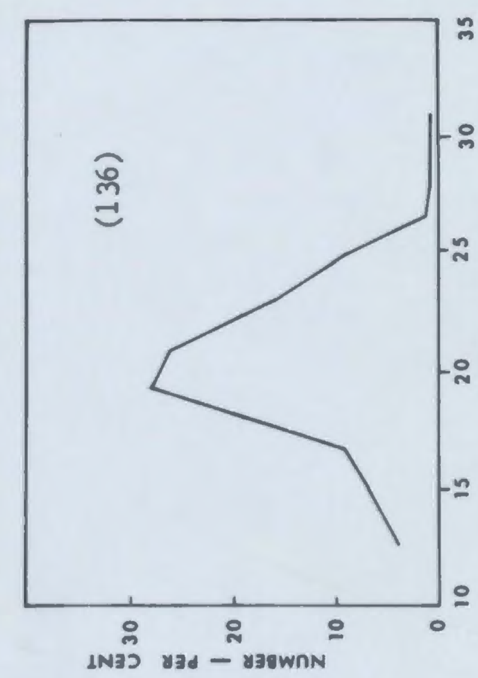
Landlocked Salmon

The 3+, 4+ and 5+ year classes were abundant in the Forest Pond population (Fig. 5b and Appendix 5b). In Ocean Pond, there were more older fish. The 3+, 4+, 5+ and 6+ year old fish were 91% of the sample (Fig. 5b and Appendix 5b).

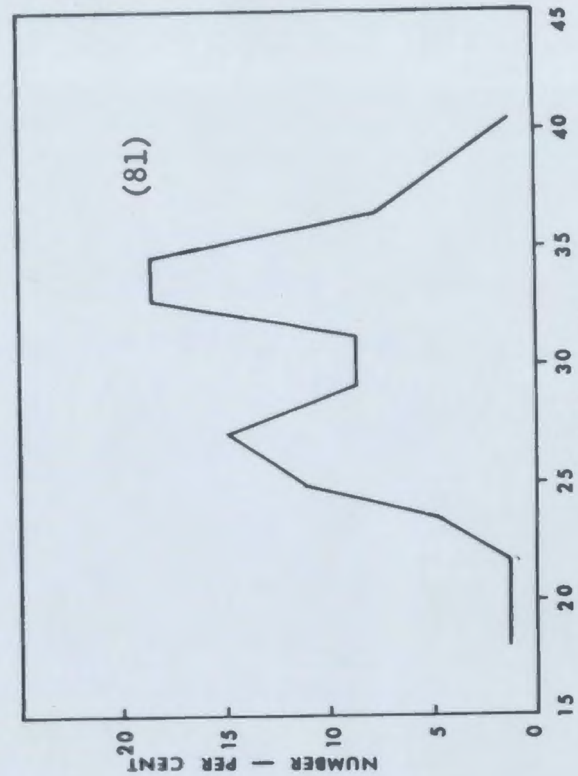
Fig. 4. Length composition of brook trout from the four ponds studied (a)* and rainbow trout from Murray's Pond (b).

Bracketed values represent the number of fish.

* See Appendix 2.


(136)
NUMBER — PER CENT
LENGTH — CM
0
10
20
30
10
15
20
25
30
35

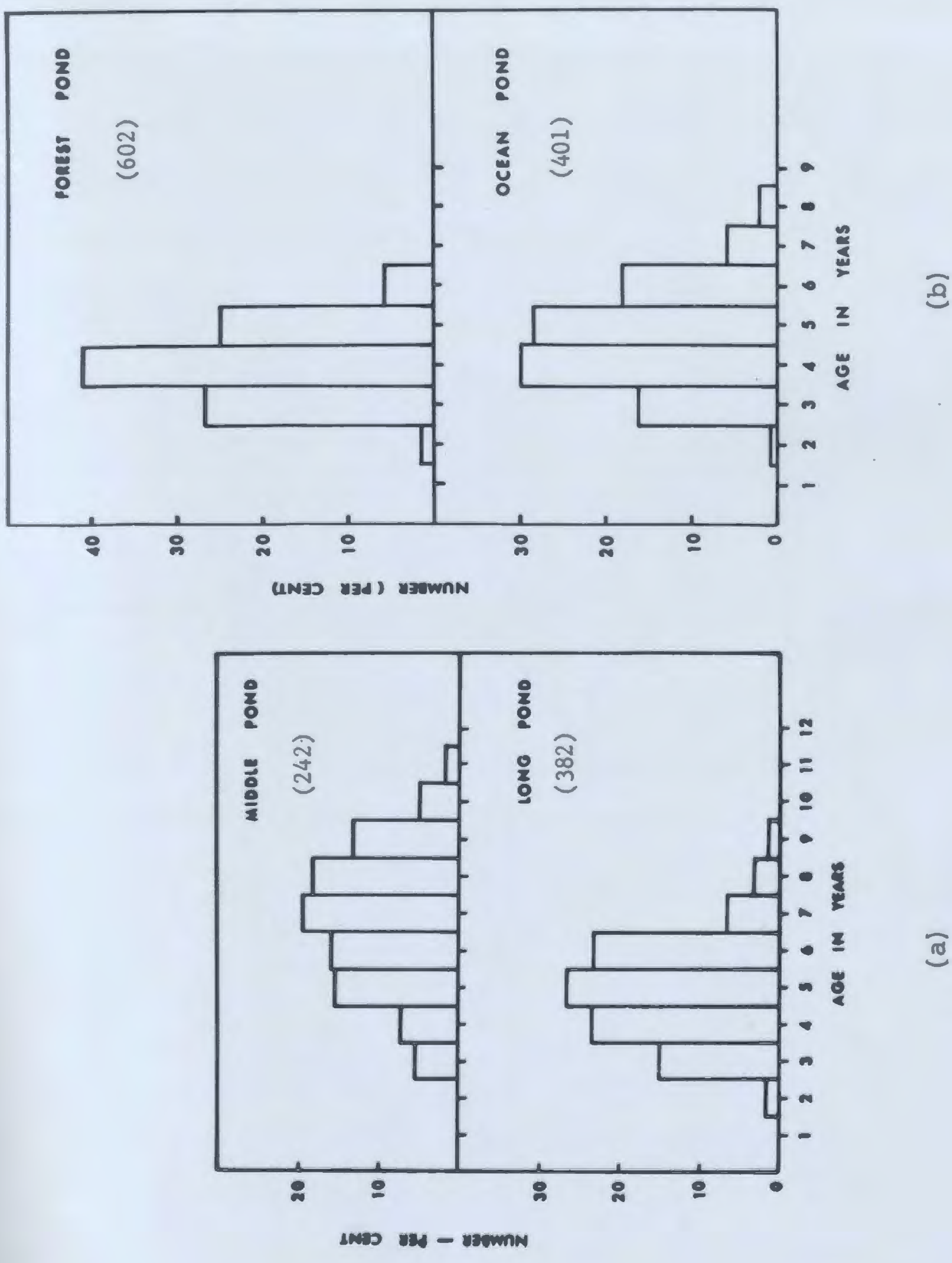
(a)


(81)
NUMBER — PER CENT
LENGTH — CM
0
5
10
15
20
15
20
25
30
35
40
45

(b)

Fig. 5. Age compositions of brown trout (a) and landlocked salmon (b) from the four study areas.

Bracketed values represent the number of fish.


FOREST POND
(602)
OCEAN POND
(401)
NUMBER (PER CENT)
AGE IN YEARS
(b)
MIDDLE POND
(242)
LONG POND
(382)
NUMBER — PER CENT
AGE IN YEARS
(a)

Rainbow Trout

With the exception of the 6+ and 9+ year fish, the other age groups were nearly equally abundant in Murray's Pond (Fig. 6b and Appendix 5c). This small sample may not be representative of the population.

Brook Trout

The 3+ year class was most abundant (53%) in the samples of brook trout from the four ponds studied. The 2+ and 4+ fish contributed 38% of the total sample (Fig. 6a and Appendix 5d).

Sex Ratio

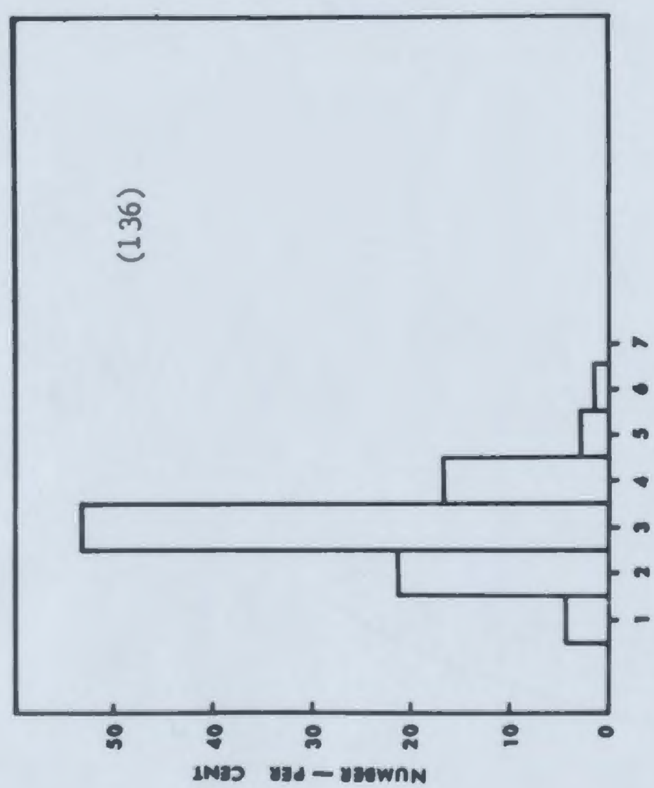
The sex ratio for each population was expressed as the percentage of females for each age group and was tested against a theoretical 1:1 ratio by the chi-square distribution (Snedcor, 1956).

Brown Trout

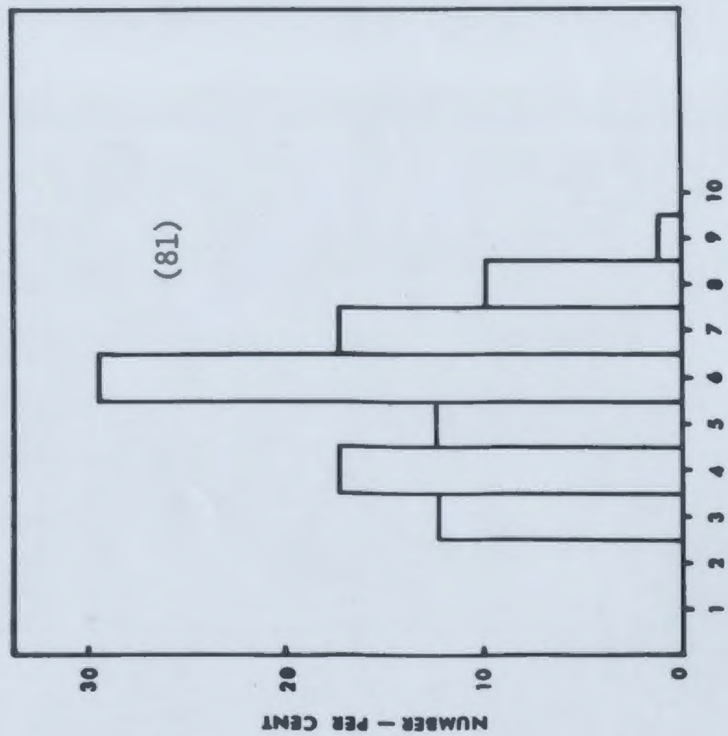
The sex ratio of brown trout was very close to the 1:1 ratio when data from Long Pond and Middle Pond were combined (Table 2). When the two populations were analysed separately, neither had a sex ratio that was significantly different from a 1:1 ratio.

Fig. 6. Age compositions of brook trout from the four ponds studied (a) and rainbow trout from Murray's Pond (b).

Bracketed values represent the number of fish.


(136)
50
40
30
20
10
0
NUMBER — PER CENT
1
2
3
4
5
6
7
AGE IN YEARS

(a)


(81)
30
20
10
0
NUMBER — PER CENT
1
2
3
4
5
6
7
8
9
10
AGE (YEARS)

(b)

Table 2. Sex ratios of brown trout by age groups from Long Pond and Middle Pond.

		II	III	IV	V	VI	VII	VIII	IX	X	XI	Total
Male	L*	3	27	42	46	48	10	8	4			188
	M**		3	7	15	14	26	23	19	6	3	116
Female	L	3	30	47	54	40	15	4	1			194
	M		9	10	22	23	21	21	13	6	1	126
% Female	L	50.0	52.6	52.8	45.5	54.0	60.0	33.0	20.0			50.9
	M		25.0	58.8	59.5	62.2	44.7	47.7	40.6	50.0	25.0	52.1
X^2 Value	L	0	0.16	0.28	0.64	0.73	1.00	1.33	1.8			1.27
	M		1.5	0.53	1.31	2.19	0.53	0.09	1.13	0	1.0	0.41
P	L		>0.5	>0.5	>0.25	>0.25	>0.25	>0.1	>0.1			>0.25
	M		>0.1	>0.25	>0.25	>0.1	>0.25	>0.75	>0.25		>0.25	>0.5

* L: Long Pond

** M: Middle Pond

Landlocked Salmon

With the exception of age group 4+ which had a predominance of females (57.6%), the sex ratio of the combined data (Forest Pond and Ocean Pond) were not significantly different from a 1:1 ratio. When data from each population were analysed separately (Table 3), both 4+ and 6+ age groups from Forest Pond were significantly different from the theoretical 1:1 ratio.

Rainbow Trout

The combined data for all the age groups of rainbow trout from Murray's Pond did not show a predominance of either sex (Table 4).

Brook Trout

Among the species studied, the brook trout was the only species in which males formed the majority of the population. The predominance of males for age groups 2+ and 3+ is clearly indicated in Table 5. Chi-square test of the combined data showed a significant difference ($x^2 = 16.94$; $p < 0.005$) between the theoretical and the observed ratio.

Table 3. Sex ratios of landlocked salmon by age groups from Forest Pond (F. P.) and Ocean Pond (O. P.) expressed as the percentage of females.

		II	III	IV	V	VI	VII	VIII	Total
Male	F. P.	8	77	93	80	27			285
	O. P.	2	31	64	52	32	12	5	198
Female	F. P.	3	83	154	70	7			317
	O. P.	0	32	59	58	38	10	6	203
% Female	F. P.	27.3	51.9	62.4	46.7	20.6	52.7		62.6
	O. P.	0	50.8	48.0	52.7	54.3	45.6	54.6	50.5
X^2 Value	F. P.	2.27	0.23	15.06*	0.67	11.76*			1.70
	O. P.	2	0.02	0.20	0.33	0.51	0.18	0.09	0.04
P	F. P.	>0.1	>0.5	<0.005	>0.25	<0.005			>0.1
	O. P.	>0.1	>0.9	>0.5	>0.5	>0.25	>0.5	>0.75	>0.75

* Significantly different between the sex ratio from 1:1 ratio.

Table 4. Sex ratio of rainbow trout by age groups from Murray's Pond.

Sex	III	IV	V	VI	VII	VIII	IX	Total
Male	8	11	4	7	4	3	0	37
Female	2	3	6	17	10	5	1	44
% Female	20.0	21.4	60.0	70.8	71.4	62.5	100	54.3
X^2 Value	3.60	4.57	0.20	4.17	2.57	0.50	1.00	0.60
P	>0.05	>0.025	>0.5	>0.025	>0.1	>0.25	>0.25	>0.25

Table 5. Sex ratio of brook trout by age groups from different areas combined.

Sex	I	II	III	IV	V	VI	Total
Male	4	25	48	13	2	0	92
Female	2	4	25	10	2	1	43
% Female	33.3	13.8	34.3	43.4	50	100	32.3
X^2 Value	0.67	7.62	7.25	0.39	0	1	16.94*
P	>0.25	>0.005	>0.005	>0.5	0.25	>0.25	>0.05

* Significantly different between the sex ratio from 1:1 ratio.

Spawning Time

Brown Trout

Brown trout are late fall to early winter spawners in the northern hemisphere. Spawning time may differ with habitat and latitude. Brown trout in British waters spawn between October and February, with the normal spawning time being November and December (Frost and Brown, 1967). In Michigan, spawning was observed between November 4 and 25 by Greeley (1932), but he believed that the period was longer. Brown trout in New Zealand generally spawn in June and July (Hobbs, 1937; Allen, 1951).

Trout in Long Pond spawn between early October and late November (Kellett, 1965, MS; Liew, 1969, MS). In 1969, two samples were taken in late September (21 and 29) both at the outlet and inlet of the pond. Some fish were ready to spawn as evidenced by free eggs in the body cavity and spawning might begin as early as late September. In Middle Pond, trout spawned between September 27 and the end of November. It is quite possible that spawning may extend to early December because some adult fish were found in the inlet of the pond on December 4.

Landlocked Salmon

Like the anadromous form, spawning of the landlocked salmon usually takes place in October and November. At Cross Lake Thoroughfare, Maine, the period extended from about 20 October to 10 November (Warner, 1962).

Landlocked salmon in Forest Pond spawned between September 29 and the end of November. No information about the spawning period was obtained for fish in Ocean Pond, but a large number of spawners (about 140 fish) were caught on October 25, 1969, in nets set across the outlet, and it seems likely that the run had reached a peak at this time.

Rainbow Trout

There are two types of spawners, fall and spring (Lewis, 1944). Trout from Murray's Pond are spring spawners. In 1969, the run began on April 19, reached a peak at the end of April, and ended in early May.

Generally lake resident and stream resident rainbow trout in Newfoundland spawn from late March to the end of April or mid-May (Frost, 1938, 1940).

Brook Trout

The spawning period of this species in other areas is between September and November (Vladykov, 1956; McFadden, 1961; Wydoski and Cooper, 1966). No information was obtained regarding the exact period of spawning. It is believed that while the time of spawning may vary with different localities, the spawning occurs in this area between October and November (Frost, 1940; Wiseman, 1969, MS).

Colour of Eggs and Flesh

The egg colour varied among the species studied from light yellow to orange red. The flesh colour of brown, rainbow and brook trout varied from white or light purple to deep orange red. Landlocked salmon flesh was white in all collections. The flesh of most of the brown trout from Middle Pond were deep orange red in colour in June and July. Most fish had white flesh at spawning. There was no relationship between the colours of eggs and flesh.

Maturation

Age and Size at First Maturity

Brown Trout

Male trout in Long Pond reach sexual maturity as early as the end of the 3rd year of life (2+). Females tend to mature at an older age (3+). Although both sexes may mature as late as their 7th year of life, the majority matured before age 4+ (Fig. 7 and Appendix 5a).

The smallest mature male and female in the Long Pond sample were 19.8 and 19.7 cm respectively, and the largest immature male and female were 27.3 and 26.4 cm respectively. While males and females differed in age at first maturity, they varied little in size at first Maturity.

Compared to Long Pond brown trout, fish in Middle Pond became sexually mature at a smaller size, but not at an earlier age (Appendix 5a).

Landlocked Salmon

In Forest Pond, male fish may reach maturity for the first time at age 2+. No female was mature at age 2+. All males and females were mature at 6+ and 5+ respectively (Appendix 5b and Fig. 8). There was little size difference between the two sexes at first maturity.

In the Ocean Pond sample, there was a wide variability for each sex in the age and size of first maturity (Appendix 5b). Three 22.9 cm long females were mature at age 3+, while a 6+, 28.4 cm female was still immature. Two 21.7 cm males were mature at age 3+, but two 6+ males 28.3 cm long were still sexually immature. While the sexes differed in size at first maturity, some of both were mature at age 3+ (Fig. 8).

Fig. 7. Percentage of immature and mature brown trout from Long Pond and Middle Pond. (□ Male; ■ Female).

