# SOME ASPECTS OF THE BIOLOGY OF LANDLOCKED SMELT, OSMERUS MORDAX (MITCHILL) 1815, IN SELECTED AVALON PENINSULA LAKES



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by

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## ABSTRACT

Smelt populations in four lakes on the Avalon Peninsula, Newfoundland, were investigated in this study. Sympatric populations of large (giant) and small (dwarf) smelt live in one of these lakes, Black River Pond. The remaining three lakes contain only the small race smelt.

Small race smelt have a very short life span, usually two years, while the large race may attain an age of six years. Small race smelt seldom exceed a length of 130 mm and many large race smelt exceed 250 mm. Small race smelt rarely attain a weight of 10 g while it is not unusual for giant smelt to weigh more than 10 times this amount.

Four of the six measured morphological characteristics showed a significant difference between the two sympatric races.

Both races are spring spawners, with the actual time of spawning varying from one locality to the next, and from year to year. They spawn both in tributaries and around the shores of the lake. Small race smelt reach sexual maturity at the end of their second growing season and the large race smelt a year later. The sympatric populations at Black River Pond are reproductively isolated temporally and perhaps spatially. The large race spawns first, starting almost two weeks prior to the beginning of spawning in the small race.

Food analysis studies showed that small race smelt are principally benthic feeders relying mainly on aquatic insect larvae and nymphs and to a lesser degree on amphipods. The relative importance of any particular aquatic invertebrate group showed regional variability. The large race at Black River Pond are very cannibalistic, feeding upon younger small race smelt. They forage on immature stages of aquatic insects to a lesser degree.

Combining information on rate of growth, life span, age and size at sexual maturity, time of spawning, feeding habits, and morphological differences, it appears evident that the two sympatric forms at Black River Pond are discrete populations, and that at least a partial barrier to gene flow exists between them.

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Landlocked American smelt from Black River Pond.
1. $V^+$ Large Race
2. $IV^+$ Large Race
3. $III^+$ Small Race
4. $II^+$ Small Race

(Photograph taken by Mr. Leo Cave, Photographer, Scientific Photo Section, Environment Canada).

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# INTRODUCTION

"Second cousin to the grayling and trout, and one of the neatest, most graceful, and delicate of all our food fishes, is that universal favorite, the smelt." (Samuels, 1904).

The American smelt, Osmerus mordax (Mitchill) 1815, occurs landlocked in many lakes and ponds throughout its range in eastern North America. Two forms, the large and small races, have been reported from a number of lakes (Greene, 1930; Zilliox and Youngs, 1958; Brooks and Deevey, 1963; Delisle, 1969). Smelt are indigenous in some of these bodies of water but they have been introduced into many others. Delisle (1969) has reported they are present in 128 Quebec lakes and rivers. Rupp (1969) has reported they are present in 114 Maine lakes. They have been introduced into all of the Great Lakes (Hankinson and Hubbs, 1922; Creaser, 1925; Van Oosten, 1937; Dymond, 1944). Many different aspects of its ecology and life history have been studied and documented in regions outside Newfoundland. References to most of these works are included in a bibliography of the smelt family, Osmeridae, by Gruchy and McAllister (1972).

Although several studies have been carried out on some of the province's anadromous smelt populations (Dyke, 1964; Copeman, 1973; Nhwani, 1973), no inventory has been done on the landlocked populations of insular Newfoundland. Scott and Crossman (1964) reported that smelt eggs were imported from New York State in 1893 and 1895 and planted in some Newfoundland lakes. They also reported that at the same time many Newfoundland lakes already contained smelt.

Since then no mention is made in the literature of the landlocked smelt except that they are found in some Newfoundland lakes.

Due to this lack of information of landlocked smelt in Newfoundland, this study was initiated to investigate some aspects of the smelt's biology and to evaluate the possibility and feasibility of introducing landlocked smelt as a potential forage fish for the resident salmonids in certain lakes on the Avalon Peninsula, Newfoundland. Rupp (1959, 1968), McCaig and Mullan (1960), Havey and Warner (1970), Warner (1972), and Havey (1973), have shown their importance as a forage for other species, particularly salmonids.

The study was designed to include investigation of growth rate; survival and mortality rates; age and size structure; food habits; and spawning times, sites, and behavior.

## DESCRIPTION OF THE STUDY AREAS

Four lakes on the Avalon Peninsula, known to contain smelt, were sampled for this study (Figure 1). These include Larkins Pond and Clarks Pond in the Placentia area; Nine Island Pond South near Avondale; and Black River Pond in the Salmonier area. Bathymetric maps of the four lakes are shown in Figures 2-5.

### Location

Larkins Pond is situated 47°13'N.53°58'W.

Clarks Pond lies at 47°13'N.54°W.

Nine Island Pond South is situated 47°22'N.53°15'W.

Black River Pond is situated 47°13'N.53°22'W.

### Drainage Area Substrate

All four lakes lie in a region of Precambrian sedimentary and volcanic rocks. The drainage basins of Larkins and Clarks Pond contain Hadrynian siltstone, arkose, conglomerate, slate, and acidic to intermediate volcanic rocks of the Musgravetown Group. The similar strata of the other two lake drainage basins belong to the Conception Group (Geological Survey of Canada, Map 1231A, 1967).

### Vegetative Cover

Most of the surrounding area of the four lakes is forested with

black spruce (Picea mariana), balsam fir (Abies balsamea), and white birch (Betula papyrifera).

Physical and Chemical Environment

The lakes range in size from 22.3 ha (Clarks Pond) to 108.6 ha (Black River Pond). Black River Pond has the greatest maximum depth (18.9 m) and mean depth (6.3 m). pH values range from 5.9 to 7.0, and conductivities range between 30.7 and 92.0 (Table 1).

Table 1. Physical and chemical properties of the four study areas

| | Larkins Pond | Clarks Pond | Nine Is. Pd. South | Black River Pond |
|---|---|---|---|---|
| Area (acres) | 61.1 | 55.1 | 203.6 | 268.3 |
| (ha) | 24.7 | 22.3 | 82.4 | 108.6 |
| Maximum depth (ft.) | 36.0 | 38.0 | 27.0 | 62.0 |
| (m) | 11.0 | 11.6 | 8.2 | 18.9 |
| Mean depth (ft) | 16.6 | 18.8 | 11.1 | 20.5 |
| (m) | 5.1 | 5.7 | 3.4 | 6.3 |
| pH | 6.9 | 7.0 | 5.9 | 6.5 |
| Specific Conductance micromhos at 25C | 92.0 | 89.4 | 30.7 | 36.3 |
| Total Hardness as $CaCO_3$ | 17.2 | 16.9 | 6.0 | 6.6 |

The lakes are usually ice-covered from early December to the latter part of April. Mean monthly surface temperatures for the ice-free

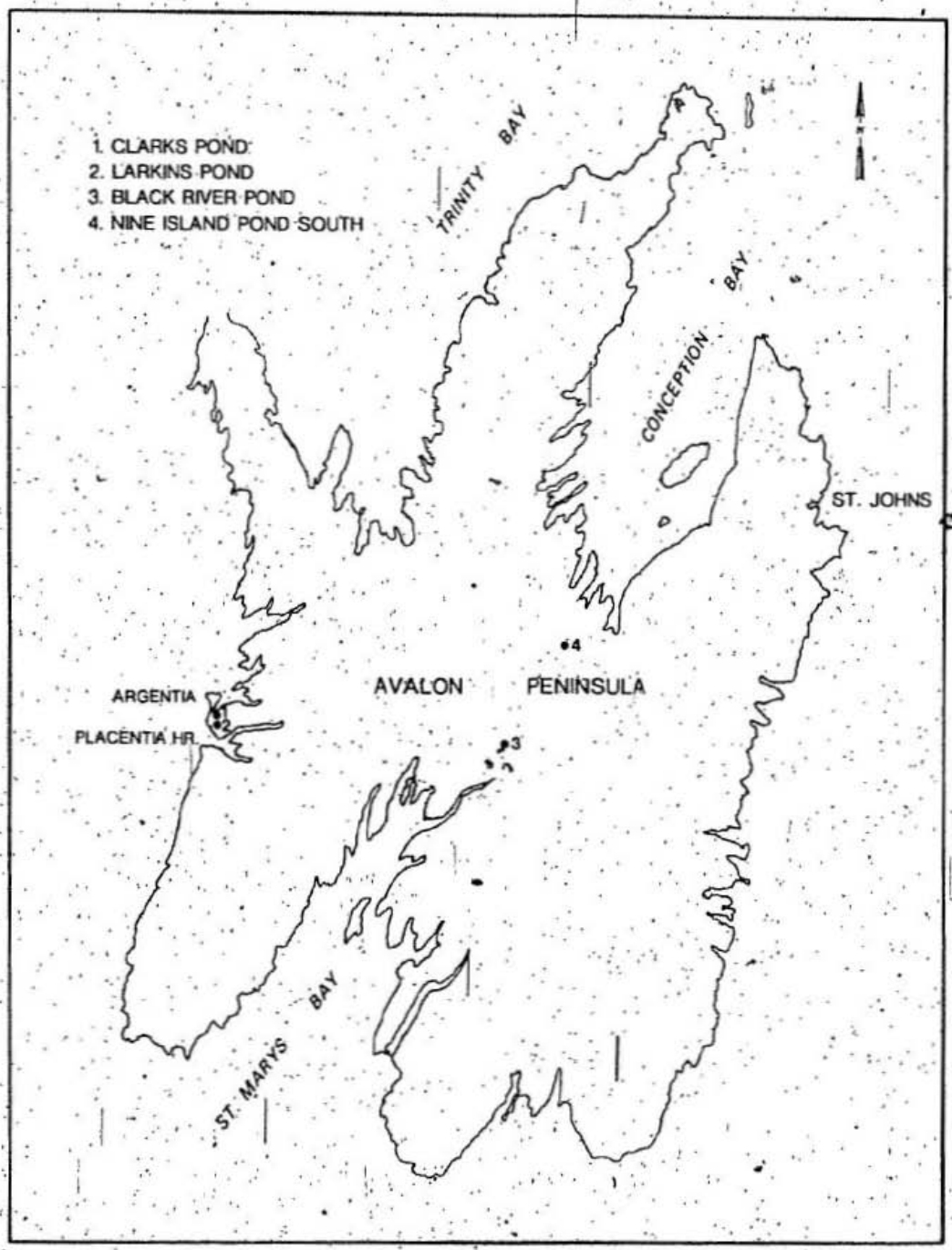
period for three of the lakes are given in Appendix 1. Dissolved oxygen concentrations taken during the summer of 1973 range from 8.3 to 9.6 mg/liter at the surface and 9.8 mg/liter at the greatest depth in Black River Pond. Oxygen and temperature readings for the four lakes are given in Appendix 2A and 2B. Wiseman (1973) and Wiseman and Whalen (1974) in an inventory of lakes on the Avalon Peninsula described these four lakes in some detail.

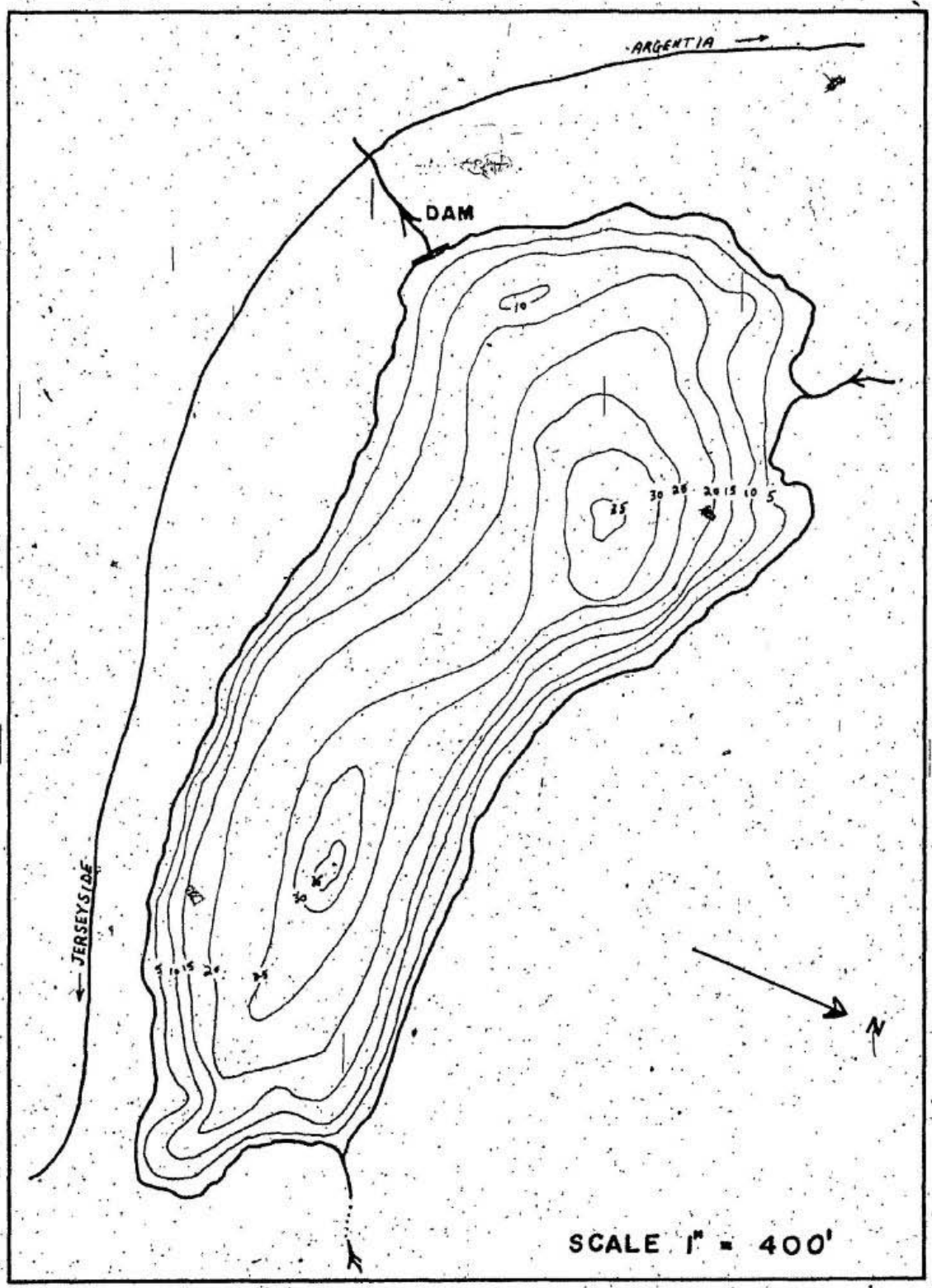
Fish Species Present

Larkins, Clarks, and Black River Ponds, besides containing landlocked smelt, Osmerus mordax, also contain brook trout, Salvelinus fontinalis, threespine stickleback, Gasterosteus aculeatus, and the American eel, Anguilla rostrata. In addition to these species, Nine Island Pond South contains ouananiche or landlocked Atlantic salmon, Salmo salar.

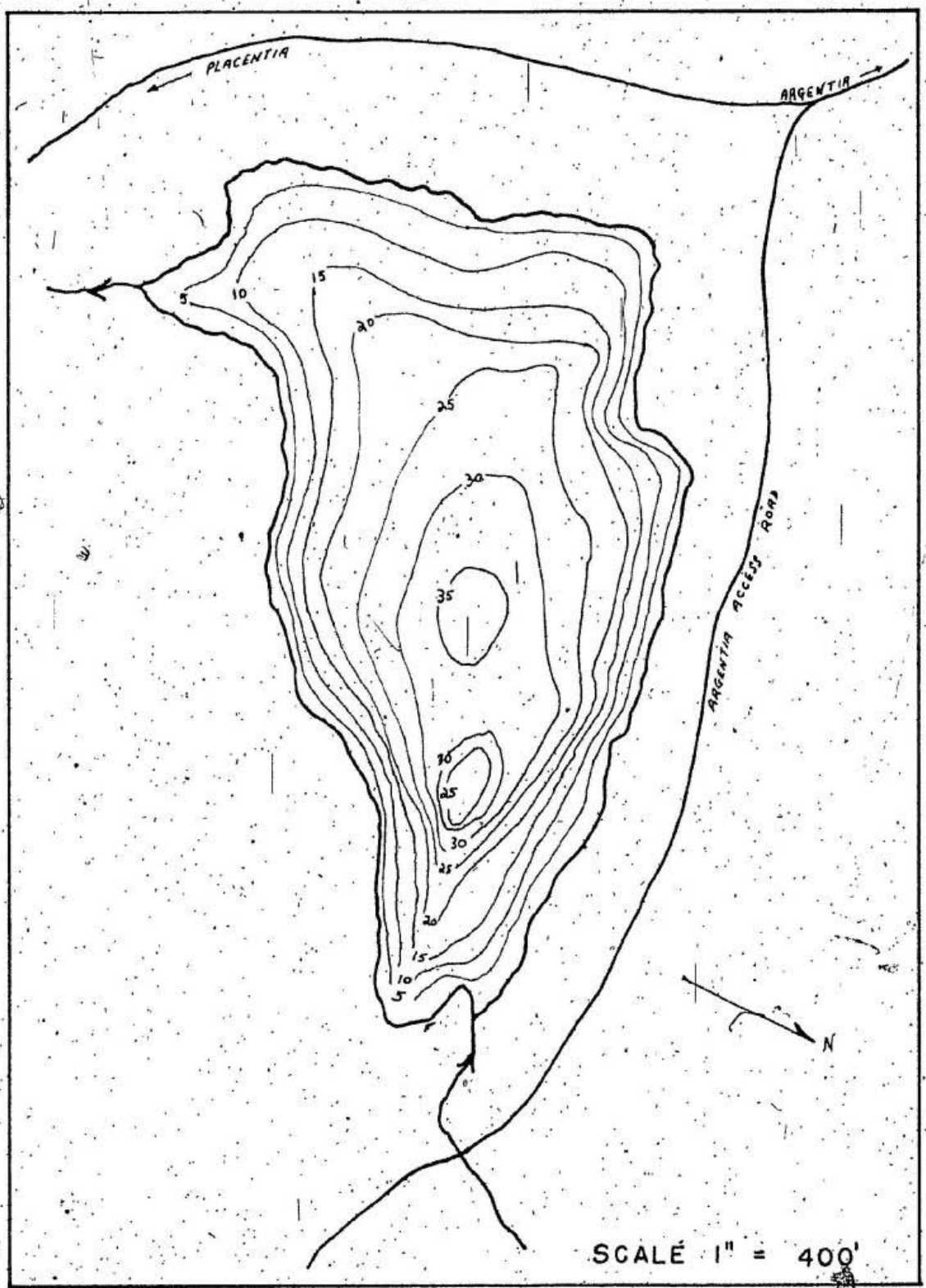
Fig. 1 . Map of Avalon Peninsula showing the four study areas.

Fig. 2-5. Bathymetric maps of the four study areas.

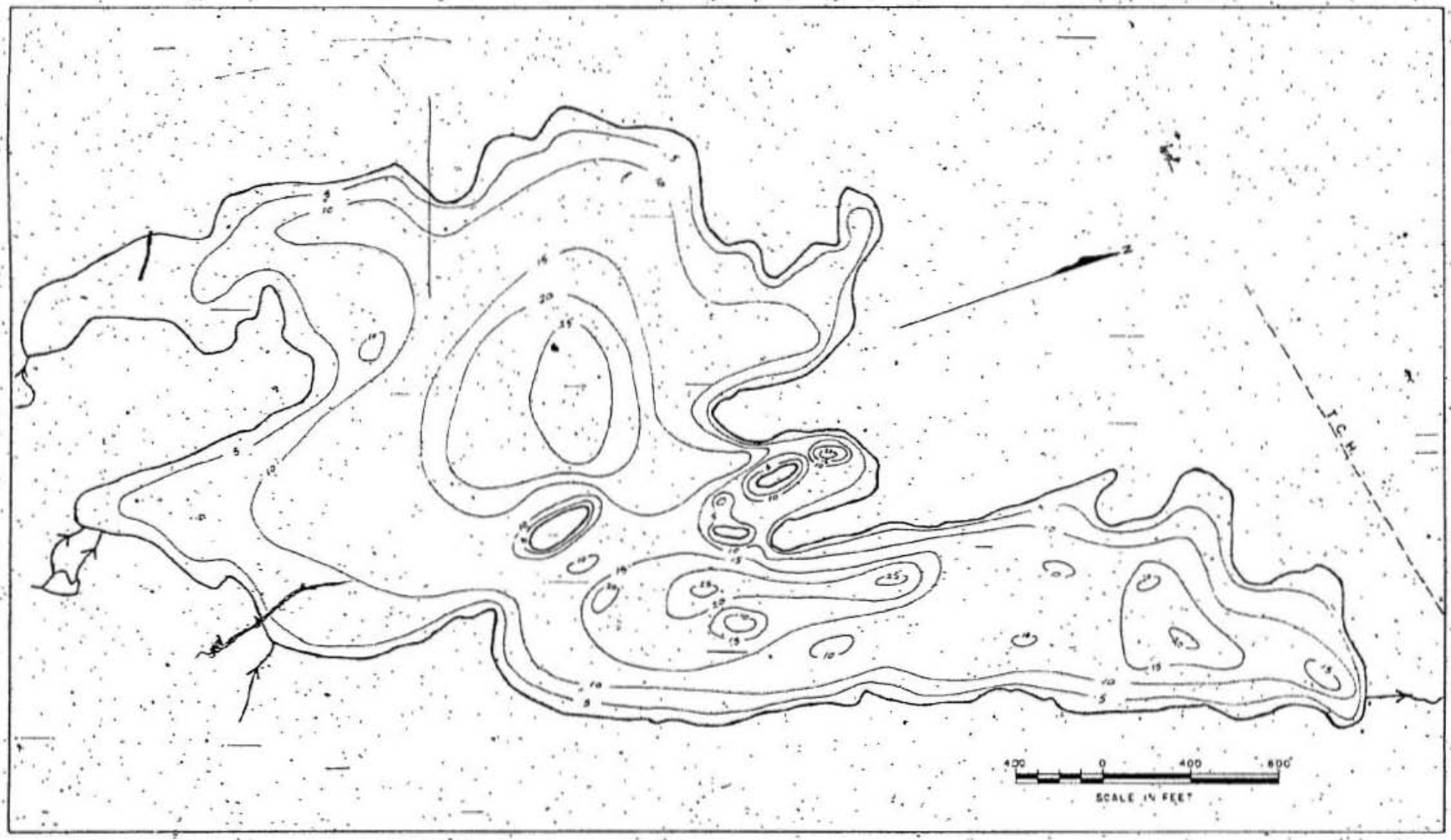

1. CLARKS POND
2. LARKINS POND
3. BLACK RIVER POND
4. NINE ISLAND POND SOUTH
TRINITY BAY
CONCEPTION BAY
ST. JOHNS
AVALON PENINSULA
ARGENTIA
PLACENTIA HR.
ST. MARYS BAY



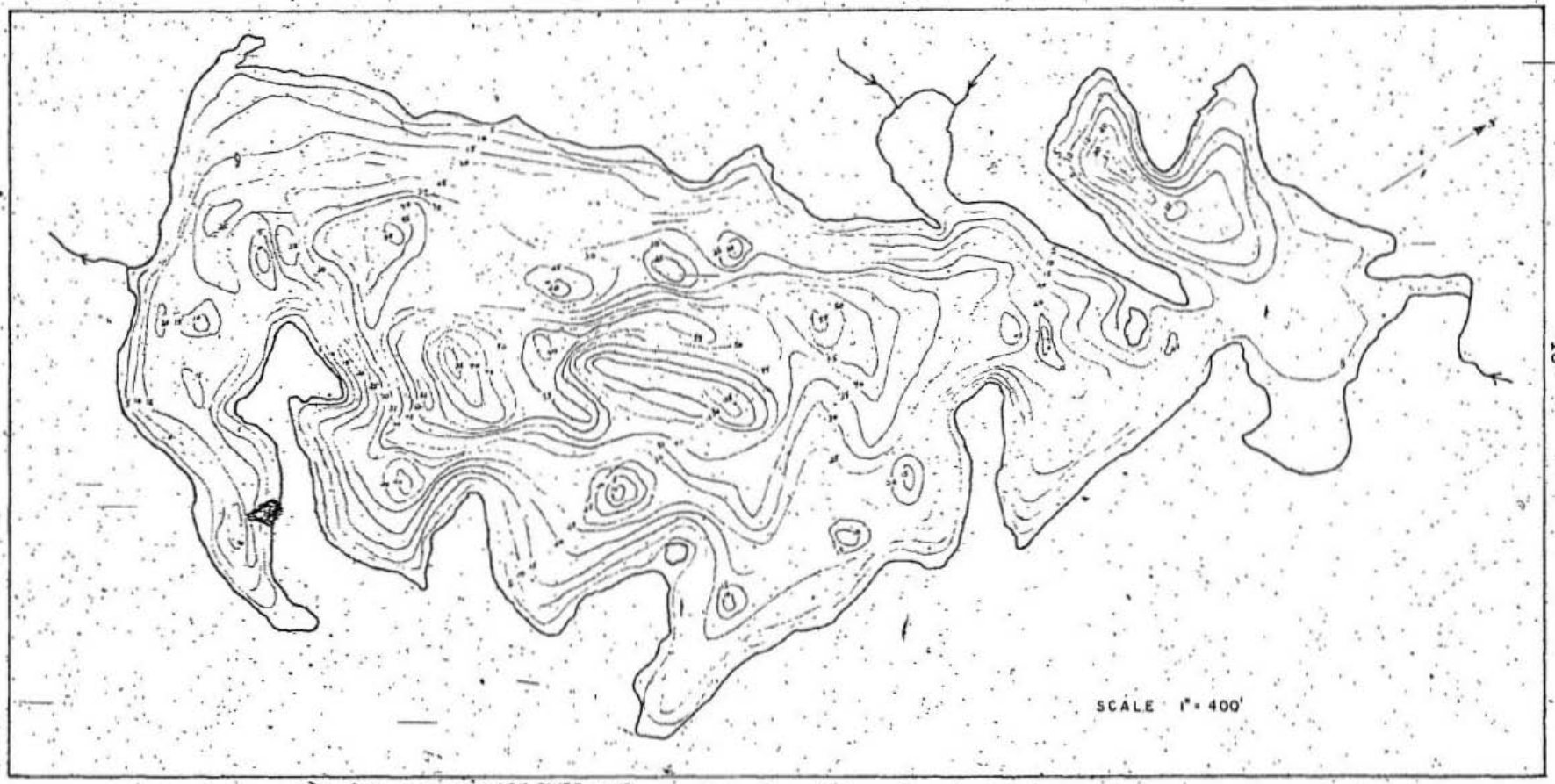

BATHYMETRIC MAP OF LARKINS POND




BATHYMETRIC MAP OF CLARKS POND.




