SELECTED ASPECTS OF THE LIFE HISTORY OF <u>SALVELINUS</u> <u>FONTINALIS</u> (MITCHILL) IN BIG NORTHERN POND, AN ACID HEADWATER POND OF THE TOPSAIL-MANUELS WATERSHED, AVALON PENINSULA, NEWFOUNDLAND, CANADA

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Selected aspects of the life history of *Salvelinus fontinalis* (Mitchill) in Big Northern Pond, an acid headwater pond of the Topsail-Manuels watershed, Avalon Peninsula, Newfoundland, Canada

by

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

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August, 1988

St. John's Newfoundland

ISBN 0-315-65300-0

Abstract

A five-year ecological investigation into the life history of *Salvelinus fontinalis* (Mitchill) was undertaken to evaluate its growth in an acidic, dystrophic, headwater habitat and to determine the seasonal aspects of feeding, reproduction and parasitism.

Young of the year fish were found to hatch and grow in water with a stream pH of 4.7 and were subject to parasitism at the onset of exogenous feeding. The growth of these fish was rapid but subject to a great deal of variation due to environmental conditions and initial times of egg deposition. Condition factors of this age group were extremely low.

Fish of age greater than zero were found to be robust, having very high condition factors (greater than 1.00). The condition was variable with season, peaking during July of most years but displaying two low periods associated with fall and spring water temperature changes.

The changes in condition were attributed to change in food supply and physiological demands. Analysis of parasites revealed only four enteric helminth species which were cyclical in nature, responding to seasonal changes in temperature and intermediate host densities. *Metechinorhynchus lateralis*, an acanthocephalan, was the only parasite maintained at high numbers throughout the year. This parasite was also the only one which showed increases in prevalence with increase in fish age. Routes of infection for *M. lateralis* were established. Parasite burden was not found to be associated with condition factor.

Growth of older fish was comparable to that of fish downstream in the watershed and other habitats which have higher pH values.

The diets of young of the year fish and that of older fish were similar with the exception of fish eggs which were found only in the stomachs of older fish. These fish utilized all available aquatic insects, molluscs, and crustaceans as well as any available terrestrial food sources. There were no cases of empty stomachs in older fish. Exogenous feeding usually began in May for young of the year fish. They showed a preference for chironomids, coleopterans, trichopterans and ceratopogonids whereas the older fish showed the highest preference for the Odonata, prey size corresponding with an increase in fish age (thus size). Feeding was affected by season and prevalence for some food items and modified by prey availability. The abundance of some food items was correlated with increases in parasitism.

S. fontinalis was the sole user of the only fluvial habitat available for spawning but was also seen utilizing redds in the pond environment. The initiation of spawning was earlier in the fluvial environment.

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Acknowledgements

I would like to express my appreciation to all the people who have in some way, large or small, helped me to undertake this study. I wish to thank the following people who were most helpful in my research. My committee: Dr. G. I. McT. Cowan, who spent countless hours in the field with me as supervisor, friend and at times, slave, Dr. R. L. Haedrich, who posed some difficult questions initially which promoted me to narrow the scope of this study, Dr. J. M. Green, who was always available for advice and encouragement and provided useful comment on the format of my thesis. The Department of Biology: The secretarial staff who provided many typing services for publication of manuscripts which have evolved from this study, the technial support staff who were always obliging whenever equipment or chemicals were required, Mr. Roy Ficken for his excellent photographic work during the preparation of figures, Dr. D. J. Larson for his help in identification of some food items and for information on the ecology of some of those organisms, Dr. R. Knoechel for his constructive criticism of this manuscript.

The graduate students for their interest, encouragement, advice, etc. You are not named but you are not forgotten.

Memorial University of Newfoundland, for the financial support towards the cost of tuition as well as for the physical structures in which I work.

I reserve my most sincere gradtitude and thanks to Mr. Brendan Hollohan and Ms. Louise Green for the onerous task of proof-reading and typing of my thesis.

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Introduction

The Topsail-Manuels watershed has had a variety of external forces exerted upon it. As early as 1890, exotic fish introductions were made. Rainbow trout (Salmo gairdneri) were released in Adams Pond and brown trout (Salmo trutta) into the Topsail Road Ponds (believed to be Octagon Pond and Neils Pond) and in 1892 in Topsail Pond (Anonymous, 1892). Gasterosteus aculeatus was introduced to the upper sections of Paddys Pond and Thomas Pond in the 1970's (Wiseman, 1971, 1972) as a potential forage fish and have subsequently spread over most of the watershed (Big Northern Pond excepted).

The physical characteristics of the watershed have been altered to provide water to the Topsail generating station. The rivers running from the various ponds on the Topsail portion were dammed during the 1930's to provide water on a continuous basis to the Topsail powerhouse and the impoundments and resulting water of Cochrane Pond and Paddys Pond were diverted to the Topsail system. The last major effort by United Towns and Electric (now Newfoundland Light and Power Co. Ltd.) to divert water took place in 1953 when the Grassy Gullies were flooded to create Thomas Pond. This pond takes all the water from the upper Manuels system and diverts it to the Topsail system. It was the linking of the Topsail-Manuels watershed which allowed range expansion by S. trutta into the Manuels portion of the watershed and this exotic has now spread throughout the system.

The 1960's gave rise to further development on the upper watershed of the Manuels system when the most southwest portion of the system became the central area of a co-operative community cattle pasture. This involved the clear-cutting and liming of a large area to provide summer forage for cattle. Since that time, the only development on the system has been of a recreational form with the addition of Boy Scout Camps and a "Diabetic Camp". Summer camping occurs on the watershed, the main areas of concentration being Thomas Pond and Northern Pond. The lower areas of the system receive considerable fishing pressure and have been termed the most heavily fished waters in insular Newfoundland (Wiseman, 1972).

Big Northern Pond, a headwater pond on the Manuels side of the linked Topsail-Manuels watershed became the focus of an ecological study in 1981. The pond was chosen because of its low pH, relative isolation, the fact that no development had occurred on the land draining into the pond, the absence of exotic species and the presence of apparently robust populations of the landlocked salmon, Salmo salar (ouananiche) and brook trout Salvelinus fontinalis (brook charr). This pond, therefore, was considered to be virgin with respect to the other areas in the system and was thus an ideal location for a long-term study of Salvelinus fontinalis.

A review of the literature reveals that most studies of the biology of S. fontinalis in Newfoundland and Labrador have neglected seasonal variation and have not taken long-term growth or developmental aspects into consideration.

Wiseman (1969) studied various aspects of the life history of this species in several localities on the Avalon Peninsula and has documented sex ratios, maximum size ranges, growth rates and other life history characteristics. Some aspects of feeding and energetics have been addressed (Cunjak, 1982) and ecological interactions between S. fontinalis and S. trutta have been noted (Nyman, 1970). This species has been examined within the Topsail-Manuels drainage system (Wiseman, 1971, 1972) in relation to fishing pressure and stock assessments, and a subsequent review of the stocks was undertaken in Paddys Pond during the mid 1980's (data unavailable) by Federal Fisheries Department of Canada.