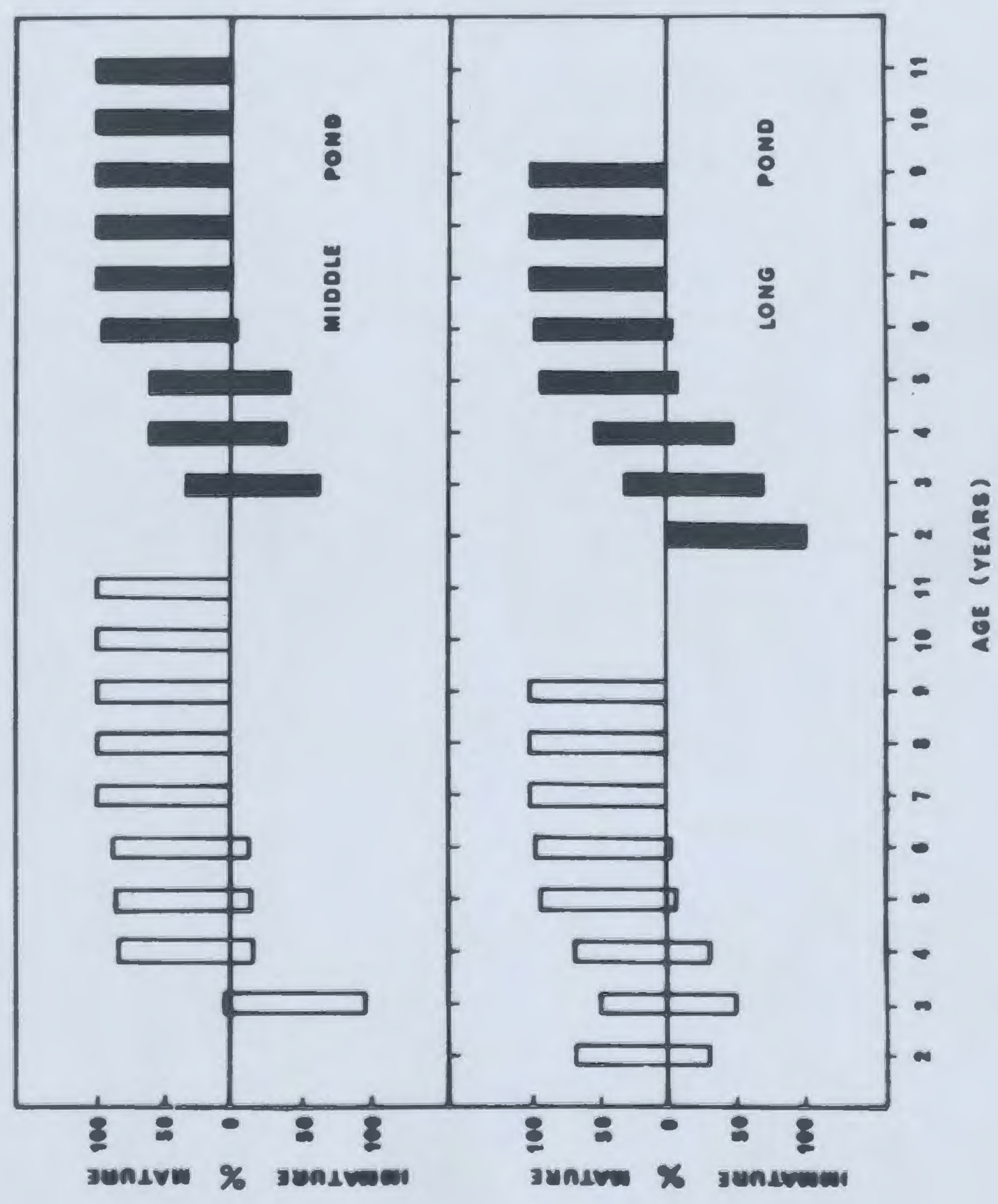
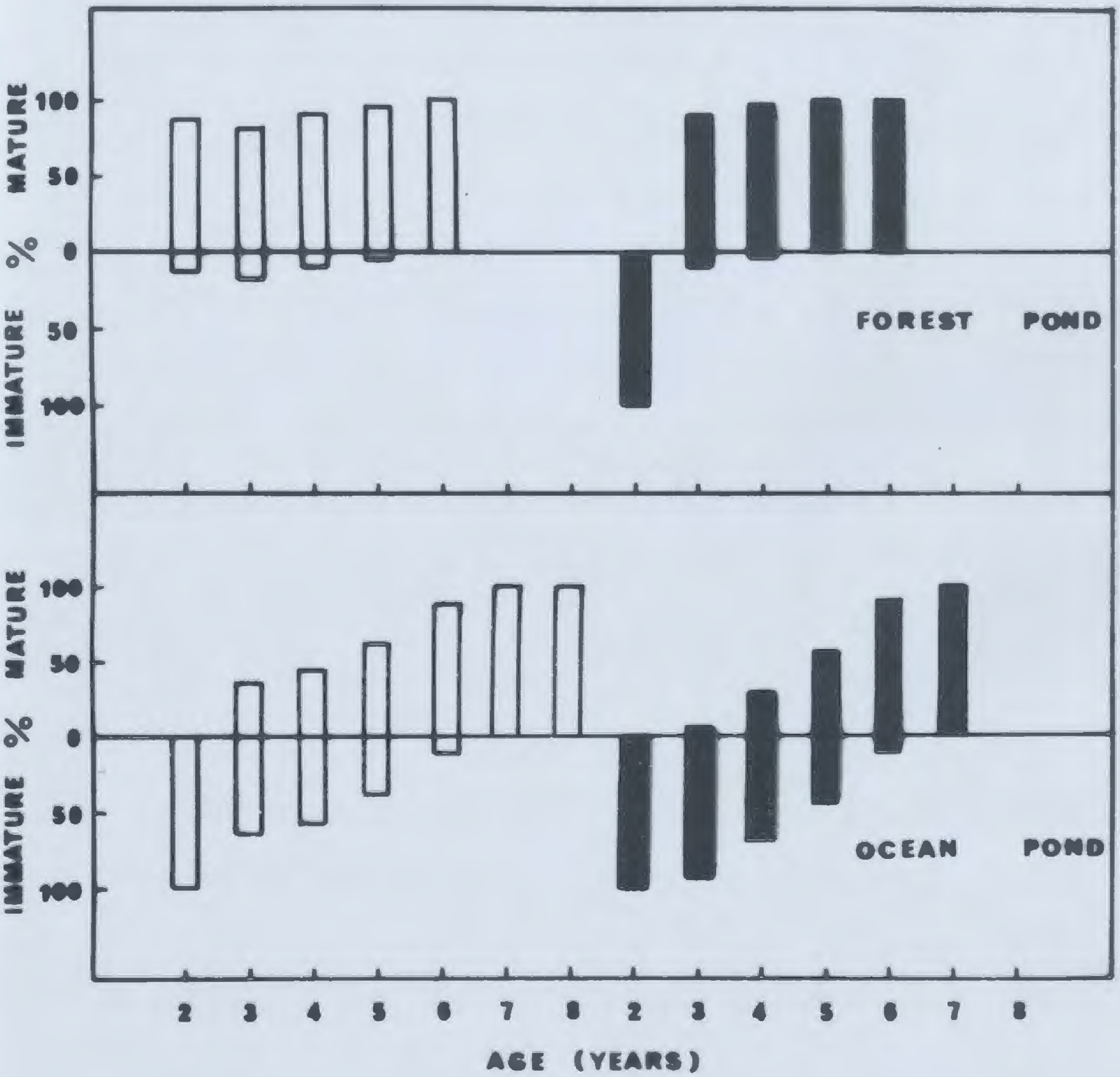

MIDDLE POND
LONG POND
AGE (YEARS)
MATURE % IMMATURE
100 50 0 50 100
2 3 4 5 6 7 8 9 10 11

Fig. 8. Percentage of immature and mature landlocked salmon from Forest Pond and Ocean Pond. (Male; Female).


IMMATURE % MATURE
100
50
0
50
100
FOREST POND
OCEAN POND
2 3 4 5 6 7 8 2 3 4 5 6 7 8
AGE (YEARS)

Data from Gambo Pond and Flatwater Pond showed that most males were sexually mature at age 2+ and the majority of females matured at age 3+ (Leggett and Power, 1969). Similar findings were reported for landlocked salmon by Blair (1937) and Warner (1962).

Rainbow Trout

Most males matured at age 3 (Fig. 9b and Appendix 5c). While females matured at age 4. Rainbow parr were observed migrating up the brook by the hatchery during the spawning season, 1969. As they were too small for capture by gill net or dip net, no information on the age and sexual condition was obtained.

Brook Trout

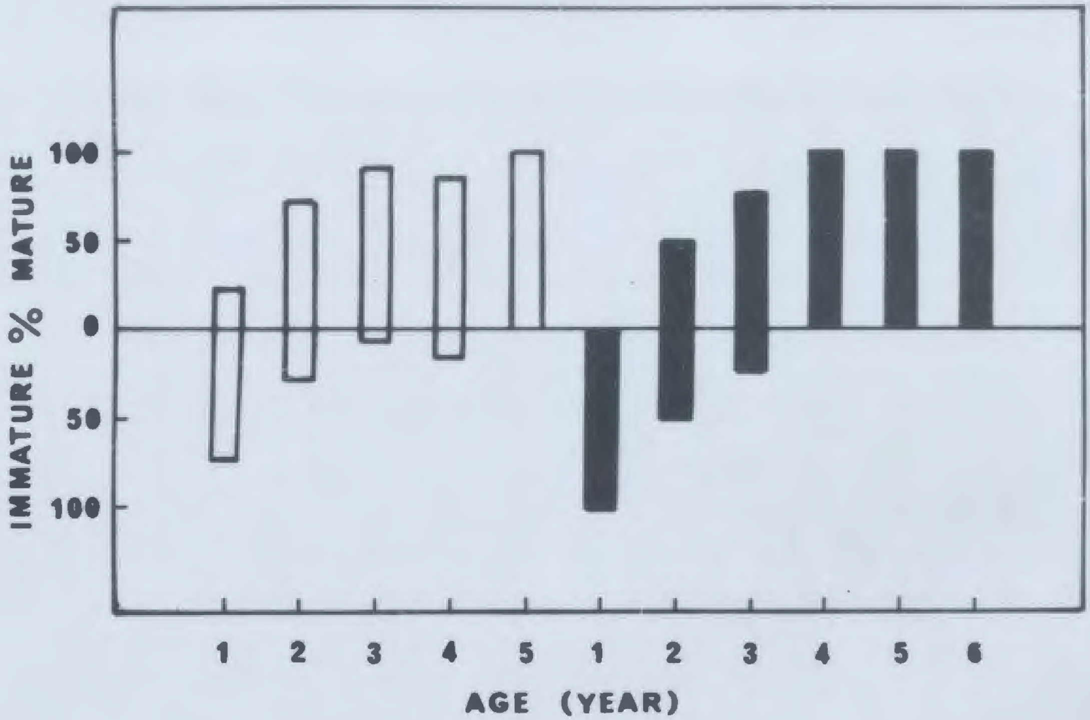
At first maturity, male brook trout were younger (1+) and smaller than females (Fig. 9a and Appendix 5d). Of the four species studied, only female brook trout were found mature at age 2+, which is, generally, one year earlier than the other three species.

Maturity Index - Seasonal Variation

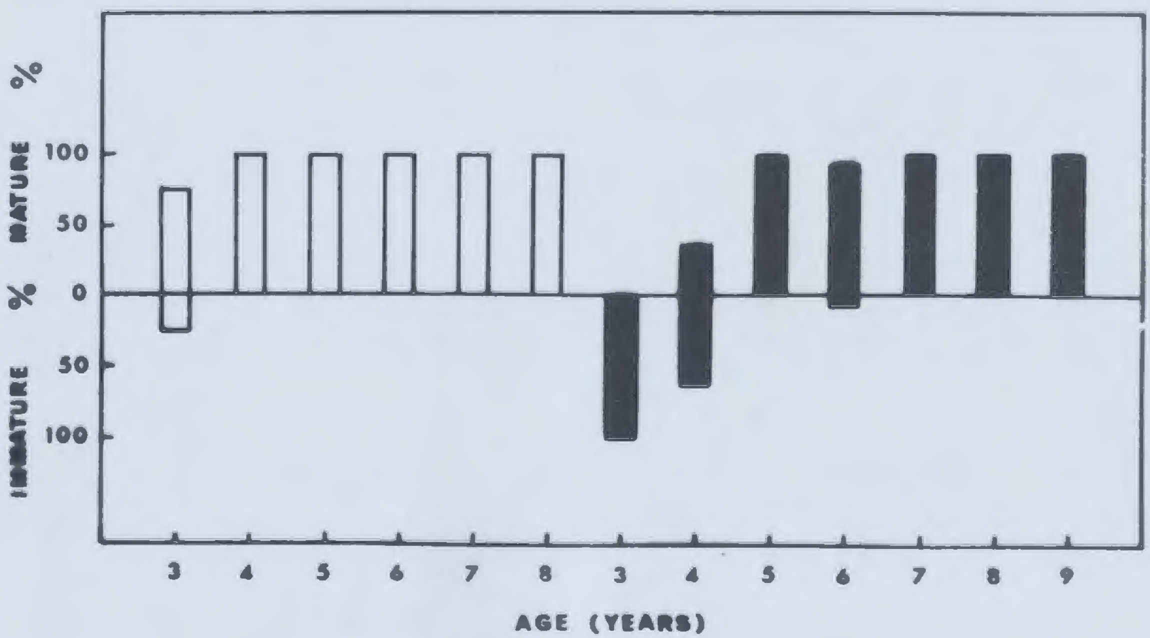
By calculating the mean maturity index (O/F) for fish collected in different months of the year, the seasonal development of the gonads can be traced. As shown in

Fig. 9 Percentage of immature and mature brook trout from the four ponds studied (a)* and rainbow trout from Murray's Pond (b).
(▭ Male; ▬ Female).

* See Appendix 2.


IMMATURE % MATURE
100
50
0
50
100
1
2
3
4
5
1
2
3
4
5
6
AGE (YEAR)

(a)


IMMATURE % MATURE %
100
50
0
50
100
3
4
5
6
7
8
3
4
5
6
7
8
9
AGE (YEARS)

(b)

Figs. 10, 11, the development began in May or June and reached a peak in September (brook trout) or October (brown trout and landlocked salmon). In May, June and July there is a nearly constant rate of development. The rate of development decreases one month before spawning (Tables 6-8).

The ranges of O/F are presented in Tables 6-8. Landlocked salmon from both ponds had the highest mean O/F (17%). In September, brown trout from Long Pond had a O/F of 12.2%, while the O/F for Middle Pond was only 8.73%. Although fish from Middle Pond had a mean O/F of 14.5% in October, it is believed that those from Long Pond would have exceeded the value, had a sample been obtained. The mean O/F of rainbow trout was 16.9%. Brook trout from the four ponds studied had the lowest O/F (12.8%) in September.

Fig. 10. Seasonal variation of maturity index (O/F, blank column) and egg diameter (stippled column) in brown trout (a) and landlocked salmon (b) from the four study areas.


MIDDLE POND
LONG POND
FOREST POND
OCEAN POND
MAY
JUN.
JUL.
AUG.
SEPT.
OCT.
DIAM. - MM
DIAM.-MM

(a)

(b)

Fig. 11. Seasonal variation of maturity index (O/F, blank column) and egg diameter (stippled column) in brook trout form the four ponds studied.

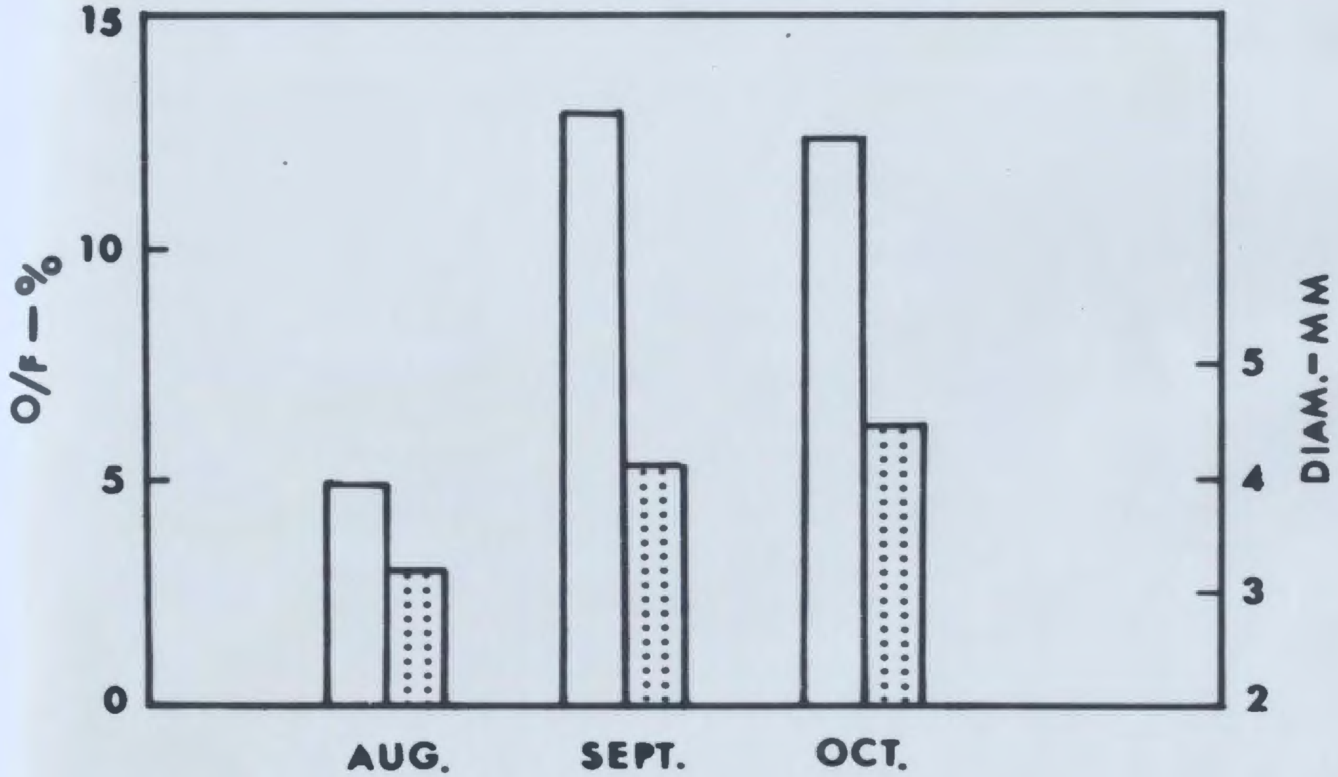

15
10
5
0
O/F — %
5
4
3
2
DIAM.-MM
AUG.
SEPT.
OCT.

Table 6. Variation in the maturity index (O/F) and diameter of eggs of brown trout in different months of the year.

Long Pond

Date	No. of fish	Diam. of eggs (mm) Range	Mean	Relative * increase (times)	O/F(%) Range	Mean	Relative* increase (times)
28/5/69	14	1.25-1.40	1.33	-	0.46-0.96	0.57	-
12/6/69	10	1.10-1.96	1.43	1.08	0.42-1.53	0.84	1.47
20/7/69	39	1.10-2.85	1.85	1.29	0.54-3.21	1.67	1.99
23/8/69	21	2.30-4.05	3.30	1.78	4.26-11.88	5.93	3.55
29/9/69	44	3.20-5.00	4.30	1.30	6.01-18.37	12.16	2.05

Middle Pond

26/6/69	18	1.20-1.45	1.32	-	0.45-1.26	0.80	-
23/7/69	20	1.50-2.90	2.06	1.56	0.99-3.99	1.79	2.24
14/8/69	7	2.45-3.05	2.76	1.34	2.20-7.19	3.95	2.21
10/9/69	36	3.10-4.80	4.04	1.46	5.05-18.43	8.73	2.21
4/10/69	18	3.95-4.95	4.62	1.14	11.59-16.40	14.15	1.62

* Calculated by the formula:

$$\frac{\text{Data for the following month}}{\text{Data for the previous month}}$$

Table 7. Variation in the maturity index (O/F) and diameter of eggs of landlocked salmon in different months of the year.

Forest Pond

Date	No. of fish	Diam. of eggs (mm) Range	Mean	Relative * increase (times)	O/F (%) Range	Mean	Relative * increase (times)
24/6/69	38	1.15-2.70	1.70	-	0.70-2.37	1.08	-
25/7/69	25	1.80-3.70	2.83	1.66	1.21-4.62	2.47	2.29
22/8/69	19	2.65-4.28	3.48	1.23	2.00-8.11	5.30	2.15
14/9/69	64	3.55-5.55	4.60	1.32	7.06-16.99	11.55	2.18
6/10/69	13	5.13-5.74	5.40	1.17	13.92-20.22	17.41	1.51

Ocean Pond

16/6/69	1	1.37	1.37	-	0.75	0.75	-
20/8/69	5	2.80-3.35	3.08	2.25	2.92-4.48	3.70	4.93
18/9/69	19	4.15-5.82	5.04	1.64	6.69-22.73	10.29	2.78
25/10/69	58	4.90-6.55	5.81	1.15	6.60-21.61	17.18	1.67

* Calculated by the formula:

$$\frac{\text{Data for the following month}}{\text{Data for the previous month}}$$

Table 8. Variation in the maturity index (O/F) and diameter of eggs of brook trout in different months of the year (collected from the four ponds studied).

Date	No. of fish	Diam. of eggs (mm) Range	Mean	Relative increase (times) *	O/F (%) Range	Mean	Relative increase (times) *
28/8/69	5	3.00-3.49	3.20	-	3.13-5.89	4.88	-
30/9/69	20	3.45-4.55	4.10	1.28	8.3 -18.47	12.84	2.63
25/10/69	5	3.75-4.55	4.48	1.09	10.86-16.07	12.32	0.96

* Calculated by the formula:

$$\frac{\text{Data for the following month}}{\text{Data for the previous month}}$$

Size of Mature Eggs

Brown Trout

Only those trout caught from late August onward with an egg diameter of 3.50 mm or over were considered as completely mature. The largest eggs (5.00 mm in diameter) came from fish in Long Pond. It is possible that eggs from Long Pond had not reached maximum size, as the fish were caught earlier than those of Middle Pond (Appendix 1).

Landlocked Salmon

The same criteria were applied regarding maturity. The mature eggs ranged from 4.05 to 6.55 mm in diameter for fish in Ocean Pond, and 4.05 to 5.74 mm for those in Forest Pond (Appendix 1). The difference in time of collection may be the reason for the size difference in mature eggs between the two populations.

Rainbow Trout

The mean diameter of mature eggs from 31 fish ranging from 26 to 39.6 cm was 4.42 mm. Mature eggs from individual females varied from 3.90 to 4.80 mm (Appendix 1).

Brook Trout

Brook trout caught in August, September and October had eggs ranging from 3.45 to 4.55 mm in diameter, but only those over 3.50 mm were considered as mature. This species had the smallest mean size of mature eggs (4.12 mm).

Egg Size - Size and Age of Fish

Wydoski and Cooper (1966) found a positive correlation between size of mature ova and the total length of brook trout. Bulkley (1967) found that egg size of steelhead (Salmo gairdneri) was positively correlated with body length both for initial spawners and older fish. However, results obtained here varied within and between species. With the exception of samples from Ocean Pond and Murray's Pond which both showed significant positive correlations between these variables, the correlations were poor (Table 9).