BATHYMETRIC MAP OF NINE ISLAND POND SOUTH




BATHYMETRIC MAP OF BLACK RIVER POND

## MATERIALS AND METHODS

Data for this study were collected between the fall of 1972 and the spring of 1974 (Table 2). Most of the fish were collected using lake trap nets (live traps) fishing overnight in water 1.2 to 3 m deep. Seines, dip nets, and gill nets were also used. The live traps were constructed of 3/4" (1.9 cm) or 1/2" (1.3 cm) stretched mesh knitted nylon. They consist of a 30.5 m leader, two 9.1 m wings, a body of 1-1.2 m frame and 4 - 0.61 m frames and a trailing cod end. The leader and wings hung 1.8 m (Figure 6). The shore seine was 1.8 m deep, 7.6 m long and was made of 3/16" (0.48 cm) knotless, square mesh ace style netting. Dip nets made of 3/4" (1.9 cm) stretched mesh netting were used to capture smelt for sex determination during the spawning run. A gang of monofilament gill nets consisting of three nets with stretched mesh size 1/2" (1.3 cm), 3/4" (1.9 cm), and 1" (2.5 cm) was also fished at varying depths throughout the seasons of one year. These nets were set underneath the ice during February and March, 1974, using the "prairie-ice jigger" technique (Sprules, 1949) (Figure 7). The holes were cut through the ice using a Stihl power chain saw. A mid-water trawl with a cod end of 3/16" knotless, square mesh ace style netting was also used in an attempt to collect young-of-the-year fish.

The lakes were echo sounded using a Ferrograph "Offshore 500" depth recorder with a transducer arm attached to the gunwhale of either a 16'7" Boston Whaler or a 14' aluminum boat. The morphometric parameters were calculated according to Welch (1948) from topographical maps from the Canadian Mines and Technical Surveys series.

Water analysis was carried out by both the Inland Waters Directorate, Water Management Service, Department of the Environment, Moncton, New Brunswick and by the Laboratory Services Unit of the Recreational Fisheries Group, Resource Development Branch, St. John's.

Table 2. Location, date, and gear used in collecting smelt from fall 1972 to spring 1974

| Location | Date | Gear Used | Sample Size |
|---|---|---|---|
| Larkins Pond | May 8 (1973) | Lake Trap Net | 57 |
| | 9 (1973) | Lake Trap Net | 12 |
| | 10 (1973) | Lake Trap Net | 81 |
| Clarks Pond | April 28 (1973) | Shore Seine | 175 |
| | May 2 (1973) | Lake Trap Net | 25 |
| Nine Is. Pd. S. | October 15 (1972) | Lake Trap Net | 21 |
| | November 19 (1972) | Lake Trap Net | 179 |
| Black River Pond (Small race) | April 19 (1973) | Lake Trap Net | 57 |
| | May 1 (1973) | Lake Trap Net | 76 |
| | 2 (1973) | Lake Trap Net | 45 |
| Black River Pond (Large race) | April 19 (1973) | Lake Trap Net | 9 |
| | May 1 (1973) | Lake Trap Net | 2 |
| | 4 (1973) | Lake Trap Net | 16 |
| | April 5 (1974) | Lake Trap Net | 40 |
| | 11 (1974) | Lake Trap Net | 18 |
| | 16 (1974) | Lake Trap Net | 28 |
| | May 4 (1974) | Lake Trap Net | 18 |

Fig. 6. Lake trap nets used to sample smelt

Fig. 7. Prairie-ice jigger used to set gill nets beneath the ice.

Temperature and oxygen determinations were made in the deepest part of each lake whenever time permitted. They were taken at 2 (0.7 m) or 4 (1.4 m) foot intervals using either a Model 85 Delta Scientific combination oxygen meter-thermistor or a Model 51A YSI combination oxygen meter-thermistor. Surface water temperature data for three of the four lakes were obtained from a continuous recording Ryan thermograph.

All specimens were frozen immediately upon capture or shortly thereafter and all pertinent measurements were made at a later date.

Measurements

The fork length (tip of head to fork in tail) of each fish was determined to the nearest millimeter. Weights were determined to the nearest 0.1 g using a Mettler 1200 balance. Excess water was drained off with paper towels before weighings were made.

Length-weight Relationships

Length-weight relationships were calculated using a Log-Log Linear Regression Program for an IBM Series 155 electronic computer.

Ageing

Scale samples were taken from the left side of each fish between the lateral line and the dorsal fin. They were placed on scale papers and then put into scale envelopes. They were later examined using a Bausch and Lomb microprojector with a magnification of 43 diameters and aged according to the 'shiny line' criterion (McKenzie, 1958). The scales were measured from the centre or focus to the mid-point of the posterior margin. The annuli, identified by the

'shiny line', were measured along the same radius. The projected image of the scale with annuli was traced on white sheets of paper from which measurements were made at a later date.

Mortality

Survival rates between age groups were calculated from the formula: $s = \frac{N_{t+1}}{N}$, where N represents the number found in each age group, in a representative sample (Ricker, 1958).

Food

Two qualitative methods of food assessment were used in this study: (1) frequency of occurrence, and (2) weight or gravimetric.

Stomach contents, removed from lower esophagus to pyloric sphincter, were placed in vials containing 10% formalin. Each stomach sample was placed in an individual vial. The samples were examined in a Petri dish using a dissecting microscope. Dry weight of food refers to weight after the food items were dried in a drying oven for 24 hours at a temperature of 80F (26.7 C). These dried food items were then weighed to the nearest 0.0001 g using a Sartorius 3400 balance.

Food organisms were identified to taxonomic order by referring to Pennak (1953), Ward and Whipple (1959), Needham and Needham (1962), and Borror and DeLong (1971).

Maturity

The sex of mature fish was determined by gross inspection of the gonads, but immature fish of age-group $0^+$ required microscopic examination. Sex could not be determined with confidence for smelt of this

age group.

Fecundity

The ovaries from 100 ripe females from Clarks Pond were preserved in 5% formalin. They were each weighed before being preserved. Fecundity was determined at a later date using the volumetric method (Burrows, 1951).

The mean actual and estimated egg count for a sample of 20 pairs of ovaries showed no significant difference ($t = 0.009$, d.f. = 38, $p$ 0.05) (Appendix 3).

Morphometric Characters

Morphometric characters were measured using Vernier calipers and a ruler (reading precision 0.1 mm). The characters measured were: body depth expressed as a ratio of fork length, head length as a ratio of fork length, caudal peduncle depth as a ratio of head length, and diameter of the orbit as a ratio of head length.

Counts were made for gill rakers and vertebrae. Separate counts were made of the upper and lower limbs of each gill arch and all rudimentary rakers were included. These counts were made using a binocular microscope. All vertebrae were counted, including those of the hypural plate. These counts were made from radiographs using an x-ray reading machine. A hand lens was also used in counting the vertebrae of the small race smelt.

Methods of measuring and counting followed those described by Hubbs and Lagler (1947).

# RESULTS

## SIZE COMPOSITION

### A. Length

Size distribution studies from each lake showed that the large and small race forms existed in Black River Pond.

The small race smelt from each lake were grouped into 10 mm length classes and the large race smelt from Black River Pond were grouped into 15 mm length classes. Fork length distributions are shown in Table 3 and presented in histogram form in Figure 8.

All of the small race length distributions are unimodal with the majority of the fish between 80 and 100 mm in length, except in the case of Nine Island Pond South where the majority fall between 70 and 90 mm. The length distribution of large race fish from Black River Pond shows a bimodal distribution. The first mode occurs between 115 and 129 mm and the second mode occurs between 235 and 249 mm.

Males and females showed similar length distributions (Table 4). The modal classes for both sexes are, for the most part, the same. Females attained the greatest length in all of the samples except at Clarks Pond.

The males exceed the females in average size in three of the five populations, but the difference is significant in only the two populations from Black River Pond. While the females had a greater mean length in the other two populations, the difference was not significant in either one.

Table 3. Length composition of landlocked smelt from the four study areas for sexes combined and sexes separated

| Length Class (mm) | Larkins Pond | | | Clarks Pond | | | Nine Island Pond South | | | Length Class (mm) | Black River Pond (Large Race) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Percentage of Fish in Each Length Class | | | | | | | | | | | | |
| | Male | Female | Combined | Male | Female | Combined | Male | Female | Combined | | Male | Female | Combined |
| 70 - 79 | - | 1.54( 2) | 1.35( 2) | - | - | - | 44.68(42) | 33.96(36) | 39.00(78) | 100-114 | - | 9.09( 3) | 2.31( 3) |
| 80 - 89 | 66.27(12) | 36.92(48) | 40.54(60) | 20.00(18) | 26.17(28) | 23.35(46) | 32.98(31) | 44.34(97) | 39.00(78) | 115-129 | 3.09( 3) | 27.27( 9) | 9.23(12) |
| 90 - 99 | 16.67( 3) | 49.23(64) | 45.27(67) | 53.34(48) | 53.27(57) | 53.30(105) | 22.34(21) | 18.87(20) | 20.50(41) | 130-144 | 1.03( 1) | 24.24* 8) | 6.92( 9) |
| 100 - 109 | 16.67( 3) | 7.69(10) | 8.79(13) | 20.00(18) | 18.69(20) | 19.29(38) | - | 2.83( 3) | 1.50( 3) | 145-159 | 2.06( 2) | 3.03( 1) | 2.31( 3) |
| 110 - 119 | - | 3.08( 4) | 2.70( 4) | 3.33( 3) | 0.93( 1) | 2.03( 4) | - | - | - | 160-174 | 1.03( 1) | 3.03( 1) | 1.54( 2) |
| 120 - 129 | - | 1.54( 2) | 1.35( 2) | 3.33( 3) | 0.93( 1) | 2.03( 4) | - | - | - | 175-189 | 3.09( 3) | - | 2.31( 3) |
| Totals | 100(18) | 100(130) | 100(198) | 100(90) | 100(107) | 100(197) | 100(94) | 100(106) | 100(200 | 190-204 | 3.09( 3) | - | 2.31( 3) |
| Mean Length | 90.28 | 92.37 | 91.74 | 95.8 | 93.83 | 94.29 | 82.32 | 83.54 | 82.97 | 205-219 | 16.49(16) | - | 12.31( 16 |
| Range | 81-107 | 76-125 | 76-125 | 83-126 | 83-122 | 83-126 | 71-96 | 75-109 | 75-109 | 220-234 | 27.89(27) | 9.09( 3) | 23.08(30) |
| Std. Dev. | 6.94 | 7.80 | 8.39 | 8.63 | 12.98 | 8.90 | 6.32 | 7.38 | 6.91 | 235-249 | 32.99(32) | 12.12( 4) | 27.69(36) |
| Std. Error | 1.63 | 0.69 | 0.69 | 0.91 | 1.26 | 0.63 | 0.65 | 0.72 | 0.49 | 250-264 | 9.28( 9) | 6.06( 2) | 8.46(11) |
| | Black River Pond-(Small Race) | | | | | | | | | 265-279 | - | 6.06( 2) | 1.54( 2) |
| 70 - 79 | 2.86( 1) | 1.45( 2) | 1.73( 3) | | | | | | | Totals | 100(97) | 100(33) | 100(130) |
| 80 - 89 | 34.29(12) | 57.25(79) | 52.60(91) | | | | | | | Mean Length | 223.39 | 167.88 | 208.77 |
| 90 - 99 | 51.43(18 | 34.78(48) | 38.15(66) | | | | | | | Range | 115-254 | 109-275 | 109-275 |
| 100 -109 | 2.86( 1) | 5.07( 7) | 4.62( 8) | | | | | | | Std. Dev. | 28.95 | 38.41 | 45.60 |
| 110 -119 | 8.57( 3) | 0.72( 1) | 2.31( 4) | | | | | | | Std. Error | 2.94 | 10.17 | 3.98 |
| 120 -129 | - | 0.72( 1) | 0.58( 1) | | | | | | | | | | |
| Totals | 100(35) | 100(138) | 100(173) | | | | | | | | | | |
| Mean Length | 92.51 | 89.65 | 89.86 | | | | | | | | | | |
| Range | 79-114 | 73-124 | 73-124 | | | | | | | | | | |
| Std. Dev. | 8.01 | 6.52 | 7.61 | | | | | | | | | | |
| Std. Error | 1.35 | 0.55 | 0.57 | | | | | | | | | | |

Fig. 8 . Fork length distribution of landlocked smelt from the four study areas.

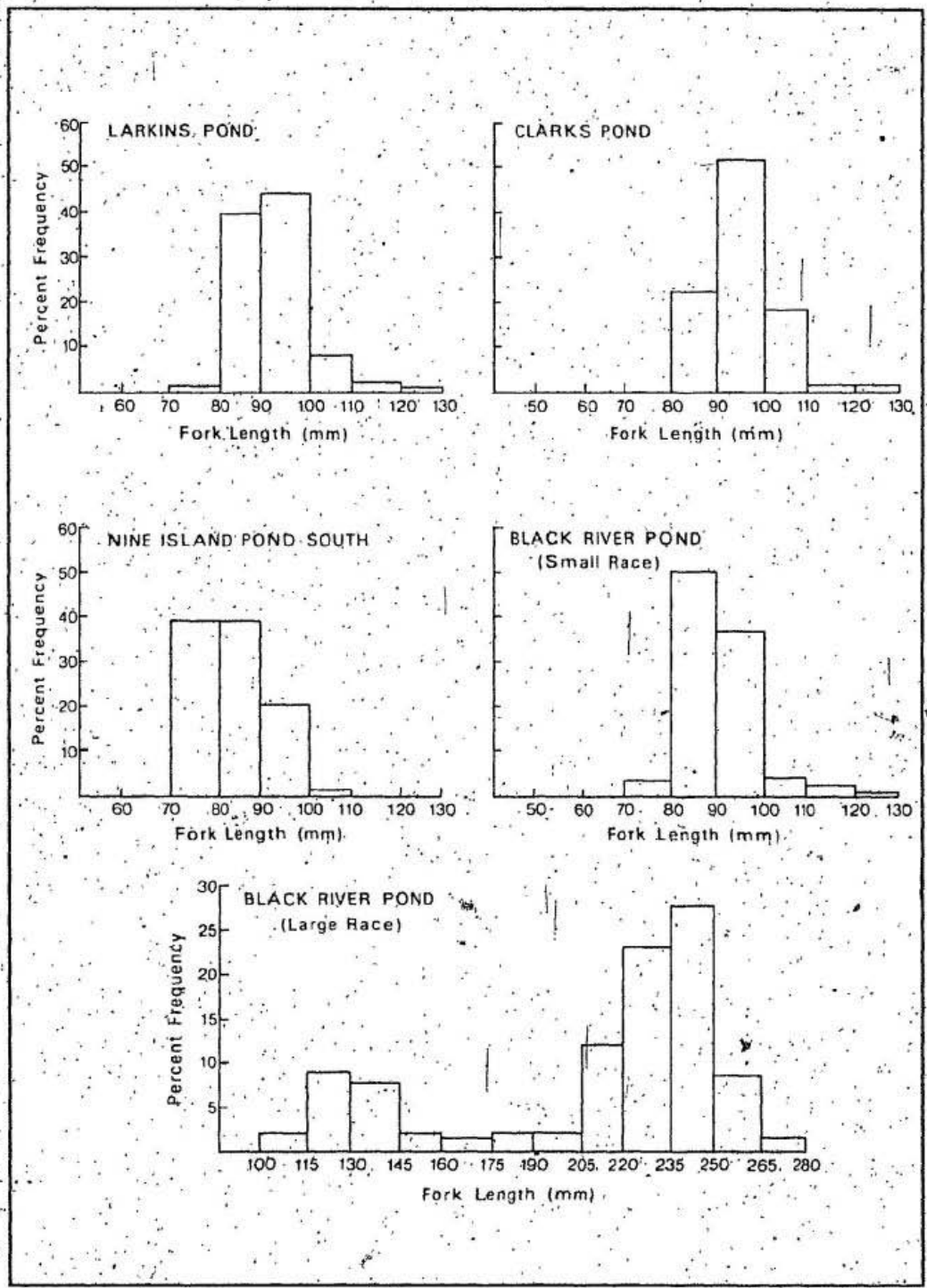

LARKINS POND
Percent Frequency
Fork Length (mm)
CLARKS POND
Fork Length (mm)
NINE ISLAND POND SOUTH
Fork Length (mm)
BLACK RIVER POND
(Small Race)
Fork Length (mm)
BLACK RIVER POND
(Large Race)
Fork Length (mm)

Table 4 . Comparison of mean fork length (mm) by sexes for landlocked smelt collected from the four study areas

| Locality | Sex | Mean length (mm) | S.D. | S.E. | d.f. | t-value |
|---|---|---|---|---|---|---|
| Larkins Pond | Male (18) | 90.28 | 6.94 | 1.63 | 146 | 1.07 |
| | Female (130) | 92.37 | 7.90 | 0.69 | | |
| Clarks Pond | Male (90) | 95.98 | 8.63 | 0.91 | 195 | 1.94 |
| | Female (107) | 93.83 | 12.98 | 1.26 | | |
| Nine Island Pond South | Male (94) | 82.32 | 6.32 | 0.65 | 198 | 1.25 |
| | Female (106) | 83.54 | 7.38 | 0.72 | | |
| Black River Pond (Small Race) | Male (95) | 92.51 | 8.01 | 1.35 | 171 | 2.21* |
| | Female(138) | 89.65 | 6.52 | 0.35 | | |
| Black River Pond (Large Race) | Male (95) | 225.60 | 24.83 | 2.55 | 113 | 3.39** |
| | Female (20) | 198.60 | 56.42 | 12.62 | | |

* Significant at $p < 0.05$

** Significant at $p < 0.01$

B. Weight

Whole weight distributions are shown in Table 5, where the small race smelt are grouped into 2 g weight classes and the large race smelt from Black River Pond are grouped into 10 g weight classes. The whole weight distributions are presented in histogram form in Figure 9.

Like the length distributions, all of the small race weight distributions are unimodal. Between 84 and 97 percent of the samples lie within the 2 to 5.9 g interval. The distribution for the large race smelt is again bimodal. The modes occur at the 0-9.9 and 100.0-109.9 intervals.

There was little difference between the male and female distributions, the modal weight classes being generally the same for both. Here again, the females attained the greatest weight in all of the samples except the sample from Clarks Pond.