It has been documented that low pH inhibits the growth of fish and invertebrates in aquatic ecosystems (Beamish, 1974; Howells et al., 1983). The effects of acid precipitation on S. fontinalis have been studied (Menendez, 1976; Beamish, 1976; Schofield, 1976) and the effects of decreased pH levels on reproduction and subsequent survival of eggs and alevins have been evaluated in the laboratory (Trojnar, 1977; Kwain, 1985; Pedder and Maley, 1986). The growth and reproduction of this species in a naturally acidic environment is less well known and its documentation was an objective of the current study.

There are other factors that influence the general well-being of a species such as parasitism, species interactions, nursery areas and food supplies.

Parasitism, in many circumstances, is of paramount importance to fishery biologists due to its effect on growth, reproductive ability and mortality. The parasites of S. fontinalis have been recorded for different geographical areas and the parasites found in or on the fish vary with the diversity of intermediate and definitive hosts (Lagler, 1956). One of the problems with exotic introductions and/or their subsequent invasion of other aquatic habitats is that new parasites may be introduced into these new areas with adverse consequences (Li and Moyle, 1981; Noble and Noble, 1976). A study of parasitism in Big Northern Pond will establish the levels of some parasites of the brook trout before further range expansion of exotic fish species takes places.

There is some knowledge of the fish parasites in Newfoundland and Labrador due to investigations into the fauna of several selected habitats. Surveys have covered some of the fish species of Labrador (Chinniah and Threlfall, 1977; Hicks and Threlfall, 1973) and insular Newfoundland (Sandeman and Pippy, 1976; Threlfall and Hanek, 1970). Population size of metazoan parasites has been examined for S. fontinalis and Salmo salar in a headwater pond (Cone and Ryan, 1984) and a possible fish kill by acanthocephalans have been reported (Pippy and Sandeman, 1967). Although the parasite fauna of some of the fish populations of the Avalon Peninsula of Newfoundland have been investigated (Threlfall and Hanek, 1970), there have been no long-term studies to characterize the changes in parasite incidence and burden throughout the fishes life cycle. This study examines, overtime, the changes of four enteric helminth parasite populations.

This study also examines the selection of prey items over time in regards to season and the age of fish and relates food selection to parasitism.

Site Description

Big Northern Pond (Fig. 1) is the headwater pond of the southeast arm of the Topsail-Manuels watershed of the Avalon Peninsula, Newfoundland ($47^{0}24'30"N$, $52^{0}53'20"W$). It is a shallow dystrophic lake with a surface area of 19.11 ha. and a perimeter of 2.47 km. Major sources of water for the system are bog drains located 0.7 km from the outflow. The pH of the water from the surrounding forest and fens has been recorded as low as pH 3.44. Studies of the pond acidity have shown pH levels to fluctuate seasonally from a low of 4.13 to a maximum of 5.12 (Cowan, Baggs and Hollohan, in press).

Situated at an elevation of 216 m, the pond is exposed to the prevailing southwest winds. The surrounding land mass reaches a maximum elevation of 220 m. Sparse scrub growth of spruce <u>Picea mariana</u>, fir <u>Abies balsamea</u> and larch <u>Larix laricinia</u>, located on the north and south ends of the pond, form what little forest there is adjacent to the pond. To the south and east lies a huge fen called the Thousand Acre Marsh and to the west is a similar but smaller area of fen. The plant life here is typical of eastern Avalon Peninsula fens. The water and nutrients derived by the pond come from these areas. Water content of the area is maintained due to the deep organic accumulations (peat) and gradual slopes towards the pond.

Big Northern Pond is an irregular, shallow depression with a maximum depth of 2.0 m and sediment depth, where encountered, of 0.3 m. (Fig. 2).

Figure 1: Aerial photograph of Big Northern Pond and surrounding watershed. Scale is 1:25,000

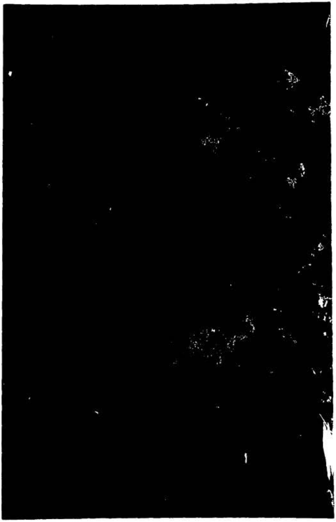
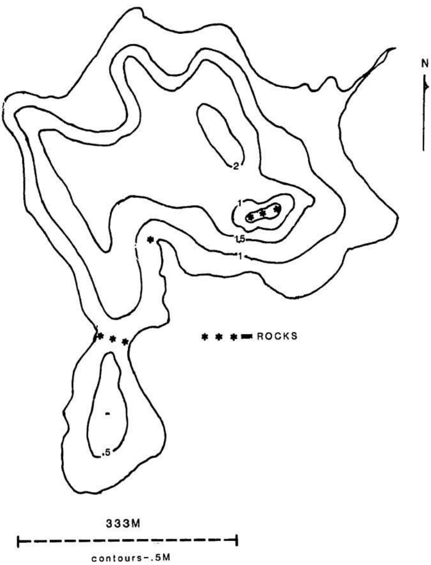


Figure 2: Bathymetric map of Big Northern Pond

BIG NORTHERN POND



This shallow brown water pond responds rapidly to air temperature changes.

Approximately 50 percent of the pond bottom consists of large rocks with areas of sand and gravel interspersed. The perimeter is made up of rock 0.3 m and greater in size. There are two shoal areas of large rock, the major one being located in the centre of the southeast portion of the pond (Fig. 2).

The outflow is located at the northeast end of the pond and drains through a shoal of large rocks into a small stream approximately 1 m wide with a maximum depth of 0.3 m. The first 50 meters of stream bed is mixed gravel and rock.

The pond supports a sparse assemblage of aquatic macrophytes in distinct zones. This assemblage includes Nuphar variegatum Eriocolon septangulare, Lobelia dortmanni, Sparganium sp., Potamogeton sp., Isoetes macrospora, and low numbers of Carex sp.

Populations of unidentified filamentous green algae and freshwater sponges also occur on the substrate.

Animals other than fish that are found either on, in or around the pond include the common loon (Gavia immer), Canada goose (Branta canadensis), the belted kingfisher (Megaceryle alcyon), various ducks (Anas sp.), gulls (Larus sp.), as well as hawks, eagles, ruffed grouse, ptarmigan, and assorted passerine species.

Mammals associated with the system include the moose (Alces alces), otter (Lutra canadensis), mink (Mustella vison), weasel (M. ermina), shrew (Sorex cinereus), voles (Microtus pennsylvanicus), hare (Lepus americanus) and beaver (Castor canadensis).

(*M. ermina*), shrew (*Sorex cinereus*), voles (*Microtus pennsylvanicus*), hare (*Lepus americanus*) and beaver (*Castor canadensis*).

Fish species of the pond are the ouananiche (*Salmo salar* L.), eels (*Anguilla rostrata*) and the subject of this study, the brook charr (*Salvelinus fontinalis* Mitchill).

Materials and Methods

Bathymetry

A map of Big Northern Pond was overlayed with scaled grids and drawn out into 50-m quadrants using easily discernable landmarks for reference points. Depths were recorded from a boat using a lead line marked in 0.1 m intervals at the points where the grid lines crossed. Further visual inspections were made to locate and record any deep holes which may have been missed using the grid. A map was then constructed using 0.5 m contours.