Atresia

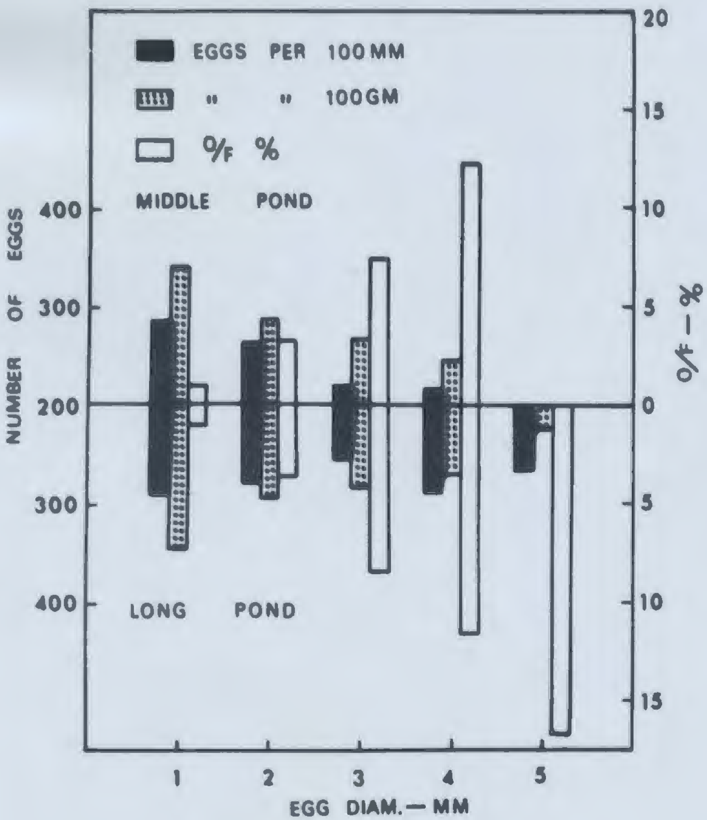
Atretic eggs (see p. 42) are opaque or white when first preserved in formalin, but become progressively darker as degeneration proceeds (Vladykov, 1956). Extent of atresia was obtained by calculating the seasonal decrease of class b eggs per 100 mm of fish. It was found that none of the species studied had over 33% atretic eggs (Fig. 12 and Appendixes 6a-6c).

Table 9. Relationships between egg diameter and length, weight and age of four species of fish from seven ponds.

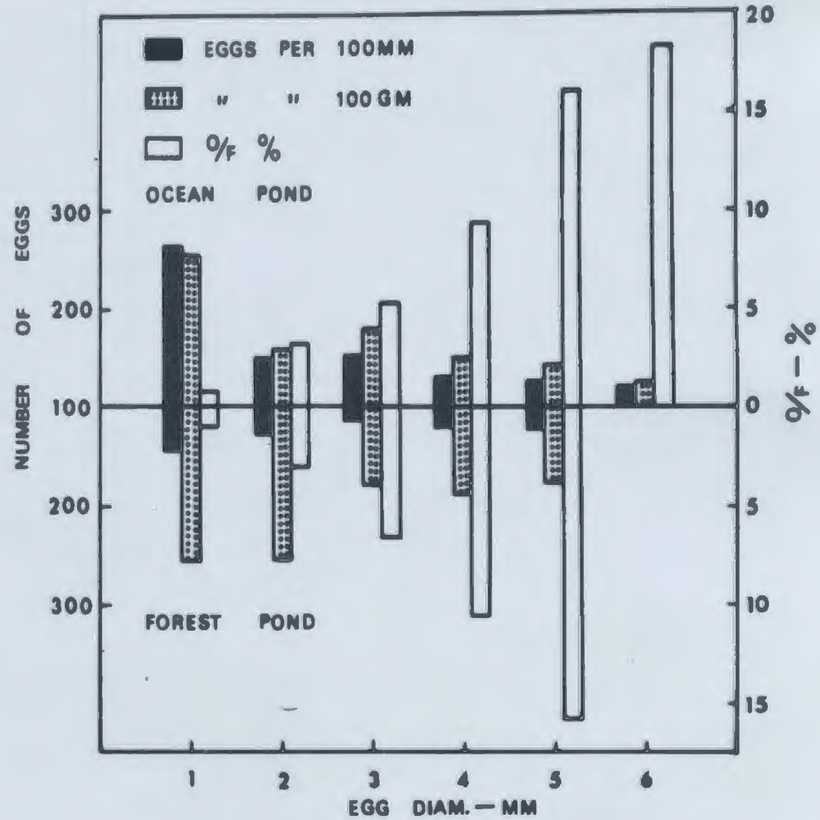
Pond	Diam. - length	Diam. - weight	Diam. - age
Long P.	$r = 0.37$ d.f. = 45 $p > 0.01$	$r = 0.26$ d.f. = 45 $p > 0.05$	$r = 0.25$ d.f. = 45 $p > 0.05$
Forest P.	$r = 0.23$ d.f. = 75 $p > 0.05$	$r = 0.35$ d.f. = 75 $p > 0.01$	$r = 0.06$ d.f. = 75 $p > 0.05$
Ocean P.	$r = 0.35$ d.f. = 75 $p < 0.01$	$r = 0.40$ d.f. = 75 $p < 0.01$	$r = 0.37$ d.f. = 75 $p < 0.01$
Murray's P.	$r = 0.38$ d.f. = 29 $p > 0.01$	$r = 0.40$ d.f. = 29 $p > 0.01$	$r = 0.50$ d.f. = 29 $p < 0.01$
Brook trout from the four ponds*	$r = 0.36$ d.f. = 23 $p > 0.05$	$r = 0.31$ d.f. = 23 $p > 0.05$	$r = 0.25$ d.f. = 23 $p > 0.05$

* Kelly's Pond, Island Pond, Ocean Pond, Middle Pond.

Fig. 12. Comparison of variations in the maturity index (O/F), number of maturing eggs per 100 mm of fork length and per 100 gm of fish weight of brown trout (a) and landlocked salmon (b) from the four study areas. Data are from the same fish listed in Appendix 2.


EGGS PER 100MM
" " 100GM
O/F %
MIDDLE POND
LONG POND
NUMBER OF EGGS
400
300
200
300
400
20
15
10
5
0
5
10
15
O/F — %
1
2
3
4
5
EGG DIAM. — MM

(a)


EGGS PER 100MM
" " 100GM
O/F %
OCEAN POND
FOREST POND
NUMBER OF EGGS
300
200
100
200
300
20
15
10
5
0
5
10
15
% — O/F
1
2
3
4
5
6
EGG DIAM. — MM

(b)

Spawning Frequency

Contrary to anadromous Atlantic salmon, spawning marks generally do not form on the scales of the landlocked form and lake resident trout. Previous spawnings, thus, can only be traced by the eggs retained either in the ovary tissue or in the body cavity.

Brook trout in Quebec (Vladykov, 1956) and brown trout in some British waters (Stuart, 1953) do not spawn annually. This is believed to be the case in the four species studied in this investigation. However, some age 6 (5+) landlocked salmon from Forest Pond were found to have spawned during two succeeding years, and were prepared to spawn in 1969. This was determined by the appearance of free eggs that were retained in the body cavity. Eggs retained from last year are similar in appearance to the mature ones, but eggs that have been retained for two or more years have most of the contents absorbed and only the shells remain.

The present study showed that a considerable number of fish had spawned previously. The percentages of fish that had spawned previously were 92% and 44% for landlocked salmon from Forest Pond and Ocean Pond respectively; 64% and 55% for brown trout from Long Pond and Middle Pond respectively; 71% for rainbow trout from Murray's Pond and 48% for brook trout from all areas.

Fecundity

Types of Eggs

As the present work was of a macroscopic nature, only those eggs which reached 1 mm in diameter or over were examined.

Three types of eggs have been described by Vladykov (1956) and are recognised here:

(a) Recruitment stock: Eggs less than 1 mm in diameter, present in clusters between maturing eggs, yolkless and transparent in fresh condition but becoming opaque when preserved (Plate I).

(b) Maturing eggs: The diameter varies from 1 to 6.55 mm in diameter. Yolk present, yellowish in early stages, orange red towards spawning and becoming progressively more transparent (Plate I).

(c) Atretic eggs: Those maturing eggs which stop growing and generally degenerate (Plate I).

Plate I. Preserved ovaries with ripe eggs from a female landlocked salmon, 29 cm in fork length, caught on October 25, 1969. Among ripe eggs are seen numerous small, round and white eggs of recruitment stock (black arrow). The white arrow indicates an atretic egg.

5 cm

Differences between Right and Left Ovaries

Data regarding the differential count from right and left ovaries were incomplete for rainbow trout and brook trout. Therefore, only brown trout and landlocked salmon data are included.

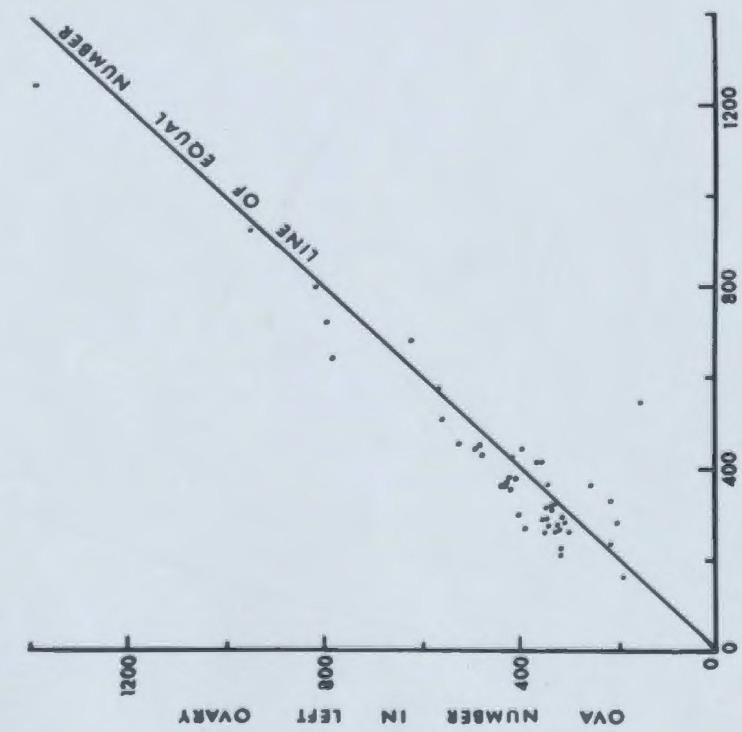
Brown Trout

A great majority of Long Pond and Middle Pond fish had larger left than right ovaries (Fig. 13). In Long Pond, 74.5% of the fish had more eggs in the left ovary than in the right one, while in Middle Pond, 73.2% had more eggs in the left ovary (Appendix 7). The chi-square test substantiated the hypothesis that the difference in number of fish which had unequal ovaries existed (Long Pond, $p < 0.005$; Middle Pond, $p < 0.005$). However, the t test did not show a significant difference in number of eggs between the left and right ovaries (Long Pond, $p < 0.05$; Middle Pond, $p < 0.01$).

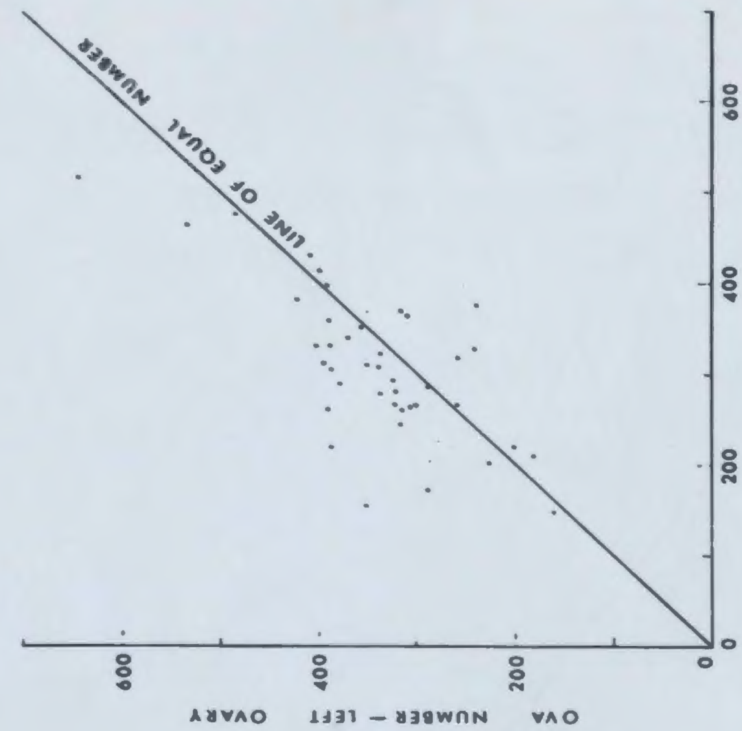
Landlocked Salmon

Opposite conditions were found in samples from Forest Pond and Ocean Pond (Fig. 14), 67.5% of Forest Pond fish had larger left ovaries, whereas 77.9% of Ocean Pond fish had larger right ovaries (Appendix). The chi-square test substantiated the hypothesis that the difference in number of fish which had unequal ovaries existed (Forest Pond, $p < 0.005$; Ocean Pond, $p < 0.005$). The t test did show a significant difference in number of eggs between the left and right ovaries (Forest Pond, $p < 0.05$; Ocean Pond, $p < 0.001$).

Fig. 13. Differential egg counts for right and left ovaries of brown trout from Long Pond (a) and Middle Pond (b). Data are from the same fish used in the fecundity regression analysis.

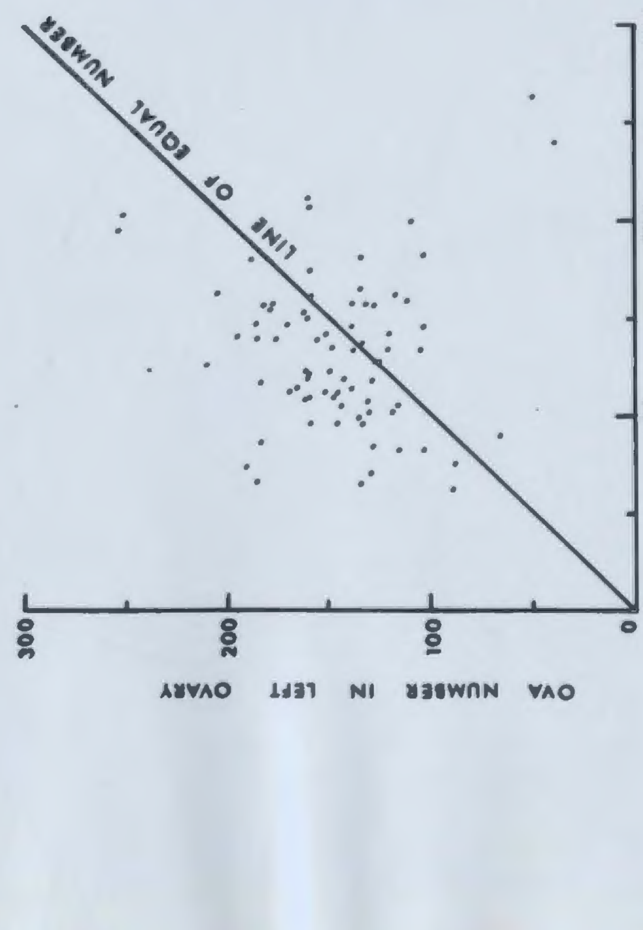

LINE OF EQUAL NUMBER
OVA NUMBER IN LEFT OVARY
OVA NUMBER IN RIGHT OVARY
0
400
800
1200

(a)


LINE OF EQUAL NUMBER
OVA NUMBER — LEFT OVARY
OVA NUMBER — RIGHT OVARY
0
200
400
600

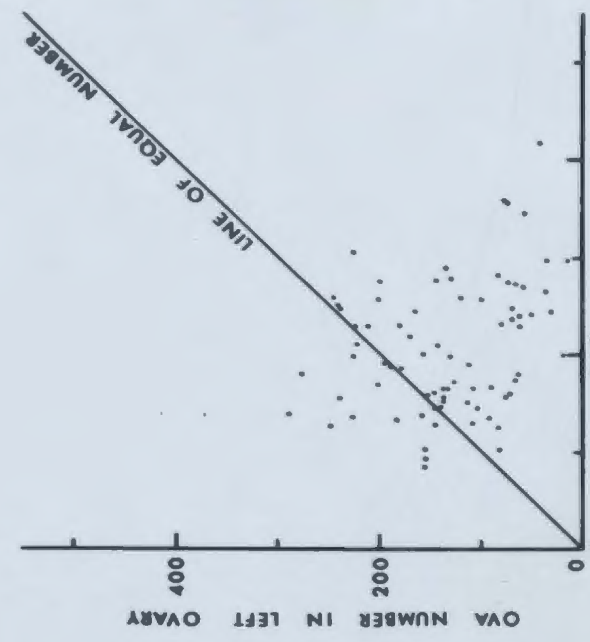
(b)

Fig. 14. Differential egg counts for right and left ovaries of landlocked salmon from Forest Pond (a) and Ocean Pond (b). Data are from the same fish used in the fecundity regression analysis.



OVA NUMBER IN LEFT OVARY
OVA NUMBER IN RIGHT OVARY
LINE OF EQUAL NUMBER
0
100
200
300

(a)



OVA NUMBER IN LEFT OVARY
OVA NUMBER IN RIGHT OVARY
LINE OF EQUAL NUMBER
0
200
400

(b)

Plate II. A dissected female landlocked salmon with both ovaries shown. The fish was 31.2 cm in fork length and caught on October 25, 1969 in Ocean Pond. White arrow indicates the posterior end of the intestine which bends to the left.

Fecundity and Length Relationship

Linear relationships were found for all the species and can be expressed as

$$Y = a + bX$$

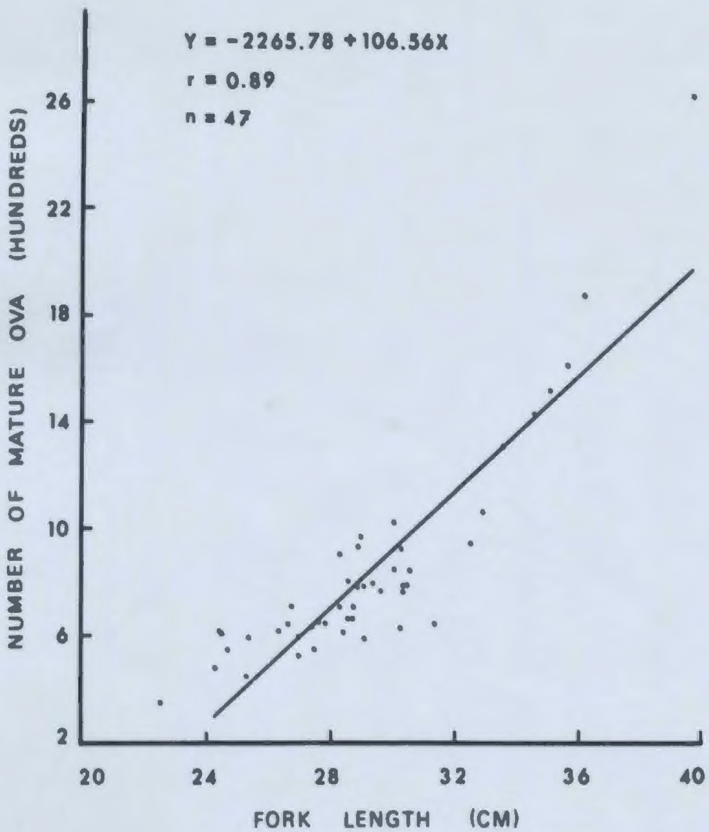
where Y is the number of mature eggs, X is the fork length in cm, a (Y intercept) and b (slope) are constants determined empirically.

Brown Trout

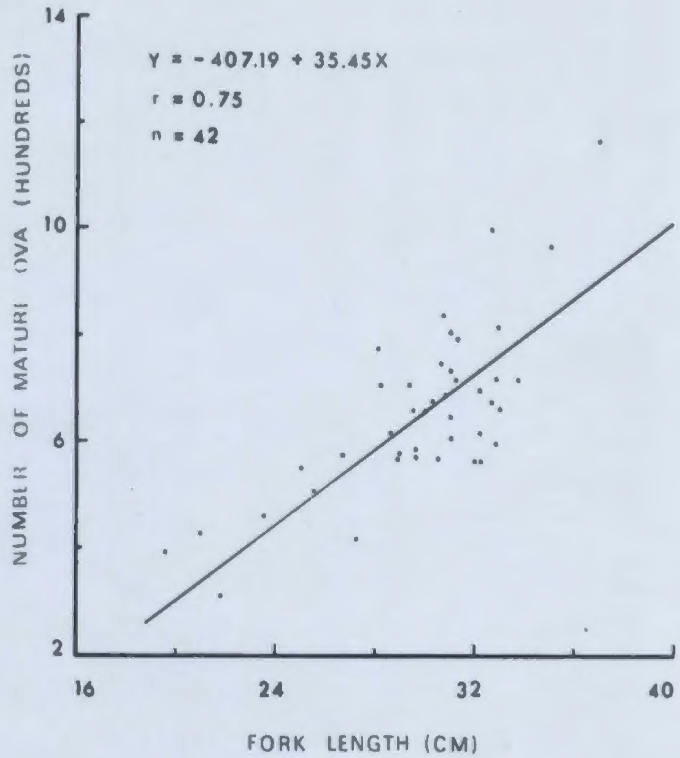
Good correlations between the two variables were obtained for Long Pond ($r = 0.89$; d.f. = 45; $p < 0.01$) and Middle Pond ($r = 0.75$; d.f. = 40; $p < 0.01$) samples (Fig. 15). The Long Pond sample had a mean length of 29.2 cm and produced an average of 848 eggs each. For the Middle Pond sample, the mean was 29.8 cm and the average egg number was 656 each. The Long Pond sample has a lower Y intercept but a much steeper slope (Fig. 17). The origins and slopes are significantly different (origins: $t = 26.66$; $p < 0.01$; slopes: $t = 3.66$; $p < 0.01$).

In relating length to relative fecundity, there is a good correlation ($r = 0.84$; $p < 0.01$) for the Long Pond sample.

Fig. 15. Fecundity and length relationships of brown trout from Long Pond (a) and Middle Pond (b).


Y = -2265.78 + 106.56X
r = 0.89
n = 47
NUMBER OF MATURE OVA (HUNDREDS)
26
22
18
14
10
6
2
20
24
28
32
36
40
FORK LENGTH (CM)

(a)


Y = - 407.19 + 35.45X
r = 0.75
n = 42
NUMBER OF MATURE OVA (HUNDREDS)
14
10
6
2
16
24
32
40
FORK LENGTH (CM)

(b)

Similar linear relationships were also found by Allen (1951) and Nicholls (1958) for samples from New Zealand and Australia respectively.