Table 5. Whole weight composition of landlocked smelt from the four study areas for sexes combined and sexes separated

Percentage Of Fish In Each Weight Class

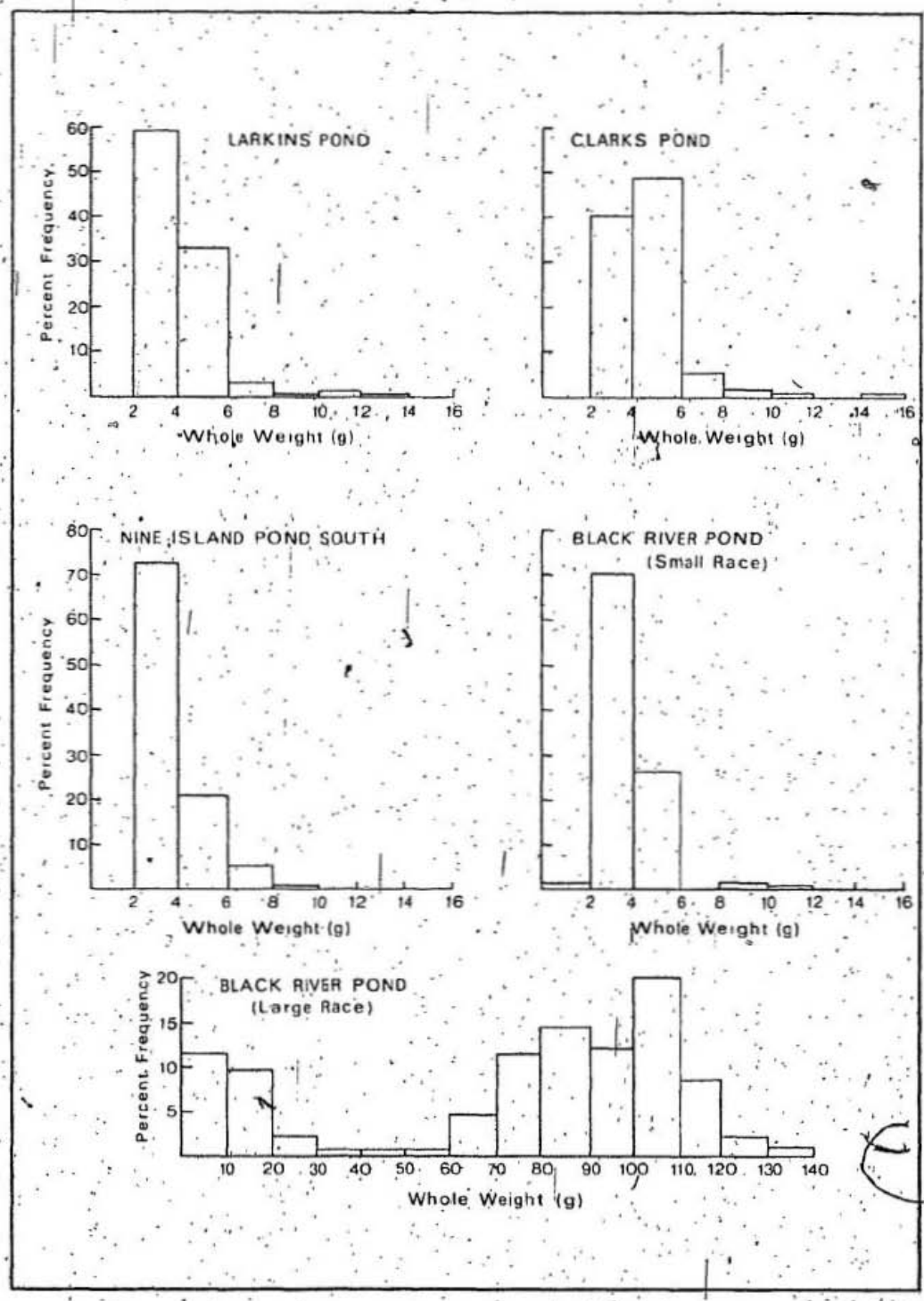
| Weight Class (g) | Larkins Pond Male | Larkins Pond Female | Larkins Pond Combined | Clarks Pond Male | Clarks Pond Female | Clarks Pond Combined | Nine Island Pond South Male | Nine Island Pond South Female | Nine Island Pond South Combined |
|---|---|---|---|---|---|---|---|---|---|
| 0- 1.9 | - | - | - | - | - | - | - | - | - |
| 2.0- 3.9 | 50.0( 9) | 61.54(80) | 60.14(89) | 26.67(24) | 42.99(24) | 33.53(70) | 73.40(69) | 71.69(76) | 72.50(145) |
| 4.0- 5.9 | 50.0( 9) | 31.54(41) | 33.78(50) | 60.00(54) | 50.46(54) | 54.82(108) | 23.40(22) | 17.92(19) | 20.50(41) |
| 6.0- 7.9 | - | 3.84( 5) | 3.38( 5) | 5.56( 5) | 5.61( 6) | 5.58(11) | 3.19( 3) | 9.43(10) | 6.50(13) |
| 8.0- 9.9 | - | .77( 1) | .68( 1) | 4.44( 4) | - | 2.03( 4) | - | .95( 1) | .50( 1) |
| 10.0-11.9 | - | 1.54( 2) | 1.35( 2) | 1.11( 1) | .94( 1) | 1.02( 2) | - | - | - |
| 12.0-13.9 | - | .77( 1) | .68( 1) | - | - | - | - | - | - |
| 14.0-15.9 | - | - | - | 2.22( 2) | - | 1.02( 2) | - | - | - |
| Totals | 100(18) | 100(130) | 100(148) | 100(90) | 100(107) | 100(197) | 100(94) | 100(106) | 100(200) |
| Mean weight | 4.03 | 4.04 | 4.00 | 4.98 | 4.43 | 4.63 | 3.80 | 4.09 | 3.93 |
| Range | 2.5-5.9 | 2.4-12.3 | 2.4-12.3 | 2.94-15.63 | 2.66-10.31 | 2.66-15.63 | 2.88-6.25 | 2.87-9.15 | 2.87-9.15 |
| Std. Dev. | 0.88 | 1.49 | 1.45 | 2.05 | 1.08 | 1.67 | 0.84 | 1.16 | 1.03 |
| Std. Error | 0.21 | 0.13 | 0.12 | 0.22 | 0.10 | 0.12 | 0.09 | 0.11 | 0.07 |

Black River Pond (Small Race)

| | | | |
|---|---|---|---|
| .0-1.9 | - | 1.45( 2) | 1.16( 2) |
| 2.0-3.9 | 48.57(17) | 76.09(105) | 70.52(122) |
| 4.0-5.9 | 42.86(15) | 21.74(30) | 26.01(45) |
| 6.0-7.9 | - | - | - |
| 8.0-9.9 | 8.57( 3) | - | 1.73( 3) |
| 10.9-12.9 | - | 0.72( 1) | 0.58( 1) |
| Totals | 100(35) | 100(138) | 100(173) |
| Mean weight | 4.38 | 3.53 | 3.64 |
| Range | 2.90-9.90 | 1.50-10.1 | 1.50-10.1 |
| Std. Dev. | 1.62 | 0.90 | 1.18 |
| Std. Error | 0.27 | 0.08 | 0.09 |

| Weight Class (g) | Black River Pond (Large Race) Male | Female | Combined |
|---|---|---|---|
| 0- 9.9 | 3.09( 3) | 33.33(11) | 10.77(14) |
| 10.0-19.9 | 3.09( 3) | 30.30(10) | 10.00(13) |
| 20.0-29.9 | 3.09( 3) | - | 2.31( 3) |
| 30.0-39.9 | - | 3.03( 1) | 0.77( 1) |
| 40.0-49.9 | 1.03( 1) | - | 0.77( 1) |
| 50.0-59.9 | 1.03( 1) | - | 0.77( 1) |
| 60.0-69.9 | 6.19( 6) | - | 4.62( 6) |
| 70.0-79.9 | 15.46(15) | - | 11.54(15) |
| 80.0-89.9 | 18.56(18) | 3.03( 1) | 14.62(19) |
| 90.0-99.9 | 15.46(15) | 3.03( 1) | 12.31(16) |
| 100.0-109.9 | 21.65(21) | 15.15( 5) | 20.00(26) |
| 110.0-119.9 | 9.28( 9) | 6.06( 2) | 8.46(11) |
| 120.0-129.9 | 2.06( 2) | 3.03( 1) | 2.31( 3) |
| 130.0-139.9 | - | 3.03( 1) | 0.77( 1) |
| Totals | 100(97) | 100(33) | 100(130) |
| Mean weight | 84.23 | 43.63 | 73.42 |
| Range | 6.9-124.2 | 4.2-134.6 | 4.2-134.6 |
| Std. Dev. | 27.02 | 47.96 | 38.09 |
| Std. Error | 2.74 | 8.35 | 3.33 |

Fig. 9 . Whole weight distribution of landlocked smelt from the four study areas.


LARKINS POND
Percent Frequency
Whole Weight (g)
CLARKS POND
Whole Weight (g)
NINE ISLAND POND SOUTH
Percent Frequency
Whole Weight (g)
BLACK RIVER POND
(Small Race)
Whole Weight (g)
BLACK RIVER POND
(Large Race)
Percent Frequency
Whole Weight (g)

The males had a significantly greater mean weight than the females in three of the populations studied. There was no significant difference between the sexes in Larkins Pond while the females possessed a significantly greater mean weight in Nine Island Pond South.

Table 6 . Comparison of mean whole weight (g) by sexes for landlocked smelt collected from the four study areas

| Locality | Sex | Mean weight (g) | S.D. | S.E. | d.f. | t-value |
|---|---|---|---|---|---|---|
| Larkins Pond | Male (18) | 4.03 | 0.88 | 0.21 | 146 | 0.04 |
| | Female (130) | 4.04 | 1.49 | 0.13 | | |
| Clarks Pond | Male (90) | 4.98 | 2.05 | 0.22 | 195 | 2.41* |
| | Female (107) | 4.43 | 1.08 | 0.10 | | |
| Nine Island Pond South | Male (94) | 3.80 | 0.84 | 0.09 | 198 | 1.98* |
| | Female (106) | 4.09 | 1.16 | 0.11 | | |
| Black River Pond (Small Race) | Male (35) | 4.38 | 1.62 | 0.27 | 171 | 4.14** |
| | Female (138) | 3.53 | 0.90 | 0.08 | | |
| Black River Pond (Large Race) | Male (95) | 99.44 | 127.12 | 13.04 | 113 | 2.61* |
| | Female (20) | 66.21 | 50.07 | 11.20 | | |

* Significant at $p < 0.05$

** Significant at $p < 0.01$

## GROWTH

### A. LENGTH DISTRIBUTION OF THE AGE GROUPS.

The length frequency distributions (fork length at time of capture) of age groups of fish from the four study areas appear in Tables 7a-c.

Age-group $0^+$ of the small race fish and age-group $I^+$ of the large race fish from Black River Pond could not be sexed. Size distributions of the other age-groups, for both races, are given by sex.

The five age group $0^+$ fish from Larkins Pond and Clarks Pond did not overlap the length distribution of fish of either sex of age-group $I^+$ in either lake. There was overlap between the $I^+$ and $II^+$ age groups for both sexes in all populations of small race smelt. The males displayed the greatest amount of overlap for these age groups. The overlap ranged from 4 mm in Nine Island Pond South to 49 mm in Clarks Pond. The females of age group $I^+$ overlapped the length range of age group $II^+$ fish by 14 mm in Black River Pond and 19 mm in the remaining three populations. The one $III^+$ female smelt from Larkins Pond fell within the $II^+$ age group female length range; the two $III^+$ females from Clarks Pond were within the $II^+$ female size range and two $III^+$ males were discrete with respect to the $II^+$ male size range. The one $III^+$ female from Black River Pond did not overlap the $II^+$ age group female length range. In the large race smelt from Black River Pond the males once again showed the greatest degree of overlap of length distribution between age groups $I^+$ and $II^+$. The overlap here was 29 mm and 14 mm for the males and females, respectively. This general situation also held true within the older age groups where the overlap ranged from 29 mm for age groups $II^+$ and $III^+$ and 59 mm between age groups $IV^+$ and

Table 7a . Length distribution of the age-groups of landlocked smelt from Larkins Pond and Clarks Pond

| Length Interval (mm) | Larkins Pond Age-Group and Sex | | | | | | | | Clarks Pond Age-Group and Sex | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0+ | | I+ | | II+ | | III+ | | 0+ | | I+ | | II+ | | III+ | |
| | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F |
| 55- 59 | - | | - | - | - | - | - | - | 2 | | - | - | - | - | - | - |
| 50- 64 | 2 | | - | - | - | - | - | - | - | | - | - | - | - | - | - |
| 65- 69 | - | | - | - | - | - | - | - | 1 | | - | - | - | - | - | - |
| 70- 74 | - | | - | - | - | - | - | - | - | | - | - | - | - | - | - |
| 75- 79 | - | | - | 2 | - | - | - | - | - | | - | - | - | - | - | - |
| 80- 84 | - | | 1 | 5 | 1 | 2 | - | - | - | | 2 | 4 | - | - | - | - |
| 85- 89 | - | | 9 | 40 | 1 | 1 | - | - | - | | 16 | 23 | - | - | - | - |
| 90- 94 | - | | 2 | 51 | - | 1 | - | - | - | | 33 | 40 | - | 7 | - | - |
| 95- 99 | - | | - | 9 | 1 | 3 | - | - | - | | 9 | 3 | 4 | 7 | - | - |
| 100-104 | - | | - | 1 | 2 | 2 | - | - | - | | 1 | 3 | 9 | 9 | - | 2 |
| 105-109 | - | | - | - | 1 | 7 | - | - | - | | 2 | 1 | 6 | 5 | - | - |
| 110-114 | - | | - | - | - | 2 | - | 1 | - | | - | - | 3 | - | - | - |
| 115-119 | - | | - | - | - | 1 | - | - | - | | - | - | - | - | - | - |
| 120-124 | - | | - | - | - | 1 | - | - | - | | - | - | 1 | 1 | - | - |
| 125-129 | - | | - | - | - | 1 | - | - | - | | - | - | - | - | 2 | - |
| No. of fish | 2 | | 12 | 108 | 6 | 21 | - | 1 | 2 | | 63 | 74 | 23 | 29 | 2 | 2 |
| Mean length | 64.0 | | 87.42 | 89.91 | 96.0 | 104.14 | - | 113.0 | 59.67 | | 92.0 | 90.69 | 104.63 | 101.0 | 125.5 | 101.0 |
| | | | 89.67 | | 102.77 | | | | | | 91.31 | | 102.46 | | 113.25 | |

Table 7b . Length distribution of the age groups of landlocked smelt from Black River Pond (small race) and Nine Island Pond South

| Length Interval (mm) | Black River Pond (Small Race) Age-Group and Sex | | | | | | Nine Island Pond South Age-Group and Sex | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I+ | | II+ | | III+ | | I+ | | II+ | |
| | M | F | M | F | M | F | M | F | M | F |
| 70- 74 | - | 1 | - | - | - | - | 1 | 1 | - | - |
| 75- 79 | 1 | 1 | - | - | - | - | 42 | 34 | - | 1 |
| 80- 84 | 3 | 18 | - | - | - | - | 29 | 40 | - | 1 |
| 85- 89 | 9 | 62 | - | - | - | - | 1 | 5 | - | 2 |
| 90- 94 | 7 | 28 | 4 | 8 | - | - | 2 | - | 18 | 8 |
| 95- 99 | 3 | 6 | 4 | 6 | - | - | - | - | 6 | 11 |
| 100-104 | - | 1 | 1 | 3 | - | - | - | - | - | 2 |
| 105-109 | - | - | - | 2 | - | - | - | - | - | 1 |
| 110-114 | - | - | 3 | 1 | - | - | - | - | - | - |
| 115-119 | - | - | - | - | - | - | - | - | - | - |
| 120-124 | - | - | - | - | - | 1 | - | - | - | - |
| No. of fish | 23 | 117 | 12 | 20 | - | 1 | 75 | 80 | 19 | 26 |
| Mean length | 89.61 | 87.84 | 98.08 | 97.60 | - | 124.0 | 74.79 | 79.95 | 93.58 | 93.92 |
| | 88.14 | | 97.78 | | | | 79.65 | | 93.78 | |

Table 7c . Length distribution of the age groups of landlocked smelt from Black River Pond (Large Race)

| Length Interval (mm) | Age-Group and Sex | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I+ | | II+ | | III+ | | IV+ | | V+ | |
| | M | F | M | F | M | F | M | F | M | F |
| 100-114 | 3 | | - | - | - | - | - | - | - | - |
| 115-129 | 9 | | 1 | 2 | - | - | - | - | - | - |
| 130-144 | 3 | | 1 | 5 | - | 1 | - | - | - | - |
| 145-159 | - | | 2 | - | - | - | - | - | - | - |
| 160-174 | - | | 1 | - | - | 1 | - | - | - | - |
| 175-189 | - | | 1 | - | 1 | - | - | - | - | - |
| 190-204 | - | | 2 | - | 1 | - | - | - | - | - |
| 205-219 | - | | - | - | 5 | - | 6 | - | 2 | - |
| 220-234 | - | | - | - | 5 | - | 18 | 2 | 1 | - |
| 235-249 | - | | - | - | - | - | 18 | 3 | 10 | 1 |
| 250-264 | - | | - | - | - | - | 1 | 2 | 7 | 1 |
| 265-279 | - | | - | - | - | - | - | 1 | - | 1 |
| No. of fish | 15 | | 8 | 7 | 12 | 2 | 43 | 8 | 20 | 3 |
| Mean length | 120.33 | | 166.25 | 136.14 | 213.92 | 153.00 | 231.70 | 241.75 | 241.50 | 259.67 |
| | | | 152.20 | | 205.21 | | 233.27 | | | |

$V^+$. The females showed a 14 mm and 44 mm overlap within these same age groups. The $III^+$ group males overlapped the $V^+$ group males by 29 mm.

B. GROWTH IN LENGTH AND WEIGHT

The mean lengths and weights of fish in each age group were determined and the results are shown in Tables 8 and 9. The lengths used were the back-calculated lengths while the weights were computed from the length-weight relationships using the back-calculated lengths. The empirical age-length and age-weight relationships for sexes combined and separated are given in Appendices 4 and 5.

Little size differences existed between the sexes in either population, so the combined sexes were used in constructing the growth curves (Figures 10 and 11). Wherever differences occurred between the sexes, sample sizes were too small to make conclusive statements concerning the observed differences. The back-calculated length for age-group I males for the large race in Black River Pond appears a little high, and the reasons for this are not completely understood.

The mean back-calculated lengths and weights for the different age-groups were used to calculate the absolute and relative rates of growth (Tables 10 and 11). These results generally show that for small race smelt the maximum increase in length occurs during the first year of life and annual increments decrease thereafter. Generally speaking, the relative rates of growth are fastest during the earliest years of life and continue to decrease thereafter.

The growth rate of the two sympatric populations at Black River Pond starts to differentiate during the second year of life. As shown from the back-calculation of growth, there is very little difference in

Table 8. Age-length (back-calculated) relationship of landlocked smelt collected from the four study areas (sample size in parentheses)

| Age (years) | Average Fork Length (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Larkins Pond | | | Clarks Pond | | | Black River Pond (Small Race) | | |
| | Male | Female | Combined | Male | Female | Combined | Male | Female | Combined |
| I | 64.72(12) | 67.86(108) | 66.58(120) | 65.81(63) | 65.82(74) | 66.68(137) | 71.89(23) | 70.92(116) | 71.43(139) |
| II | 86.03( 6) | 89.28( 21) | 90.01( 27) | 91.92(23) | 86.40(29) | 90.50(52) | 86.35(12) | 90.13(20) | 90.06( 32) |
| III | - | 95.19( 1) | 95.40( 1) | 112.08( 2) | 92.57( 2) | 97.00( 4) | - | 99.07( 1) | 99.08( 1) |
| | Nine Island Pond South | | | | | | | | |
| I | 70.29(75) | 69.08(80) | 69.70(155) | | | | | | |
| II | 84.10(19) | 83.64(26) | 82.24( 45) | | | | | | |
| III | - | - | - | | | | | | |
| | Black River Pond (Large Race) | | | | | | | | |
| I | 106.39(2) | 63.61(13) | 72.49(15) | | | | | | |
| II | 147.03(8) | 119.40( 7) | 128.59(15) | | | | | | |
| III | 184.39(12) | 164.25( 2) | 171.16(14) | | | | | | |
| IV | 211.69(43) | 215.66( 8) | 208.45(51) | | | | | | |
| V | 228.22(20) | 245.52( 3) | 230.20(23) | | | | | | |

Table 9. Age-weight (back-calculated) relationship of landlocked smelt collected from the four study areas (sample sizes in parentheses)

| Age (years) | Average Weight (g) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Larkins Pond | | | Clarks Pond | | | Black River Pond (small race) | | |
| | Male | Female | Combined | Male | Female | Combined | Male | Female | Combined |
| I | 1.62(12) | 1.50(108) | 1.47(120) | 1.36(63) | 1.60(74) | 1.52(137) | 1.95(23) | 1.76(116) | 1.77(139) |
| II | 3.48( 6) | 3.50( 21) | 3.63( 27) | 4.14(23) | 3.45(29) | 3.93( 52) | 3.42(12) | 3.52( 20) | 3.59( 32) |
| III | - | 4.26( 1) | 4.33( 1) | 8.01( 2) | 4.19( 2) | 4.88( 4) | - | 4.63( 1) | 4.80( 1) |
| | Nine Island Pond South | | | | | | | | |
| I | 2.49(75) | 2.35(80) | 2.42(155) | | | | | | |
| II | 3.97(19) | 4.02(26) | 3.80( 45) | | | | | | |
| III | - | - | - | | | | | | |
| | Black River Pond (Large Race) | | | | | | | | |
| I | 4.37( 2) | 0.58(13) | 0.95(15) | | | | | | |
| II | 15.35( 8) | 6.58( 7) | 8.95(15) | | | | | | |
| III | 33.37(12) | 22.53( 2) | 27.35(14) | | | | | | |
| IV | 63.30(43) | 64.46( 8) | 59.07(51) | | | | | | |
| V | 84.78(20) | 106.32( 3) | 87.06(23) | | | | | | |

Fig.10 . Average lengths (mm) of the different age groups of landlocked smelt from the four study areas.

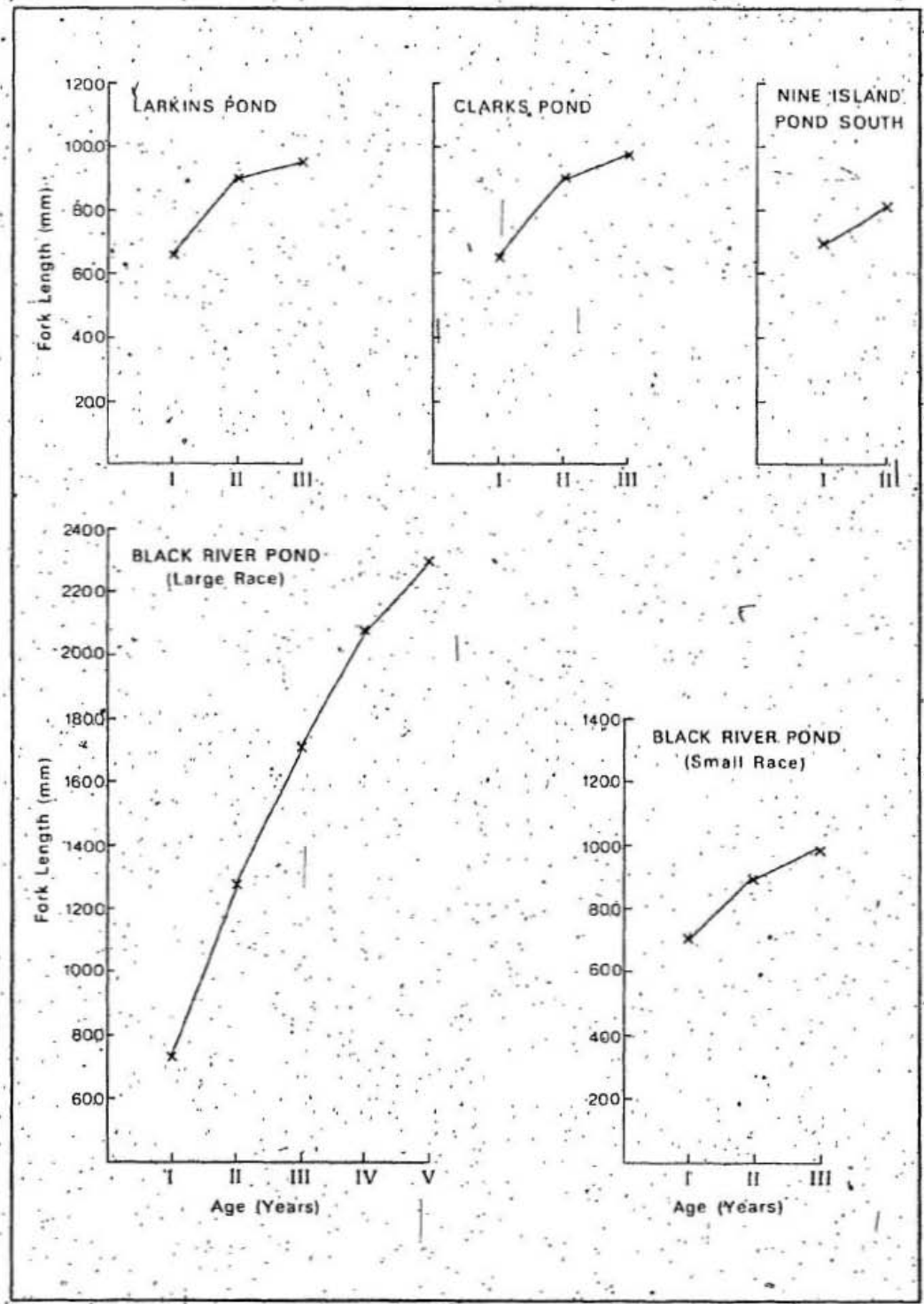

LARKINS POND
CLARKS POND
NINE ISLAND POND SOUTH
BLACK RIVER POND (Large Race)
BLACK RIVER POND (Small Race)
Fork Length (mm)
Age (Years)
I
II
III
IV
V
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400

Fig. 11 . Average weights (g) of the different age groups of landlocked smelt from the four study areas.