Physical, Chemical and Microbiological Parameters

Physical Data

The water temperature of Big Northern Pond was taken during times of sample collections, and was recorded for both the stream sample station and the pond stations. Water levels were measured using a meter stick.

The flow rate (0.5 to 1.0 m/sec) of the small stream was calculated using a crumpled piece of aluminum foil floated over a distance of 3 m. The depths and widths of the stream were measured using a meter stick.

Water Chemistry

Bimonthly samples were collected for chemical analysis during 1982. Collection of water was made at the outflow of the pond at a depth of 0.3 m using Nalgene sample bottles previously prepared by the Water Analysis Facility of Memorial University.

These samples were shipped immediately to the Water Analysis Facility and determinations of pH, Gran alkalinity and chemical parameters for water quality (A.P.H.A., 1980) were conducted.

Microbiological Data

The total and fecal coliform bacterial flora of Big Northern Pond was evaluated over the period of one year (1982). These samples were collected at a depth of 0.3m using a sterile evacuated bottle and a Johnson-Zobell sampler. Collections were made biweekly on a bimonthly basis. Culture and evaluation was carried out using the multiple tube fermentation (MPN) technique outlined by the American Public Health Association (A.P.H.A., 1980). Samples were maintained on ice during transport and cultures were prepared by the author within 4 hours of collection.

Fish Sample Collections

Alevin Collection (0+)

It was determined through observation that a small portion of the outlet stream immediately adjacent to the pond contained an area suitable for spawning and previously, in 1981, *S. fontinalis* were seen engaged in this activity at this site. The stream spawning population of fish offered a situation whereby populations of 0+ fish could be obtained over a period of time, and observations could be repeated and data collected and evaluated over a period of years. The sampling effort, however, was restrained in this area because it was desirable to obtain enough individuals over the period of the development of the young to supply meaningful data and to allow members of the population to survive and enter the pond environment.

Collections of 0+ fish were obtained in the stream for the years 1983-86 on a monthly basis with the first samples being obtained immediately after emergence (usually mid May).

Specimens were obtained using a Smith-Root Type V electrofisher and a dipnet.

Collections of Older Fish

Fish with an age of 1 year or greater were obtained using angling techniques, fyke traps, an electrofisher and multi-panels of gill net with stretched mesh sizes of 18, 25 and 37 mm.

With the exception of the anniversary samples taken in August of each year, the use of gill nets was restricted to 1 hr soak time to avoid unnecessary damage to the fish stock. These nets were always attended by the investigator. Yearly and monthly samples were obtained from the same sample station locations.

Preservation of Samples

All fish were transported on ice and frozen within three to five hours. Alevins were examined and then preserved in buffered 10% formalin. Older fish were examined and the viscera preserved in buffered 10% formalin for future examination.

Specimens of food items and parasites obtained from the stomachs and intestines were preserved in a solution of 5% glycerine in 95% ethanol.

Morphological Examinations

All specimens were measured using a Helios dial caliper to the nearest 0.01 mm. Weights of fish were obtained using a Mettler PL 1200 self-taring electronic balance to the nearest 0.01 g.

Sex determination was accomplished through gross examination of gonads in older fish and with a dissecting or compound microscope, when necessary, for alevins (as per Lagler, 1978).

Maturity

The maturity of S. fontinalis was determined using the modified classification of Nikolsky (1963) (in Bagenal, 1978) whereby Nikolsky's step V and Vl are combined to form step V so that this level combines both spawning and spent individuals. This was done because spawning in Big Northern Pond is protracted and individuals of both states were encountered. There are various classification schemes for determining maturity and Nikolsky's method is suited to fish with relatively short spawning periods (Lagler, 1978).

Age Determination

Scales were removed from the dorsal region of the body surface below the posterior aspect of the dorsal fin and above the lateral line on the left side of the fish. The scales were then spread and dry mounted between two glass slides. Aging was accomplished using a Bosch & Lomb micro projector (43X) and the annulus criteria of Cooper (1951). Tracings of scales were made for back calculations in a manner prescribed by Bagenal and Tesch (1978).

Mortality for fish of age $\geq$ 1+

Mortality was determined graphically from "catch curves" whereby a curve results from plotting the logarithms of numbers of fish of a given age against age (Kennedy, 1954).

Condition Factors

Fulton's Condition Factor (Bagenal and Tesch, 1978) for fitness or well being of fish was calculated using the equation:

$$K = \frac{W \times 100}{L^b}$$

where K = coefficient of condition

W = weight in grams

L = forklength in centimeters

b = slope of the weight-length regression.

The value of "b" was calculated for each year for whole and gutted weights (Table 5,) and changes in condition factor by month for each year were calculated from these values.

Food Data

The stomachs and intestines of the fish were removed from formalin, separated at the pyloric valve and subsequently opened up and the contents flushed out into petri dishes for examination of food items. Relative quantities of food were recorded for each organ and specimens were collected and identified to Order and/or Family. Retained specimens were stored in a solution of 5% glycerine in 95% ethanol.

Parasite Data

Parasites were collected and recorded from the digestive tract only. The parasites were collected and counted at the time of food analysis and specimens were retained separately. Preservation was in 5% glycerine in 95% ethanol. Identification of specimens was accomplished using the methodology of Fernando et al. (1972) and the criteria of Pippy (1970). Terminology used is according to Margolis et al. (1982).

Analysis of Data

Statistical analysis was carried out using the SPSSX version 4 statistical package. Comparisons of length-weight regressions were done using a hierarchial F test for slopes and intercepts. Means were statistically evaluated using one way analysis of variance. Parasite data were tested using the Student-Newman-Keul Multiple Means Tests and the term "significant" is used in the text for values of $P \leq .05$.

Results

Physical, Chemical and Microbiological Water Quality

Temperature

The temperature regime of the Avalon Peninsula is variable depending on wind direction, exposure, elevation, and the proximity to the coast. Table 1 shows the mean temperature by month for the years 1981 through 1986. The period when the ponds of the upper reaches of the Topsail-Manuels system were most stable was during December through March when the ponds were ice-covered and not subject to the water mixing caused by the high winds which sweep this region. Big Northern Pond is not sheltered from wind and the water temperature is subject to rapid changes. The water, due to its brown color, is also capable of reaching high temperatures (20°C, maximum recorded) with daily swings of up to 4°C in mid summer (August). The effect of water temperature was most noticeable in the outlet stream of the pond.

Chemical Water Quality

The lowest pH recorded for Big Northern Pond was 4.13 for April, 1982 (Table 2). The input of acid precipitation over the winter season is thought to be the cause of this depression and is due to the magnified effects caused by sublimation of snow. The more obvious effect of acid input can be seen in August 1982 where the pH was again reduced to 4.68 from a high of 5.10 recorded in June of the year. This followed a rainfall over the previous seven days of 60mm.