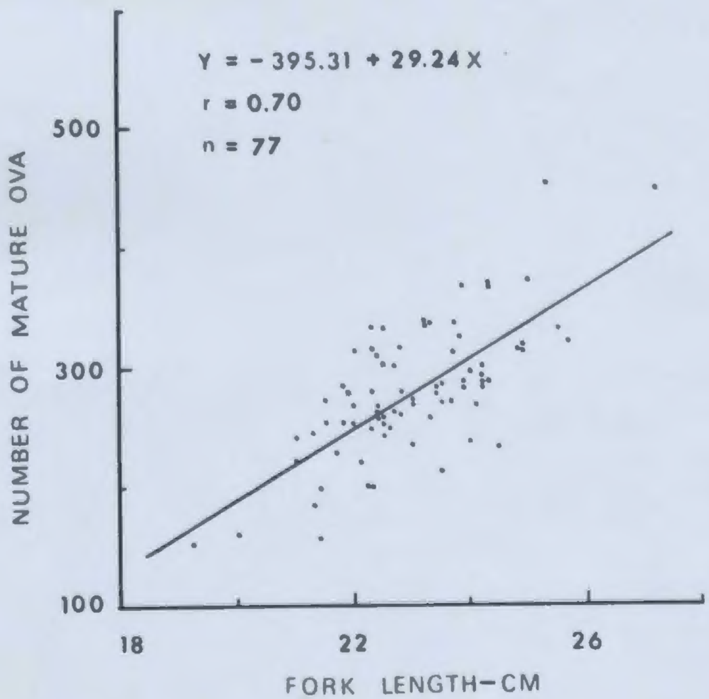
Landlocked Salmon

The distributions of points for both samples fall about a straight line (Fig. 16). The correlations between fecundity and length were significant both for Forest Pond ($r = 0.70$; d.f. = 75; $p < 0.01$) and Ocean Pond ($r = 0.78$; d.f. = 75; $p < 0.01$) samples. The Forest Pond sample had a mean length of 23 cm and produced an average of 279 eggs each. The Ocean Pond sample had a mean length of 27.4 cm and produced an average of 346 eggs each.

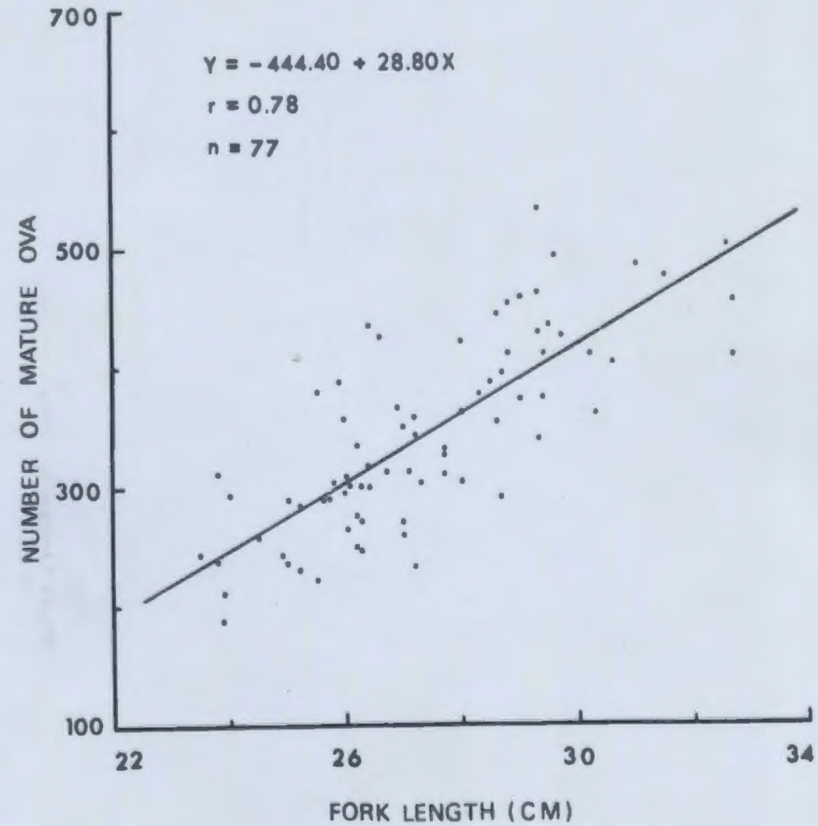
The two nearly parallel regression lines (Fig. 17) show that fish of any corresponding length from Forest Pond were consistently producing more eggs than fish from Ocean Pond. A comparison of the two lines showed significant difference in origins ($t = 16.83$; $p < 0.01$) but not in slopes ($t = 0.06$).

A positive correlation was found between the relative fecundity and the length of fish for both ponds (Table 9). Data from Ocean Pond showed a smaller variation ($r = 0.57$; $p < 0.01$) than that of Forest Pond ($r = 0.41$; $p < 0.01$).

Fig. 16. Fecundity and length relationships of landlocked salmon from Forest Pond (a) and Ocean Pond (b).

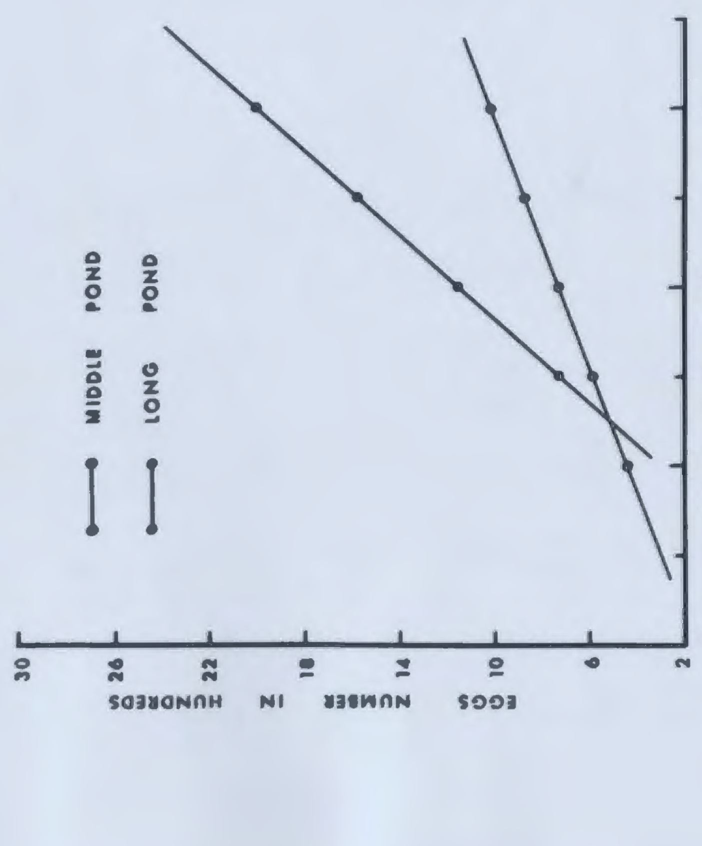

Y = - 395.31 + 29.24 X
r = 0.70
n = 77
NUMBER OF MATURE OVA
500
300
100
18
22
26
FORK LENGTH-CM

(a)

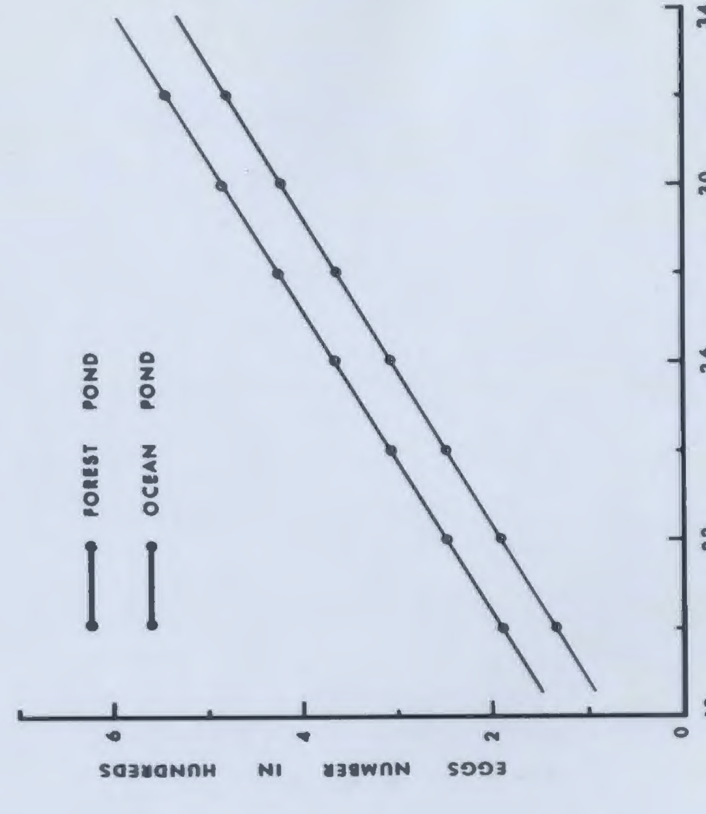

Y = -444.40 + 28.80X
r = 0.78
n = 77
NUMBER OF MATURE OVA
700
500
300
100
22
26
30
34
FORK LENGTH (CM)

(b)

Fig. 17. Comparison of regression lines of fecundity on length for brown trout (a) and landlocked salmon (b) from the four study areas.


MIDDLE POND
LONG POND
EGGS NUMBER IN HUNDREDS
30
26
22
18
14
10
6
2
16
24
32
40
LENGTH - CM

(a)


FOREST POND
OCEAN POND
EGGS NUMBER IN HUNDREDS
6
4
2
0
18
22
26
30
34
LENGTH - CM

(b)

Rainbow Trout

A curvilinear relationship between fecundity and body length of Scott Creek steelhead was found by Shapovalov and Taft (1954). However, a straight line may adequately describe the relationship between the two variables in samples from Tasmania (Nicholls, 1958) and, in the present study, from Murray's Pond (Fig. 18). As shown in the regression equation, the fecundity increased by about 134 eggs for each increase in body length of 1 cm within the range of 26 to 40 cm. The sample had a mean length of 33.5 cm and produced an average of 1508 eggs each.

The correlation of relative fecundity was significant at the 1% level (r = 0.70).

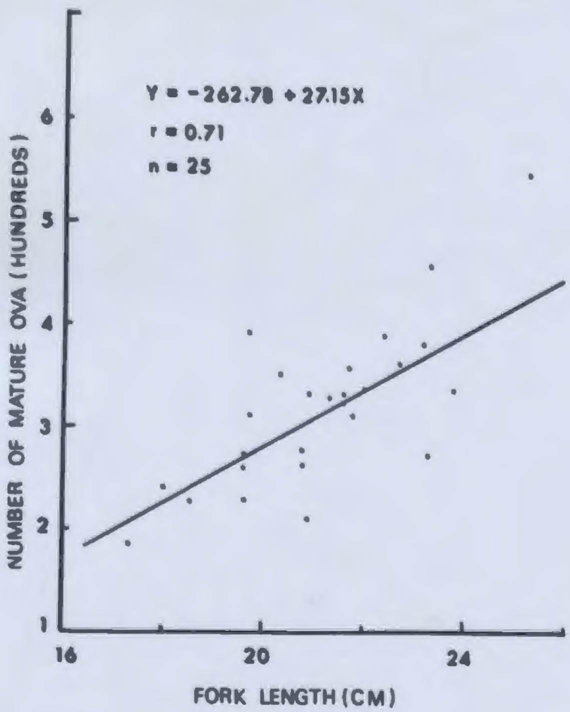
Brook Trout

The linear equation obtained here (Fig. 18) agrees with those found by Allen (1956) and McFadden (1961) but disagrees with data presented by Ricker (1932), Vladykov and Legendre (1940), Smith (1947) and Vladykov (1956), all of whom expressed fecundity of brook trout as being curvilinear.

The correlation is significant at the 1% level (r = 0.71). The mean length of the samples from four ponds

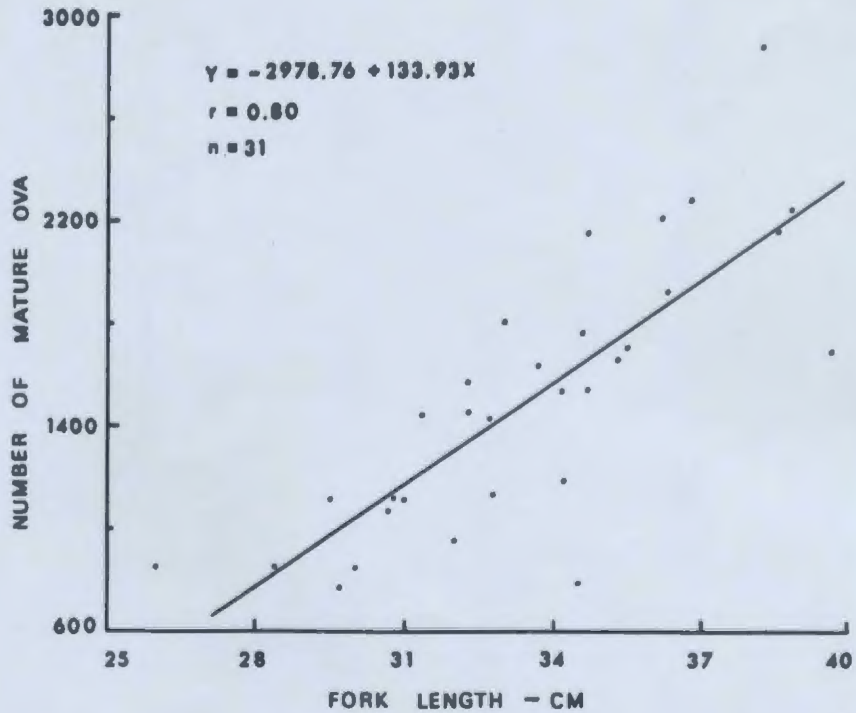
Fig. 18. Fecundity and length relationships of brook trout from the four ponds studied (a)* and rainbow trout from Murray's Pond (b).

* See Appendix 2.



Y = -262.78 + 27.15X
r = 0.71
n = 25
NUMBER OF MATURE OVA (HUNDREDS)
1
2
3
4
5
6
16
20
24
FORK LENGTH (CM)

(a)



Y = -2978.76 + 133.93X
r = 0.80
n = 31
NUMBER OF MATURE OVA
600
1400
2200
3000
25
28
31
34
37
40
FORK LENGTH - CM

(b)

studied was 21.3 cm and the fish produced an average of 317 eggs each.

Fecundity and Weight Relationship

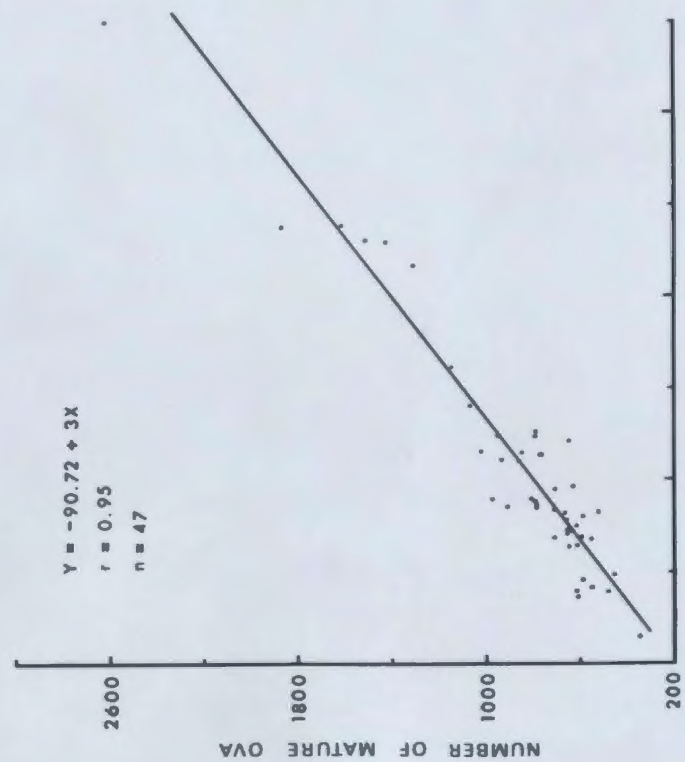
Brown Trout

The relationships between fecundity and weight were found to be linear (Fig. 19). Both samples from Long Pond and Middle Pond showed higher correlation between fecundity and weight than between fecundity and length. 90% and 69% of the variation was association with weight for Long Pond ($r = 0.89$; $p < 0.01$) and Middle Pond ($r = 0.83$; $p < 0.01$) data respectively.

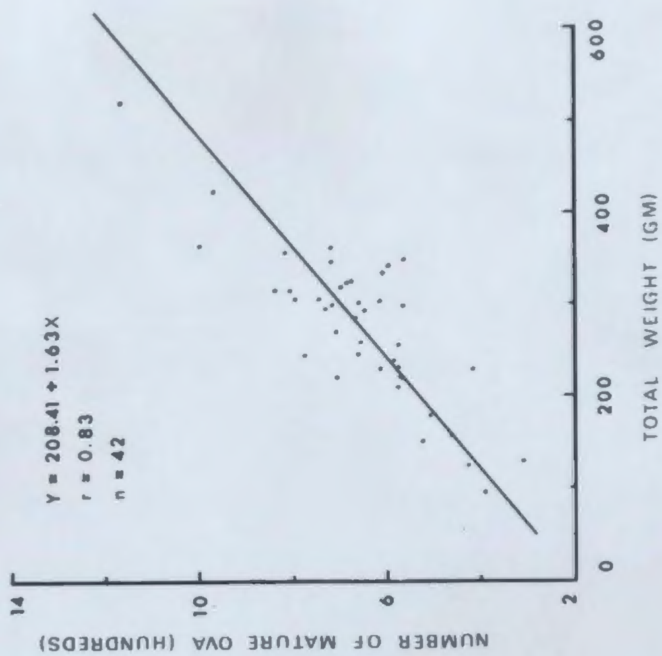
As shown in Fig. 21, fish from Long Pond were less fecund than those from Middle Pond before they reached a total weight of about two hundred grams. Long Pond fish larger than 200 grams were more productive than Middle Pond fish of comparative size. The difference in fecundity between the two populations progressively increases as the fish grew larger than 200 grams. A comparison of the two regression lines was made and significant differences were found both in origins ($t = 5.73$; $p < 0.01$) slopes ($t = 2.14$; $p < 0.05$).

The Long Pond sample had a mean weight of 312 gm and the Middle Pond sample had a mean weight of 276 gm. The former produced an average of 846 eggs each and the latter 656 eggs each.

Fig. 19. Fecundity and weight relationships of brown trout from Long Pond (a) and Middle Pond (b).


Y = -90.72 + 3X
r = 0.95
n = 47
NUMBER OF MATURE OVA
200
1000
1800
2600
100
300
500
700
TOTAL WEIGHT-GM

(a)


Y = 208.41 + 1.63X
r = 0.83
n = 42
NUMBER OF MATURE OVA (HUNDREDS)
2
6
10
14
0
200
400
600
TOTAL WEIGHT (GM)

(b)

Landlocked Salmon

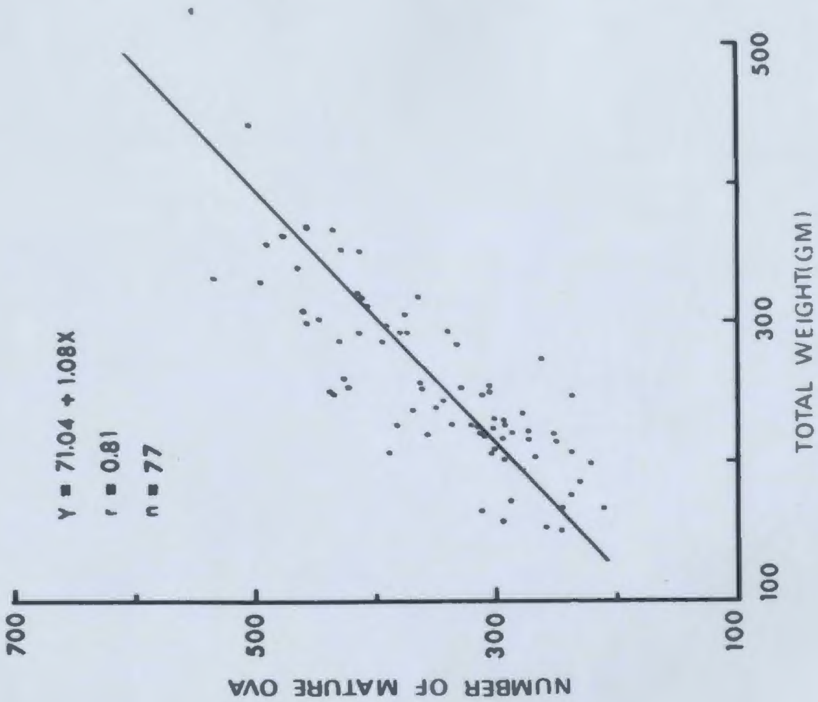
The regression lines for both Forest Pond and Ocean Pond samples clearly show a linear relationship (Fig. 20). A higher correlation of fecundity on body weight than on body length was found (Forest Pond: $r = 0.73$; $p < 0.01$; Ocean Pond: $r = 0.81$; $p < 0.01$). Fish from Forest Pond produced more eggs at any weight within the weight range. The difference in fecundity progressively increases as they grew larger (Fig. 21). A comparison of the two regression lines was made and significant difference was found in origins ($t = 3.93$; $p < 0.01$) but not in slopes ($t = 1.64$).

The Forest Pond sample had a mean weight of 153 gm and the Ocean Pond sample had a mean weight of 254 gm. The former produced an average of 279 eggs each and the latter 346 eggs each.

Rainbow Trout

A straight line relationship was found (Fig. 22), which agrees with the findings of Bulkley (1967). Again, fecundity was better correlated with body weight ($r = 0.80$) than body length ($r = 0.70$). The correlation is significant at the 1% level. The sample had a mean weight of 470 gm and produced an average of 1508 eggs each.

Fig. 20. Fecundity and weight relationships of landlocked salmon from Forest Pond (a) and Ocean Pond (b).