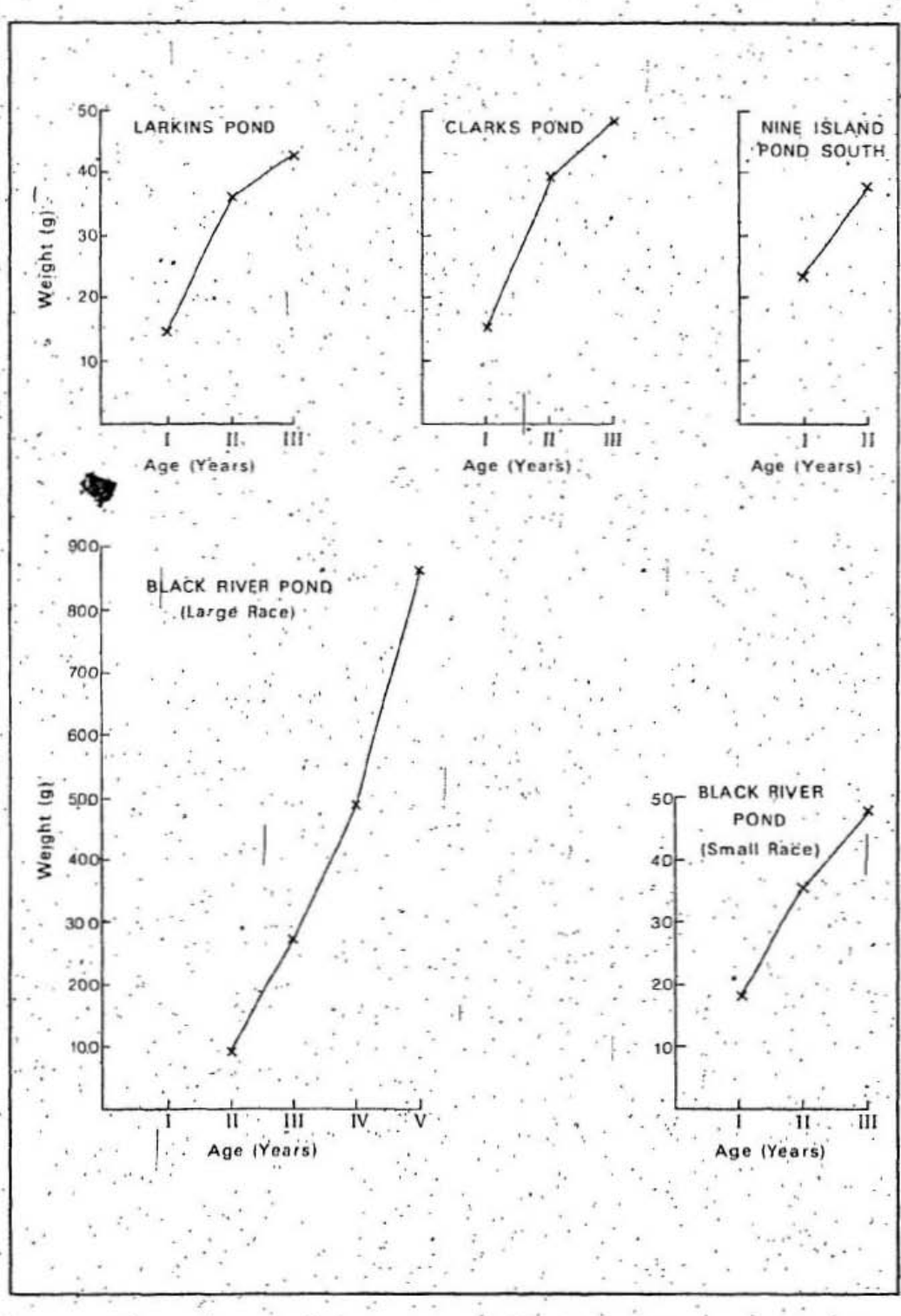

LARKINS POND
CLARKS POND
NINE ISLAND POND SOUTH
BLACK RIVER POND (Large Race)
BLACK RIVER POND (Small Race)
Weight (g)
Age (Years)
I
II
III
IV
V

Table 10. Age, length, and growth of landlocked smelt collected from the four study areas

| Age (years) | Larkins Pond Mean Length (mm) | Larkins Pond Length Absolute Growth (mm/yr) | Larkins Pond Length Relative Growth (% increase) | Clarks Pond Mean Length (mm) | Clarks Pond Length Absolute Growth (mm/yr) | Clarks Pond Length Relative Growth (% increase) | Black River Pond (small race) Mean Length (mm) | Black River Pond (small race) Length Absolute Growth (mm/yr) | Black River Pond (small race) Length Relative Growth (%increase) |
|---|---|---|---|---|---|---|---|---|---|
| I | 66.58 | | | 66.68 | | | 71.43 | | |
| | | 23.43 | 35.19 | | 23.82 | 35.72 | | 18.63 | 26.08 |
| II | 90.01 | | | 90.50 | | | 90.06 | | |
| | | 5.39 | 5.99 | | 6.50 | 7.18 | | 9.02 | 10.02 |
| III | 95.40 | | | 97.00 | | | 99.08 | | |
| | Nine Island Pond South | | | | | | | | |
| I | 69.70 | | | | | | | | |
| | | 12.54 | 17.99 | | | | | | |
| II | 82.24 | | | | | | | | |
| | Black River Pond (large race) | | | | | | | | |
| I | 72.49 | | | | | | | | |
| | | 56.10 | 77.39 | | | | | | |
| II | 128.59 | | | | | | | | |
| | | 42.57 | 33.11 | | | | | | |
| III | 171.17 | | | | | | | | |
| | | 37.29 | 21.79 | | | | | | |
| IV | 208.45 | | | | | | | | |
| | | 21.75 | 10.43 | | | | | | |
| V | 230.20 | | | | | | | | |

Table 11. Age, weight, and growth of landlocked smelt collected from the four study areas

| Age (years) | Larkins Pond Weight (g) Mean Weight (g) | Absolute Growth (g/yr) | Relative Growth (% increase) | Clarks Pond Weight (g) Mean Weight (g) | Absolute Growth (g/yr) | Relative Growth (% increase) | Black River Pond (small race) Weight (g) Mean Weight (g) | Absolute Growth (g/yr) | Absolute Growth (% increase) |
|---|---|---|---|---|---|---|---|---|---|
| I | 1.47 | | | 1.52 | | | 1.77 | | |
| | | 2.16 | 147.94 | | 2.41 | 158.55 | | 1.82 | 102.82 |
| II | 3.63 | | | 3.93 | | | 3.59 | | |
| | | 0.70 | 19.28 | | 0.95 | 24.17 | | 1.21 | 33.70 |
| III | 4.33 | | | 4.88 | | | 4.80 | | |
| | Nine Island Pond South | | | | | | | | |
| I | | | | | | | | | |
| | 2.42 | | | | | | | | |
| II | | 1.38 | 57.02 | | | | | | |
| | 3.80 | | | | | | | | |
| | Black River Pond (large race) | | | | | | | | |
| I | 0.95 | | | | | | | | |
| II | 8.95 | | | | | | | | |
| | | 18.4 | 205.59 | | | | | | |
| III | 27.35 | | | | | | | | |
| | | 31.72 | 115.98 | | | | | | |
| IV | 59.07 | | | | | | | | |
| | | 27.99 | 47.38 | | | | | | |
| V | 87.06 | | | | | | | | |

length between the two populations at the end of the first growing season. At the end of the second growing season the large race smelt are approximately 129 mm while the small race smelt are approximately 90 mm. This difference in size between the same age groups of the two races increases with age.

Small race smelt do not gain the greatest weight increment during the first growing season as was the case with length. Annual increments in weight do not follow the same trends as length increments and they vary from one population to another. In three of the small race populations the greatest weight increment occurred between the first and second year of life, while the Nine Island Pond South population attained the greatest weight the first year of life.

The calculated weight at age one for large race smelt in Black River Pond is much too low and wasn't used in calculating either the absolute or the relative rates of growth. Reasons for this low value are not completely understood.

## C. COMPARISON OF GROWTH WITH OTHER NORTH AMERICAN POPULATIONS

When comparing the growth rates of Newfoundland smelt with other localities in North America the two races must be distinguished. Most of the growth studies on freshwater smelt deal with the large race smelt. Another difficulty in comparing growth rates within different localities is the differences in age terminology concerning 'plus growth' and time of capture.

Only studies where the author was sure of similar age designations were included for comparison purposes in this study. Large race smelt in Newfoundland appear to grow at an equal or even greater rate during

the first year as do smelt of the Great Lakes but they do not grow as fast in subsequent years (Table 12). An interesting feature in Table 12 is the similar growth patterns exhibited by sympatric races both in Lake Heney, Quebec, and Black River Pond, Newfoundland. Both races in Black River Pond display a slightly faster growth rate than those in Lake Heney (Figure 12). Unlike the situation in Black River Pond where there is no difference in length between the two races at the end of one growing season, the large race smelt (giants) in Lake Heney are approximately 15 mm longer than the small race smelt (dwarfs) at the completion of the first growing season.

D. LENGTH-WEIGHT RELATIONSHIP

The analysis of length-weight data in fisheries biology has usually been directed towards two rather different objectives: (1) describing mathematically the relationship between length and weight, primarily so that one may be converted into the other; and (2) measuring the variation from the expected weight for length of individual fish or relevant groups of individuals as indications of fatness, general "well-being", gonad development, etc. (LeCren, 1951).

The length-weight relationship $W = cL^n$ is expressed in the logarithmic form: $\text{Log } W = \log c + n \log L$, where $c$ and $n$ are constants which can be determined by fitting a line to the logarithms of $L$ and $W$ by the method of least squares.

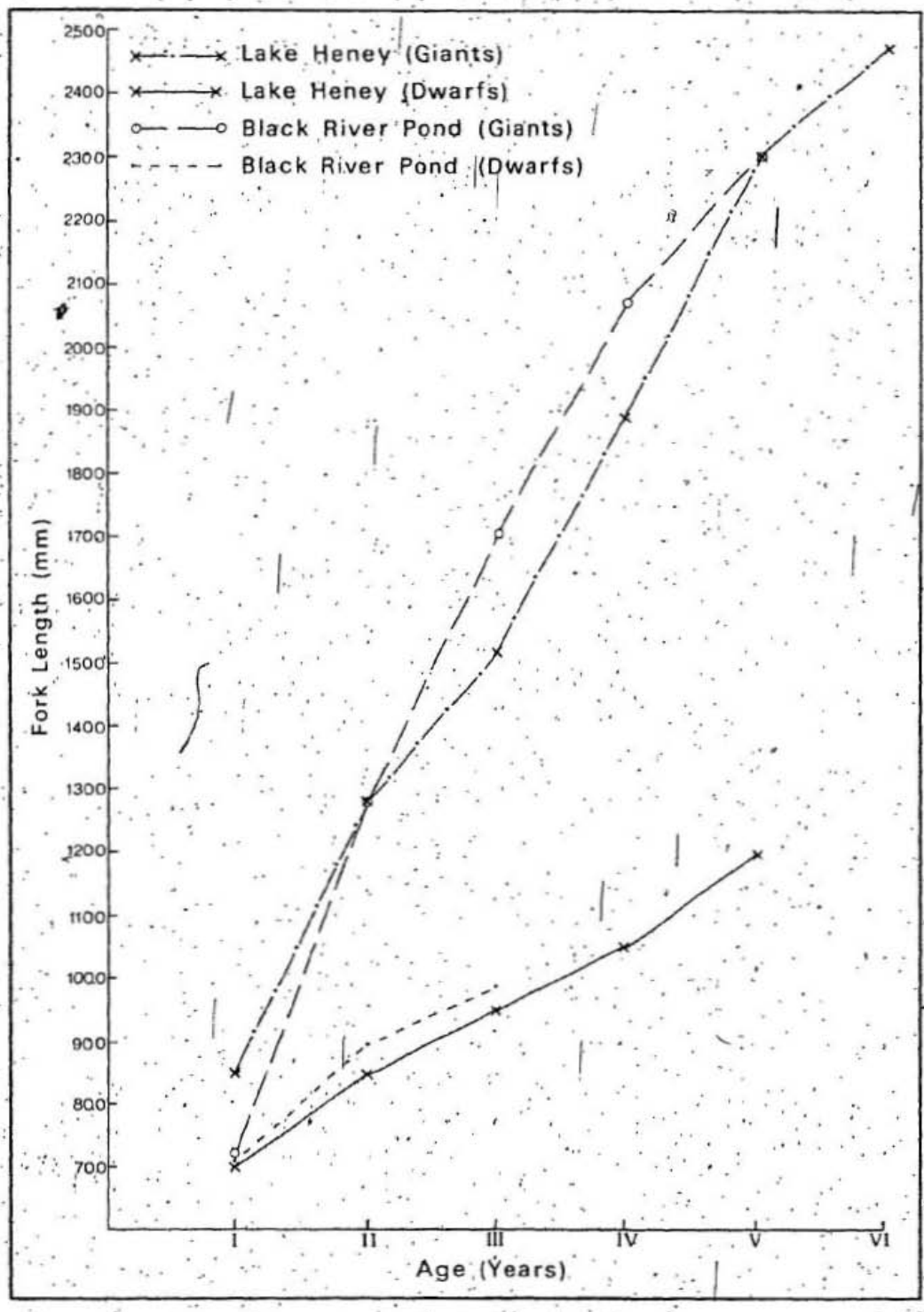
The general length-weight equations, determined by fitting a straight line to the logarithms of length and weight, are given in Table 13 for sexes separated and combined. A t-test was used to check for significance of differences between the slopes of the line

Table 12. Comparison of growth rates of freshwater smelt from various North American localities.

| Location | Age-Group and Length (mm) | | | | | |
|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI |
| Western Lake Superior (Bailey, 1964) | 66.04 | 150.0 | 190.50 | 210.82 | 228.60 | 258.92 |
| Gull Lake, Michigan (Burbidge, 1969) | 60.2 | 149.8 | 163.2 | 188.2 | 197.7 | 186.5 |
| Main Lakes (Ruppe, 1968) | 88.90 | 128.01 | 166.10 | 203.36 | 261.62 | - |
| Lake Champlain (Giants) (Greene, 1930) | - | 237.76 | 269.24 | 289.56 | 294.64 | - |
| Lake Champlain (Dwarfs) (Greene, 1930) | - | 149.86 | 160.02 | - | - | - |
| Lake Heney (Dwarfs) (Delisle, 1969) | 70.00 | 85.00 | 95.00 | 105.00 | 120.00 | - |
| Lake Heney (Giants) (Delisle, 1969) | 85.0 | 128.00 | 152.00 | 190.00 | 230.00 | 248.00 |
| Black River Pond (Dwarfs) | 71.43 | 90.06 | 99.08 | - | - | - |
| Black River Pond (Giants) | 72.49 | 128.59 | 171.16 | 208.45 | 230.20 | - |

describing each sex. Whenever there was a significant difference between the sexes, both curves were plotted for the one population

Fig. 12 . Comparision of growth rates of landlocked sympatric smelt populations in Lake Heney, Quebec, and Black River Pond, Newfoundland.


Lake Heney (Giants)
Lake Heney (Dwarfs)
Black River Pond (Giants)
Black River Pond (Dwarfs)
Fork Length (mm)
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
I
II
III
IV
V
VI
Age (Years)

(Figure 13). When no significant difference existed between the sexes, the combined data were presented graphically (Figures 14 and 15). The mean weights calculated (using the computed length-weight equations) for the mean lengths of fish in each length group are the basis for the curves in Figures 13-15. There was good agreement between the empirical and calculated weights in each population (Tables 14 and 15). The greatest discrepancy in each population occurred for the longest fish and in each case there were very few fish in these length intervals. The largest discrepancies were 2.99 g and 32.5 g for the small and large races, respectively.

There was a significant difference in the exponent value between the sexes in Clarks Pond and Nine Island Pond South. The males were heavier than the females for a given length at Clarks Pond. This observation appears real and not the influence of gonad weight because the female gonads make up a greater percentage of the body weight during this time of year. Smelt from Nine Island Pond South had the lowest exponent values.

The exponent or 'n' values for sexes combined and separated in each locality were all very close to 3, with a range from 2.6021 for the males in Nine Island Pond South to 3.9066 for the sexes combined for the large race smelt at Black River Pond.

The high values for the correlation coefficients (r) in Table 13, ranging from 0.87 to 0.98, indicate a high degree of relationship and predictability between length and weight.

Table 13. Length-weight relationships (sexes combined and separated of landlocked smelt collected from the four study areas.

| | Log Regression Form | Exponential Form | r | t |
|---|---|---|---|---|
| **Larkins Pond** | | | | |
| Combined | Log W = 3.0071 Log L-5.3165 | $W = 0.000004825L^{3.0071}$ | 0.87 | |
| Males | Log W = 2.6819 Log L-4.6465 | $W = 0.00002257L^{2.6819}$ | 0.91 | 0.9262 |
| Females | Log W = 3.0908 Log L-5.4858 | $W = 0.000003267L^{3.0908}$ | 0.88 | |
| **Clarks Pond** | | | | |
| Combined | Log W = 3.1110 Log L-5.4925 | $W = 0.000003217L^{3.1110}$ | 0.93 | |
| Males | Log W = 3.3321 Log L-5.9254 | $W = 0.000001187L^{3.3321}$ | 0.95 | 3.0463** |
| Females | Log W = 2.8232 Log L-4.9295 | $W = 0.00001176L^{2.8232}$ | 0.92 | |
| **Nine Island Pond South** | | | | |
| Combined | Log W = 2.7329 Log L-4.6543 | $W = 0.00002217L^{2.7329}$ | 0.96 | |
| Males | Log W = 2.6021 Log L-4.4093 | $W = 0.00003897L^{2.2601}$ | 0.96 | 2.0271* |
| Females | Log W = 2.8151 Log L-4.8072 | $W = 0.00001559L^{2.8151}$ | 0.97 | |
| **Black River Pond (small race)** | | | | |
| Combined | Log W = 3.0407 Log L-5.3880 | $W = 0.000004093L^{3.0407}$ | 0.89 | |
| Males | Log W = 3.0760 Log L-5.4220 | $W = 0.000003784L^{3.0760}$ | 0.91 | 0.7414 |
| Females | Log W = 2.8879 Log L-5.0987 | $W = 0.000007967L^{2.8879}$ | 0.89 | |
| **Black River Pond (large race)** | | | | |
| Combined | Log W = 3.9066 Log L-7.2880 | $W = 0.000000052L^{3.9066}$ | 0.97 | |
| Males | Log W = 3.8868 Log L-7.2381 | $W = 0.000000058L^{3.8868}$ | 0.96 | 0.1517 |
| Females | Log W = 3.8585 Log L-7.1956 | $W = 0.000000064L^{3.8585}$ | 0.98 | |

** Significant at the .05 and .01 level
* Significant at the .05 level

Table 14. Length-weight relation of landlocked smelt (sexes separated) from Clarks Pond and Nine Island Pond South (the lengths and empirical weights are averages for fish in 6 mm and 4 mm intervals), the calculated weights were computed from the equations given in the text

| Clarks Pond | | | | | | | |
|---|---|---|---|---|---|---|---|
| Males | | | | Females | | | |
| Number of fish | Avg. length (mm) | Weight (g) Empir. | Calc. | Number of fish | Avg. length (mm) | Weight Empir. | Calc. |
| 1 | 80.5 | 2.94 | 2.70 | 2 | 80.5 | 2.92 | 2.82 |
| 17 | 86.5 | 3.73 | 3.38 | 26 | 86.5 | 3.63 | 3.46 |
| 37 | 92.5 | 4.20 | 4.22 | 49 | 92.5 | 4.07 | 4.18 |
| 16 | 98.5 | 4.92 | 5.21 | 12 | 98.5 | 5.25 | 4.99 |
| 9 | 104.5 | 6.14 | 6.34 | 13 | 104.5 | 6.04 | 5.90 |
| 6 | 110.5 | 7.14 | 7.64 | 4 | 110.5 | 5.45 | 6.90 |
| 1 | 116.5 | 8.69 | 9.12 | - | 116.5 | - | - |
| 2 | 122.5 | 12.56 | 10.77 | 1 | 122.5 | 10.31 | 9.24 |
| 1 | 128.5 | 15.63 | 12.64 | - | 128.5 | - | - |
| Nine Island Pond South | | | | | | | |
| 1 | 71.5 | 3.14 | 2.60 | 10 | 75.5 | 3.13 | 3.02 |
| 13 | 75.5 | 3.10 | 3.00 | 55 | 79.5 | 3.52 | 3.49 |
| 50 | 79.5 | 3.34 | 3.43 | 10 | 83.5 | 3.84 | 4.00 |
| 9 | 83.5 | 3.80 | 3.90 | 6 | 87.5 | 4.38 | 4.57 |
| 2 | 87.5 | 3.66 | 4.41 | 6 | 91.5 | 4.98 | 5.18 |
| 13 | 91.5 | 5.04 | 4.95 | 11 | 95.5 | 5.88 | 5.84 |
| 7 | 95.5 | 5.44 | 5.53 | 3 | 99.5 | 6.41 | 6.56 |
| 1 | 99.5 | 5.99 | 6.15 | 2 | 103.5 | 7.12 | 7.33 |
| | | | | 1 | 107.5 | 9.15 | 8.16 |

Table 15. Length-weight relation of landlocked smelt (sexes combined) from Larkins Pond and Black River Pond (the lengths and empirical weights are averages for fish in 6 mm and 15 mm intervals, the calculated weights were computed from the equations given in the text

| Larkins Pond | | | | Black River Pond (small race) | | | |
|---|---|---|---|---|---|---|---|
| Number of fish | Avg. length (mm) | Weight (g) Empir. | Calc. | Number of fish | Avg. length (mm) | Weight (g) Empir. | Calc. |
| 1 | 74.5 | 2.50 | 2.06 | 2 | 74.5 | 1.70 | 2.02 |
| 4 | 80.5 | 2.85 | 2.60 | 16 | 80.5 | 2.68 | 2.55 |
| 56 | 86.5 | 3.45 | 3.22 | 76 | 86.5 | 3.29 | 3.18 |
| 56 | 92.5 | 3.73 | 3.94 | 53 | 92.5 | 3.88 | 3.89 |
| 15 | 98.5 | 4.61 | 4.76 | 16 | 98.5 | 4.36 | 4.71 |
| 5 | 104.5 | 5.90 | 5.69 | 3 | 104.5 | 4.98 | 5.64 |
| 6 | 110.5 | 7.35 | 6.73 | 3 | 110.5 | 7.90 | 6.68 |
| 3 | 116.5 | 8.30 | 7.90 | 1 | 116.5 | 9.50 | 7.86 |
| 2 | 122.5 | 10.20 | 9.17 | 1 | 122.5 | 10.10 | 9.15 |
| Black River Pond (Large race) | | | | | | | |
| 3 | 107.0 | 4.83 | 4.37 | | | | |
| 12 | 122.0 | 8.40 | 7.29 | | | | |
| 9 | 137.0 | 11.65 | 11.55 | | | | |
| 3 | 152.0 | 14.85 | 17.19 | | | | |
| 2 | 167.0 | 25.38 | 24.84 | | | | |
| 3 | 182.0 | 33.30 | 34.78 | | | | |
| 3 | 197.0 | 70.80 | 47.39 | | | | |
| 16 | 212.0 | 83.32 | 63.08 | | | | |
| 30 | 227.0 | 97.66 | 82.39 | | | | |
| 36 | 242.0 | 107.87 | 105.83 | | | | |
| 11 | 257.0 | 113.40 | 133.81 | | | | |
| 2 | 272.0 | 134.60 | 167.11 | | | | |

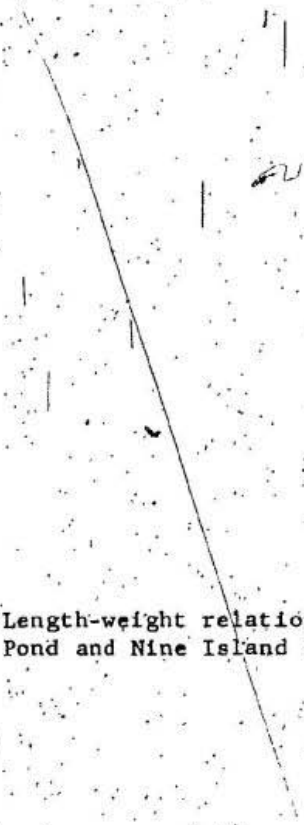
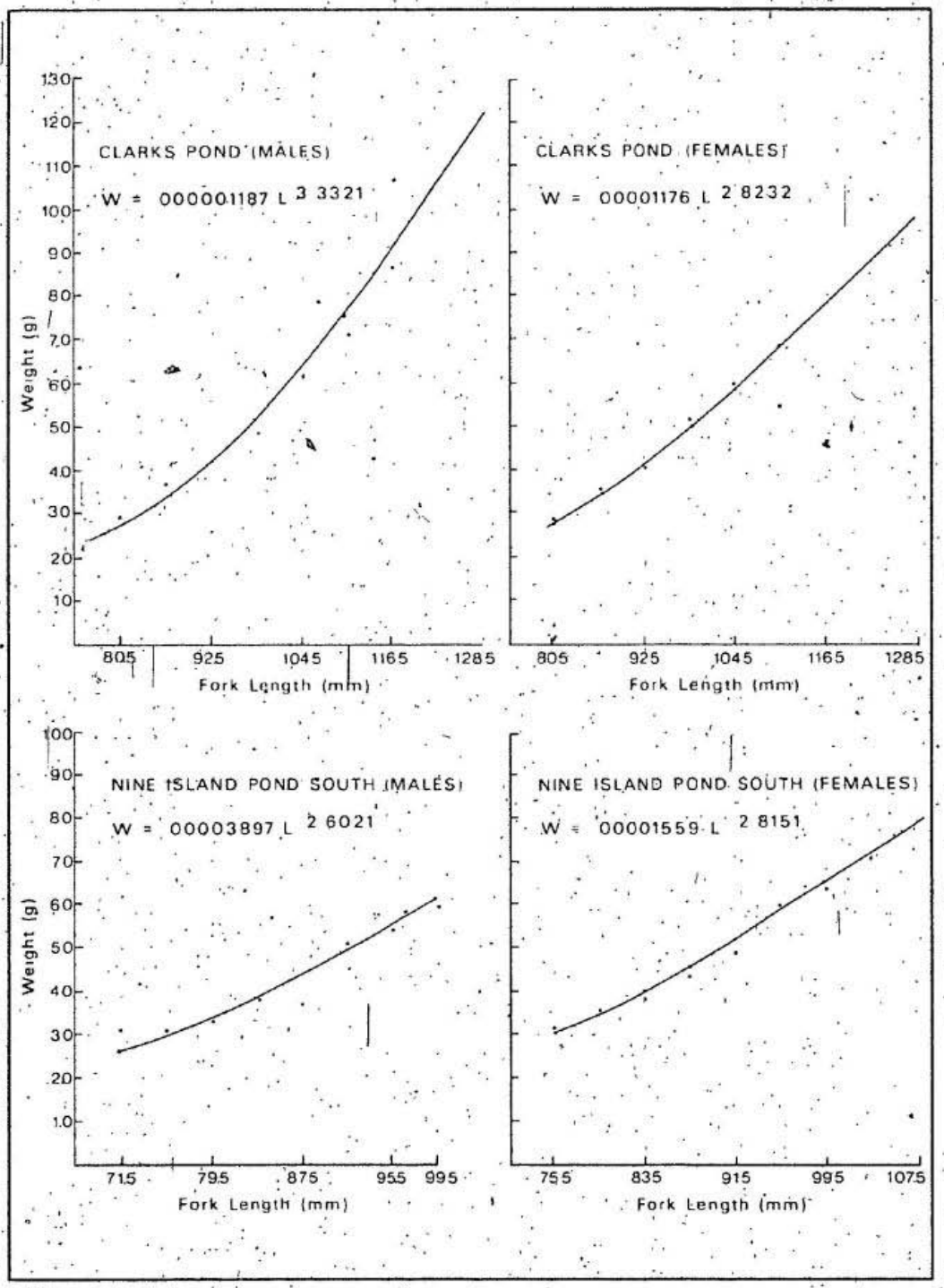


Fig.13 . Length-weight relationship of landlocked smelt from Clarks Pond and Nine Island Pond South (sexes separated).