Table *1 ; Mean Air Temperatures (^{0}C) for the Topsail-Manuels Watershed

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Yearly Mean
1981	-2.2	-2.1	-0.1	3.3	9.2	11.6	14.8	15.7	12.2	8.3	4.4	0.7	6.30
1982	-3.9	-6.2	-3.2	2.4	6.0	7.7	15.8	15.4	13.2	5.8	4.4	-1.1	4.20
1983	-2.5	-3.5	-0.5	4.7	7.7	11.9	17.0	14.8	12.3	8.2	2.7	-1.2	5.96
1984	-4.5	-1.1	-1.0	0.3	8.6	10.6	18.3	17.4	12.4	5.1	2.6	-1.3	5.60
1985	-5.0	-5.4	-4.4	0.5	5.0	10.7	18.8	14.4	10.8	6.0	0.5	-2.8	4.00
1986	-2.3	-4.6	-3.2	4.6	6.5	12.1	13.6	15.5	10.1	5.3	0.8	-2.9	4.60

* Data obtained from the Federal Department of Agriculture, Mt. Pearl, Newfoundland

Table 2: Water chemical parameters for Big Northern Pd. on a bi monthly basis.

Parameter (mg/1)	SAMPLE DATES					
	12-11-81	27-01-82	07-04-82	14-06-82	30-08-82	24-11-82
PH	5.06	4.65	4.13	5.10	4.68	5.20
Gran Alkalinity ($CaCO_3$)	0.00	-0.45	-	-0.10	-0.20	-0.20
Acidity ($CaCO_3$)	7.00	5.00	9.00	3.00	6.00	4.00
Hardness($CaCO_3$)	3.92	5.05	3.27	2.60	2.93	3.87
Al	1.00	0.04	0.03	0.02	0.05	0.16
NH_3	0.01	0.01	0.01	0.02	-	0.04
K	0.17	0.58	0.16	0.15	0.36	0.22
Cu	0.01	0.01	0.02	0.02	0.01	0.02
Ca	0.74	0.87	0.46	0.47	0.52	0.74
Na	3.33	4.63	3.00	3.31	4.13	3.48
Si	0.56	0.85	0.44	0.02	0.09	0.03
Fe	0.26	0.25	0.35	0.02	0.07	0.20
Mn	0.01	0.01	0.03	0.02	0.01	0.01
Mg	0.39	0.59	0.35	0.33	0.36	0.40
PO_4 (ortho)	0.01	0.01	0.01	0.01	0.01	0.01
PO_4 (Total)	0.01	0.01	0.02	0.02	0.02	0.02
N	0.03	0.15	0.002	0.021	0.002	0.002
COD	23	19	19	10	14	20
TANNIN /LIGNIN	1.2	1.3	1.2	0.93	1.0	1.7

- no sample evaluation made.

Examination of the ionic components (Table 2) shows the levels to be extremely low, this being due to the type of rock which consists of well-bedded clastic and locally cherty sedimentary rocks (Bruckner, 1979) the pond sits on and the fact that much of the water input is filtered through large areas of peat bog.

Bacteriological Parameters

Table 3 shows the total and fecal coliform counts for Big Northern Pond for the period of September 1981 through November 1982. This pond is located between two community cattle pastures and it was decided to determine whether or not activities in these areas were impacting on the system. The counts for total coliforms were low. The fecal coliforms, Escherichia coli, are enteric bacteria of warm-blooded vertebrates and are indicators of fecal pollution. The low numbers seen were probably due to input of fecal material from the various animals associated with a natural system, i.e. birds, muskrats, etc., and not due to man.

Table 3 . Physical and bacteriological parameters for Big Northern Pd.

Sample Date	Coliform Bacteria Total	Fecal	Rainfall[a] (mm)	Temp. C	pH[b]
25/09/81	130	0	72.0	10	
02/10/81	4	4	17.6	9	
12/11/81	170	8	77.1	4	5.06
22/11/81	170	2	59.0	4	
27/01/82	49	0	53.2	-1	4.65
08/02/82	49	0	33.0	0	
07/04/82	49	2	44.9	1	4.13
14/04/82	240	0	49.0	1	
07/06/82	220	0	2.2	14	
14/06/82	49	0	0.0	15	5.10
24/08/82	23	0	30.3	15	
30/08/82	31	0	60.2	16	4.68
15/11/82	31	0	8.2	5	
24/11/82	180	0	16.7	3	5.20

[a]Total rainfall for 7 days preceeding sample collection

[b]pH determined during bimonthly water chemistry samples.

Biological Parameters

Young of the Year

Emergence

The time of emergence of the free-swimming young of the year *S. fontinalis* in the outlet stream of Big Northern Pond was quite variable with individuals emerging at the beginning of May in some years while in other years the emergence was delayed until mid-June. This affected the sample size obtained (Table 4).

The data (Table 4) show the number of individuals taken by month for years 1983 through 1986 as well as the mean condition factors for these specimens. In all, a total of 161 fish larvae were examined. This table also indicates the months when emergent larvae were available in the water column. Samples were taken each year within two or three days of the middle of each month to give comparable growth periods. During the May 1985 sampling trips, no emergent larvae were obtained from open water. The water temperatures were high ($\geq 20^{0}C$) during August of 1984 and 1986 and no fish were found in the stream.

Morphometric Characteristics

Table 5 demonstrates some of the physical parameters related to forklength of young of the year fish. The measurements shown all have high R^2 values. The most significant parameters to be noted are those for the slopes of the length-weight relationships. It is generally accepted that the slope

Table 4; Condition factors for 0^+ S. fontinalis in Big Northern Pond

	Year	Sex	May(N)	June(N)	July(N)	August(N)	October(N)
Whole Weight Condition Factor	1983	F	0.70(5)	0.76(8)	0.86(4)	0.80(4)	-
		M	0.75(2)	0.82(12)	0.90(8)	0.74(12)	-
	1984	F	0.50(2)	0.57(7)	0.54(9)	-	-
		M	0.45(2)	0.61(7)	0.55(9)	-	-
	1985	F	-	0.66(16)	0.72(1)	0.68(6)	0.61(2)
		M	-	0.66(9)	0.72(8)	0.68(6)	0.58(2)
	1986	F	0.63(3)	0.70(7)	0.64(6)	-	-
		M	0.59(6)	0.63(5)	0.61(6)	-	-
Gutted Weight Condition Factor	1983	F	0.44(5)	0.33(8)	0.48(4)	0.44(4)	-
		M	0.38(2)	0.38(12)	0.48(8)	0.41(12)	-
	1984	F	0.10(2)	0.07(7)	0.09(9)	-	-
		M	0.07(2)	0.09(7)	0.10(9)	-	-
	1985	F	-	0.43(16)	0.51(1)	0.44(5)	0.38(2)
		M	-	0.44(9)	0.49(9)	0.45(6)	0.38(2)
	1986	F	0.08(3)	0.06(6)	0.08(6)	-	-
		M	0.07(6)	0.06(5)	0.07(6)	-	-

Table 5: Statistics for linear regression of log depth, whole weight and gutted weight versus the log of fork-length for 0 fish of Big Northern Pond.

Year	Parameter	Slope	Intercept	r^2	N
	Depth	1.2358	-1.9959	.966	57
1983	Whole Weight	3.3032	-4.8373	.988	57
	Gutted Weight	3.5313	-5.5137	.957	57
	Depth	1.4203	-2.2247	.980	36
1984	Whole Weight	3.3032	-5.2019	.989	36
	Gutted Weight	4.6687	-7.0685	.965	36
	Depth	1.4089	-2.2476	.955	42
1985	Whole Weight	3.4058	-5.0080	.993	42
	Gutted Weight	3.5582	-5.4250	.994	41
1986	Depth	1.3795	-2.2037	.979	25
	Whole Weight	3.4431	-5.0706	.994	34
	Gutted Weight	4.5674	-7.3108	.990	33

for salmonids is equal to a value approximating 3 (Wiseman, 1966) and this value is appropriate when the growth is isometric (Bagenal and Tesch, 1978). It is shown however (Table 5) that the values for 0+ fish are not indicative of isometric growth but rather an allometric pattern (all values of the slope of whole fish being greater than 3.3 and those of gutted fish being greater than 3.5 and with some values greater than 4.0). The slopes for fish older than age 0 were found to be similar and not significantly different from a value of 3.