Y = 71.04 + 1.08X
r = 0.81
n = 77
NUMBER OF MATURE OVA
TOTAL WEIGHT(GM)
700
500
300
100
100
300
500

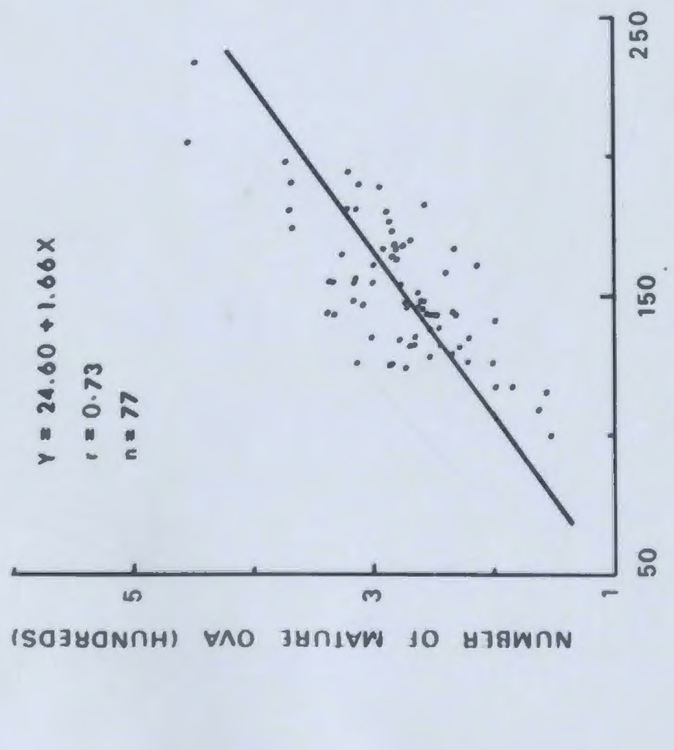
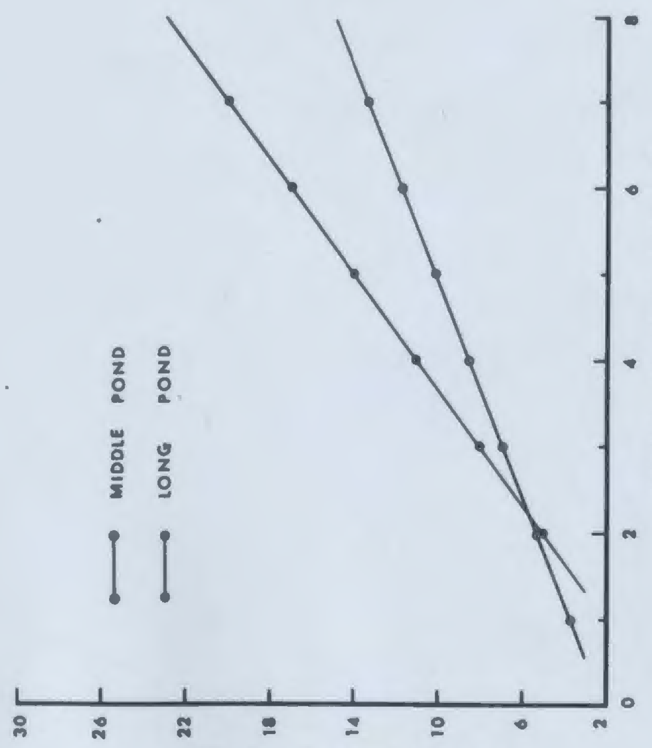
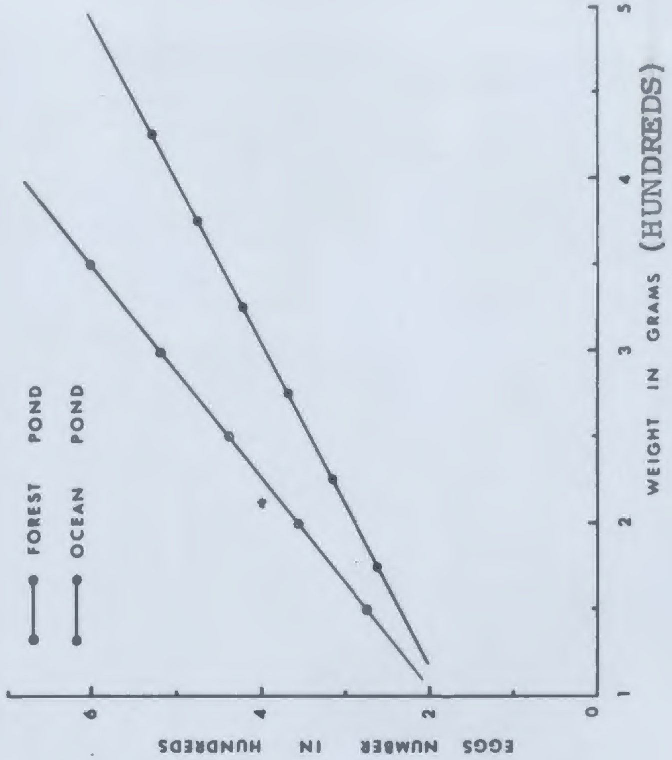

Y = 24.60 + 1.66X
r = 0.73
n = 77
NUMBER OF MATURE OVA (HUNDREDS)
TOTAL WEIGHT (GM)
5
3
1
50
150
250

Fig. 21. Comparison of regression lines of fecundity on weight for brown trout (a) and landlocked salmon (b) from the four study areas.


MIDDLE POND
LONG POND
EGGS NUMBER IN HUNDREDS
30
26
22
18
14
10
6
2
0
2
4
6
8
WEIGHT IN GRAMS (HUNDREDS)

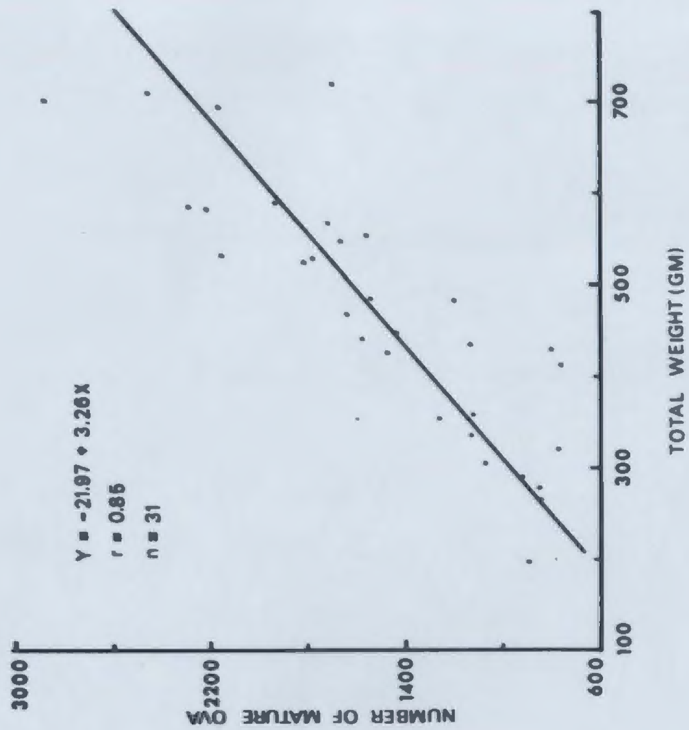
(a)

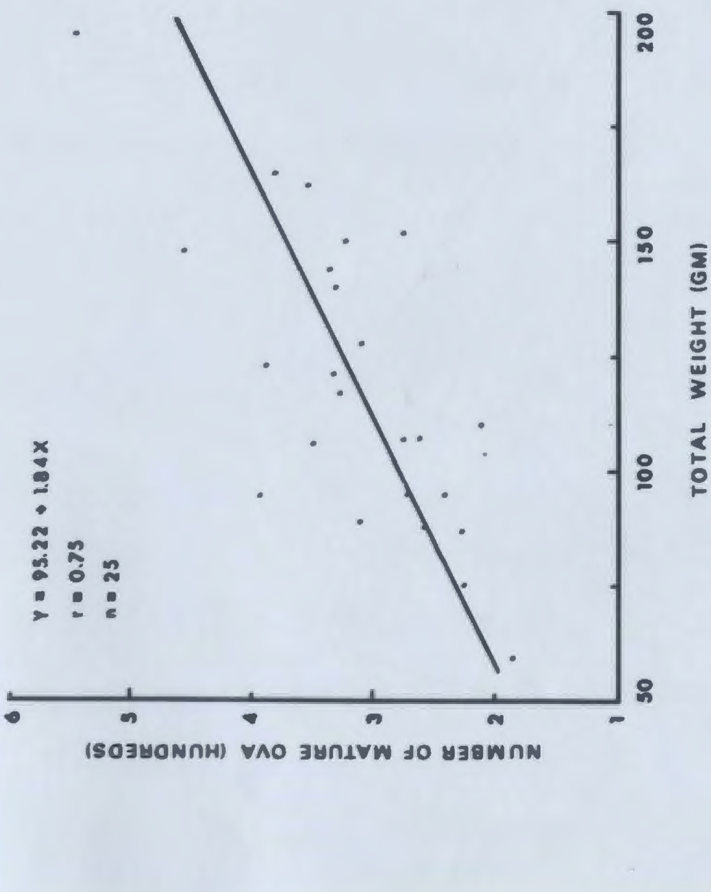

FOREST POND
OCEAN POND
EGGS NUMBER IN HUNDREDS
6
4
2
0
1
2
3
4
5
WEIGHT IN GRAMS (HUNDREDS)

(b)

Fig. 22. Fecundity and weight relationships of brook trout from the four ponds studied (a)* and rainbow trout from Murray's Pond (b).

* See Appendix 2.


Y = -21.97 + 3.26X
r = 0.86
n = 31
NUMBER OF MATURE OVA
3000
2200
1400
600
100
300
500
700
TOTAL WEIGHT (GM)


Y = 95.22 + 1.84X
r = 0.75
n = 25
NUMBER OF MATURE OVA (HUNDREDS)
6
5
4
3
2
1
50
100
150
200
TOTAL WEIGHT (GM)

Brook Trout

The relationship between fecundity and weight was linear (Fig. 22). The general trend of slightly closer correlation ($r = 0.75$; $p < 0.01$) of egg number on body weight than body length was also observed. The mean weight for the sample was 120 gm with average production being 317 eggs.

Fecundity and Age Relationship

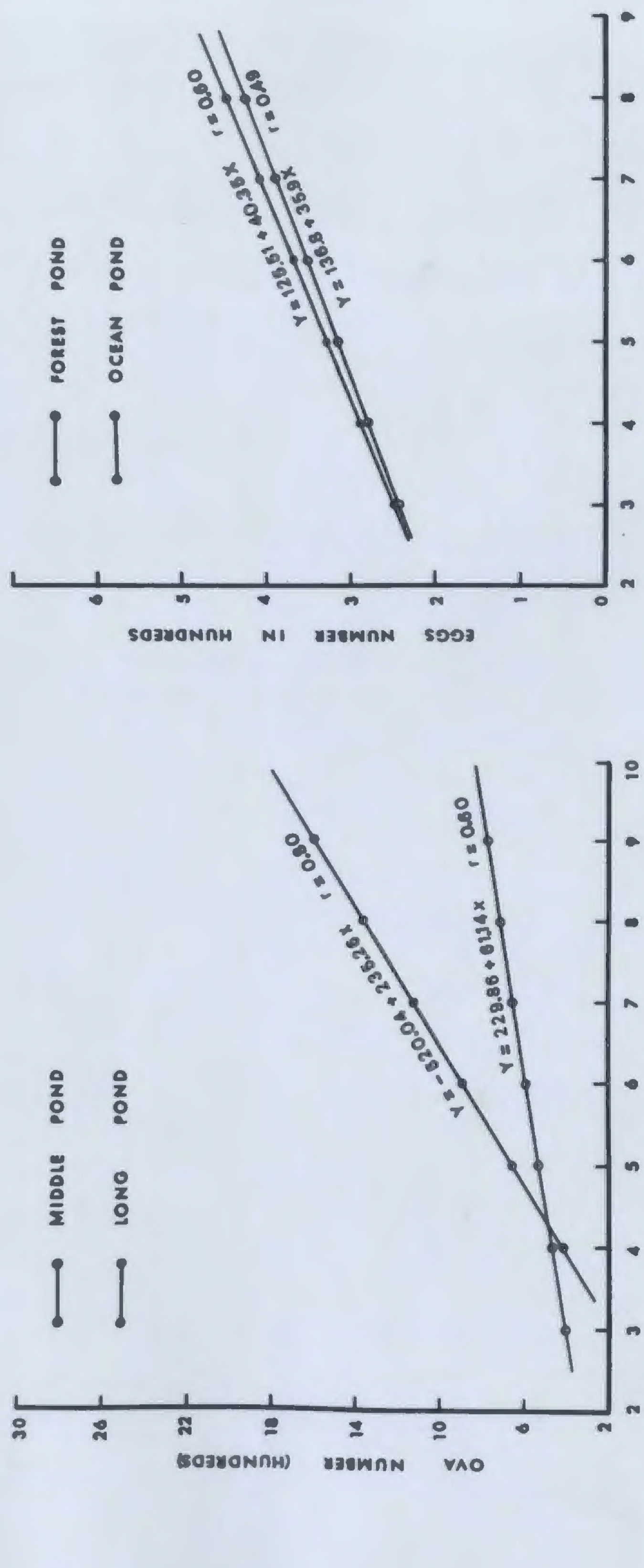
Brown Trout

The relationship between fecundity and age was linear (Fig. 23). A closer correlation was found for the Long Pond sample (Long Pond: $r = 0.80$; $p < 0.01$; Middle Pond: $r = 0.60$; $p < 0.01$). Long Pond fish were less fecund before age 5, but thereafter were more fecund than fish from Middle Pond. The difference in egg number progressively increases as the fish grew older.

Landlocked Salmon

Linear relationship were found for samples from Forest Pond and Ocean Pond (Fig. 23). The correlations were significant at the 1% level for both samples (Forest Pond, $r = 0.49$; Ocean Pond, $r = 0.60$). Ocean Pond fish were slightly more fecund than those from Forest Pond, however, the difference was not statistically significant.

Fig. 23. Comparison of regression lines of fecundity on age for brown trout (a) and landlocked salmon (b) from the four study areas.


FOREST POND
OCEAN POND
Y = 126.51 + 40.36 X
r = 0.60
Y = 136.8 + 35.9 X
r = 0.49
EGGS NUMBER IN HUNDREDS
AGE IN YEARS
MIDDLE POND
LONG POND
Y = -520.04 + 236.26 X
r = 0.80
Y = 228.86 + 61.34 X
r = 0.60
OVA NUMBER (HUNDREDS)
AGE (YEARS)

(b)

(a)

Rainbow Trout

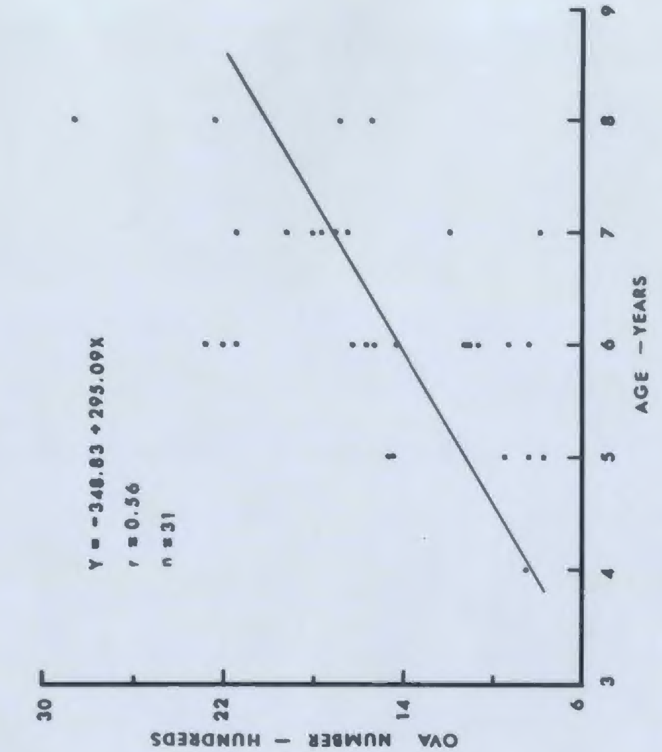
Greater variation in number of eggs within the age groups resulted in a lower correlation of fecundity on age of fish from Murray's Pond ($r = 0.56$; $p < 0.01$). As shown in Fig. 24, the egg number within each age group differed greatly.

Brook Trout

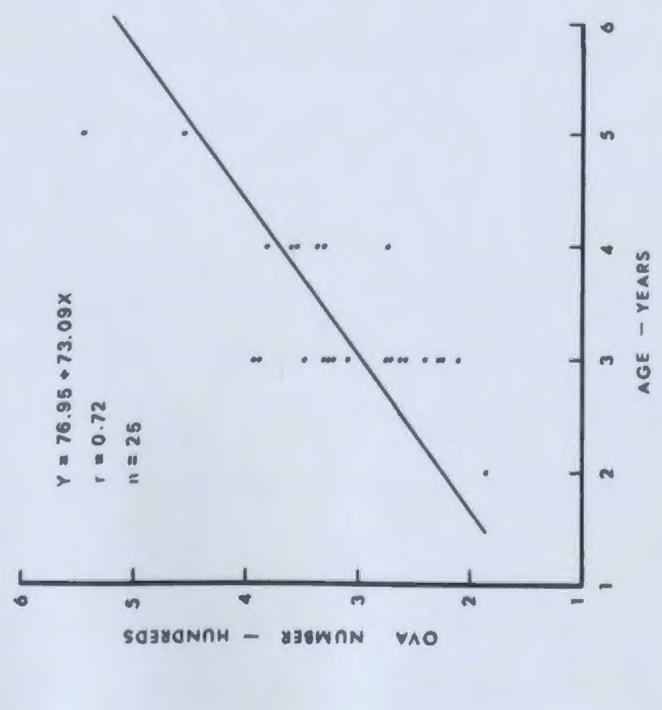
Less variation of fecundity on age was found for brook trout from four ponds. The correlation for the linear relationship was significant ($r = 0.72$; $p < 0.01$).

Fig. 24. Fecundity and age relationships of brook trout from the four ponds studied (a)* and rainbow trout from Murray's Pond (b).

* See Appendix 2.


Y = -348.83 + 295.09X
r = 0.56
n = 31
OVA NUMBER — HUNDREDS
AGE — YEARS

(b)


Y = 76.95 + 73.09X
r = 0.72
n = 25
OVA NUMBER — HUNDREDS
AGE — YEARS

(a)

DISCUSSION

Sex Ratio

A knowledge of sex ratios is essential in estimating reproductive potential and also in determining the mortality differences between sexes and age groups. Other than 1:1 sex ratios have been reported frequently for various species of fish and also different populations of the same species. There is commonly a progressive decrease in the proportion of older males in a population. Gustafson (1951) found a predominance of females (70%) in the spawning brown trout (Salmo trutta) from Damman. However, several authors (Shapovalov and Taft, 1954; Runnström, 1957; McFadden et al., 1962; Warner, 1962; Withler, 1966; Wydoski and Cooper, 1966) found ratios very close to 1:1 for various species of salmonids.

The over all sex ratios in the present study were close to a 1:1 ratio with the exception of brook trout from Kelly's Pond. The latter may be because of sexual segregation during the spawning season, high mortality of females for the age groups involved or the short period of sampling. Finally, a difference in spawning frequency between the sexes could also be a factor affecting the sex ratio of the spawning fish (Withler, 1966).

Maturation

The time of maturation may be affected by many factors. Age and size (thus growth rate) are generally considered as two important factors (McFadden et al., 1965).

Miller (1947) found whitefish (*Coregonus clupeaformis*) would mature at younger and younger age if older fish were progressively removed from a population. Scott (1962) demonstrated that an inadequate supply of food retarded maturation in rainbow trout. Thus food supply and population density which usually influence growth may also have direct effects on reproduction.

In all four species studied, within each age group, a higher percentage of the larger fish were mature. Within each size group, more old females were sexually mature than younger ones.

Growth rates of brown trout in different waters are reported to be correlated with environment fertility (McFadden and Cooper, 1962). This may be the case for brown trout in Long Pond and Middle Pond. The different condition factors (Appendix 3) and growth rates of the fish may indicate a difference in fertility in the two ponds. The present study of brown trout did not agree with the results obtained by McFadden et al. (1965), who found differences in age at first maturity between two populations inhabiting fertile and infertile streams. The similarity in age at first maturity in the two populations studied here may be, besides other factors, because of the small number of young fish in the Middle Pond sample.

The relationship between age and maturation may be affected by different conditions which trout may experience. Wild brook trout in Quebec usually reached maturity at the age of 3 or 4, but among hatchery-raised trout, many fish of both sexes can spawn at a precocious age of 12-18 months (Vladykov, 1956). Brook trout in the present study appeared to be intermediate in age of first maturity between the wild and the hatchery-reared populations.

There was no difference in age at first maturity in fish from Forest Pond and Ocean Pond, but , a difference in percentage maturity in young fish of the same age groups did exist. The fact that no landlocked salmon in Forest Pond and no brook trout in the four ponds studied were older than 6+ years may indicate that these fish have a comparatively shorter life span than fish in other ponds. Thus earlier attainment of sexual maturity in these populations might have some ecological significance in the maintenance of population size. It is possible that average age at first maturity varies among and within populations, so as to compensate for extremes of environmental productivity or population density.

Besides influences of environmental fertility, genetic control of maturation has been reported for brown trout by Alm (1959) and for Arctic char (*Salvelinus alpinus*) by Määr (1949). Although no critical evalution of genetic control of maturation in brook trout has been attempted, it is possible that the delayed maturation in some populations may be an inheritable characteristic (Cooper and Fuller, 1945; Doan, 1948).

Atresia

It has been proposed by Vladykov (1956) that atresia functions as a "safety valve" in the development of the ovary. If it were not for atresia, the increase in volume of the ovaries would be greater than the available body cavity. In the fecundity study on Quebec brook trout, Vladykov (1956) found a loss of 39 - 40% of eggs through atresia. Desmarais (1959) reported a loss of 7% in another population of Quebec brook trout at a different stage of maturity.