CLARKS POND (MALES)
W = 000001187 L 3 3321
CLARKS POND (FEMALES)
W = 00001176 L 2 8232
NINE ISLAND POND SOUTH (MALES)
W = 00003897 L 2 6021
NINE ISLAND POND SOUTH (FEMALES)
W = 00001559 L 2 8151
Weight (g)
Fork Length (mm)
805
925
1045
1165
1285
715
795
875
955
995
755
835
915
995
1075

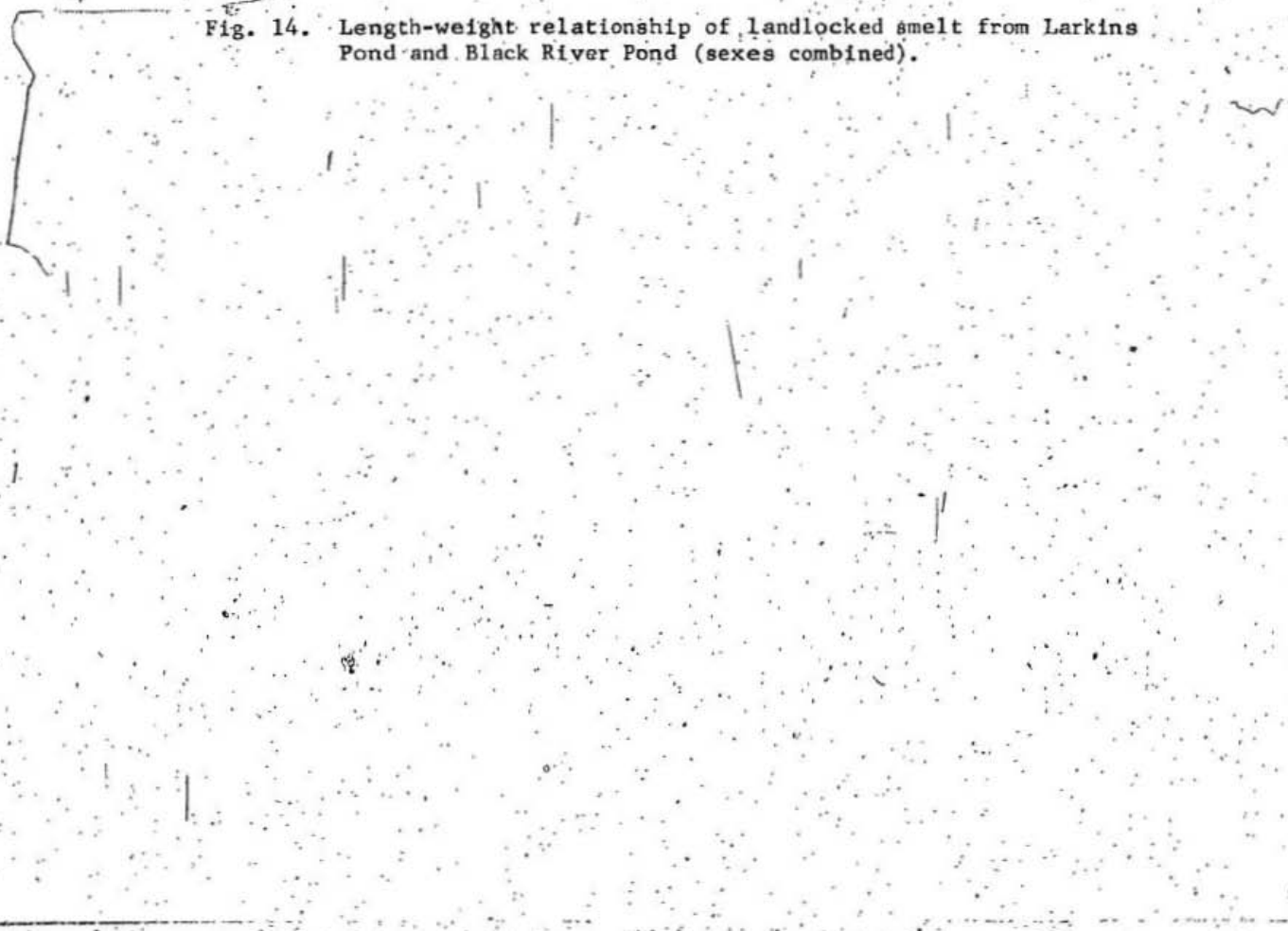
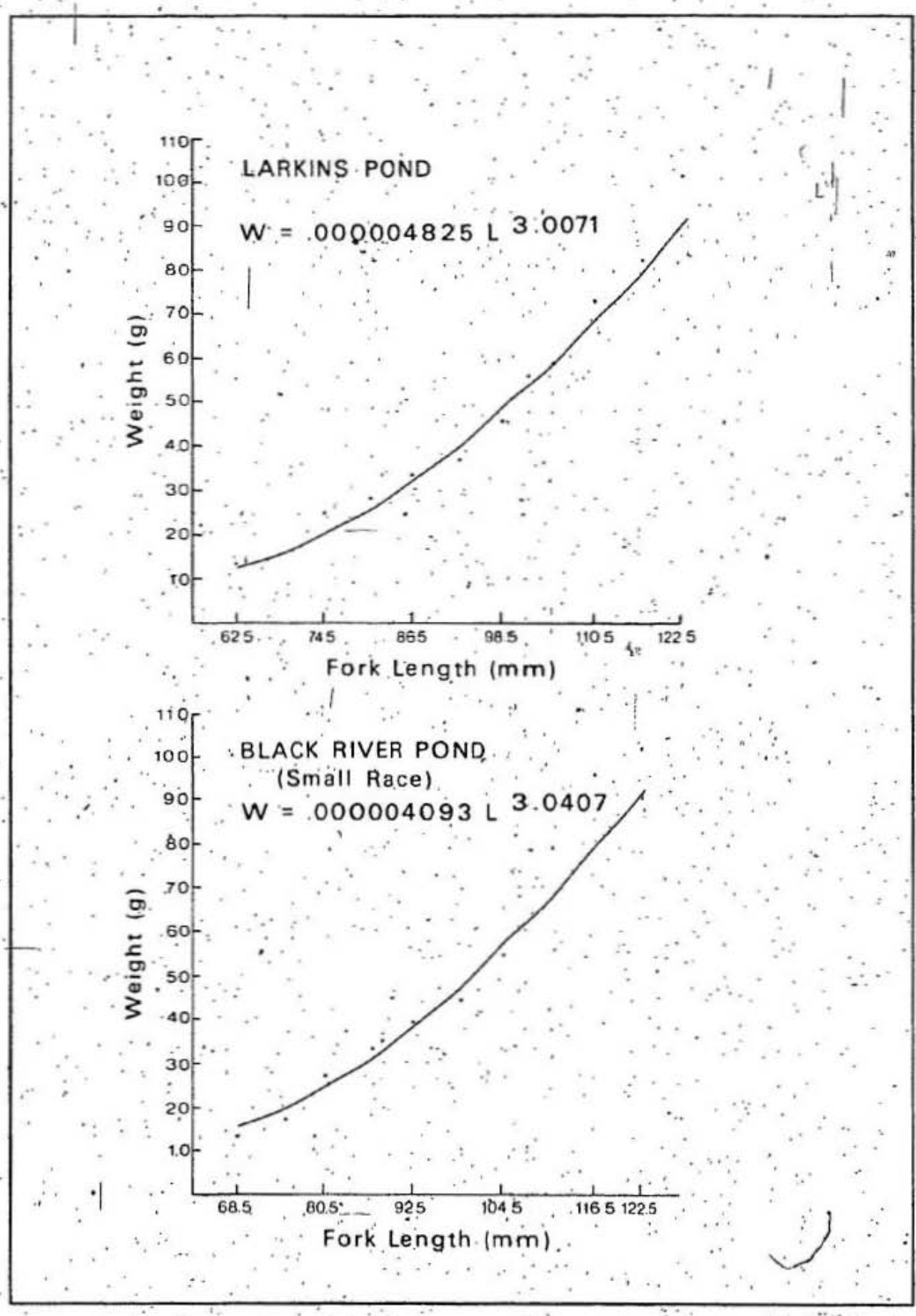


Fig. 14. Length-weight relationship of landlocked smelt from Larkins Pond and Black River Pond (sexes combined).


LARKINS POND
W = .000004825 L 3.0071
Weight (g)
110
100
90
80
70
60
50
40
30
20
10
62.5
74.5
86.5
98.5
110.5
122.5
Fork Length (mm)
BLACK RIVER POND
(Small Race)
W = .000004093 L 3.0407
Weight (g)
110
100
90
80
70
60
50
40
30
20
10
68.5
80.5
92.5
104.5
116.5
122.5
Fork Length (mm)

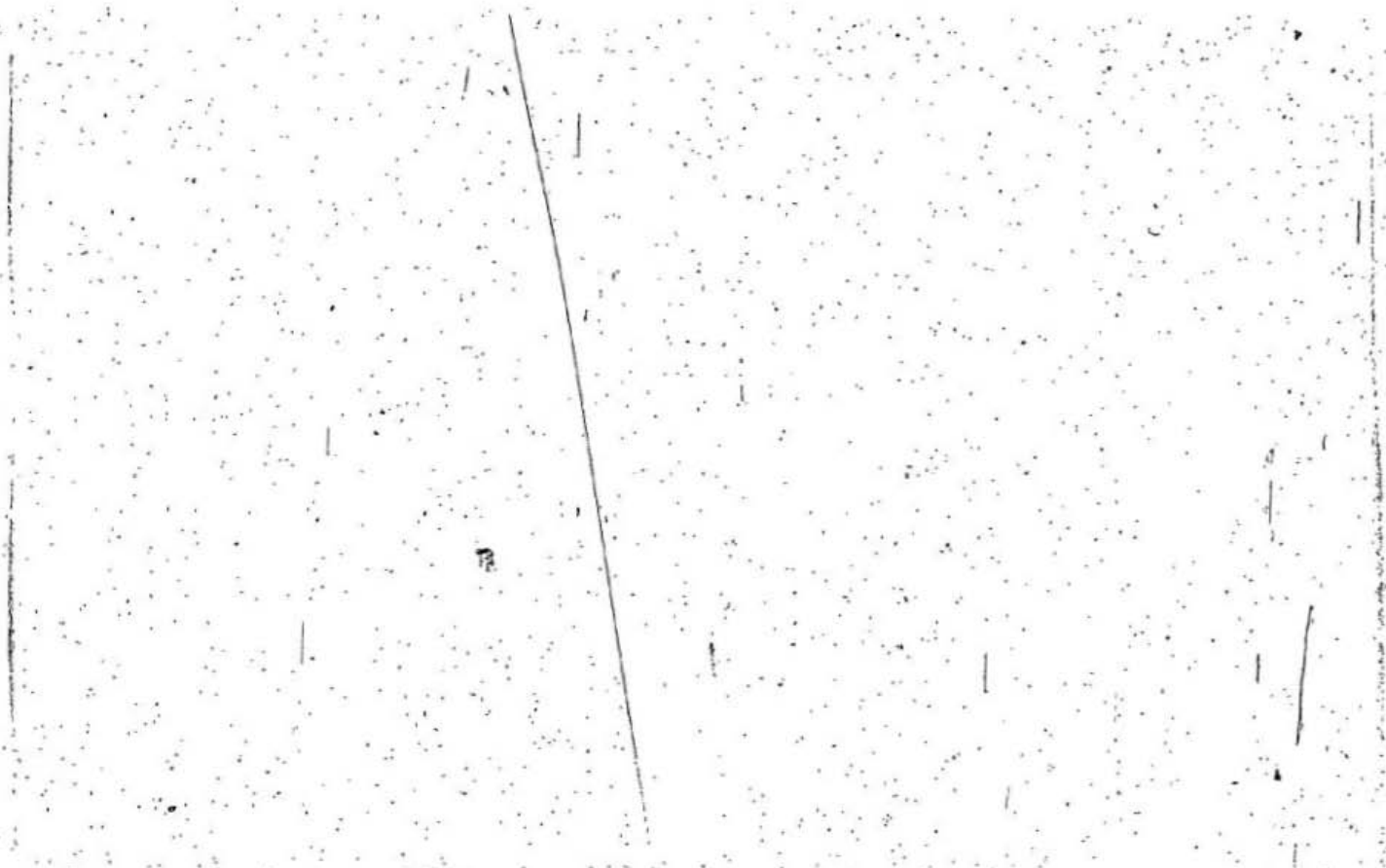
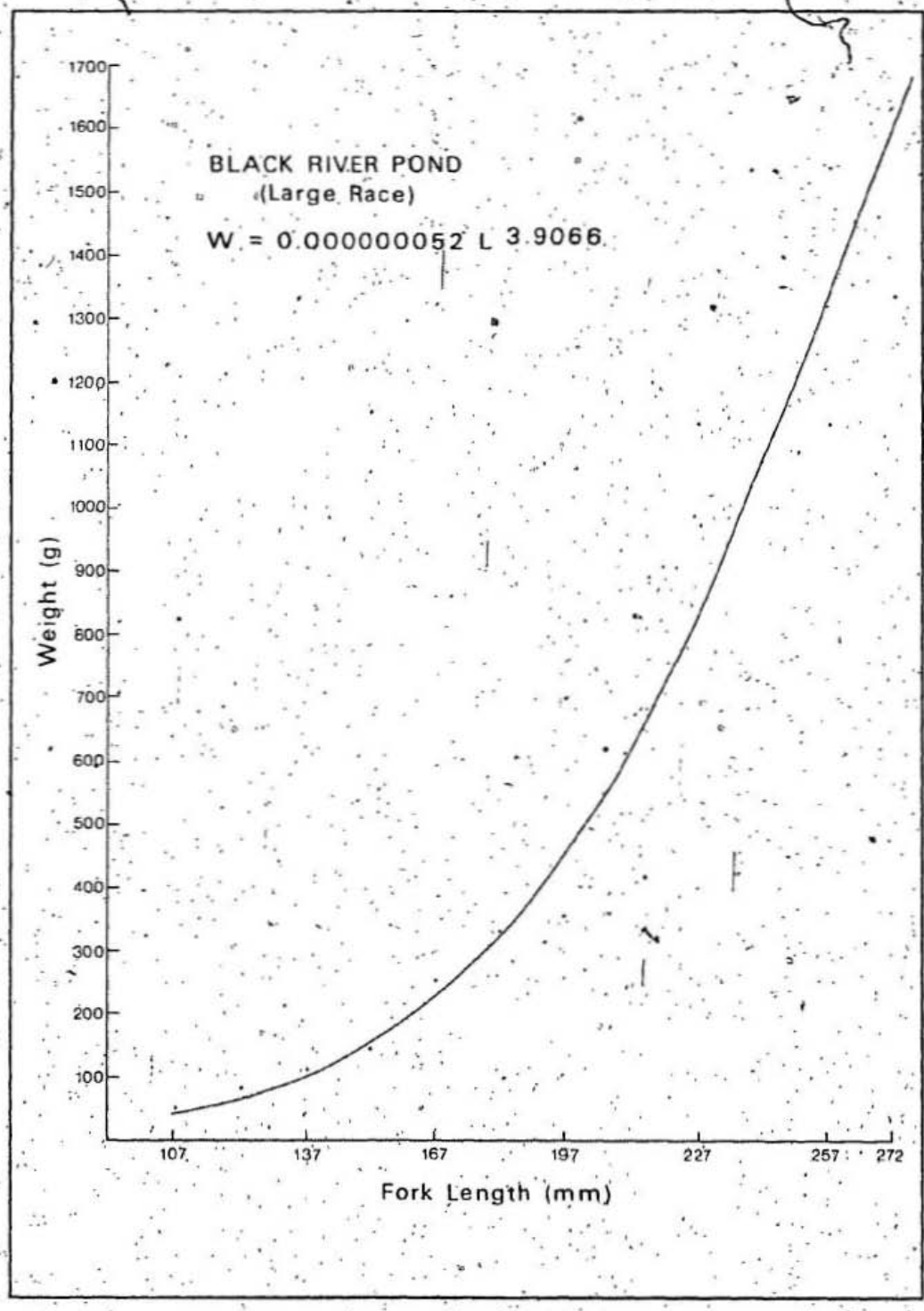


Fig. 15 . Length-weight relationship of large race smelt from Black River Pond (sexes combined).


BLACK RIVER POND
(Large Race)
W = 0.000000052 L 3.9066
Weight (g)
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
107
137
167
197
227
257
272
Fork Length (mm)

## AGE, DETERMINATION, AGE COMPOSITION AND MORTALITY

### A. TIME OF ANNULUS FORMATION

The majority of smelt in this study laid down the annulus after spawning. This usually occurred around the month of June. A few fish were observed to have the annulus on the edge of the scale during spawning. This means that fish showing one annulus ($1^+$) have actually completed two seasons (winter) growth. They are virtually II year olds. The same age terminology applies to all the older age fish in this study.

### B. BACK CALCULATION OF GROWTH

The 'back-calculation' of growth of a fish from its scales has been applied to many species. The method is based on the annual character of the check and on there being a proportional relationship between the growth of the fish and its scales. In making any back-calculation of growth of any species, it is necessary first to determine empirically the actual relationship between the growth of some dimension of the scale (in this case scale length) and the length of the fish. For this purpose a plot of fish length against scale radius is made from as large a series as is available of scale measurements and corresponding fish lengths (Ricker, 1970). Scale readings were made of all the collected smelt to test if this relationship held true for Newfoundland smelt.

#### a. Body-Scale Relationship

Most of the samples in this study were taken during early spring before annulus formation and this accounts for the great amount of 'plus-growth'. All fish lengths and scale diameters (except for age

$0^+$ fish) from each study area were used to determine the body-scale diameters for each population indicated the data was best described by a straight line (Figure 16). The regression line for each population is a graphic representation of the calculated regression equation, while the scatter plots represent the empirical data of average fish lengths and average scale diameters (Table 16).

The calculated lengths for the various age groups of fish from the four study areas are given in Table 17.

The lengths at time of capture are smaller in most cases. This is because the fish have not laid down their annulus yet and some growth occurs before annulus formation. The reason that fish length at capture exceeds calculated lengths for age III fish from Larkins Pond and Clarks Pond may be attributed to the small number of $III^+$ old fish in both populations. There was only one $III^+$ old fish in the Larkins Pond sample and three in the sample from Clarks Pond.

C. AGE COMPOSITION

The age composition of landlocked smelt from the four lakes sampled in this study is given in Table 18 and presented graphically in histogram form in Figure 17.

From these data it is evident that landlocked smelt are short lived. The small race smelt very seldomly reach age IV ($III^+$) (less than 1% in this study) while the majority (71-81%) live two-years. They hatch in a given year, spawn two years later and die before the subsequent year. The oldest large race smelt from Black River Pond were $V^+$ years old. Approximately 20% of the sample was in this age class with age-group $IV^+$ dominating the spawning run of

Fig. 16. Body length scale relationship for smelt from the four study areas.