Length-Depth Relationships

The relationship of body depth on forklength by year for young of the year fish is presented in Table 5. The slope is statistically different for 1983. This can be best explained by different times of emergence, the period during which feeding was initiated and the rate at which the yolk sack was resorbed. The general relationship is illustrated in Fig. 3. The two outliers are real and could possibly be due to the later emergence of young from a specific egg batch and/or the late emergence of young due to the prolonged period of spawning whereby those spawned early would have an advantage over late spawners. This effect is exemplified in length-weight data.

Length-Depth Relationships of fish age greater than 0

The mean values for length and depth characteristics are shown by sex and age by year (Table 6a) and are plotted for all

Figure 3: Log of body depth (cm x 10^{-2}) with log of forklength (cm x 10^{-2}) for S. fontinalis. Age 0^{+}

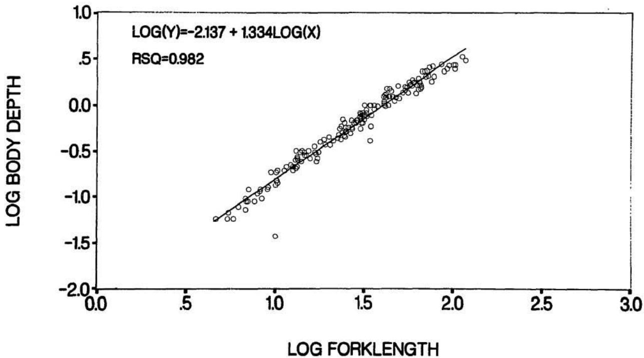

LOG(Y)=-2.137 + 1.334LOG(X)
RSQ=0.982
LOG BODY DEPTH
1.0
.5
0.0
-0.5
-1.0
-1.5
-2.0
0.0
.5
1.0
1.5
2.0
2.5
3.0
LOG FORKLENGTH

Table 6a: Mean values of morphometric characteristics by age for year for S. fontinalis in Big Northern Pond

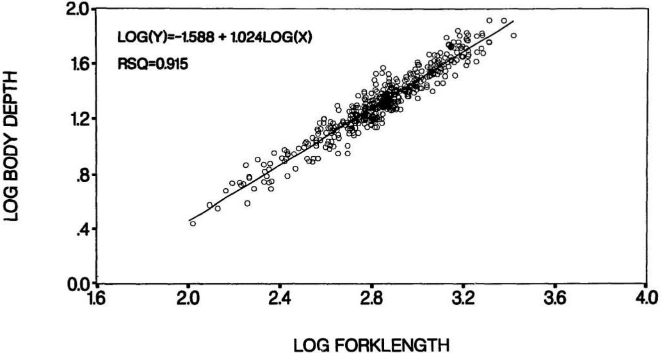
Year	Sex	0^+(N)	1^+(N)	2^+(N)	3^+(N)	4^+(N)	5^+(N)
				Length (cm)			
1982	F	5.90(02)	13.87(06)	16.59(27)	17.51(15)	19.97(03)	25.79(09)
	M	7.10(02)	14.08(04)	16.62(21)	17.54(09)	20.00(03)	--
1983	F	4.21(21)	13.06(02)	13.06(02)	17.65(12)	20.53(34)	23.79(02)
	M	5.12(34)	12.26(08)	15.17(17)	20.12(14)	22.66(03)	--
1984	F	3.91(18)	12.36(07)	16.13(21)	18.31(07)	22.82(02)	26.99(02)
	M	3.65(18)	12.57(11)	16.22(17)	19.41(03)	25.08(06)	--
1985	F	4.00(18)	11.92(12)	17.88(03)	19.84(05)	21.85(04)	26.21(02)
	M	4.20(23)	12.73(13)	16.24(28)	19.52(03)	22.21(08)	24.40(05)
1986	F	4.18(16)	14.75(04)	16.37(04)	20.41(16)	24.77(03)	--
	M	4.09(17)	14.08(09)	18.21(09)	22.31(08)	24.72(03)	29.20(1)
				Depth (cm)			
1982	F	1.23	2.71	3.55	3.87	4.17	5.36
	M	1.49	3.10	3.62	3.66	4.39	--
1983	F	0.80	2.84	3.91	4.33	5.45	5.60
	M	1.04	2.67	3.36	4.35	5.25	--
1984	F	0.82	2.58	3.31	3.83	4.75	5.99
	M	0.70	2.84	3.49	4.10	5.39	--
1985	F	0.77	2.65	4.14	4.35	4.66	6.45
	M	0.83	2.86	3.86	4.63	5.27	5.96
1986	F	0.93	2.92	3.47	4.44	5.42	--
	M	1.04	3.24	4.07	5.25	5.80	6.77

Table 6b: Mean values of morphometric charactristics by age for year for S. fontinalis in Big Northern Pond (continued)

Year	Sex	0^{+}(N)	1^{+}(N)	2^{+}(N)	3^{+}(N)	4^{+}(N)	5^{+}(N)
				Whole Weight (g)			
1982	F	2.21	33.70	61.46	74.26	108.53	230.08
	M	4.27	39.35	64.10	71.55	108.53	—
1983	F	1.21	31.34	76.18	112.56	175.98	188.50
	M	2.24	26.31	48.20	108.36	160.56	—
1984	F	1.41	24.70	51.30	78.57	142.83	262.62
	M	0.75	25.92	53.67	91.92	185.47	
1985	F	1.15	23.60	74.78	98.37	131.08	270.98
	M	1.32	25.69	54.24	105.11	136.50	184.51
1986	F	1.30	36.73	51.13	115.83	201.41	—
	M	1.39	38.54	74.89	144.42	202.82	326.90
				Gutted Weight (g)			
1982	F	2.23	30.69	54.96	65.13	97.13	208.75
	M	—	34.85	57.52	64.74	99.14	—
1983	F	0.94	17.82	67.60	98.88	152.07	168.90
	M	1.72	23.24	42.91	97.71	138.77	
1984	F	1.10	21.97	45.68	70.42	127.13	234.10
	M	0.56	22.77	48.61	82.41	168.64	
1985	F	0.93	19.99	65.73	83.16	112.87	216.05
	M	1.12	22.66	48.99	93.25	125.58	169.74
1986	F	1.05	32.81	44.81	101.51	176.62	
	M	1.08	33.83	67.05	129.42	183.99	292.40

years (Fig 4). The pooled sample shows a high correlation (R^2 = .915) for depth on length. Generally speaking the data assume a fairly linear relationship with equal variances over the range of forklengths. The increase in depth (Table 6a) shows that the degree of change is variable between sex as well as between years, being due in part to sexual maturity. The maximum depth recorded was for a 5+ male collected in October 1986.

Figure 4: Log of depth (cm x 10^{-2}) with log of forklength (cm x 10^{-2}) for S. fontinalis. Age greater than 0^+.