As shown in Appendix 6, Middle Pond fish had a higher number of eggs than fish from Long Pond when the eggs were 1 - 1.99 mm in diameter, but atretic loss was more than twice as much for the former. This is probably caused by poor nutrition throughout the developmental season as reflected by the K factor in the Middle Pond sample (Appendix 3). The condition factors of Forest Pond and Ocean Pond fish were quite similar (Appendix 3) as was the rate of atresia. Thus, it seems that food is the major factor in atresia. Under poor nutritional conditions and thus growth, eggs may stop development and be resorbed. When conditions are favourable for growth, such as in a hatchery, as little as 5% of the developing eggs may become atretic (Henderson, 1963). Continuing growth of the fish allows more room for the increase in size of the individual eggs. In wild populations, especially those in infertile waters, the amount of atresia may be higher than 50% (Wydoski and Cooper, 1966). Thus the environment has a great influence over the fecundity through the nutrition of the ovary and growth of the female (Woodhead, 1960). Scott (1962) showed experimentally an association of follicular atresia with degree of starvation during the maturation period of rainbow trout.

Egg Size and Egg Number

Although relationships did exist between egg size and size and age of fish in the Ocean Pond and Murray's Pond samples, no consistent relationships between these variables were observed in the other species and populations. One must keep in mind that except for the Ocean Pond sample, the others were not collected in a single day, and the eggs may have still been growing. The existence of greater variation between the variables might also weaken the relationship. In the Murray's Pond sample, fish used in the fecundity study were collected within a short period of time and immediately prior to spawning. This might minimize the variation in egg size.

Smith (1947) stated that the size of eggs did not depend upon the size of fish. Scott (1962) concluded that factors other than size of fish or diet predetermined egg size of non-migratory rainbow trout of the same age. However, others (Belding et al., 1932; Rounsefell, 1957; Pope et al., 1961; Frost and Brown, 1967) concluded that larger eggs are in general produced by larger females, and that egg size may depend in part upon the size of the female and in part upon heredity.

Svärdson (1949) regards egg size as resulting from natural selection through intraspecific competition for food and space. However, Robertson (1922) pointed out that a race of small size sockeye salmon that spawn in Harrison Rapids, a tributary of the Fraser River, produce larger eggs than the other races of sockeye in the Fraser. Since this is one of the few races of sockeye in which the young go to sea as fry (Gilbert, 1919)*, it would seem that larger fry would have a better chance to survive and reproduce.

Difference between Right and Left Ovaries

The right and left ovaries are usually unequal both in size and number of eggs despite of the fact that both maintain the same rate of development (Rounsefell, 1957). Kendall (1921) observed that in most cases the left ovary was the longer and as the ova approached maturity, this resulted in a disproportional extension of the ovaries to the posterior end of the abdominal cavity.

The description given by Brown and Kamp (1942) is probably the best:

> "In the brown trout, the posterior portion of the intestine usually bends strongly to the right, thus crowding the right ovary at its caudal end. The length of ovary is inversely proportional to the degree of crowding. However, the left ovary is not always the longer. One fish was observed to have a longer right ovary and it was interesting to note that this specimen had an intestine which bent to the left instead of the right. In one or two fish the ovaries were of approximately equal length, with the intestine bending neither to the right nor the left."

The present results indicate that the difference between the ovaries varies greatly and that the major trend

* Cited from R. E. Foerster, 1969. p.8.

of bending of the intestine is characteristic of populations (Appendix 7). The bending of the intestine was not the major factor which caused the difference observed in the Ocean Pond sample (see Appendix 7 foot note). This disagreement with the literature (Kendall, 1921; Brown and Kamp, 1942) induced speculations, as mentioned by Rounsefell (1957), as to whether this is under genetic control or is caused by environmental differences.

Although the size and number differences between ovaries have been noted by several workers on salmonids (Snyder, 1921; McGregor, 1922, 1923; Vladykov, 1956; Rounsefell, 1957; Allen, 1960; Hartman & Conkle, 1960; Wydoski and Cooper, 1966) no definite conclusion has been reached.

Variation in Fecundity

More work has been done on length than on weight of fish in fecundity studies, mainly because length has an advantage over weight as a measure of size in that fish will not shrink greatly but can lose considerable weight (Pope et al., 1961).

Vladykov (1956) found a definite increase in egg numbers in practically all diameter groups with increase in length of brook trout in Quebec. In Pennsylvania, egg counts of brown trout were found to increase at the rate of 2.44 power on length (McFadden et al., 1965). A quite similar result (b = 2.3345) was obtained for naadromous Atlantic salmon in Scottish rivers (Pope et al., 1961). Studies done by other workers (Ricker, 1932; Shapovalov and Taft, 1954; Allen, 1956; Nicholls, 1958; Wydoski and Cooper, 1966; Bulkley, 1967) also confirm a positive relationship between the two variables. The present results agree with theirs. However, different results were obtained on brown trout by Brown and Kamp (1942) who found no marked correlations between the length, and weight of the female and number of eggs produced.

Although researchers are of the opinion that length should be used preferably as indicator of fecundity, it is somewhat surprising that egg numbers agree more closely with body weight than length. As trout do not lose condition (see Appendix 3 on K factors) through gonad development, body weight may be just as suitable a criterion as body length in predicting egg numbers.

The study of fecundity in relation to age derives from Orton's (1929) suggestion that fish may die as a direct or indirect result of over expending themselves in reproduction. Based on this idea, age has been investigated by several authors. An increase in egg number was found for older lake trout (<u>Cristivomer</u> <u>namaycush</u>) of the same population (Fry, 1949).

Data given by Berg and Grimaldi (1965) suggested a strong relationship between age and fecundity for whitefish (Coregonus) from Lake Maggiore. Rounsefell (1957) found that sockeye spending two years at sea produced more eggs than fish at the same length with three years of sea life and concluded that the length of time spent at sea had the greatest effect on fecundity. The same was reported for Salmo salar by Belding (1940). Gerking (1959) in reviewing the relationship between fecundity and age in haddock, long rough dab, herring and plaice, states that individual variation in fecundity is very great and masks any effect that age may have. He found the fecundities of the species mentioned do not increase in proportion to the gonad weight, so either larger ovaries produce larger but fewer eggs or connective tissue increases disproportionately in the ovary of the larger fish. However, this is not the case in the present study as shown in Fig. 25. Though further information are needed for the support of this contention, fecundity is related to age of fish within a certain range of age groups.

Pronounced variations in fecundity have been observed in various species of salmonids over different parts of the world (Figs. 26-30). A trend of increasing fecundity toward the southern part of the range of steelhead (Salmo gairdneri) was found by Bulkley (1967) who concluded that the great difference in fecundity between the Scott Creek (southern)

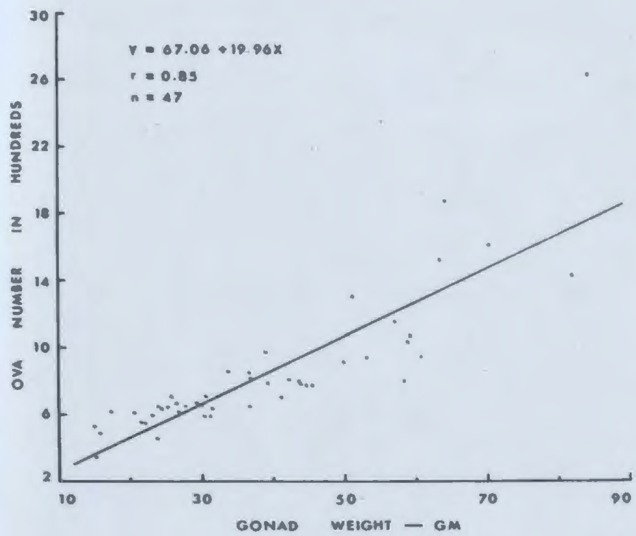
Fig. 25. Regression lines of fecundity on gonad weight of brown trout (a, b) and landlocked salmon (c, d) from the four localities.

a. Long Pond

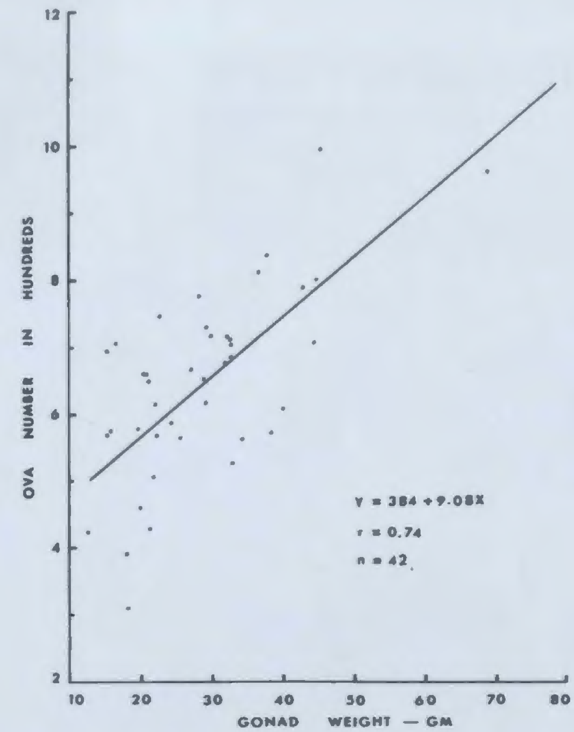
b. Middle Pond

c. Forest Pond

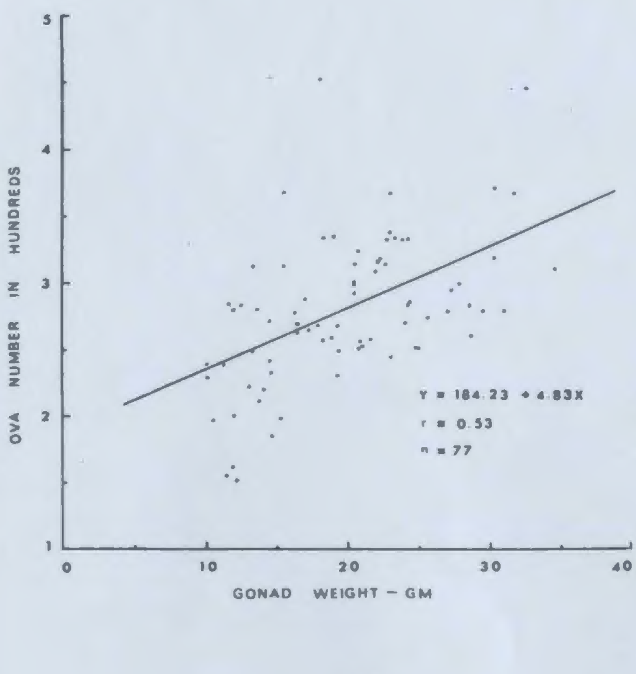
d. Ocean Pond


Y = 67.06 + 19.96X
r = 0.85
n = 47
OVA NUMBER IN HUNDREDS
GONAD WEIGHT — GM

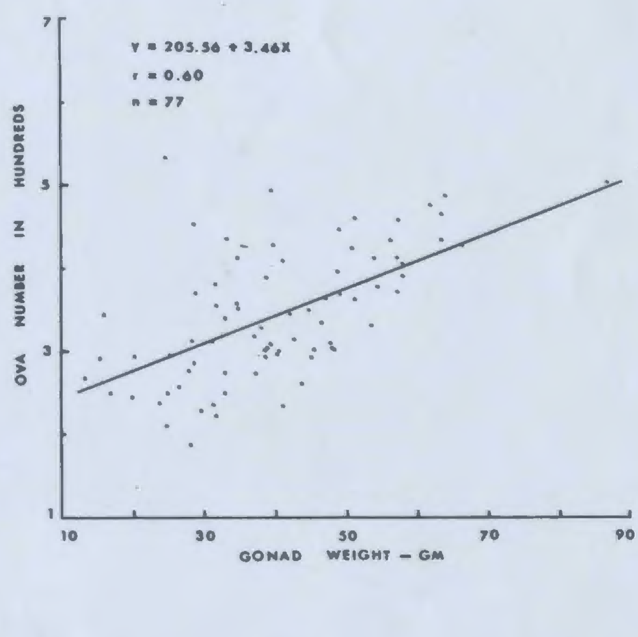
(a)


Y = 384 + 9.08X
r = 0.74
n = 42
OVA NUMBER IN HUNDREDS
GONAD WEIGHT — GM

(b)


Y = 184.23 + 4.83X
r = 0.53
n = 77
OVA NUMBER IN HUNDREDS
GONAD WEIGHT - GM

(c)


Y = 205.56 + 3.46X
r = 0.60
n = 77
OVA NUMBER IN HUNDREDS
GONAD WEIGHT - GM

(d)

Fig. 26. Comparison of regression lines of fecundity on length of brown trout found in the present study with data from five other studies. (Horokiwi data are from Allen, 1951; Michigan data are from Cooper, 1953; Spring Creek data are from McFadden et al., 1965; Tasmania data are from Nicholls, 1958; Long Pond data for 1967 are from Liew, 1969).

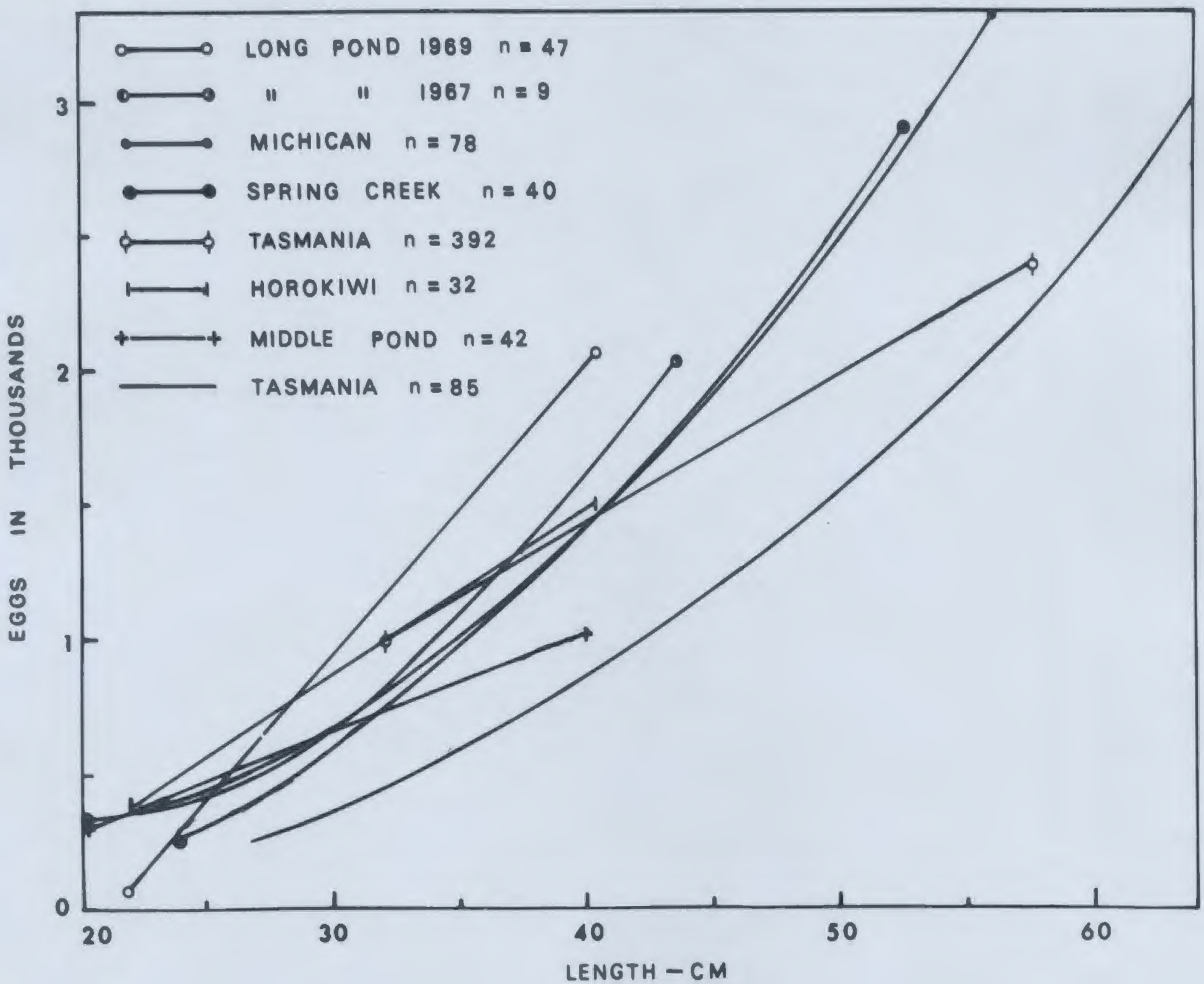

LONG POND 1969 n = 47
" " 1967 n = 9
MICHICAN n = 78
SPRING CREEK n = 40
TASMANIA n = 392
HOROKIWI n = 32
MIDDLE POND n = 42
TASMANIA n = 85
EGGS IN THOUSANDS
0
1
2
3
20
30
40
50
60
LENGTH — CM

Fig. 27. Comparison of regression lines of fecundity on weight of brown trout found in the present study with data from three other studies. (Spring Creek data are from McFadden et al., 1965; Tasmania data are from Nicholls, 1958; Long Pond data (1967) are from Liew, 1969).

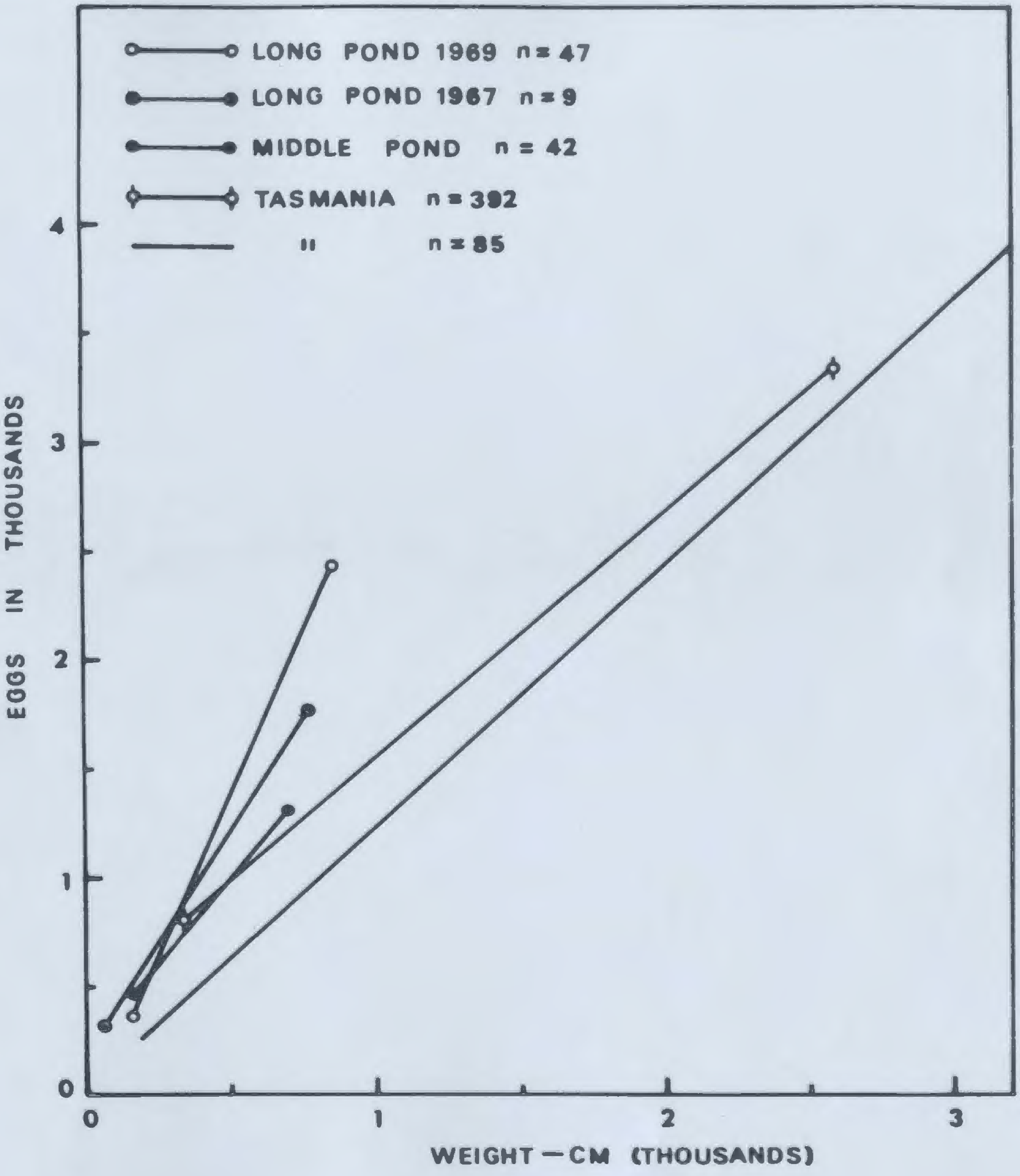

LONG POND 1969 n = 47
LONG POND 1967 n = 9
MIDDLE POND n = 42
TASMANIA n = 392
" n = 85
EGGS IN THOUSANDS
0
1
2
3
4
WEIGHT — CM (THOUSANDS)

Fig. 28. Comparison of regression lines of fecundity on length of rainbow trout found in the present study with data from four other areas. (Oregon and Big Creek data are from Bulkley, 1967; Tasmania data are from Nicholls, 1958; Scott Creek data are from Shapovalov and Taft, 1954).