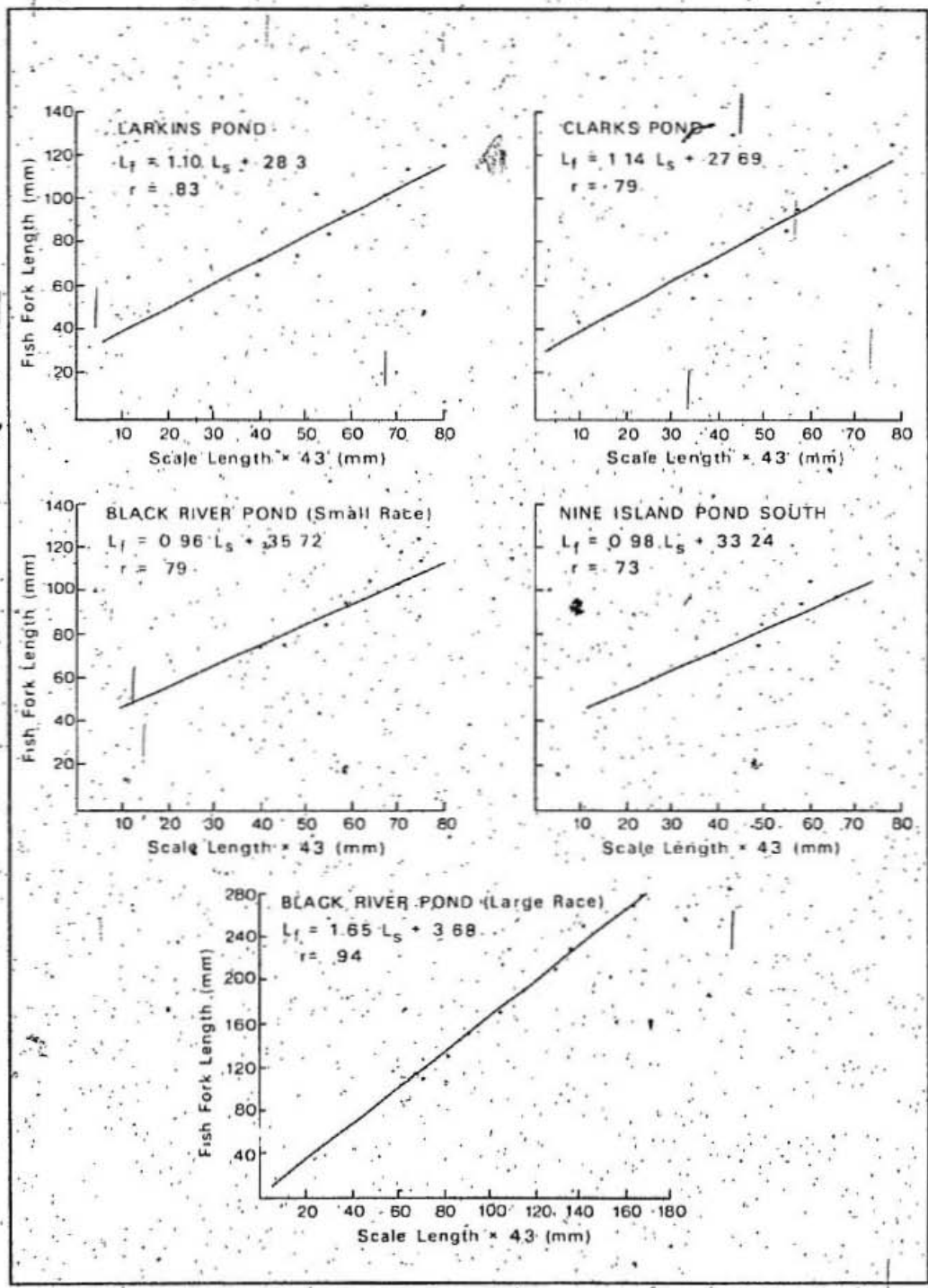

LARKINS POND
$L_f$ = 1.10 $L_s$ + 28 3
r = .83
CLARKS POND
$L_f$ = 1 14 $L_s$ + 27 69
r = .79
BLACK RIVER POND (Small Race)
$L_f$ = 0 96 $L_s$ + 35 72
r = .79
NINE ISLAND POND SOUTH
$L_f$ = 0 98 $L_s$ + 33 24
r = .73
BLACK RIVER POND (Large Race)
$L_f$ = 1.65 $L_s$ + 3 68
r = .94
Fish Fork Length (mm)
Scale Length × 43 (mm)

Table 16. Relation between fork length of fish (mm) and magnified (X43) scale diameter of smelt from the four study areas

| Larkins Pond | | | Clarks Pond | | |
|---|---|---|---|---|---|
| Number of fish | Average length[1] (mm) | Average Scale Dm. (mm) | Number of fish | Average length (mm) | Average Scale Dm. (mm) |
| - | 54.5 | - | 2 | 54.5 | 34.5 |
| 2 | 64.5 | 39.5 | 1 | 64.5 | 37.0 |
| 2 | 74.5 | 48.0 | - | 74.5 | - |
| 60 | 84.5 | 55.4 | 45 | 84.5 | 54.8 |
| 67 | 94.5 | 57.7 | 104 | 94.5 | 57.2 |
| 13 | 104.5 | 67.2 | 37 | 104.5 | 63.3 |
| 4 | 114.5 | 72.0 | 4 | 114.5 | 67.8 |
| 2 | 124.5 | 79.5 | 4 | 124.5 | 77.5 |
| Black River Pond (Small Race) | | | Nine Island Pond South | | |
| 4 | 74.5 | 45.3 | 80 | 74.5 | 48.6 |
| 91 | 84.5 | 54.4 | 77 | 84.5 | 49.2 |
| 65 | 94.5 | 58.4 | 40 | 94.5 | 57.8 |
| 7 | 104.5 | 63.6 | 3 | 104.5 | 59.8 |
| 4 | 114.5 | 74.8 | - | - | - |
| 1 | 124.5 | 74.0 | - | - | - |
| Black River Pond (Large Race)[2] | | | | | |
| 7 | 109.5 | 70.9 | 16 | 209.5 | 128.7 |
| 15 | 129.5 | 81.5 | 38 | 229.5 | 136.3 |
| 6 | 149.5 | 90.5 | 30 | 249.5 | 141.8 |
| 3 | 169.5 | 104.7 | 2 | 269.5 | 163.0 |
| 2 | 189.5 | 114.5 | | | |

[1] Mean for fish within a 10 mm interval [2] Mean for fish within a 20 mm interval

Table 17. Calculated fish lengths (mm) at formation of annulus for smelt from the four study areas. (Lengths at time of capture, before annulus formation, are given in parentheses)

| Locality | Age I | II | III | IV | V |
|---|---|---|---|---|---|
| Larkins Pond | 66.58 (64.0 ) | 90.01 (89.67) | 95.4 (102.77) | | |
| Clarks Pond | 66.68 (59.67) | 90.50 (91.31) | 97.0 (102.46) | | |
| Nine Island Pond South | 69.70 - | 82.24 (79.65) | - - | | |
| Black River Pond (Small Race) | 71.43 - | 90.06 (88.14) | 99.08 (97.78) | | |
| Black River Pond (Large Race) | 72.49 - | 128.59 (120.33) | 171.16 (152.20) | 208.45 (205.21) | 230.23 (233.27) |

1974 (43.2%).

Age-group $0^+$ fish were not included in the analyses for this study. Ten age $0^+$ fish were collected during this study. Two in Larkins Pond (64 mm each); three in Clarks Pond (55, 59, and 65 mm); and five from Black River Pond (68, 69, 70 and (2) 71 mm). It is not known whether these five fish from Black River Pond belonged to the small race or large race. As shown earlier from back-calculation of growth, there is very little difference between them in length after one growing season.

D. MORTALITY

Results from survival and mortality estimates for age groups within the four study areas (Table 19), show that between age groups $II^+$ and $III^+$, the mortality rate ranges from 62 to 78% for the small

Fig. 17 . Age composition of landlocked smelt from the four study areas.

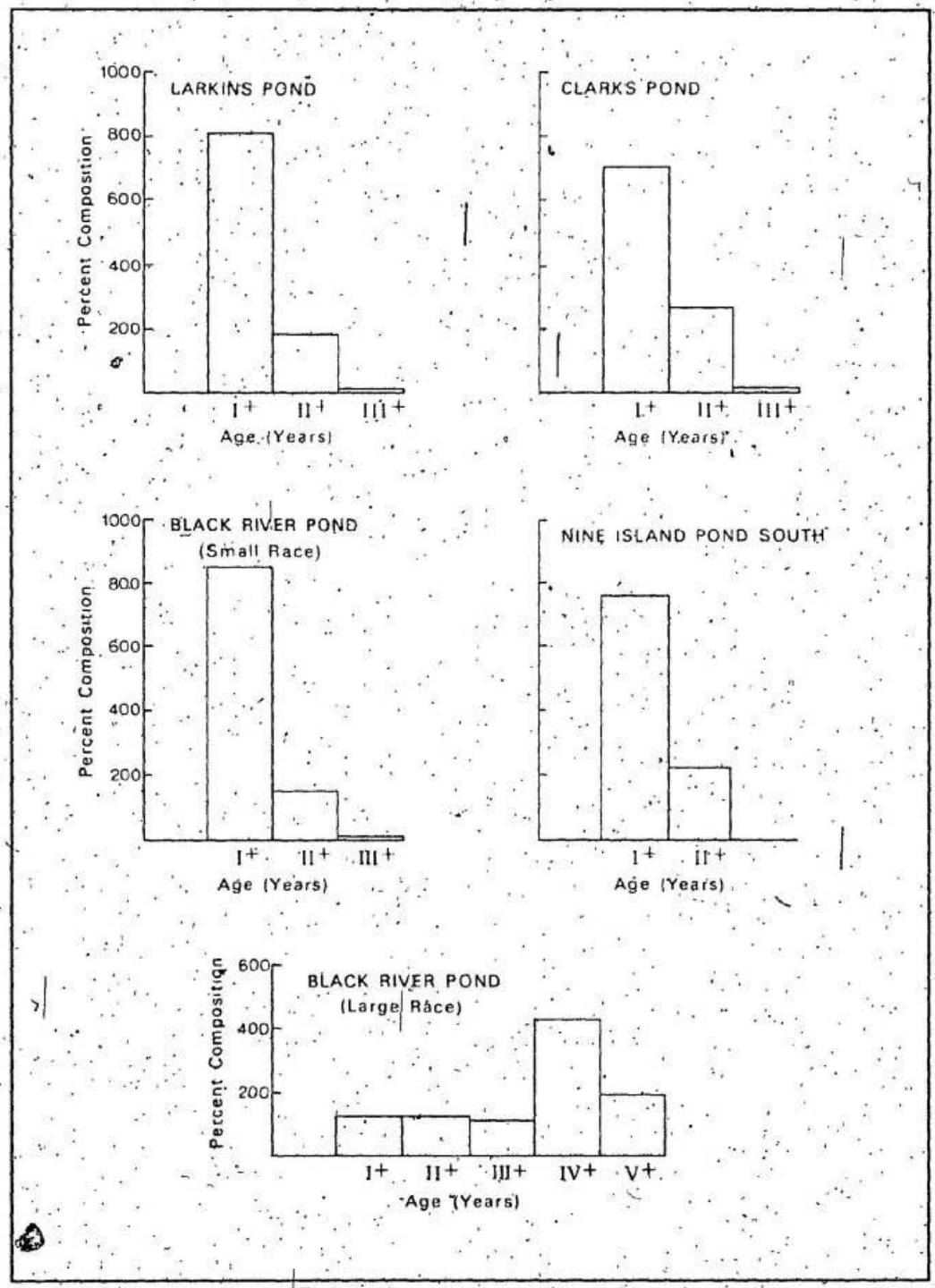

LARKINS POND
CLARKS POND
BLACK RIVER POND
(Small Race)
NINE ISLAND POND SOUTH
BLACK RIVER POND
(Large Race)
Percent Composition
1000
800
600
400
200
I+
II+
III+
IV+
V+
Age (Years)

Table 18. Age composition (sexes combined and separated) of landlocked smelt collected from the four study areas (percentages in parentheses)

| | Larkins Pond | | | | Clarks Pond | | | |
|---|---|---|---|---|---|---|---|---|
| | I+ | II+ | III+ | N | I+ | II+ | III+ | N |
| Males and Females | 120 (81.1) | 27 (18.2) | 1 (0.67) | 148 (100.0) | 137 (71.0) | 52 (26.9) | 4 (2.1) | 193 (100.0) |
| Males | 12 (66.67) | 6 (33.33) | - - | 18 (100.0) | 63 (71.59) | 23 (26.14) | 2 (2.27) | 88 (100.0) |
| Females | 108 (83.08) | 21 (16.15) | 1 (0.77) | 130 (100.0) | 74 (70.48) | 29 (27.62) | 2 (1.90) | 105 (100.0) |
| | Nine Island Pond South | | | | Black River Pond (Small Race) | | | |
| Males and Females | 155 (77.50) | 45 (22.50) | - - | 200 (100.0) | 140 (80.92) | 32 (18.99) | 1 (0.58) | 173 (100.0) |
| Males | 75 (79.79) | 19 (20.21) | - - | 94 (100.0) | 23 (65.71) | 12 (34.29) | - - | 35 (100.0) |
| Females | 80 (75.47) | 26 (24.53) | - - | 106 (100.0) | 117 (84.78) | 20 (14.49) | 1 (0.72) | 138 (100.0) |

Black River Pond (Large Race)

| | I+ | II+ | III+ | IV+ | V+ | N |
|---|---|---|---|---|---|---|
| Males and Females | 15 (12.7) | 15 (12.7) | 14 (11.9) | 51 (43.2) | 23 (19.5) | 118 (100.0) |
| Males | - | 8 (9.6) | 12 (14.5) | 43 (51.8) | 20 (24.1) | 83 (100.0) |
| Females | - | 7 (35.0) | 2 (10.0) | 8 (40.0) | 3 (15.0) | 20 (100.0) |

race smelt. Large race smelt in Black River Pond show a 55% mortality rate between age groups $IV^+$ and $V^+$. There is a 94.3% mortality rate for the large race smelt between the age-groups $III^+$ and $V^+$.

Table 19. Survival and mortality rates calculated from age composition for landlocked smelt collected from the four study areas (sexes combined)

| Locality | Survival ( ) and Mortality (1- ) Rates | | |
|---|---|---|---|
| | Age Classes | Survival Rate | Mortality Rate |
| Larkins Pond | $I^+ - II^+$ | 0.225 | 0.775 |
| | $II^+ - III^+$ | 0.037 | 0.963 |
| Clarks Pond | $I^+ - II^+$ | 0.380 | 0.620 |
| | $II^+ - III^+$ | 0.077 | 0.923 |
| Nine Island Pond South | $I^+ - II^+$ | 0.290 | 0.710 |
| Black River Pond (Small Race) | $I^+ - II^+$ | 0.229 | 0.771 |
| | $II^+ - III^+$ | 0.031 | 0.969 |
| Black River Pond (Large Race) | $II^+ - III^+$ | 0.933 | 0.007 |
| | $IV^+ - V^+$ | 0.451 | 0.549 |

There is very little difference in mortality rate between the sexes of the small race smelt in Clarks Pond and Nine Island Pond South, or the large race smelt in Black River Pond (Table 20).

Table 20. Survival and mortality rate calculated from age composition for landlocked smelt collected from the four study areas (sexes separated)

| Locality | Sex | Survival (.) and Mortality (1- ) Rates: Age Classes | Survival Rate | Mortality Rate |
|---|---|---|---|---|
| Larkins Pond | Male | $I^+ - II^+$ | 0.500 | 0.500 |
| | Female | $I^+ - II^+$ | 0.194 | 0.806 |
| | | $II^+ - III^+$ | 0.048 | 0.952 |
| Clarks Pond | Male | $I^+ - II^+$ | 0.365 | 0.635 |
| | | $II^+ - III^+$ | 0.087 | 0.913 |
| | Female | $I^+ - II^+$ | 0.392 | 0.608 |
| | | $II^+ - III^+$ | 0.069 | 0.931 |
| Nine Island Pond South | Male | $I^+ - II^+$ | 0.253 | 0.747 |
| | Female | $I^+ - II^+$ | 0.325 | 0.675 |
| Black River Pond (Small Race) | Male | $I^+ - II^+$ | 0.522 | 0.478 |
| | Female | $I^+ - II^+$ | 0.171 | 0.829 |
| | | $II^+ - III^+$ | 0.050 | 0.950 |
| Black River Pond (Large Race) | Male | $IV^+ - V^+$ | 0.465 | 0.535 |
| | Female | $II^+ - III^+$ | 0.286 | 0.714 |
| | | $IV^+ - V^+$ | 0.375 | 0.625 |

The females of the small race show a relatively high mortality than males between age groups $I^+$ and $II^+$ in Larkins Pond and Black River Pond.

## FOOD OF LANDLOCKED SMELT AND SMELT AS FORAGE FOR SALMONIDS

### A. FOOD HABITS - QUALITATIVE ANALYSIS

Benthic organisms comprised the main food (percentage occurrence and weight) of all fish sampled except the large race fish from Black River Pond (Table 21). Ephemeroptera nymphs, Trichoptera larvae, amphipods, and Diptera pupae were the most common food items. Their relative order of importance varied from sample to sample. The only fish remains (mostly smelt) were found in the large smelt from Black River Pond. Zooplankton occurred in all of the small race smelt samples but were never a major component of the diet. No large race smelt had consumed plankton. Hydracarina occurred in only one (three fish) and smelt eggs occurred in all samples except the one from Nine Island Pond South.

The unidentifiable insect remains consist mostly of antennae segments and leg parts. Most of the debris appeared to consist of twigs and stones used in construction of the caddisfly cases.

An interesting feature observed in a large number of the smelt stomachs examined was the presence of smelt scales.

### B. FOOD OF FISH FROM THE VARIOUS STUDY AREAS

#### 1. Larkins Pond

The dominant food organisms by percentage of occurrence were caddisfly larvae (Trichoptera), mayfly nymphs (Ephemeroptera), amphipods (Amphipoda), copepods (Copepoda), blackfly pupae (Diptera) and water fleas (Cladocera).

2. Clarks Pond

The dominant food organisms by percentage of occurrence were mayfly nymphs (Ephemeroptera), caddisfly larvae (Trichoptera), amphipods (Amphipoda), blackfly pupae (Diptera), water mites (Hydracarina), and copepods (Copepoda).

3. Nine Island Pond South

The dominant food items consumed here were mayfly nymphs (Ephemeroptera), amphipods (Amphipoda), copepods (Copepoda), water fleas (Cladocera), and caddisfly larvae (Trichoptera).

4.(a) Black River Pond (Small Race)

The major food items consumed here were mayfly nymphs (Ephemeroptera), amphipods (Amphipoda), blackfly pupae (Diptera), water fleas (Cladocera), and caddisfly larvae (Trichoptera).

4.(b) Black River Pond (Large Race)

The main food items utilized by these smelt were fish (mostly smelt), mayfly nymphs (Ephemeroptera), blackfly pupae (Diptera), dragonfly nymph (Odonata) and amphipods (Amphipoda).

C. FOOD OF THE SYMPATRIC POPULATIONS

Black River Pond is the only lake studied which contains sympatric populations. Here the small race smelt rely on aquatic insects, amphipods and plankton. The large race relies mainly on fish, mostly smelt, and aquatic insects, particularly mayfly nymphs. The mayfly nymph is an important constituent in the food of both races where it comprises 72% and 40% (by weight) of the diet for the small and large races, respectively.

D. SEASONAL VARIATION IN THE FOOD OF LANDLOCKED SMELT

In this study most samples were taken during the spring spawning run and didn't permit a seasonal comparison of food. However, 32 small race smelt were taken in June and July, 1973, from Black River Pond. Eighteen of these stomachs were empty. Cladocerans were present in 9 of the stomachs containing food and insects were present in eight. The Nine Island Pond South sample was taken in the fall. Insect larvae and remains were prominent in the diet with a frequency of 54 percent. Crustaceans were present in 38% of the stomachs containing food. In all the small race spawning smelt, insects were the dominant food - 52 percent frequency of occurrence in Larkins Pond, 83 percent occurrence in Clarks Pond, and 91 percent occurrence in Black River Pond. In the large race smelt, insects occurred in 56.6 percent of the stomachs and fish remains in 58.5 percent. However, fish remains accounted for 96.6 percent of the food by weight.

From the above discussion and Table 21 it appears that smelt are opportunistic feeders and will eat whatever is available. Also, there is no substantial evidence to suggest that smelt cease feeding during the spawning run.

No definite statement can be made with respect to the food of the smelt during the winter. A number of small mesh (½", 3/4", 1") monofilament gill net sets underneath the ice in Clarks Pond and Black River Pond during 1974 failed to capture any smelt.

Table 21. The food of landlocked smelt in the four areas studied expressed as percentage of occurrence and weight (number in parentheses represents sample size)

| Food Item | Larkins Pond (130) | | | | Clarks Pond (200) | | | | Nine Island Pond South (200) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Frequency | % | Wt (g) | % | Frequency | % | Wt (g) | % | Frequency | % | Wt (g) | % |
| Ephemeroptera (nymph) | 14 | 15.5 | .0130 | 27.3 | 52 | 39.7 | .0427 | 33.1 | 21 | 17.0 | .0155 | 18.7 |
| Trichoptera (larva) | 17 | 20.0 | .0104 | 21.8 | 30 | 22.9 | .0152 | 11.8 | 8 | 6.5 | .0385 | 46.4 |
| Amphipoda | 11 | 12.9 | .0110 | 23.1 | 18 | 13.7 | .0191 | 14.8 | 20 | 16.2 | .0133 | 16.0 |
| Diptera pupae | 5 | 5.9 | .0045 | 9.4 | 9 | 6.9 | .0041 | 3.2 | - | - | - | - |
| Hydracarina | - | - | - | - | 3 | 2.3 | .0011 | trace | - | - | - | - |
| Copepoda | 9 | 10.6 | trace | trace | 3 | 2.3 | trace | trace | 18 | 14.6 | trace | trace |
| Cladocera | 2 | 2.4 | trace | trace | - | - | - | - | 9 | 7.3 | trace | trace |
| Smelt eggs | 12 | 14.1 | - | - | 9 | 6.9 | - | - | - | - | - | - |
| Unidentifable insect remains | 8 | 9.4 | .0087 | 18.2 | 17 | 13.0 | .0022 | 1.7 | 38 | 30.9 | .0154 | 18.6 |
| Debris | 6 | 7.0 | .0001 | trace | 40 | 30.5 | .0447 | 34.6 | 5 | 4.1 | trace | trace |
| Empty | 65 | 43.3 | - | - | 69 | 34.5 | - | - | 77 | 38.5 | - | - |
| Total | - | - | .0477 | 100.0 | - | - | .1291 | 100.0 | - | - | .083 | 100.0 |
| | Black River Pond (Small Race) (178) | | | | Black River Pond (Large Race) (131) | | | | | | | |
| Ephemeroptera (nymph) | 57 | 61.3 | .0665 | 71.7 | 21 | 39.6 | .0470 | 1.8 | | | | |
| Trichoptera (larva) | 2 | 2.2 | trace | - | - | - | - | - | | | | |
| Odonata nymph | - | - | - | - | 3 | 5.7 | .005 | 0.2 | | | | |
| Amphipoda | 11 | 11.8 | .0239 | 25.8 | 1 | 1.9 | .005 | 0.2 | | | | |
| Diptera Pupae | 10 | 10.8 | .0023 | 2.5 | 5 | 9.4 | trace | - | | | | |
| Copepoda | - | - | - | - | - | - | - | - | | | | |
| Cladocera | 6 | 6.5 | trace | - | - | - | - | - | | | | |
| Smelt eggs | 5 | 5.4 | - | - | 1 | 1.9 | - | - | | | | |
| Unidentifable insect remains | 16 | 17.2 | trace | - | 1 | 1.9 | trace | - | | | | |
| Debris | 1 | 1.1 | trace | - | 3 | 5.7 | .0272 | 1.1 | | | | |
| Fish remains[1] | - | - | - | - | 31 | 58.5 | 2.4798 | 96.6 | | | | |
| Empty | 85 | 47.8 | - | - | 78 | 59.5 | - | - | | | | |
| Total | - | - | .0927 | 100.0 | - | - | 2.5663 | 100.0 | | | | |

[1] Most of the fish remains were smelt

## REPRODUCTIVE BIOLOGY

### A. SEX RATIOS

The sex ratios for the five populations sampled in this study varied greatly (Table 23). These ratios may not be representative of the total population. Sex ratios change during the spawning season and also in a single night. Both samples from Black River Pond were taken towards the end of the spawning run. In the case of the large race smelt, males were dominant at this time. In the small race the females outnumbered the males 4 to 1. The Clarks Pond sample, taken before spawning had actually started, had a nearly 1:1 ratio. The Nine Island Pond South sample was the only one not taken during the spawning season and this shows an approximate 1:1 ratio. This should be representative of the total population in the lake because both sexes were caught the same time of year using the same type of gear.

Table 22. Sex ratios of landlocked smelt collected from the four study areas

| Locality | Sex Ratio Male:Female | X=N-1=1 d.f. $X^2$ Value | Difference |
|---|---|---|---|
| Larkins Pond | 18:130 | 84.76 | Significant at p 0.001 |
| Clarks Pond | 90:107 | 1.46 | No significance |
| Nine Island Pond South | 94:106 | 0.72 | No significance |
| Black River Pond (Small Race) | 35:137 | 60.48 | Significant at p 0.001 |
| Black River Pond (Large Race) | 97:33 | 31.50 | Significant at p 0.001 |

Classifying the sex ratios by age-groups for the small race samples from all lakes studied, females are dominant in each age-group for each population (Table 24). They comprise 68.4%, 61.5%, and 71.4% of age-groups $I^+$, $II^+$ and $III^+$, respectively. Overall, they constitute 67% of the total number of spawning smelt. Five of the 7 $III^+$ age-group were females.

Smelt of age-group $I^+$ made up 77.2% of the combined samples while age-group $II^+$ comprised 21.8%. Age-group $III^+$ individuals made up only 1% of the spawning fish.

There were no $I^+$ mature fish in the large race sample from Black River Pond. Age-group $IV^+$ dominated the sample making up 50% of the spawning run. Age-group $V^+$ followed (22.5%) while age-groups $II^+$ and $III^+$ made up 13.7% each. The males outnumbered the females in the last three age-groups.