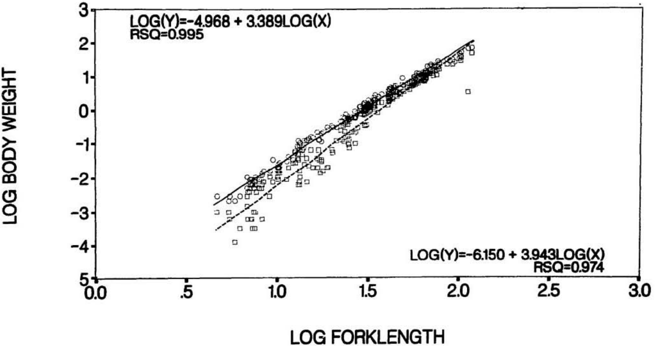


LOG(Y)=-1.588 + 1.024LOG(X)
RSQ=0.915
LOG BODY DEPTH
LOG FORKLENGTH
2.0
1.6
1.2
.8
.4
0.0
1.6
2.0
2.4
2.8
3.2
3.6
4.0

Length-Weight Relationship (Age Equal to 0)

The length-weight relationships for 0+ fish were variable between years and are presented in (Table 5). The comparison for pooled data in Fig. 5 (all years combined) shows the relationships of gutted weight to whole weight are different. The gutted weight (broken line and squares) showed more initial variability than that of the whole weight (solid line and circles). This variability changed over time and the fish approached a relatively common point where most members resembled each other in length and weight. A possible explanation of this phenomenon would be a higher mortality of smaller individuals. However, samples of fish age >1+ showed the same variability that one would expect within any population. Fig. 5 demonstrates that there is a change in the physiological state of the larval fish. The regression lines for whole and gutted weights cross at an approximate log value for fork length of 2.25. These trends show a change in body development whereby the relationship of the whole weights-gutted weights reverse indicating a change where there is a relative increase in total body weight while there is a lower increase in the somatic weight. This change in the ratio of gutted to whole weights then remains constant in older fish (see results later in text).

Figure 5: Log of body weight (g) on log forklength (cm x 10^{-2}) for whole and gutted weights of S. fontinalis of age 0^{+}. Solid line represents whole weight, broken line represents gutted weight



LOG(Y)=-4.968 + 3.389LOG(X)
RSQ=0.995
LOG(Y)=-6.150 + 3.943LOG(X)
RSQ=0.974
LOG BODY WEIGHT
LOG FORKLENGTH
3
2
1
0
-1
-2
-3
-4
5
0.0
.5
1.0
1.5
2.0
2.5
3.0

The comparison of length-weight relationships by year for 0+ fish (Table 7) shows that there are significant differences in the slopes between 1982 and 1986, 1983 and 1986, and 1984 and 1985. The slopes, which represent the changes in weight with length, are variable and demonstrate differences which may not be seen when repetitive samples are not available.

The intercepts for the years under study are shown (Table 8) and it was found that the intercepts for some years were significantly different from each other (Table 7). This is indicative of the differing emergence times.

Length-Weight Relationship (Age Greater than 0)

The mean values for lengths and weights for ages and sexes by year can be seen in Tables 6a and b for fish of age greater than 0. Regressions for these data are shown in Table 8 for each year 1982 through 1986. Relationships of length with both whole and gutted weights had very high R^2 values(>.97). The slopes approximated the value (3) reported as normal for salmonids in general (Wiseman, 1969) and other salmonids in this system in particular (Wiseman, 1971, 1972; Baggs and Cowan, unpublished data). Similar results for this species were found in Labrador (Wheeler, 1977). It would appear that the patterns of growth in <u>S. fontinalis</u> are similar in terms of the length-weight

Table 7: Comparison of regression lines of log whole weight with log fork length of Salvelinus fontinalis. Age = 0

Comparison (years)	Slope (Sig)	Intercept (Sig)
82/83	NS[1]	NS
82/84	NS	NS
82/85	NS	NS
82/86	S[2]	S
83/84	NS	S
83/85	NS	S
83/86	S	NS
84/85	S	S
84/86	NS	S
85/86	NS	S

1. NS - Not Significant

2. S - Significant $P \leq 0.05$

Table 8: Log of depth, whole weight and gutted weight with the log of fork length for all fish, age equal to zero not included.

Year	Parameter	Slope	Intercept	R^2	N
1982	Depth	1.0066	-1.5633	.869	97
	Whole Weight	3.0464	-4.4427	.981	97
	Gutted Weight	3.0622	-4.5955	.984	97
1983	Depth	1.0242	-1.5976	.934	103
	Whole Weight	2.9624	-4.2352	.983	103
	Gutted Weight	2.9835	-4.4223	.982	102
1984	Depth	0.9552	-1.4273	.932	86
	Whole Weight	2.9214	-4.1821	.983	86
	Gutted Weight	3.0026	-4.5196	.984	84
1985	Depth	1.0815	-1.6940	.935	87
	Whole Weight	3.0105	-4.4031	.983	87
	Gutted Weight	3.0803	-4.7258	.977	87
1986	Depth	1.0404	-1.6240	.910	57
	Whole Weight	3.0598	-4.5525	.973	57
	Gutted Weight	3.0791	-4.7322	.974	57

relationships in different areas of Newfoundland and Labrador. A comparison of the length-weight regressions was undertaken using a hierarchial F test (Table 9) to determine if any differences exist on a year to year basis. No significant differences were detected between years. The evaluation of the intercepts, however, revealed significant differences. Since the data were not significantly different between years, they were pooled and plotted (Fig. 6) for both whole and gutted weights. A Pearson correlation coefficient was determined (r = .998) for gutted versus whole weights. These results indicate no differences due to sex, age, or maturity. In this instance there was no change in the pattern of growth as the gutted or lower weights (broken line) always remain to the left. The R^2 values for whole weight ($R^2 = 0.981$) and gutted weight ($R^2 = 0.980$) are similar.

Condition Factor

Condition Factors of Age 0+ Fish

The most noticeable characteristic of the condition factor was that the changes in whole weights and gutted weights were not necessarily synchronous. The data of all years (Fig. 7) exemplifies that there were considerable differences in the gutted condition when compared to whole weight condition factors. The peaks in condition (whole weight) varied. Peaks seen in 1983 and 1985 occurred in July while June appears to be the

Table 9: Comparrison of regression lines of morphometric characters by year for *Salvelinus fontinalis* in Big Northern Pond. Age > 0.