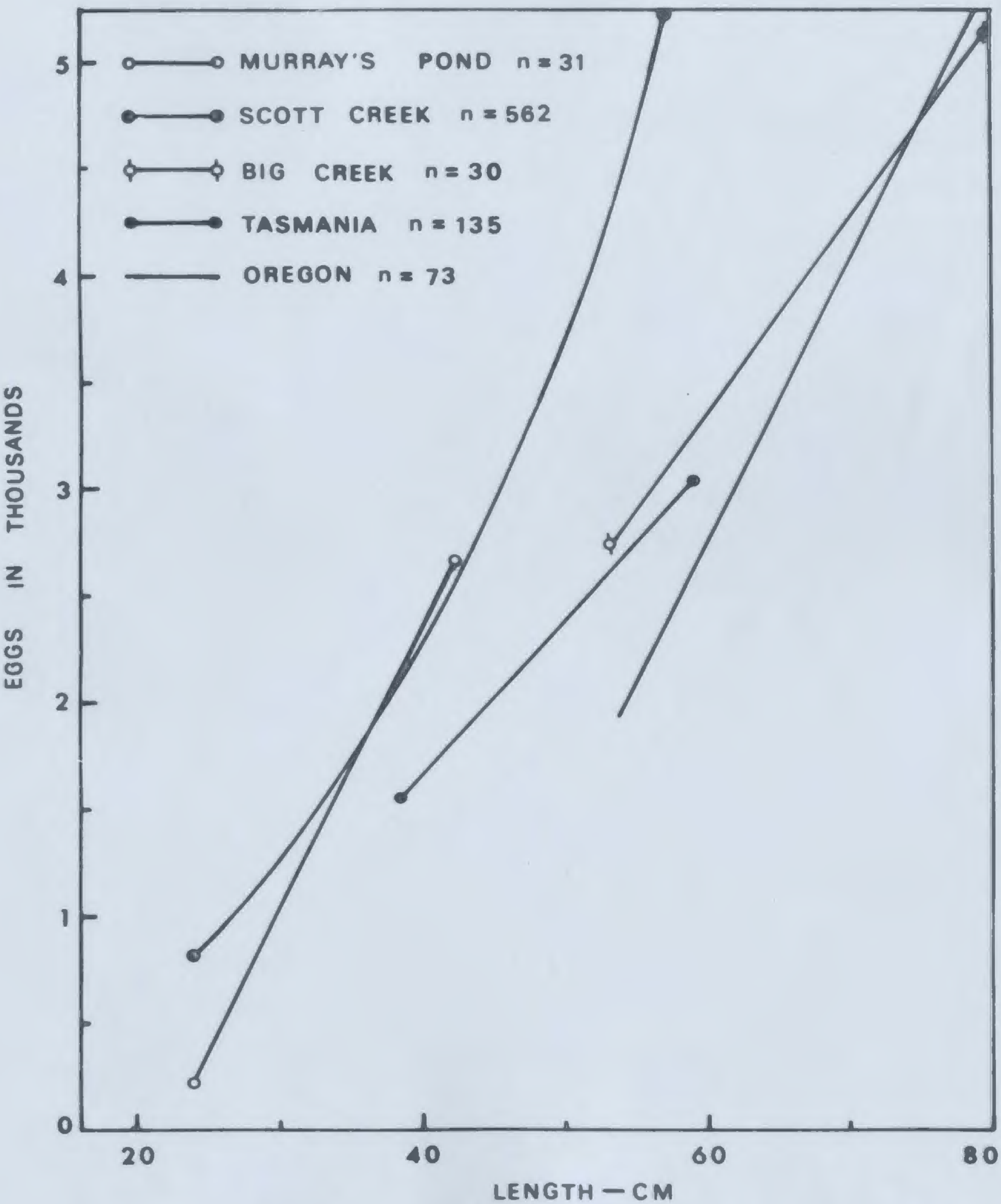

MURRAY'S POND n = 31
SCOTT CREEK n = 562
BIG CREEK n = 30
TASMANIA n = 135
OREGON n = 73
EGGS IN THOUSANDS
0
1
2
3
4
5
20
40
60
80
LENGTH — CM

Fig. 29. Comparison of regression lines of fecundity on weight of rainbow trout found in the present study with data from three other areas. (California data are from Allen, 1960; Oregon data are from Bulkley, 1967; Tasmania data are from Nicholls, 1958).

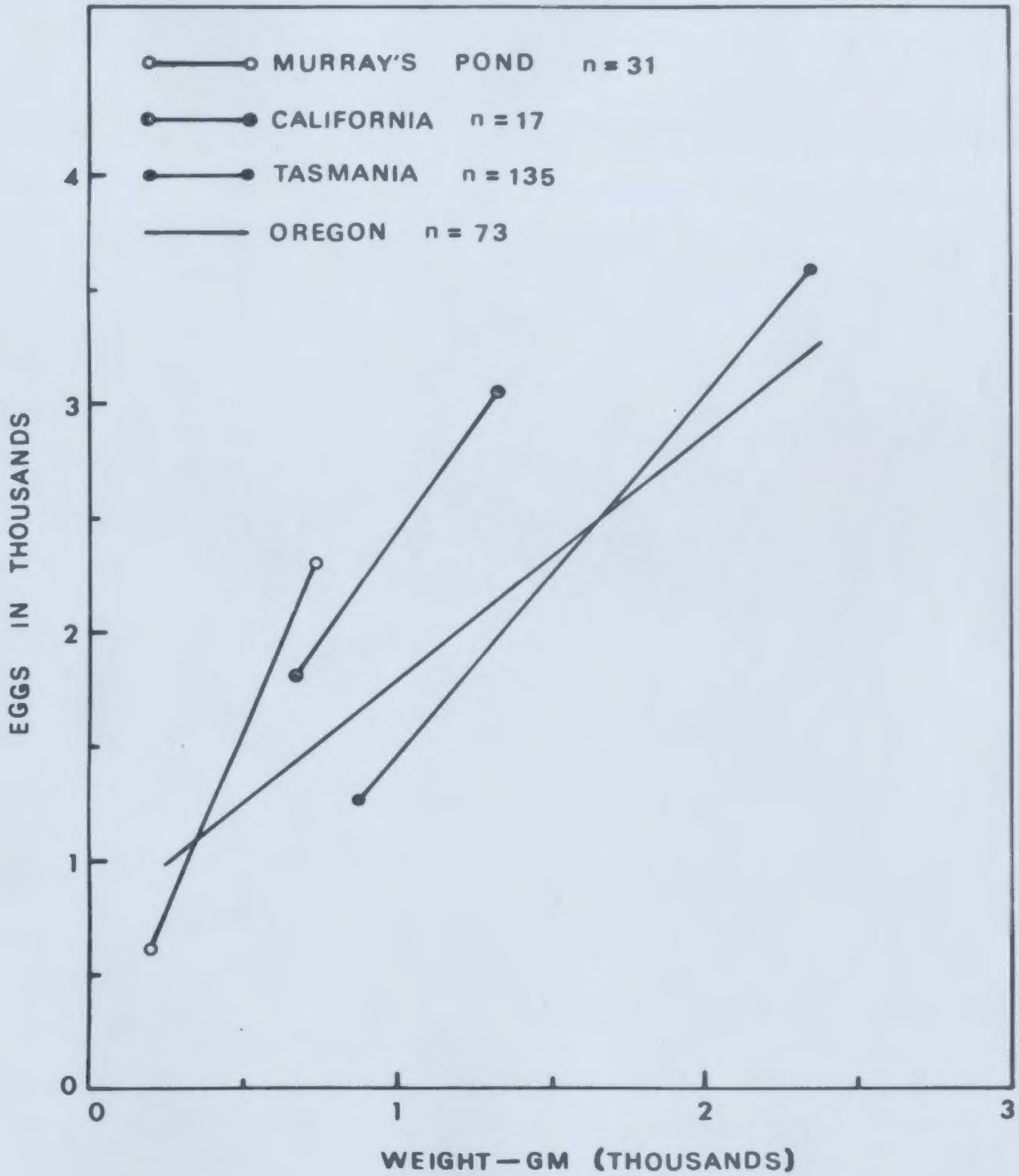
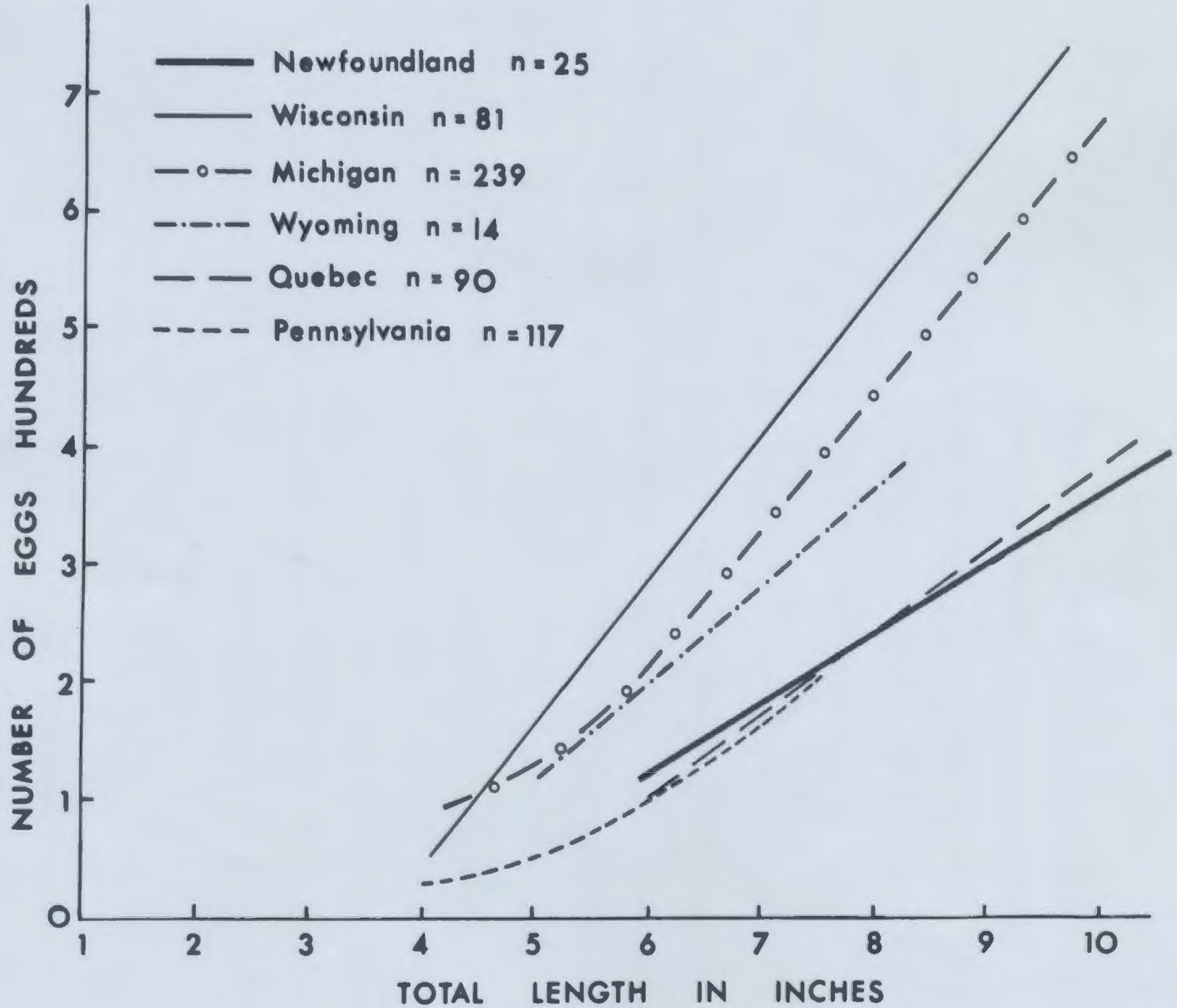

MURRAY'S POND n = 31
CALIFORNIA n = 17
TASMANIA n = 135
OREGON n = 73
EGGS IN THOUSANDS
WEIGHT—GM (THOUSANDS)
0
1
2
3
4

Fig. 30. Comparison of regression lines of fecundity on length of brook trout found in the present study with data taken from Fig. 12 of Wydoski and Cooper (p. 646], 1966.


Newfoundland n = 25
Wisconsin n = 81
Michigan n = 239
Wyoming n = 14
Quebec n = 90
Pennsylvania n = 117
NUMBER OF EGGS HUNDREDS
0
1
2
3
4
5
6
7
1
2
3
4
5
6
7
8
9
10
TOTAL LENGTH IN INCHES

and Alsea River (northern) populations could not be attributed to increased growth rate of the former. He was of the opinion that a trend toward higher fecundity of steelheads at their southern range is obviously of ecological advantage, as the fish subjected to hazardous freshwater conditions more frequently than in the northern portion. Rounsefell (1957) reported a similar trend in Oncorhynchus and suggested growth rate as a possible factor worth exploring.

Rainbow trout from Murray's Pond were as fecund as those from Scott Creek, California (Figs. 28, 29). If Bulkley's argument is right, then the fish in this study might have encountered a similar level of hazardous conditions. However, the possibilities could also be that either they still maintain the high reproductive ability of their ancestors*, or because of the abundance of food available. As Murray's Pond was artificially fertilized for several years (Dominey,1965), it seems that better nutrition may have been important. However, this contention is reserved as fecundity data from other localities (in the same area) are unavailable.

Svärdson (1949) explained the difference in fecundity in terms of natural selection by environmental factors. In populations with weak intraspecific competition

* see introduction.

for food and space, the number of eggs would increase with decrease of egg size. On the other hand, the number of eggs would decrease accompanied by increase of egg size in populations with strong intraspecific competition. However, Wydoski and Cooper (1966) found no substantiative evidence to explain differences in fecundity on the basis of natural selection in natural brook trout populations. Though they did find populations of high density with reduced fecundity, it is not known whether this was a genotypic or phenotypic characteristic.

Thompson (1959) regards fecundity as an adaptation of the fish to its environment. The deeper a fish penetrates into protected localities and the more perfect the mechanism of survival, the fewer eggs it needs. Semko (1954) found that fecundity is higher for those species of Pacific salmon in which the young spend a longer period of time in freshwater prior to seaward migration and concluded that these reflect more severe conditions for survival of the young salmon in fresh water than in the sea. Neave (1948) also reported that species of Pacific salmon with high fecundity inhabit more hazardous environments when in fresh water.

Present studies show that the number of eggs produced depends to a great extent upon the size of fish.

The fecundity-length regression for brown trout from Long Pond and Middle Pond are significantly different in slopes and origins. The higher origin shows that the latter fish may be more fecund genetically than the former. If environmental conditions are truely reflected by the K factors of the fish (Appendix 3), then Long Pond seems to be more fertile than Middle Pond. Hence, the larger Middle Pond fish failed to produce the expected number of eggs, probably because of poor nutrition.

The fecundity-length regression for landlocked salmon from Forest Pond and Ocean Pond have significantly different origins but not slopes. It is possible that fish from both ponds experienced the same environmental fertility as indicated by the K factors (Appendix 3), hence, hereditary factors may account for the difference in origins between the populations.

Long Pond is located in the city of St. John's and is heavily enriched by domestic sewage, the high fecundity may result from increased fertility of the water.

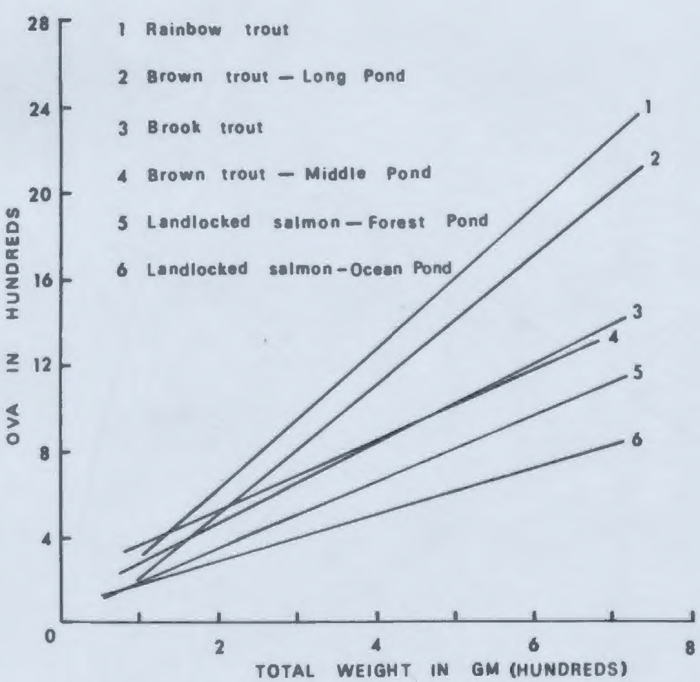
The low fecundity of Quebec and Pennsylvania brook trout was found to be correlated with very low environmental fertility (Fig. 30). Though the possibility of genetic differences in fecundity has not been ruled out, Vladykov (1956) is of the opinion that abundance and availability of food are the most important factors. Although no attempt was made to determine the fertility of the ponds studied, it seems quite possible that food was the main factor that caused the low fecundity of brook trout in this area.

The largest eggs are found in landlocked salmon which are the least fecund among the species studied (Fig. 31). This can be attained only by the sacrifice of number. It is possible that there is a certain point at which the forces favouring size are exactly balanced by those favouring number. This point varies between habitats, tending to produce genetic variation between populations for egg size and number (Rounsefell, 1957).

McFadden et al. (1965) concluded that differences of fecundity of brown trout from infertile and fertile streams were due to environmental conditions. Thus the low fecundity of brook trout, and brown trout (from Middle Pond) may be due to the low fertility present. Hence, this environmental condition indirectly serves as a mechanism to affect population density through fecundity.

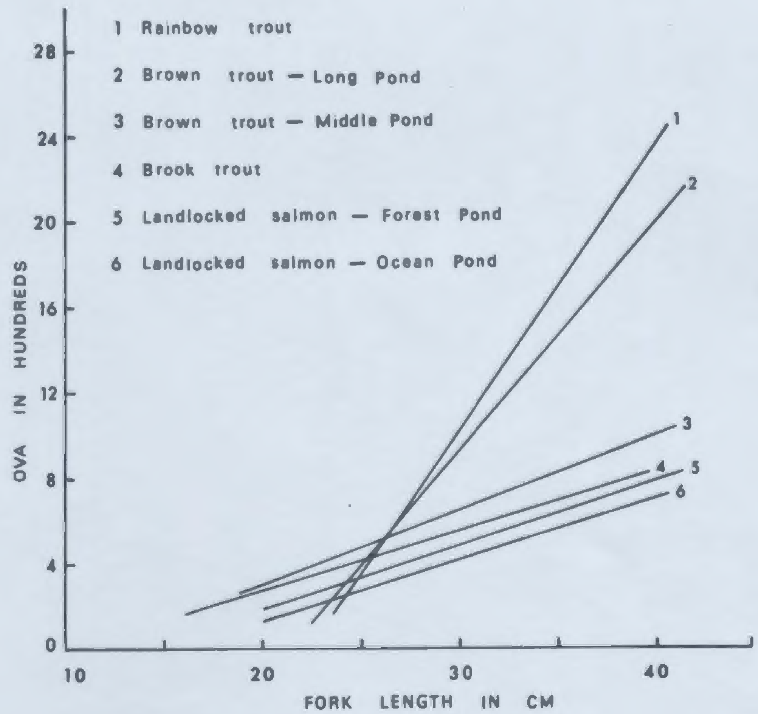
Fig. 31. (a) Comparison of regression lines of fecundity on weight of the four species studied.

(b) Comparison of regression lines of fecundity on length of the four species studied.



1 Rainbow trout
2 Brown trout — Long Pond
3 Brook trout
4 Brown trout — Middle Pond
5 Landlocked salmon — Forest Pond
6 Landlocked salmon — Ocean Pond
OVA IN HUNDREDS
TOTAL WEIGHT IN GM (HUNDREDS)
0
2
4
6
8
12
16
20
24
28

(a)



1 Rainbow trout
2 Brown trout — Long Pond
3 Brown trout — Middle Pond
4 Brook trout
5 Landlocked salmon — Forest Pond
6 Landlocked salmon — Ocean Pond
OVA IN HUNDREDS
FORK LENGTH IN CM
0
4
8
12
16
20
24
28
10
20
30
40

(b)

SUMMARY

1. A total of 530 female rainbow trout, brown trout, landlocked Atlantic salmon and brook trout collected from seven ponds on the Avalon Peninsula, Newfoundland, in 1969 are included in this investigation.

2. Except for brook trout which had a predominance of males, the sex ratios of the other three species were not significantly different from a 1 : 1 ratio.

3. Females of the four species generally mature one year later than males. Female brook trout matured one year earlier (2+) than the other three species.

4. Although both sexes of brown trout and landlocked salmon differed in age at first maturity, they varied little in size at first maturity.

5. Landlocked salmon from both Forest Pond and Ocean Pond had the largest eggs of all fish examined.

6. Egg size was more variable and could not be consistently correlated with size and age of fish in all species studied.

7. Egg number significantly correlated with size and age of fish and the relationships between the variables were linear.

8. Fecundity and weight were more closely correlated than fecundity and length.

9. Within each species, the K factor of the fish was inversely correlated with atresia and positively correlated with fecundity.

10. Fecundities of the four species in descending order are: rainbow trout, brown trout, brook trout and landlocked salmon.

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APPENDIX

Appendix 1. Length, weight and fecundity data used in the regression analysis.