Table 23. Sex ratios of landlocked smelt, by age-group, collected at the four study areas

| Locality | Age I+ M | I+ F | II+ M | II+ F | III+ M | III+ F | IV+ M | IV+ F | V+ M | V+ F |
|---|---|---|---|---|---|---|---|---|---|---|
| Larkins Pond | 12 | 108 | 6 | 21 | - | 1 | - | - | - | - |
| Clarks Pond | 63 | 74 | 23 | 29 | 2 | 2 | - | - | - | - |
| Nine Island Pond South | 75 | 80 | 19 | 26 | - | - | - | - | - | - |
| Black River Pond (small race) | 23 | 116 | 12 | 20 | - | 1 | - | - | - | - |
| Total | 175 | 378 | 60 | 96 | 2 | 5 | - | - | - | - |
| Black River Pond[1] (large race) | - | - | 7 | 7 | 12 | 2 | 43 | 8 | 20 | 3 |

B. AGE AT FIRST MATURITY

Small race smelt mature at the end of their second growing season ($I^+$) and both sexes mature at the same age (Table 25).

The large race smelt in Black River Pond do not mature until the end of their third growing season or $II^+$ years (Table 25).

[1] 12 large race smelt had all regenerated scales and therefore couldn't be aged.

Table 24. Percentage of mature smelt by age class in samples from the four study areas (sexes separated)

| Locality | Sex | Age-Class I+ | II+ | III+ | IV+ | V+ | Number |
|---|---|---|---|---|---|---|---|
| Larkins Pond | Male | 99.4 | 100.0 | - | - | - | 18 |
| | Female | 99.2 | 100.0 | 100.0 | - | - | 130 |
| Clarks Pond | Male | 100.0 | 100.0 | 100.0 | - | - | 88 |
| | Female | 100.0 | 100.0 | 100.0 | - | - | 105 |
| Nine Island Pond South | Male | 100.0 | 100.0 | 100.0 | - | - | 94 |
| | Female | 100.0 | 100.0 | - | - | - | 106 |
| Black River Pond (small race) | Male | 100.0 | 100.0 | - | - | - | 35 |
| | Female | 100.0 | 100.0 | 100.0 | - | - | 138 |
| Black River Pond (large race) | Male | 0.0 | 100.0 | 100.0 | 100.0 | 100.0 | 97 |
| | Female | 0.0 | 100.0 | 100.0 | 100.0 | 100.0 | 33 |

C. FECUNDITY

a. Variation in Fecundity

Fecundity in fish is known to vary between individuals of the same size, seasons of the year, habitat, and size of the fish. This last factor is considered one of the most important variables and will be discussed here in some detail.

b. Variation with Length

In fishes there is a direct relationship between fish length and total fecundity. This ratio is usually curvilinear (Ricker, 1932; Smith, 1947; Vladykov, 1956) and is expressed by an equation of the type $F=aL^b$. Such an exponential equation can be changed to its linear form by converting to logarithms, i.e. $\log F = a + b \log L$, where F = fecundity, L = length of the fish (mm), and a and b are constants.

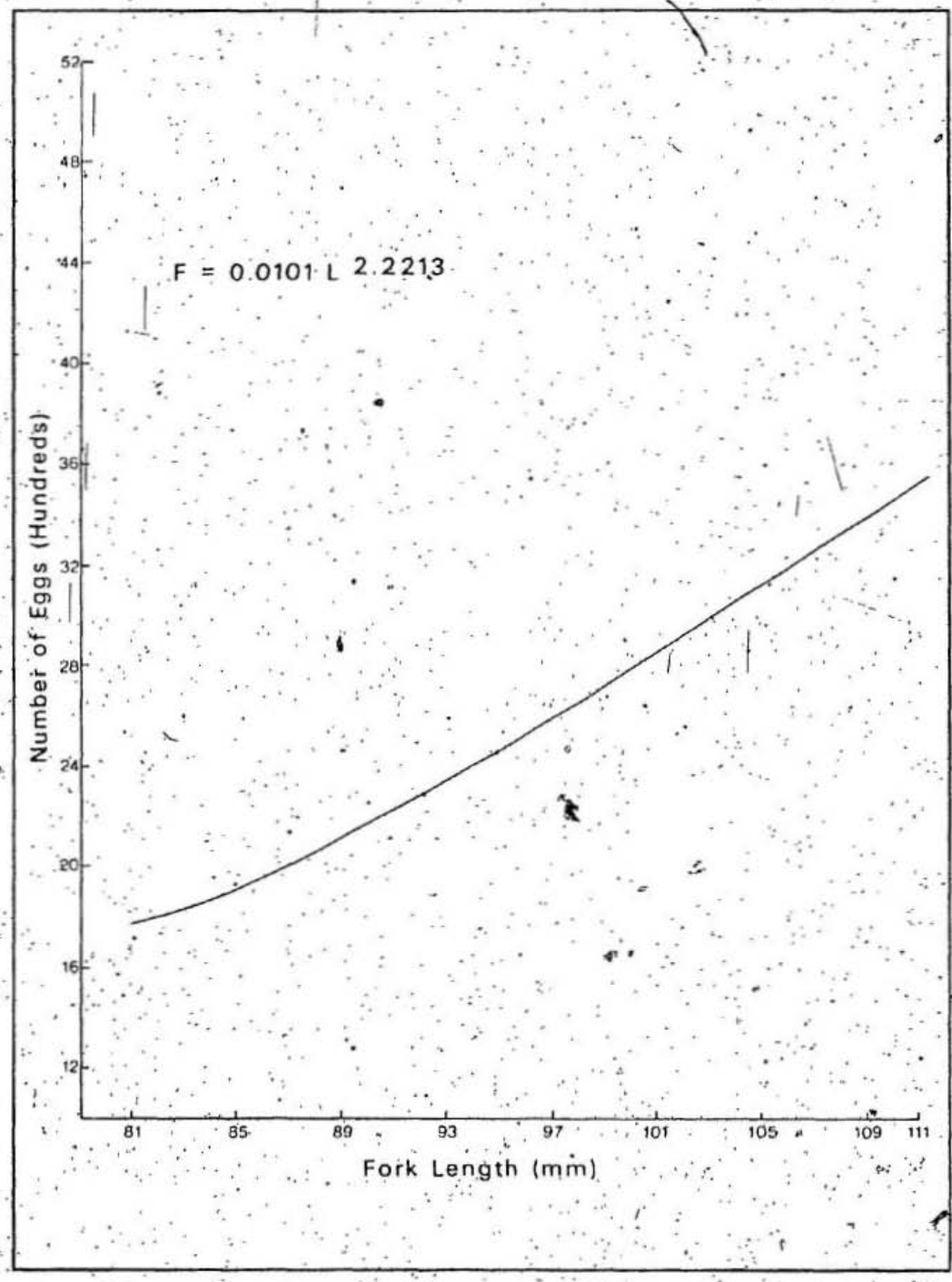
A logarithmic transformation was applied to the length and estimated fecundity of the 100 females, giving the equation Log F = 2.2213 Log L -0.9945 or expressed exponentially $F = 0.0101L^{2.2213}$ (N=100, r=.36). The co-efficient of correlation (r=.36) for this relationship is significant at the 0.01 level.

The 100 female fish were then arranged into 3.0 mm length classes and the mean number of eggs was computed for each length class (Table 26). The wide variation demonstrated by two of the estimated values plotted for larger fish (Figure 18) may be attributable to the small number of fish in these two size intervals. It was also noticed that some of the larger females appear to have large eggs, thus causing them to contain proportionately fewer eggs.

Table 25. The relationship between the number of mature eggs per fish and fork length for 100 female smelt from Clarks Pond

| Fork Length | Estimated Number of Eggs | Calculated Number of Eggs |
|---|---|---|
| 81 | 1,722 | 1,757 |
| 84 | 1,960 | 1,905 |
| 87 | 2,140 | 2,060 |
| 90 | 2,266 | 2,221 |
| 93 | 2,608 | 2,388 |
| 96 | 3,551 | 2,563 |
| 99 | 2,689 | 2,744 |
| 102 | 2,568 | 2,932 |
| 105 | 3,608 | 3,128 |
| 108 | 4,647 | 3,329 |
| 111 | 1,247 | 3,538 |

Fig. 18. The relationship between fork length and egg number in landlocked smelt from Clarks Pond.


F = 0.0101 L 2.2213
Number of Eggs (Hundreds)
52
48
44
40
36
32
28
24
20
16
12
81
85
89
93
97
101
105
109
111
Fork Length (mm)

Only four large race smelt contained eggs in the present study. Their lengths and estimated egg counts are given in Table 27. The low egg count for two of the larger fish seems to indicate these fish may have been partially spent because they were caught during the spawning run.

Table 26. Fork length (mm) and estimated egg count for four large race smelt from Black River Pond

| Fork Length (mm) | Estimated Egg Count |
|---|---|
| 234 | 41,467 |
| 244 | 14,312 |
| 245 | 27,122 |
| 275 | 15,486 |

D. SPAWNING PERIOD

a. Spawning Time of the Smelt Populations from the Areas Studied

1) Black River Pond (1973)

A lake trap net was set at the mouth of the major inlet on April 17, this being the first day that there was enough open water to set the trap. Catches during the following week indicated that the smelt had started spawning before ice-out. The first night the trap caught approximately 800 small race smelt, nearly all of which were spent. It also contained 9 large race smelt; some of which were immature and the others spent. The trap caught few smelt the following nights indicating we had caught the end of the spawning run. Except for this area of open water, the lake was still ice-covered.

These smelt were caught in approximately 1-3.5 feet (0.30-1.1 m)

of water, but no eggs were found. An intensive search for eggs throughout the river and the surrounding shoreline proved unsuccessful. No trap was set in the vicinity of the minor inlet that spring.

1974 Results from trap nets set in the two inlet areas showed the two races spawned at different times and perhaps different places. The large race smelt had commenced spawining sometime before April 3, this being the first day the trap was emptied. They were spawning in the area of the minor inlet. Except for the inlet areas the lake was covered with snow and ice (Figure 19). Most of the spawning was completed by April 16 (Table 28). Eggs of the large race smelt were found on April 8 in approximately 18 inches (45.7 cm) of water 75 feet (22.9 m) off-shore.

The small race smelt did not start spawning until April 16 and continued into early May. Although some small race smelt were taken in the same trap as the large race fish, it is not known whether they use the same spawning grounds since no eggs of the small race smelt could be found.

2) Nine Island Pond South

1973 Spawning also started before ice-out. Trap net catches on April 19-21 in the area of the major inlet revealed spawning was in progress. Most other parts of the lake were still covered with ice. Again, intensive searches for eggs throughout both rivers and the surrounding shoreline proved unsuccessful.

3) Clarks Pond

1973 Spawning in the stream (river) started around May 2, approximately 20 days after ice-out. The spawning run lasted for nearly two weeks.

Table 27. Analysis of spawning-run catches for the two smelt races of Black River Pond (spring of 1974)[1]

| Date | Major Run-In | | | | | | | | | | Minor Run-In | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Large Race | | | | | Small Race | | | | | Large Race | | | | | Small Race | | | | |
| | Males | | Females | | Imm. | Males | | Females | | | Males | | Females | | | Males | | Females | | |
| | Ripe | Spent | Ripe | Spent | | Ripe | Spent | Ripe | Spent | Total | Ripe | Spent | Ripe | Spent | | Ripe | Spent | Ripe | Spent | Total |
| Apr. 3 | - | - | - | - | - | 3 | - | 2 | - | 5 | - | - | - | - | - | - | - | - | - | - |
| Apr. 5 | - | 2 | - | - | - | 7 | - | 43 | - | 50 | - | 33 | - | 5 | - | - | - | - | - | 7 |
| Apr. 8 | - | - | - | - | - | 11 | - | 35 | - | 46 | - | 2 | - | - | - | - | - | - | - | - |
| Apr. 11 | - | - | - | - | - | - | - | - | - | - | - | 18 | - | - | - | - | - | - | - | - |
| Apr. 16 | - | - | - | - | 1 | 1 | - | 1 | - | 2 | - | 25 | - | 2 | - | 40 | - | - | 10 | 50 |
| Apr. 17 | - | - | - | - | - | - | - | 1 | 5 | 6 | - | - | - | - | 2 | - | - | - | 8 | 8 |
| Apr. 19 | - | - | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - | 1 | 1 | 5 | 46 | 53 |
| Apr. 22 | - | - | - | - | - | - | 10 | - | 270 | 280 | - | 1 | - | - | - | 100 | 5 | 500 | 10 | 615 |
| Apr. 24 | - | - | - | - | - | - | 20 | - | 180 | 200 | - | - | - | - | - | - | 1 | - | 4 | 5 |
| Apr. 26 | - | - | - | - | - | - | 5 | - | 95 | 100 | - | - | - | Trap Collapsed | | - | - | - | - | - |
| Apr. 29 | - | - | - | - | - | - | 20 | - | 80 | 100 | - | - | - | - | - | - | 6 | - | 6 | 12 |
| Apr. 30 | - | - | - | - | - | - | 4 | - | 9 | 13 | - | - | - | - | - | - | 1 | - | - | 1 |
| May 1 | - | - | - | - | - | - | 2 | - | 2 | 4 | - | - | - | - | - | - | 3 | - | 4 | 7 |

[1] Approximate counts were made rather than sacrifice all the fish

1974 The smelt were approximately two weeks later starting spawning this year. The lake had been ice-free for approximately 5 weeks. The smelt did not use the stream for spawning this year. Some eggs were found in 2-4 feet (0.61-1.2 m) of water on debris and rocks just off the river mouth.

4) Larkins Pond

1973 In 1973 the smelt in this lake spawned approximately the same time as those in Clarks Pond. This was nearly 3 weeks after the ice had left the pond. The major inflow from Clarks Pond was impassable because of a rock barrier. No eggs were found in the lake throughout the study period.

No observations of smelt spawning were carried out at this lake in 1974.

## E. SPAWNING SITE

During this study only one spawning population was observed to use a stream. This was the 1973 spawning run at Clarks Pond. Smelt moved 76 m upstream where they encountered a culvert with a water drop of 35.6 cm. Most of the spawning occurred within 20 m of the culvert (Figure 20).

As no eggs of the small race smelt were found in the streams or along the shoreline in the immediate vicinity of streams in Larkins Pond, Nine Island Pond South, and Black River Pond, spawning either occurred in deep water or in other areas around the shore.

## F. WATER TEMPERATURES DURING THE SPAWNING SEASON

Results from this study show great variability in spawning time

Fig. 19. Spawning site of large race smelt at Black River Pond.

Fig. 20. Smelt eggs deposited on stone from Clarks Pond inlet.

with respect to water temperature. In Black River Pond and Nine Island Pond South in 1973 spawning was observed when the water temperature was between 3 and 7 C. In 1974 the large race smelt spawned at water temperatures between 1.1 and 3.9 C. The small race in Black River Pond spawned in water between 3 and 8 C, with a mean of 5.5 C. In 1973 the two populations in the Placentia area lakes didn't spawn until the water temperature was about 9 C. In 1974 the smelt in Clarks Pond spawned in the lake at a temperature around 8.5 C.

G. SPAWNING BEHAVIOUR OF LANDLOCKED SMELT

Spawning behaviour of stream spawners was observed at Clarks Pond between April 28 and May 15, 1973.

Smelt were first observed to be lingering around the mouth of the river at 1100 hours, April 28. They were swimming randomly in schools. Some moved into the river for short intervals. A seine haul made at the mouth of the river at 1300 hours caught approximately 200 smelt. There was approximately a 1:1 sex ratio in this sample. This was four days before spawning actually started. Later that evening smelt were observed moving up the stream in schools. They travelled up for short distances on either side of the river after dusk. During these short movements into the river they sometimes drifted sideways across the main river current and then fell back to the river mouth, always facing upstream. No smelt entered the river that night after dusk. During the next few nights they exhibited similar behaviour but moved further upstream each night. Daytime observations showed that some smelt were near the river mouth swimming close to the lake surface. They also made daytime movements into the river where they swam close to the

bottom. During these earlier stages they were easily startled by artificial lights or water disturbance.

Actual spawning was first observed the night of May 2 in 3-4 inches of riffles over a clean gravel bottom. The smelt were clustered together and facing upstream. When spawning they do not respond to light.

Smelt continued spawning the following nights but they changed their 'spawning grounds'. This may have been a response to current and water level changes in the river. Spring flow plus rainfall this time of year causes the river levels to fluctuate. It is believed the same smelt return to the stream a number of nights because partially spent females were collected on several occasions in the evening as they were just starting to run.

Observations on May 4 and 5 revealed that the heaviest spawning occurs between 2150 and 2400 hours. Few remained after 0130 hours and all fish had returned to the pond before daylight. During the peak of the run (in this case May 5 and 6) smelt were at times 5 or 6 deep over the spawning grounds.

No smelt entered the river on the nights of May 7 and 8 because of an unusually heavy flow resulting from a few days of heavy rain plus the increase in control flow into the lake. Clarks Pond is a reservoir supplying drinking water for the U.S. Naval Station at Argentia and as such experiences significant inflow variations due to upstream regulation. The spawning run resumed the night of the 9th and fewer fish entered each subsequent night. Spawning was completed by May 18.

All throughout the run, schools of sticklebacks were seen in close association with the smelts. Brook trout also followed the smelt up

the river and were seen foraging on smelt both in the daytime and during the night, but mostly at night.

Fourteen dead male smelt were collected over three days in the river. They all appeared to have died as a result of spawning stress as there were no signs of injury on any fish.

## H. INTERGONADAL RATIO

Smelt gonads are asymmetrical, with the left gonad occupying the greater portion of the abdominal cavity. The intergonadal ratio is expressed as $\frac{R.G. \times 100}{L.G.}$ with R.G. equal to the weight of the right gonad (ovary or testis) and L.G., the weight of the left gonad. A sub-sample was taken from the Clarks Pond sample and was used to determine the ratio between the weights of the right and left gonads.

Results show that on the average the weight of the right ovary is equal to 20.4% of the left ovary while the right testis, on the average is equal to 21.4% of the left testis (Table 29).

The reason for this disparity in gonad size is not clearly understood.

Table 28. Intergonadal ratio of Clarks Pond smelt during the spawning period

| Females | | | | Males | | | |
|---|---|---|---|---|---|---|---|
| N. | Avg. Weight of Left Ovaries (g) | Avg. Weight of Right Ovaries (g) | Ratio | N | Avg. Weight of Left Testis (g) | Avg. Weight of Right Testis (g) | Ratio |
| 76 | 0.49 | 0.10 | 20.41 | 26 | 0.14 | 0.03 | 21.43 |

## MORPHOLOGY OF THE TWO RACES IN BLACK RIVER POND

### A. MERISTICS COUNTS

#### 1) Gill Rakers

There was no significant difference ($p$ 0.05, $t$=0.61, $N$=40) between total gill raker counts for the large and small races. There was very little range in gill raker counts for either race and the two populations displayed great overlap in this character. Counts for the lower limb were identical for both populations but there was some disparity in the upper limb counts (Table 30). A gill raker in smelt is considered deformed when it is branched and consequently has more than one arm. None of the small race smelt had deformed gill rakers while all the large race smelt possessed them.

#### 2) Vertebrae

The mean vertebrae count for large race smelt (62.0) was significantly higher ($p$ 0.05, $t$=2.85, $N$=38) than the mean count for small race smelt (61.7). There was no range in vertebral counts in this study for the large race smelt and the small race smelt counts varied a maximum of 1 vertebra for the 20 fish examined.

#### 3) Body Ratios

Three of the four measured body ratios showed a significant difference between the two races. The body depth-to-fork length ratio showed no significant difference between the two populations ($p$ 0.05, $t$=0.55, $N$=40). There was almost complete overlap between the range in counts for the two races for this character. The most useful ratio found in this study distinguishing the two races was the diameter of the orbit-to-head length ratio ($p$ 0.05, $t$=13.88, $N$=40). There was no

overlap in range of values for this character between the two races. A significant difference was also found for the head length-to-fork length ratio ($p < 0.01$, $t=2.45$, $N=40$) and the caudal peduncle length-to-head length ($p < 0.05$, $t=5.63$, $N=40$) between the two races. The latter character displayed more overlap in range between the two populations than the former (Table 30).

Table 29. Comparison of certain meristic and morphological characters of the large and small race smelt from Black River Pond

| | Gill Rakers | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper Limb | | | Lower Limb | | Total | | | Deformities | | |
| | 10 | 11 | 12 | 20 | 21 | 30 | 31 | 32 | Normals | Abnormals | |
| Large Race | 3 | 16 | 1 | 15 | 5 | 2 | 13 | 5 | - | 20 | |
| Small Race | | 20 | | 15 | 5 | | 15 | 5 | 20 | | |

| | Vertebrae | | | Body Depth/ Fork Length | | | | | | | Head Length/ Fork Length | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 61 | 62 | Avg. | .10 | .11 | .12 | .13 | .14 | .15 | .16 | .22 | .23 | .24 | .25 | .26 | .27 |
| Large Race | - | 20 | 62.0 | 1 | 1 | 1 | 2 | 6 | 5 | 4 | - | - | 7 | 9 | 3 | 1 |
| Small Race | 6 | 14 | 61.7 | - | - | 4 | 2 | 9 | 3 | 2 | 1 | 3 | 8 | 7 | 1 | - |

| | Caudal Peduncle Depth/Head Length | | | | | | | | Diameter of the Orbit/Head Length | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | .18 | .19 | .20 | .21 | .22 | .23 | .24 | .25 | .18 | .19 | .20 | .21 | .22 | .23 | .24 | .25 | .26 | .27 | .28 | .29 | .30 | .31 | .32 |
| Large Race | 2 | 9 | 2 | 5 | 2 | - | - | - | 2 | 10 | 3 | 2 | - | 1 | 2 | - | - | - | - | - | - | - | - |
| Small Race | - | 2 | 1 | 1 | 5 | 6 | 3 | 2 | - | - | - | - | - | - | - | - | 5 | 5 | 3 | 3 | 1 | 2 | 1 |

## DISCUSSION

Results from this study show that generally landlocked smelt populations are fairly homogenous from one area to another on the Avalon Peninsula, Newfoundland. This is true for the four lakes surveyed in this study containing allopatric small race smelt populations. One of the four lakes, Black River Pond, contained a sympatric large race population whose members displayed different ecological and behavioural characteristics than their counterparts in the small race population.

With any fishery investigation of this sort, the time of sampling is very important, and influences some of the inferences drawn from the study. The ideal situation would be to sample the population throughout the year. This was attempted with one lake (Black River Pond), but gill nets set underneath the ice proved unsuccessful in taking any fish.

Samples from three of the lakes were taken during the spawning run while the remaining one (Nine Island Pond South) was taken during the fall of the year. Therefore, it should be remembered that some observations made during the spawning time, e.g. sex ratios and feeding habits, may not be representative of the population throughout the year.

With these considerations in mind, the following discussion is divided into two sections: (1) a comparison of the biology of the small race smelt from the four studied lakes, and (2) a discussion of the two races co-existing in Black River Pond.

Size and Age Composition

Smelt from the four study areas showed similar length and weight distributions which were all unimodal with the majority of the fish between the 70-100 mm interval. Very little difference was observed in the length and weight distributions between the sexes in the four populations. The shortest and longest smelt sampled were 55 mm and 126 mm respectively and they were collected in Clarks Pond. These fish weighed 0.60 g and 15.63 g respectively.

These size distributions are in turn reflected in the age distribution of each population. These distributions represent spawning fish which, in most cases, are spawning for the first time. Small race smelt reach sexual maturity at the age $I^+$ years and this age group is dominant among spawners in each lake. The age group $I^+$ constitute between 71.0% (Clarks Pond) and 81.1% (Larkins Pond) of the spawning fish. The smelt from Nine Island Pond South were not spawning when captured but the gonads were starting to mature. Age group $II^+$ made up between 18.2% (Larkins Pond) and 26.9% (Clarks Pond) of the mature fish. Age group $III^+$ seldom constitutes more than 1.0% of the spawning population and only in Clarks Pond does it exceed this (2.1%). This evidence suggests that small race smelt have a very short life cycle, approximately two years. They hatch in a given year, spawn two years later, and die before the end of the subsequent year. Rupp (1968), reporting on a 10 year study of landlocked smelt in Maine, states the mean longevity there is only slightly greater than two years, and the oldest individuals found were between six and seven years old. Saunders and Power (1970) found only one $VII^+$ smelt in Matamek Lake, Creaser (1925), Hale (1960), and Bailey (1964) have reported six year old smelts in the

Great Lakes, while Baldwin (1950) and Burbidge (1969) reported five year olds as the oldest fish for these same waters.