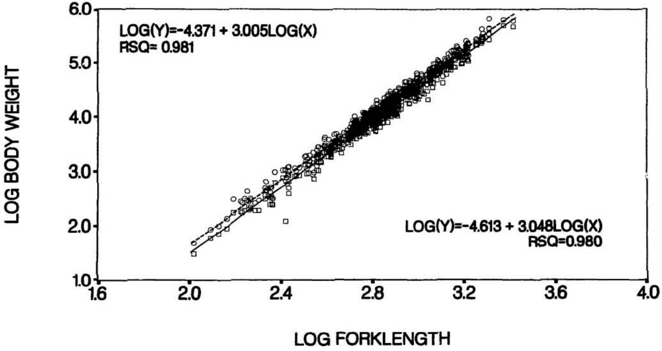
Comparrison (years)	LWW[1] with LFL[2] Slope (Sig)	Intercept (Sig.)	Lgut[3] with LFL Slope (Sig.)	Intercept (Sig.)	LLV[4] with LFL Slope (Sig.	Intercept (Sig.)
82/83	NS[5]	S[6]	NS	S	NS	S
82/84	NS	S	NS	S	NS	S
82/85	NS	S	NS	S	NS	NS
82/86	NS	S	NS	S	NS	S
83/84	NS	S	NS	S	NS	S
83/85	NS	S	NS	NS	NS	NS
83/86	S	NS	NS	NS	NS	NS
84/85	NS	NS	NS	NS	NS	NS
84/86	NS	NS	NS	NS	NS	S
85/86	NS	S	NS	NS	NS	NS

1. Log whole weight
2. Log Forklength
3. Log Gutted Weight
4. Log Liver Weight
5. NS - Not Significant
6. S - Significant

Figure 6: Log of whole weight (g) and gutted weight (g) on log of forklength (cm x 10^{-1}) for S. fontinalis. Age greater than 0^+.

(A) Broken line represents whole weight

(B) Solid line represents gutted weight



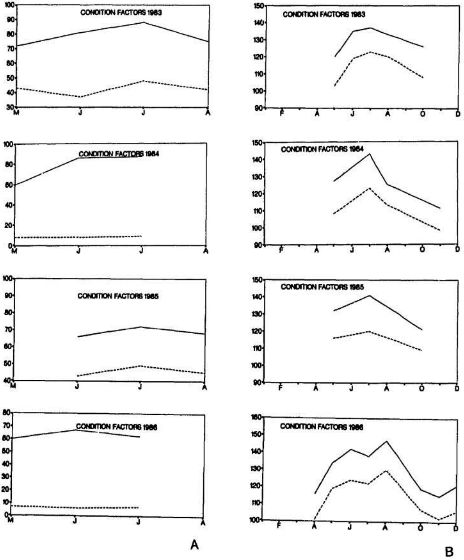
LOG(Y)=-4.371 + 3.005LOG(X)
RSQ= 0.981
LOG(Y)=-4.613 + 3.048LOG(X)
RSQ=0.980
LOG BODY WEIGHT
LOG FORKLENGTH
6.0
5.0
4.0
3.0
2.0
1.0
1.6
2.0
2.4
2.8
3.2
3.6
4.0

Figure 7: Coefficient of Condition (X100) by month by year of *S. fontinalis* for *(A) Young of the year fish. **(B) Fish age $\geq$ 1

Solid line represents whole weight

Broken line represents gutted weight

*   See (Table 4) for means
**   See (Table 6a) for means


CONDITION FACTORS 1983
M J J A
CONDITION FACTORS 1983
F A J A O D
CONDITION FACTORS 1984
M J J A
CONDITION FACTORS 1984
F A J A O D
CONDITION FACTORS 1985
M J J A
CONDITION FACTORS 1985
F A J A O D
CONDITION FACTORS 1986
M J J A
CONDITION FACTORS 1986
F A J A O D
A
B

month at which peak condition was reached in 1984 and 1986.

The condition factor for older fish was determined in a fashion similar to that used for young of the year fish. It was found that the cube law applied.

The depression of whole weight condition was seen in August of 1983 and 1985 and commenced earlier in 1986 (July). The gutted condition factor of the young of the year fish for the years under study showed a more variable pattern than that for the whole weights. There was a depression in gutted condition in June of 1983.

The fish collected in 1984 and 1986 were, in terms of the gutted condition, the poorest of all specimens collected. The whole weight condition would suggest that these fish were on a par with other years. However, when the gutted condition was compared there was no increase in condition for these two year classes during the study period.

Condition Factor of Fish Age Greater than 0

Seasonal changes in condition for both whole and gutted weights are presented in Fig. 7(B). The gutted condition factor closely paralleled that of the whole weight condition factor. Generally speaking there was a peak in condition during July for most years. This was delayed, however, in 1986 to August due most probably to temperature. The temperature regime for 1986 was lower than all other years and may well have slowed emergence of prey items allowing for better feeding. It is also noted that the peak condition was higher in 1986 than other years and this was most probably due to more stable water temperatures which cause lowered physiological stress.

There were two apparent low periods in condition. These were seen in November and April. These lows were noted also for S. salar in this pond (Cowan, unpublished data). The low seen in April is not felt to be due to food shortages as the fish were actively feeding, but rather to changes in temperature. Stability in temperature appears to allow for increasing condition factor while fluctuating temperatures cause lowered condition factors. This effect can be exacerbated in April by the episodic depression in pH seen in spring runoffs.

Age Composition

The size of S. fontinalis when first scales appeared was 4.0 cm., these scales obtainable in July samples. Scale development followed a similar course to that described by Curtis (1988) for

S. fontinalis in the lower part of the Topsail-Manuels system. The regression for 5 years pooled data for *S. fontinalis* is presented in Figure 8. The R^2 value of 0.879 indicates a high relationship between forklength and scale length.

The incremental growth based on back calculations is presented in Table 10. The data are variable and reflect the individuality of a growing population. There does appear to be a trend towards a lower growth rate as the fish increase in age.

Cohort Analysis

A hierarchial F test to compare the slopes of cohorts was applied to the regressions (Table 11) and there was no significant difference. There was, however, a significant difference between the intercepts for 1979 and 1982, as well as 1980 and 1982.

The age structure (Fig. 9) of *S. fontinalis* in Big Northern Pond falls within the ages reported for insular Newfoundland by Wiseman (1969). The combined age frequency for all years is presented in Fig. 10. Fish of age 5+ were consistently encountered during the course of the study.

Figure 8: Regression plot of log forklength (cm x 10^{-2}) versus log scalelength (cm x 10^{-2}) for *S. fontinalis*.

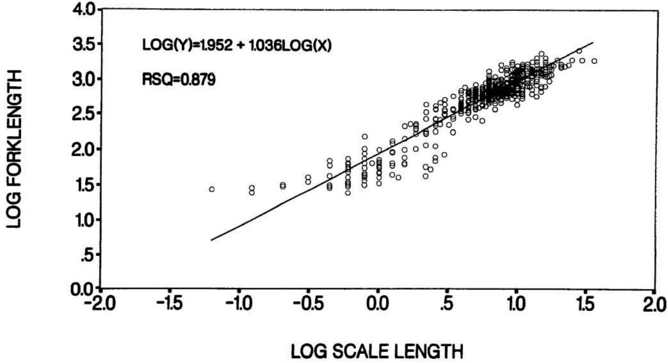

LOG(Y)=1.952 + 1.036LOG(X)
RSQ=0.879
LOG FORKLENGTH
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0.0
-2.0
-1.5
-1.0
-0.5
0.0
.5
1.0
1.5
2.0
LOG SCALE LENGTH

Table 10: Mean Incremental growth of scales (cm x 43) of <u>Salvelinus fontinalis</u> from Big Northern Pond