Species	Pond	Length (cm) Range	Length (cm) Mean	Weight (gm) Range	Weight (gm) Mean	N[1]	Ovary weight (gm) Range	Ovary weight (gm) Mean	Egg number Range	Egg number Mean	Egg diam. (mm) Range	Egg diam. (mm) Mean
Brown trout	Long Pond	22.6-24.7	24.0	130-184	169	5	15.25-22.00	18.22	345-548	519	3.65-4.35	3.98
		25.3-29.7	27.9	198-326	257	25	15.00-53.05	32.26	449-979	697	3.50-4.80	4.22
		30.0-34.5	31.4	292-559	376	13	31.50-81.95	48.71	635-1426	942	4.05-5.00	4.49
		35.1-39.7	36.7	560-798	627	4	63.30-84.05	70.49	1519-2623	1907	4.13-4.25	4.20
	Middle Pond		19.6		95	1		17.95		391		4.15
		21.0-23.5	22.1	125-156	136	3	20.00-21.30	19.85	310-460	399	4.09-4.50	4.31
		25.0-29.6	28.3	150-271	228	12	12.55-44.25	24.75	418-708	607	3.50-4.70	3.97
		30.0-33.7	31.7	220-364	314	24	15.20-45.30	31.38	568-998	698	3.55-4.95	4.00
		35.0-37.0	36.0	422-519	471	2	68.90-73.00	70.95	965-1161	1163	4.73-4.80	4.77
Landlocked salmon	Forest Pond		19.8		99	1		12.15		152		5.10
		20.0-24.9	23.2	109-190	150	71	10.05-34.55	19.41	155-369	274	4.05-5.74	4.82
		25.0-27.2	25.7	143-234	195	5	23.80-32.47	29.01	320-453	385	4.00-5.45	4.89
	Ocean Pond	23.5-24.9	24.0	150-176	163	8	19.90-28.35	25.16	187-294	236	4.97-6.08	5.45
		25.0-29.7	27.3	185-351	251	60	13.35-66.15	39.23	221-533	343	4.05-6.40	5.67
		30.2-32.7	31.3	291-441	350	9	47.10-86.95	61.13	364-503	439	5.68-6.55	6.05
Rainbow trout	Murray's Pond	26.0-29.7	28.4	196-320	270	4	38.50-56.50	41.78	771-917	845	4.20-4.55	4.35
		30.0-34.7	32.8	266-553	432	18	34.00-122.40	72.34	794-2154	1367	3.90-4.80	4.42
		35.3-39.6	37.2	547-720	634	9	83.60-154.70	114.10	1657-2879	2084	4.07-4.63	4.45
Brook trout from the 4 ponds[2]		17.3-19.6	19.0	59-95	85	8	4.80-12.56	10.42	185-391	264	3.50-4.15	3.90
		20.3-23.8	22.3	106-165	133	16	11.10-24.30	16.00	211-455	329	3.70-4.55	4.26
			25.3		195	1		11.50		544		3.65

1. Number of fish.
2. Kelly's Pond, Island Pond, Middle Pond, Ocean Pond.

Appendix 2. Total number of females of the four species used in the present study.

Diam. of eggs (mm)	Pond	Murray's	Long	Middle		Forest	Ocean		Island	Kelly's	Total
	Species	rainbow trout	brown trout	brown trout	brook trout	landlocked salmon	landlocked salmon	brook trout	brook trout	brook trout	
1.0-1.9		-	47	26	-	36	1	-	-	-	110
2.0-2.9		-	24	16	-	25	2	-	-	-	67
3.0-3.9		2	17	27	3	21	3	-	2	9	84
4.0-4.9		29	39	30	1	50	9	3	1	11	173
5.0-5.9		-	1	-	-	27	46	-	-	-	74
6.0-6.9		-	-	-	-	-	22	-	-	-	22
Total		31	128	99	4	159	83	3	3	20	530

Appendix 3. Seasonal variation in K factor of brown trout, landlocked salmon and brook trout from the ponds studied.

Brown trout

Long Pond				Middle Pond			
Date	No. of fish	K factor Range	Mean	Date	No. of fish	K factor Range	Mean
28/5/69	14	0.87-1.18	1.02	26/6/69	18	0.90-1.25	0.92
12/6/69	10	0.93-1.26	1.11	23/7/69	20	0.89-1.15	0.96
20/7/69	39	0.96-1.54	1.25	14/8/69	7	0.91-1.11	1.02
23/8/69	21	1.07-1.46	1.29	10/9/69	36	0.85-1.14	0.99
29/9/69	44	1.04-1.50	1.22	4/10/69	18	0.97-1.12	1.01
4/11/69	5*	1.07-1.18	1.12				

Landlocked salmon

Forest Pond				Ocean Pond			
24/6/69	38	0.88-1.45	1.18	16/6/69	1	1.11	1.11
25/7/69	25	1.16-1.39	1.27				
22/8/69	19	0.97-1.42	1.28	20/8/69	5	1.09-1.38	1.18
14/9/69	64	1.11-1.45	1.24	18/9/69	19	1.18-1.36	1.18
6/10/69	13	1.14-1.47	1.28	25/10/69	58	0.97-1.39	1.23
28/10/69	6*	1.09-1.23	1.18				

* Spent fish.

Appendix 3. (contd.)

Brook trout

From the four ponds studied

Date	No. of fish	K factor Range	Mean
28/8/69	5	1.18-1.34	1.26
30/9/69	20	1.04-1.34	1.20
25/10/69	5	1.14-1.22	1.19

Appendix 4a. Length distribution of age groups of brown trout from Long Pond.

Length intervals (cm)	Age groups: II		III		IV		V		VI		VII		VIII		IX		Total		
	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F & M
18.0-19.9	3	3	2	3													5	6	11
20.0-21.9			18	13	3	8											21	21	42
22.0-23.9			9	10	12	11	2	1									23	22	45
24.0-25.9			1	1	20	9	5	5	1	1							27	16	43
26.0-27.9					11	13	28	18	9	6	2	-					50	37	87
28.0-29.9					1	1	16	15	17	18	1	1	-	1			35	36	71
30.0-31.9							3	5	10	13	7	1	1	2	-	1	21	22	43
32.0-33.9							-	2	3	7	3	2	1	1			7	12	19
34.0-35.9									-	2	1	5	-	3	-	1	1	11	12
36.0-37.9									-	1	1	1	1	1	1	-	3	3	6
38.0-39.9													1	-			1	0	1
42.0-43.9															-	1	0	1	1
44.0-45.9															-	1	0	1	1
Total	3	3	30	27	47	42	54	46	40	48	15	10	4	8	1	4	194	188	382
Average length	19.1	19.7	21.7	21.7	24.8	24.5	26.8	27.4	29.4	30.0	31.4	33.5	34.5	32.8	36.2	38.6			

Appendix 4b. Length distribution of age groups of brown trout from Middle Pond.

Length intervals (cm)	Age groups III		IV		V		VI		VII		VIII		IX		X		XI		Total		
	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F & M
14.0-15.9	0	1																	0	1	1
16.0-17.9	3	1																	3	1	4
18.0-19.9	4	1	7	4															11	5	16
20.0-21.9	2	0	3	2															5	2	7
22.0-23.9			0	1	12	11	5	4											17	16	33
24.0-25.9					8	4													8	4	12
26.0-27.9					2	0	6	8	4	5	1	2							13	15	28
28.0-29.9							8	2	8	11	4	10	1	2					21	25	46
30.0-31.9							4	0	6	8	8	3	6	5	2	0			26	16	42
32.0-33.9									3	2	7	8	4	9	3	4	1	3	18	26	44
34.0-35.9											1	0	1	3	1	1			3	4	7
36.0-37.9													1	0	0	1			1	1	2
Total	9	3	10	7	22	15	23	14	21	26	21	23	13	19	6	6	1	3	126	116	242
Average length	19.2	19.5	20.2	20.7	24.0	23.9	27.6	26.1	29.8	29.5	31.2	30.4	32.3	32.3	32.5	33.9	32.2	33.0			

Appendix 4c. Length distribution of age groups of landlocked salmon from Forest Pond.

Length intervals (cm)	Age groups II		III		IV		V		VI		Total		
	F	M	F	M	F	M	F	M	F	M	F	M	F & M
12.0-13.9	0	1									0	1	1
14.0-15.9	1	4									1	4	5
16.0-17.9	0	2	2	0							2	2	4
18.0-19.9	2	1	17	24	7	0					26	25	51
20.0-21.9			43	40	73	50	17	25			133	115	248
22.0-23.9			21	13	65	38	40	37	5	18	131	106	237
24.0-25.9					9	5	13	15	1	9	23	29	52
26.0-27.9							0	2	1	0	1	2	3
28.0-29.9							0	1			0	1	1
Total	3	8	83	77	154	93	70	80	7	27	317	285	602
Average length	17.2	15.5	18.9	20.8	22.2	22.4	23	22.8	23.3	23.4			

Appendix 4d. Length distribution of age groups of landlocked salmon sample from Ocean Pond.

Length intervals (cm)	Age groups														Total		
	II		III		IV		V		VI		VII		VIII				
	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F & M
16.0-17.9	0	1													0	1	1
18.0-19.9	0	1	0	1											0	2	2
20.0-21.9			5	6	3	2									8	8	16
22.0-23.9			18	18	25	31	4	10							47	59	106
24.0-25.9			9	6	26	23	22	8	3	6					60	43	103
26.0-27.9					4	8	24	24	18	11	1	1	0	1	47	45	92
28.0-29.9					1	0	7	7	15	10	4	4	4	0	31	21	52
30.0-31.9							1	3	1	3	4	4	0	3	6	13	19
32.0-33.9									1	2	1	2	2	1	4	5	9
34.0-35.9											0	1			0	1	1
Total	0	2	32	31	59	64	58	52	38	32	10	12	6	5	203	198	401
Average length		17	23.1	24.4	24.3	24.8	26	26.4	27.8	27.9	29.8	30.4	30.3	31			

Appendix 4e. Length distribution of age groups of rainbow trout from Murray's Pond.

Length intervals (cm)	Age groups														Total		
	III		IV		V		VI		VII		VIII		IX				
	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F & M
18.0-19.9	0	1													0	1	1
20.0-21.9	0	1													0	1	1
22.0-23.9	1	3													1	3	4
24.0-25.9	1	3	1	4											2	7	9
26.0-27.9			2	7			1	2							3	9	12
28.0-29.9					2	1	2	2							4	3	7
30.0-31.9					1	2	4	0							5	2	7
32.0-33.9					3	1	5	3	1	2					9	6	15
34.0-35.9							3	0	6	2	2	2			11	4	15
36.0-37.9							2	0	2	0	2	1			6	1	7
38.0-39.9									1	0	1	0			2	0	2
40.0-41.9													1	0	1	0	1
Total	2	8	3	11	6	4	17	7	10	4	5	3	1	0	44	37	81
Average length	24.1	22.9	26.5	26.2	31.2	30.9	32.4	30.3	35.2	33.7	36.2	35	40.3				

Appendix 4f. Length distribution of age groups of brook trout from the four ponds studied.

Length intervals (cm)	Age groups												Total		
	I		II		III		IV		V		VI				
	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F & M
12.0-13.9	1	2	0	2									1	4	5
14.0-15.9	1	1	2	5									3	6	9
16.0-17.9	0	1	1	9	0	1							1	11	12
18.0-19.9			1	9	8	19	0	1					9	29	38
20.0-21.9					9	18	3	5					12	23	35
22.0-23.9					6	7	4	4					10	11	21
24.0-25.9					2	4	2	2	1	1			5	7	12
26.0-27.9							1	1					1	1	2
28.0-29.9									1	0			1	0	1
30.0-31.9											1	0	1	0	1
Total	2	4	4	25	25	48	10	13	2	1	1	0	44	92	136
Average length	13.5	14.6	16.9	16.9	21.4	20.6	23.3	22.6	26.7	24.3	31.9				

Appendix 5a

The relationship of size and age to sexual maturity in brown trout from the two study areas. {Total number of individuals (T); number of mature fish (M)}.

Age group	Fork length (cm)	Female						Male					
		Long P.		Middle P.		Total		Long P.		Middle P.		Total	
		T	M	T	M	T	%M	T	M	T	M	T	%M
II	18.0-19.9	3	0			3	0	3	2			3	66.6
	Total	3	0			3	0	3	2			3	66.6
III	14.0-15.9			0	0	0	0			1	1	1	100.0
	16.0-17.9			3	0	3	0			1	1	1	100.0
	18.0-19.9	2	1	4	1	6	33.3	3	1	1	1	4	50.0
	20.0-21.9	18	4	2	2	20	30.0	13	7	0	0	13	53.8
	22.0-23.9	9	3	0	0	9	33.3	10	5	2	0	12	41.7
	24.0-25.9	1	1			1	100.0	1	1			1	100.0
	Total	30	9	9	3	39	30.8	27	14	5	3	32	53.1
Iv	18.0-19.9			7	3	7	42.9			4	4	4	100.0
	20.0-21.9	3	2	3	3	6	83.3	8	4	2	2	10	60.0
	22.0-23.9	12	4	0	0	12	33.3	11	8	1	0	12	66.6
	24.0-25.9	20	8			20	40.0	9	5			9	55.6
	26.0-27.9	11	9			11	80.9	13	11			13	84.6
	28.0-29.9	1	1			1	100.0	1	1			1	100.0
	Total	47	24	10	6	57	52.6	42	29	7	6	49	71.4
V	22.0-23.9	2	2	12	7	14	54.3	1	1	11	9	12	83.3
	24.0-25.9	5	4	8	4	13	61.5	5	4	4	4	9	90.0
	26.0-27.9	28	25	2	2	30	90.0	18	16	0	0	18	88.9
	28.0-29.9	16	15			16	93.8	15	15			15	100.0
	30.0-31.9	3	3			3	100.0	5	5			5	100.0
	32.0-33.9	0	0			0	0	2	2			2	100.0
	Total	54	49	22	13	76	81.6	46	43	15	13	61	91.8
VI		40	39	23	22	63	97.0	48	47	14	13	62	96.8
VII		15	15	21	21	36	100.0	10	10	26	26	36	100.0
VIII		4	4	21	21	25	100.0	1	1	23	23	24	100.0
IX		1	1	13	13	14	100.0	4	4	19	19	23	100.0
X				6	6	6	100.0			6	6	6	100.0
XI				1	1	1	100.0			3	3	3	100.0

Appendix 5b. The relationship of size and age to sexual maturity in landlocked salmon from the two study areas. {Total number of individual (T); number of mature fish (M)}.

Age group	Fork length (cm)	Female						Male					
		Forest P.		Ocean P.		Total		Forest P.		Ocean P.		Total	
		T	M	T	M	T	%M	T	M	T	M	T	%M
II	12.0-13.9	0	0			0	0	1	1			1	100.0
	14.0-15.9	1	0			1	0	4	4			4	100.0
	16.0-17.9	0	0	0	0	0	0	2	2	1	0	1	66.6
	18.0-19.9	2	0	0	0	2	0	1	0	1	0	2	0
	Total	3	0	0	0	3	0	8	7	2	0	10	88.9
III	16.0-17.9	2	0			2	0	0	0			0	0
	18.0-19.9	17	12	0	0	17	70.6	24	14	1	0	25	56.0
	20.0-21.9	43	41	5	0	48	85.4	40	35	6	2	46	80.4
	22.0-23.9	21	21	18	3	39	61.5	13	13	18	9	31	73.6
	24.0-25.9			9	0	9	0			6	0	6	0
	Total	83	74	32	3	115	67.0	77	62	31	11	108	67.6
IV	18.0-19.9	7	7			7	100.0	0	0			0	0
	20.0-21.9	73	71	3	2	76	96.1	50	45	2	1	52	88.5
	22.0-23.9	65	64	25	4	90	75.6	38	34	31	14	69	69.6
	24.0-25.9	9	9	26	12	35	60.0	5	5	23	9	28	50.0
	26.0-27.9			4	2	4	50.0			8	4	8	50.0
	28.0-29.9			1	1	1	100.0			0	0	0	0
	Total	154	151	59	21	213	80.8	93	84	64	28	157	71.3
V	20.0-21.9	17	17			17	100.0	25	23			25	92.0
	22.0-23.9	40	40	4	1	44	93.2	37	36	10	9	47	95.7
	24.0-25.9	13	13	22	7	35	57.1	15	15	8	4	23	82.6
	26.0-27.9	0	0	24	18	24	75.0	2	2	24	18	26	76.9
	28.0-29.9	0	0	7	5	7	71.4	1	1	7	6	8	87.5
	30.0-31.9			1	1	1	100.0			3	3	3	100.0
	Total	70	70	58	32	128	79.7	80	77	52	40	132	88.6
VI		7	7	38	34	45	91.1	27	27	32	29	59	94.9
VII				10	10	10	100.0			1	1	1	100.0
VIII				6	6	6	100.0			5	5	5	100.0

Appendix 5c. The relationship of size and age to sexual maturity in rainbow trout from Murray's Pond. {Total number of individual (T); number of mature fish (M)}.

Age group	Fork length (cm)	Female			Male		
		T	M	%M	T	M	%M
III	18.0-19.9	0	0	0	1	1	100.0
	20.0-21.9	0	0	0	1	1	100.0
	22.0-23.9	1	0	0	3	3	100.0
	24.0-25.9	1	0	0	3	1	33.3
	Total	2	0	0	8	6	75.0
IV	24.0-25.9	1	0	0	4	4	100.0
	26.0-27.9	2	1	50.0	7	7	100.0
	Total	3	1	33.3	11	11	100.0
V		6	6	100.0	4	4	100.0
VI		17	16	94.1	7	7	100.0
VII		10	10	100.0	4	4	100.0
VIII		5	5	100.0	3	3	100.0
IX		1	1	100.0	0	0	0

Appendix 5d. The relationship of size and age to sexual maturity in brook trout from the four ponds studied. {Total number of individual (T); number of mature fish (M)}.

Age group	Fork length (cm)	Female			Male		
		T	M	%M	T	M	%M
I	12.0-13.9	1	0	0	2	0	0
	14.0-15.9	1	0	0	1	0	0
	16.0-17.9	0	0	0	1	1	100.0
	Total	2	0	0	4	1	25.0
II	12.0-13.9	0	0	0	2	1	50.0
	14.0-15.9	2	0	0	5	2	40.0
	16.0-17.9	1	1	100.0	9	6	66.6
	18.0-19.9	1	1	100.0	9	9	100.0
	Total	4	2	50.0	25	18	72.0
III	16.0-17.9	0	0	0	1	0	0
	18.0-19.9	8	4	50.0	19	16	84.2
	20.0-21.9	9	8	88.9	18	18	100.0
	22.0-23.9	6	6	100.0	7	7	100.0
	24.0-25.9	2	1	50.0	4	4	100.0
	Total	25	19	76.0	49	45	91.8
IV	18.0-19.9	0	0	0	1	1	100.0
	20.0-21.9	3	3	100.0	5	3	60.0
	22.0-23.9	4	4	100.0	4	4	100.0
	24.0-25.9	2	2	100.0	2	2	100.0
	26.0-27.9	1	1	100.0	1	1	100.0
	Total	10	10	100.0	13	11	84.6
V		2	2	100.0	1	1	100.0
VI		1	1	100.0	0	0	0

Appendix 6a. Average number of eggs in both ovaries, average number of eggs per 100 gm of fish, and average number of eggs per 100 mm of fork length arranged according to egg diameter for brown trout from Long Pond (L. P.) and Middle Pond (M. P.). Bracketed values represent the number of fish.

Diam. (mm)	No. of eggs L. P.	No. of eggs M. P.	Eggs per 100 gm L. P.	Eggs per 100 gm M. P.	Eggs per 100 mm L. P.	Eggs per 100 mm M. P.
1.00-1.49	738 (23)	993 (11)	361	366	296	324
1.50-1.99	714 (24)	630 (15)	326	311	275	252
2.00-2.49	758 (16)	795 (7)	315	292	274	268
2.50-2.99	774 (8)	733 (9)	273	284	279	260
3.00-3.49	971 (10)	606 (15)	286	268	281	219
3.50-3.99	599 (7)	650 (12)	278	252	230	220
4.00-4.49	921 (30)	657 (22)	277	254	298	220
4.50-4.99	797 (9)	663 (8)	250	224	256	218
5.00-5.49	791 (1)	-	225	-	254*	-

* Data from a single female, therefore, not used in the calculation of percentage of atretic eggs.

Appendix 6b. Average number of eggs in both ovaries, average number of eggs per 100 gm of fish weight and average number of eggs per 100 mm of fork length arranged according to egg diameter for landlocked salmon from Forest Pond (F. P.) and Ocean Pond (O. P.). Bracketed values represent the number of fish.

Diam. (mm)	No. of eggs		Eggs per 100 gm		Eggs per 100 mm	
	F. P.	O. P.	F. P.	O. P.	F. P.	O. P.
1.00-1.49	261 (15)	809 (1)	265	255	142	264*
1.50-1.99	271 (21)		238		143	
2.00-2.49	264 (14)		226		129	
2.50-2.99	265 (11)	399 (2)	202	179	127	151
3.00-3.49	262 (17)	408 (3)	194	159	119	149
3.50-3.99	216 (4)		166		108	
4.00-4.49	292 (18)	359 (4)	192	145	126	132
4.50-4.99	265 (32)	345 (5)	186	156	118	129
5.00-5.49	278 (23)	343 (12)	176	148	121	128
5.50-5.99	276 (4)	343 (34)	174	140	120	125
6.00-6.49		341 (21)		124		120
6.50-6.99		503 (1)		114		154

* Data from a single female, therefore, not used in the calculation of percentage of atretic eggs.

Appendix 6c. Average number of eggs in both ovaries, average number of eggs per 100 gm of fish weight, and average number of eggs per 100 mm of fork length arranged according to the egg diameter. Bracketed values represent the number of fish.

Rainbow trout from Murray's Pond

Diameter (mm)	No. of eggs	Eggs per 100 gm	Eggs per 100 mm
3.50-3.99	1276 (2)	361	409
4.00-4.49	1368 (13)	335	419
4.50-4.99	1650 (16)	306	467

Brook trout from the four localities

Diameter (mm)	No. of eggs	Eggs per 100 gm	Eggs per 100 mm
3.00-3.49	324 (4)	292	150
3.50-3.99	332 (8)	289	179
4.00-4.49	341 (11)	274	168
4.50-4.99	266 (5)	224	125

Appendix 7. The number and percentage of fish with different egg counts in the ovaries and the difference in egg number between the left (L) and right (R) ovaries of brown trout (B. T.) and landlocked salmon (L. S.) from the ponds studied.

Pond	Species	No. & % of fish		X^2	P	Average No. of eggs		Standard error		P
		L > R	R > L			L	R	L	R	
Long P.	B.T.	35	12	11.26	<0,005	431	407	31.26	29.19	<0.5
		74.5%	25.5%							
Middle P.	B.T.	30	11(1)	8.80	<0.005	345	309	14.07	13.76	<0.1
		73.2%	26.8%							
Forest P.	L.S.	52	25	9.47	<0.005	146	133	4.11	4.97	<0.05
		67.5%	32.5%							
Ocean P.	L.S.	17	60(2)	24.01	<0.005	138	208	7.39	7.77	<0.001
		22.1%	77.9%							

(1) One fish which had a single ovary is not included.

(2) 18 fish which had larger right ovaries still had the intestine bending to the right. Four fish which had larger right ovaries had the intestine neither bending to the right nor left.