Growth

Age and growth have been determined for freshwater smelt in the Great Lakes (Creaser, 1925; Schnerberger, 1937; Baldwin, 1950; Hale, 1960: Bailey, 1964; Burbidge, 1969), several New England lakes (Kendall, 1927; Greene, 1930; Zillox and Youngs, 1958; Rupp, 1959, 1968; Rupp and Redmond, 1966); Crystal Lake, Michigan (Beckman, 1942); Lake Heney, Quebec (Delisle, 1969); and Matamek Lake, Quebec (Saunders and Power, 1970).

Growth rates, using back-calculated lengths to previous annuli, showed similar trends in the four lakes containing small race smelt. Each smelt population attained the greatest length increment during its first year of life with subsequent increments showing a gradual decrease. Age-length relationships were quite similar for each population except in the case of two year olds from Nine Island Pond South. These fish were smaller at this age than fish of the same age for the remaining three populations. At this age these fish are 82 mm in length while fish of the other populations have attained a length of 90 mm. The calculated lengths of fish of each sex for different age groups showed very little difference in either population.

Smelt did not have their best growth in weight during the first year as was the case with growth in length. In two of the three populations where $III^{+}$ individuals occurred, the greatest increment in weight occurred between the third and fourth years.

Length-weight relationship exponents ("n" values) were very close

to 3 in three of the four populations, suggesting isometric growth. The Nine Island Pond South sample showed the lowest exponent value (2.7329). This, together with slower growth than that demonstrated by the other three populations after the first year of life, suggests this is a slower growing population generally. Bailey (1964) has reported an "n" value of 2.9523 for the smelt in western Lake Superior and Burbidge (1969) gave a value of 2.9539 for the smelt in Gull Lake, Michigan.

Reproductive Biology

Smelt mature and spawn for the first time at the end of the second year of growth ($I^+$). Creaser (1925), Greene (1930), Baldwin (1950), Hale (1960), and Rupp (1968) have reported similar findings. Greene (1930) also found that some smelt of the Finger Lakes spawn at the end of the first growing season. Less than 20% of the population spawns more than once.

Smelt are principally spring spawners and they spawn during the night. The actual time of spawning varies from one area to another and also from year to year. Although the majority of populations spawn during or shortly after ice-out (Langlois, 1935; Hoover, 1936; Baldwin, 1950), some populations spawn before ice-out (Creaser, 1925; Rupp, 1959; Legault and Delisle, 1968). Rupp (1959), in a survey of 114 smelt runs in Maine, reported that 10 took place wholly before ice-out, 31 on the date of ice-out, and 73 after ice-out. However, the 10 populations spawning before ice-out actually spawned in ice-free tributaries. The first run started February 23 and the last one ended May 25. Spawning runs in this study occurred between the middle of April (Black River Pond) to the middle of May (Clarks Pond).

Smelt are both stream spawners (Creaser, 1925; Kendall, 1927; Langlois, 1935; Rothschild, 1961), and shore spawners (Van Oosten, MS 1940; Lievense, 1954; Rupp, 1959, 1965; Delisle, 1969), they also spawn in deeper water. Delisle (1969) reported that Ferguson (1964, unpublished results) collected smelt eggs in 100 feet (30.5 m) of water in Lake Erie. Greene (1930) mentioned that smelt in Lake Champlain may spawn in water 10 feet (3.0 m) deep, or more.

The distance they travel upstream depends upon current and the presence of obstructions in the system. Smelt are not very strong swimmers and strong currents and/or a slight falls (up to 1 foot (0.3 m)) are major obstacles to them. Usually, they spawn within a few hundred yards above the mouth of the stream but they may migrate as far as 5 miles (8.0 km) (Rupp, 1968). The stream spawning population in Clarks Pond (1973) spawned in the first 76 m of the stream.

Smelt do not guard their eggs and they shed them indiscriminately over a variety of materials; small rocks, boulders, sand, aquatic vegetation, sticks, mud and clay banks, and almost anything else that is present. The eggs are very adhesive and stick to the first thing they touch. This lack of parental care over the eggs is compensated for by the high fecundity of the smelt in comparison with other fish of a similar size which display parental care.

Fecundity varies with the size of the fish. In this study actual egg counts for 20 females in Clarks Pond ranged from 1,538 (82 mm) to 3,740 (101 mm) and on the average, a 95 mm smelt contained approximately 2,760 eggs. Most fecundity work on landlocked smelt reports the number of eggs for a given fish length. Kendall (1927) reported a smelt 11.8 cm from a New England lake contained 5,893 eggs. Langlois

(1935) reported that smelt between 185 mm and 195 mm in Crystal Lake contained on the average 25,102 eggs. Saunders and Power (1970) found the average number of eggs per female with lengths between 202 and 280 mm was 44,964 and ranged from 14,269 to 61,910. Bailey (1964) reported that smelt in Lake Superior between 185 and 224 mm contained 31,338 eggs on the average with a range from 21,534 to 40,894.

Smelt do not necessarily spawn in the same locality each year as was evidenced by the 1973 and 1974 spawning runs at Clarks Pond. In 1973 the smelt spawned in the main tributary to Clarks Pond and the following year they spawned in the lake around the mouth of the tributary. A few smelt did enter the stream in 1974, but no spawning occurred there. Rupp (1968) suggested that stream or lake level fluctuations, which in turn change current patterns, may be one of the factors responsible for this variation.

No one stimulus is believed responsible for inducing the spawning behaviour of smelt. The release of reproductive behaviour seems to be the result of the effect of external and internal stimuli (Fabricius, 1950). Evidence from the timing of spawning runs in Black River Pond (underneath ice cover) and Clarks Pond (after ice-out) seem to rule out the possibility of light being the controlling factor in initiating smelt spawning. Water temperatures recorded during these runs ranged from 1.1 C to 9.0 C. Smelt spawning has been reported to have taken place in water temperatures ranging from 0 to 15 C (Greene, 1930; Hoover, 1936; Marcotte and Tremblay, 1948; Rupp, 1959; Hale, 1960; McKenzie, 1964; Legault and Delisle, 1968), with the majority occurring when the water is around 7 C.

Food and Feeding

Kendall (1927) reviewed the published data on the feeding habits of landlocked smelt. From this summary, and the results of his own work in New England waters, he concluded that smelt were predominantly plankton feeders while they occasionally ate insects and small fish. Creaser (1929), Greene (1930), Hoover (1936), Van Oosten (1937a), Schnerberger (1937), Beckman (1942), Baldwin (1950), Roecker (1961), Ferguson (1965), Rupp (1968), Burbidge (1969), and Delisle (1969), have studied the food habits of smelt. Although they all report finding zooplankton, benthic invertegrates (mostly insect larvae and nymphs) and fish remains, they sometimes disagree on the relative importance of these particular food items.

Food analysis of the four small race smelt populations in this study revealed these fish were primarily benthic feeders, relying primarily on aquatic insect larvae and nymphs and to a lesser degree, amphipods. The relative importance of any particular aquatic insect group varied between the four populations. The low frequency of occurrence of zooplankton in smelt stomachs is of particular interest. Since smelt samples were taken in the spring, summer, and fall they should be fairly representative of seasonal trends in food habits. Studies on the zooplankton of Newfoundland lakes are very scarce (Davis, 1972, 1973; Dagget, 1973), and since no quantitative plankton samples were taken during this study, no comparisons can be made with other lakes. Davis (1972) reported that the quantity of zooplankton in Hogans Pond, Avalon Peninsula, is low compared to that of Lake Erie.

The above evidence, together with the sampling methods (lake trap nets) used, suggests that smelt move into the littoral zone during the

night to feed. Most traps were set from shore each morning and hauled the next morning. Occasional checking of the traps during the late afternoon almost always showed the absence of smelt. The same trap hauled the next day contained smelt. This would indicate the smelt were either moving inshore from the deeper areas or from other inshore areas sometime between evening and early morning. The presence of food in smelt stomachs suggests they were feeding during this time. Ferguson (1965), found smelt near the bottom feeding throughout the day with feeding being most intense in the late morning. He reported those at midwater fed primarily at dusk and dawn with very little feeding activity in the early morning.

Large and Small Race Constituents in Black River Pond

The most striking difference between members of the two races is size, one being the 'giant' form and the other the 'dwarf' form. This is a common occurrence when sympatric populations exist for any species (Fenderson, 1964; Behnke, 1970; 1972).

There is also a difference in the life span of both races. Less than 1% of the small race smelt attain an age of four years ($III^+$) while 20% of the large race smelt were nearly six years old ($V^+$). Most of the small race smelt live a two year life span for less than 20% exceeded an age of $I^+$ years. On the other hand, approximately 87% of the large race members exceeded this same age. The dominant age class of the large race spawning run was $IV^+$ years while the $I^+$ age group was dominant in the small race spawning run.

Concomitant with this difference in longevity between the two races is the attainment of sexual maturity at different ages. Members

of the small race attain sexual maturity at age I+ while the large race smelt do not mature until a year later. This earlier attainment of sexual maturity by the small or dwarf form was also observed for sympatric populations of lake whitefish in Maine (Fenderson, 1964). Generally good growth is associated with early maturity and poor growth with late maturity (Alm, 1959), but Fenderson (1964) states this rule does not apply in the case of extremely slowly growing dwarfed populations. He states "In these populations unknown physiological factors apparently compensate for extreme slow growth by accelerating maturity".

In order for sympatric populations of the one species to co-exist, they must be reproductively isolated. This can happen in a number of ways: the sympatric populations may spawn at different times, and/or in different places. Any one of these situations will act as a barrier to gene flow.

This reduction of gene flow between the two races in Black River Pond is realized by the two races spawning at different times and perhaps even at different locations. The large race smelt spawned first in Black River Pond in the vicinity of the minor inflow. The large race smelt also spawned before the small race smelt in Lake Heney, Quebec (Legault and Delisle, 1968). In the spring of 1974 the large race smelt in Black River Pond commenced spawning sometime before April 3 and spawning was completed by April 16. Although some small race smelt were taken in the same vicinity during this interval, they were not spawning as no milt or roe was running at this time.

The small race smelt did not commence spawning in 1974 until April 16, the last day of spawning for the large race smelt, and continued into the first week of May. The majority of spawning and spent

small race smelt were taken in the vicinity of the major inflow (Black River) but large numbers were also taken in the area of the minor inflow. Eggs of the large race smelt were located in approximately 18 inches (7.1 cm) of water in the vicinity where the adults had been captured. Even though spent small race smelt were captured in the same area it is not known for sure if they spawned here since no eggs could be found. For this reason no conclusive statements can be made concerning the overlap in spawning sites of the two races.

The fact that their spawning times overlap by one day suggests that hybridization between the two races may take place even though there was no evidence for it during the study. It is quite conceivable that smelt may be spawning in other areas around the lake. Most of the lake is covered with ice during spawning time and observations were confined to the two inlet areas.

Spatial segregation between the two races in the lake is not complete. Evidence for this is seen in the stomach contents of the large race smelt. They are mainly cannibalistic, feeding mostly upon members of the small race smelt. Apart from this, and the fact that both races may be collected together during the spawning season, they are not taken together during the summer months. Trap net catches during June and July, 1973, caught only small race smelt. Little can be said concerning the distribution of either race during the winter months for gill net settings beneath the ice failed to catch fish from either population.

Distinct differences in diet occur between the two races in Black River Pond. As stated above the large race are mainly cannibalistic but they also eat the immature stages of aquatic insects. The small race

are mainly benthic feeders, eating immature aquatic insect forms and amphipods. They also eat zooplankton. Greene (1930) in Lake Champlain, and Delisle (1969), in Lake Heney, found zooplankton to constitute the main food item in the small race smelt diet while the large race smelt fed primarily on small race smelt. In this study, members of both races were collected during the spawning season and statements concerning their feeding habits during other times of the year cannot be made.

One of the 2 meristic counts (vertebrae) showed a significant difference between the two races. The large race had a significantly higher mean number as was the case with the large race smelt of Lake Heney (Delisle, 1969). An interesting feature in the gill raker studies was the presence of deformed gill rakers in all of the small race smelt and none in the large race. Delisle (1969) comparing 50 each of large and small race smelt in Lake Heney, Quebec, found only 2 (4%) small race to possess deformed rakers while (46) 92% of the large race smelt possessed them. He suggests the different food habits of each race may be a causative factor for this deformity. He also found gill raker number to range between 30 and 37 while 32 was the highest recorded for any fish in this study. Scott and Crossman (1973) have given 8-11 + 18-24 for the number of gill rakers for rainbow smelt.

Three of the 4 morphological ratios showed a significant difference between the two races. However, the sample size was small and further work is necessary before statements concerning the taxonomic relationships can be made.

## SUMMARY

1. Size and age distributions of the fish sampled in this study show that the two forms of smelt (large and small races) occur sympatrically in at least one lake on the Avalon Peninsula, Newfoundland.

2. The dwarf form found in the four lakes are very slow growing. They attain their greatest length increment during the first year and increments decrease thereafter. They seldom exceed an age of two years and less than 1% of all the fish sampled were older than three years. Large race smelt are very fast growing. They attain their greatest length increment during their second year of life and they may attain an age of six years.

3. Smelt are spring spawners and they spawn during the night. They spawn both in the lake and tributaries to the lake if they are present. Smelt may switch their spawning location from year to year. The two sympatric populations appear to be temporally isolated during spawning and they may be spatially isolated as well during spawning.

4. Benthic invertebrates, particularly aquatic insect larvae and nymphs, are the main food of the small race smelt. The most important groups are mayfly nymphs (Ephemeroptera) and caddisfly larvae (Trichoptera). The relative importance of each group varies from lake to lake. These smelt also eat amphipods (Amphipoda) and zooplankton (Cladocera and Copepoda), but to a lesser degree. The large race smelt are mainly piscivorous eating members of the sympatric small race population. They also eat benthic invertebrates; mayfly nymphs, dragonfly nymphs, amphipods, and dipteran pupae.

5. Morphological and meristic variation existed between four of the six characteristics investigated in this study. Sample sizes used

for these measurements were small and therefore no conclusive statements concerning the comparative morphology of the races were made.

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Appendix 1.. Monthly surface water temperatures (C) of Clarks Pond, Nine Island Pond South, and Black River Pond during the ice-free period 1973, 1974

| Month | Clarks Pond (1974) Mean | High | Low | Nine Island Pond South (1973) Mean | High | Low |
|---|---|---|---|---|---|---|
| April | 4.2 | 4.6 | 3.9 | I C E C O V E R | | |
| May | 6.2 | 7.7 | 4.0 | 7.3 | 10.2 | 2.5 |
| June | 9.9 | 13.3 | 7.0 | 12.4 | 15.8 | 10.0 |
| July | 13.8 | 16.1 | 11.4 | 18.1 | 20.7 | 15.3 |
| August | 14.9 | 16.8 | 13.9 | 15.1 | 19.0 | 13.5 |
| September | 13.0 | 14.3 | 11.1 | 13.4 | 16.0 | 10.8 |
| October | 8.5 | 12.0 | 5.0 | 8.3 | 11.0 | 4.7 |
| November | 3.4 | 5.0 | 0.9 | 3.1 | 5.4 | 1.5 |
| December | I C E C O V E R | | | I C E C O V E R | | |

| Month | Black River Pond (1973) Mean | High | Low |
|---|---|---|---|
| April | I C E C O V E R | | |
| May | 8.6 | 10.3 | 5.0 |
| June | 12.4 | 16.1 | 10.3 |
| July | 18.1 | 21.0 | 15.4 |
| August | 16.1 | 17.4 | 15.5 |
| September | 13.9 | 16.7 | 11.1 |
| October | 8.4 | 11.1 | 4.9 |
| November | 3.4 | 5.5 | 1.7 |
| December | I C E C O V E R | | |

Appendix 2A. Temperature (C) and dissolved oxygen (mg/liter) readings for Black River Pond and Nine Island Pond South (June 1, 1973).

| Black River Pond | | | Nine Island Pond South | |
|---|---|---|---|---|
| Depth (ft) | Temp (C) | D.O. (mg/l) | Temp (C) | D.O (mg/l) |
| Surface | 18.5 | 9.4 | 19.5 | 8.3 |
| 2 | 18.0 | 9.3 | 19.5 | 8.2 |
| 4 | 18.0 | 9.3 | 19.5 | 8.3 |
| 6 | 17.8 | 9.4 | 19.7 | 8.3 |
| 8 | 17.8 | 9.4 | 19.7 | 8.2 |
| 10 | 17.5 | 9.4 | 19.7 | 8.1 |
| 12 | 17.2 | 9.5 | 19.5 | 8.2 |
| 14 | 17.0 | 9.5 | 19.3 | 8.2 |
| 16 | 17.0 | 9.6 | 19.2 | 8.2 |
| 18 | 17.0 | 9.7 | 19.1 | 8.1 |
| 20 | 17.0 | 9.6 | 19.0 | 8.0 |
| 22 | 16.8 | 9.6 | | |
| 24 | 16.7 | 9.8 | | |
| 26 | 16.5 | 9.8 | | |
| 28 | 15.9 | 9.8 | | |
| 30 | 15.0 | 9.9 | | |
| 32 | 14.9 | 9.9 | | |
| 34 | 14.1 | 9.9 | | |
| 36 | 14.0 | 9.8 | | |
| 38 | 13.8 | 9.8 | | |
| 40 | 13.8 | 9.8 | | |
| 42 | 13.6 | 9.8 | | |
| 44 | 13.6 | 9.8 | | |

Appendix 2A (cont'd.)

| | Black River Pond | | Nine Island Pond South | |
|---|---|---|---|---|
| Depth (ft) | Temp (C) | D.O. (mg/l) | Temp (C) | D.O. (mg/l) |
| 46 | 13.6 | 9.8 | | |
| 48 | 13.6 | 9.8 | | |
| 50 | 13.6 | 9.8 | | |

Appendix 2B. Temperature (C) and dissolved oxygen (mg/liter) readings for Clarks Pond and Larkins Pond (June, 1973)

| | Clarks Pond | | Larkins Pond | |
|---|---|---|---|---|
| Depth (ft) | Temp (C) | D.O. (mg/l) | Temp (C) | D.O. (mg/l) |
| Surface | 15.0 | 9.1 | 16.0 | 9.6 |
| 2 | 15.0 | 9.1 | 16.0 | 9.6 |
| 4 | 15.0 | 9.1 | 15.9 | 9.6 |
| 6 | 15.0 | 9.1 | 15.8 | 9.5 |
| 8 | 15.0 | 9.1 | 15.8 | 9.5 |
| 10 | 15.0 | 9.1 | 15.8 | 9.5 |
| 12 | 15.0 | 9.1 | 15.8 | 9.5 |
| 14 | 14.9 | 9.1 | 15.8 | 9.5 |
| 16 | 14.9 | 9.1 | 15.8 | 9.5 |
| 18 | 14.9 | 9.1 | 15.8 | 9.5 |
| 20 | 14.9 | 9.1 | 15.8 | 9.4 |
| 22 | 14.9 | 9.0 | 15.8 | 9.4 |
| 24 | 14.9 | 9.0 | 15.8 | 9.4 |
| 26 | 14.9 | 9.0 | 15.8 | 9.4 |
| 28 | 14.9 | 9.0 | 15.8 | 9.4 |
| 30 | 14.9 | 9.0 | 15.8 | 9.4 |
| 32 | 14.9 | 9.0 | 15.7 | 9.4 |

Appendix 3. Variation between the actual and estimated egg counts of 20 landlocked smelt using the volumetric method

| Fork length (mm) | Actual count | Estimated count | Difference | % |
|---|---|---|---|---|
| 98 | 3227 | 5641 | +2414 | +74.8 |
| 94 | 2810 | 2316 | - 494 | -17.6 |
| 100 | 3480 | 2672 | - 808 | -23.2 |
| 99 | 2710 | 1900 | - 810 | -29.9 |
| 105 | 3630 | 3474 | - 156 | - 4.3 |
| 88 | 2649 | 2969 | + 320 | +12.1 |
| 110 | 3400 | 1247 | -2153 | -63.3 |
| 82 | 1538 | 1722 | + 184 | +12.0 |
| 91 | 2327 | 2464 | + 137 | + 5.9 |
| 109 | 3680 | 2910 | - 770 | -20.9 |
| 92 | 2727 | 3563 | + 836 | +30.7 |
| 89 | 2090 | 2435 | + 345 | +16.5 |
| 89 | 2500 | 1841 | - 659 | -26.4 |
| 84 | 1927 | 1722 | - 205 | -10.6 |
| 107 | 3982 | 4157 | + 175 | + 4.4 |
| 91 | 2383 | 2969 | + 586 | +24.6 |
| 101 | 3740 | 3533 | - 207 | - 5.5 |
| 87 | 2330 | 3533 | +1203 | +51.6 |
| 83 | 2170 | 2969 | + 799 | +36.8 |
| 94 | 1860 | 1128 | - 732 | -39.4 |
| | | | Average | + 1.4% |

Appendix 4. Age-length (empirical) relationship of landlocked smelt collected from the four study areas (sample sizes in parentheses)

| Age (years) | Average Fork Length (mm) | | | | | |
|---|---|---|---|---|---|---|
| | Larkins Pond | | | Clarks Pond | | |
| | Male | Female | Combined | Male | Female | Combined |
| $0^+$ | - | - | 64.0( 2) | - | - | 59.67( 3) |
| $I^+$ | 87.42(12) | 89.91(108) | 89.67(120) | 92.00( 63) | 90.69(74) | 91.31(137) |
| $II^+$ | 96.00( 6) | 104.14( 21) | 102.77( 27) | 104.43(23) | 101.00(29) | 102.46( 52) |
| $III^+$ | - | 113.00( 1) | 113.00( 1) | 125.5( 2) | 101.00( 2) | 113.25( 4) |
| | Black River Pond (small race) | | | Nine Island Pound South | | |
| $I^+$ | 89.61(23) | 87.84(116) | 88.14(139) | 74.49(75) | 79.95(80) | 79.65(155) |
| $II^+$ | 98.08(12) | 97.60( 20) | 97.78( 32) | 93.58(19) | 93.92(26) | 93.98( 45) |
| $III^+$ | - | 124.00( 1) | 124.00( 1) | | | |
| | Black River Pond (large race) | | | | | |
| $I^+$ | 118.50( 2) | 120.62(13) | 120.33(15) | | | |
| $II^+$ | 166.25( 8) | 136.14( 7) | 152.20(15) | | | |
| $III^+$ | 213.92(12) | 153.00( 2) | 205.21(14) | | | |
| $IV^+$ | 231.70(43) | 241.75( 8) | 233.27(51) | | | |
| $V^+$ | 241.50(20) | 259.67( 3) | 243.87(23) | | | |

Appendix 5. Age-weight (empirical) relationship of landlocked smelt collected for the four study areas (sample sizes in parenthesis).

| Age (years) | Average Weight (g) | | | | | |
|---|---|---|---|---|---|---|
| | Larkins Pond | | | Clarks Pond | | |
| | Male | Female | Combined | Male | Female | Combined |
| $0^+$ | - | - | 1.30( 2) | - | - | 1.04( 3) |
| $I^+$ | 3.74(12) | 3.57(108) | 3.59(120) | 4.19(63) | 3.98(74) | 4.08(137) |
| $II^+$ | 4.60( 6) | 6.30( 21) | 5.92( 27) | 6.31(23) | 5.46(29) | 5.84( 52) |
| $III^+$ | | 7.40( 1) | 7.40( 1) | 15.04( 2) | 5.58( 2) | 10.31( 4) |
| | Black River Pond (small race) | | | Nine Island Pond South | | |
| $I^+$ | 3.86(23) | 3.32(116) | 3.42(139) | 3.45(75) | 3.50(80) | 3.47(155) |
| $II^+$ | 5.38(12) | 4.30( 20) | 4.70( 32) | 5.20(19) | 5.68(26) | 5.48( 45) |
| $III^+$ | - | 10.10( 1) | 10.10( 1) | | | |
| | Black River Pond (large race) | | | | | |
| $I^+$ | 7.10( 2) | 8.90(13) | 8.66(15) | | | |
| $II^+$ | 30.48( 8) | 10.20( 7) | 21.01(15) | | | |
| $III^+$ | 75.77(12) | 25.75( 2) | 68.62(14) | | | |
| $IV^+$ | 91.61(43) | 107.28( 8) | 94.07(51) | | | |
| $V^+$ | 98.43(20) | 114.33( 3) | 100.50(23) | | | |