Annular Increment	Age at capture	1978	1979	1980	1981	1982	1983	1984	1985	1986
1	1					7.40 (1)	5.25 (6)	5.96 (24)	6.49 (14)	7.19 (13)
	2				5.28 (7)	4.95 (14)	4.97 (7)	5.52 (31)	6.13 (26)	
	3			5.25 (2)	5.15 (6)	5.28 (10)	5.59 (42)	6.59 (26)		
	4		4.23 (2)	5.94 (8)	6.12 (51)	6.04 (31)	6.79 (12)			
	5	5.69 (9)	4.20 (6)	5.43 (24)	8.25 (48)	9.27 (10)				
2	2					3.41 (7)	4.30 (1)	3.90 (6)	5.22 (24)	6.35(13)
	3				4.25 (2)	4.77 (6)	3.53 (14)	4.25 (7)	4.50 (31)	
	4			3.48 (2)	4.11 (8)	4.53 (51)	4.08 (10)	4.57 (42)		
	5		3.43 (9)	2.98 (6)	3.64 (24)	4.32 (48)	4.87 (31)			
3	3					4.75 (2)	4.24 (7)	2.80 (1)	5.75 (6)	5.84 (24)
	4				4.48 (2)	5.94 (8)	5.78 (6)	5.13 (14)	5.92 (7)	
	5			4.10 (9)	3.72 (6)	3.92 (23)	5.58 (51)	5.02 (10)		
4	4					5.28 (2)	4.05 (2)	4.12 (7)	6.10 (1)	4.98 (6)
	5				4.83 (9)	3.85 (6)	3.71 (8)	4.63 (6)	4.69 (14)	
5	5					4.03 (9)	3.50 (2)	5.10 (2)	4.26 (6)	2.40 (1)

Table 11: Comparison of regression lines of log of whole weight with log of fork length of *Salvelinus fontinalis*. Co-hort analysis.

Comparison (years)	Slope (Sig.)	Intercept (Sig.)
79/80	NS	NS
79/81	NS	NS
79/82	NS	S
79/83	NS	NS
80/81	NS	NS
80/82	NS	S
80/83	NS	NS
81/82	NS	NS
81/83	NS	NS
82/83	NS	NS

NS - Not significant.
S - Significant.

Figure 9: Age Frequency of <u>S. fontinalis</u> by years.

AGE FREQUENCY, S. FONTINALIS

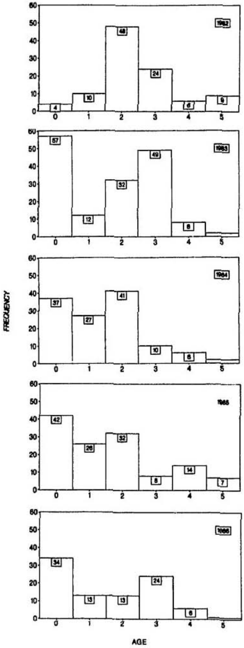
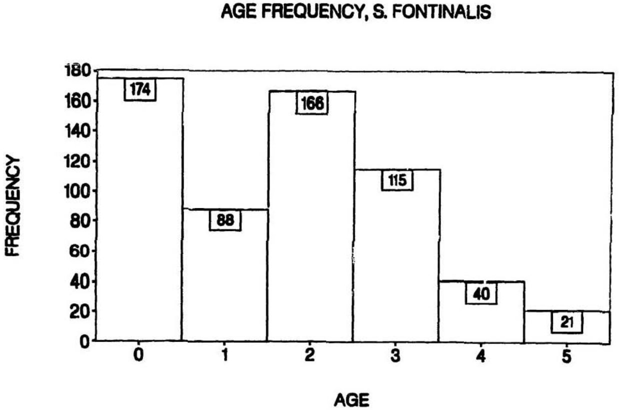


Figure 10: Age frequency of *S. fontinalis*: 5 years pooled data.


AGE FREQUENCY, S. FONTINALIS
FREQUENCY
0
20
40
60
80
100
120
140
160
180
174
88
166
115
40
21
0
1
2
3
4
5
AGE

Mortality

The mortality curves from pooled data for each year plus the pooled data of all years are presented (Fig. 11).

The data show that for 1982, 1984 and 1986 the mortality rates were relatively similar whereas in 1983 and 1986, which also appear similar, there was an interruption in the decline in the mortality rates. This is most likely to be an effect of strong year classes in the previous years. The 2+ year class of 1982 seems to have carried over to 1983 and the 2+ year class of 1985 seems to translate into a strong 3+ year class during 1986. The catch of brook charr was not greatly different in 1982 (N=97) and 1985 (N=83). The stations and nets where the fish were obtained for all years of the study were exactly the same. If one assumes that the behaviors of the fish were the same from year to year, then the year class data would suggest that some environmental or physiological factors led to the presence of strong year classes.

Growth

The mean lengths of S. fontinalis by age for Big Northern Pond and other ponds in the Topsail-Manuels watershed are shown in Table 12. The values for length for all areas were similar even though there was a difference in ecotypes and it would appear that pH does not limit the growth of S. fontinalis in Big Northern Pond (mean pH=4.7) when compared to the mean pH of Three Arm Pond (which has a value of 5.6). The data for Big Northern Pond were remarkably similar for each year with very little

Figure 11: Catch curves for S. fontinalis

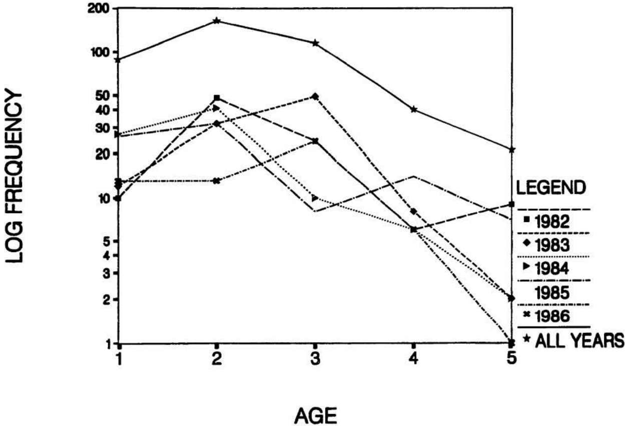

LOG FREQUENCY
200
100
50
40
30
20
10
5
4
3
2
1
1
2
3
4
5
AGE
LEGEND
1982
1983
1984
1985
1986
ALL YEARS

Table 12: Mean lengths (cm) for ages of *Salvelinus fontinlis* during different years at different sites in the Topsail-Manuels watershed.

Year/Site	AGE 0^{+}	1^{+}	2^{+}	3^{+}	4^{+}	5^{+}
1965 Thomas Pond	-	14.20(2)	19.47(47)	22.07(56)	-	-
1982 Paddy's Pond (Manual's River)	-	11.62(37)	-	-	-	-
1981 Three Arm Pond	-	14.57(16)	18.49(1)	20.75(3)	-	-
1982 Big Northern Pond	6.5(4)	13.95(10)	16.60(48)	17.52(24)	19.88(6)	25.79(9)
1983 "	4.74(57)	12.17(12)	16.20(32)	20.42(49)	23.65(49)	23.79(2)
1984 "	3.78(36)	11.57(27)	16.10(41)	18.64(10)	24.32(6)	26.99(2)
1985 "	4.08(42)	12.32(26)	16.40(32)	1972(8)	22.20(14)	24.92(7)
1986 "	4.13(34)	14.29(13)	17.64(13)	21.04(24)	24.75(6)	29.20(1)

variation in mean lengths. There tends to be a slight increase in the mean sizes by age in 1986 which may be due to lower sample numbers taken that year.

The length and weight frequencies for each year are presented in Tables 1 to 10 in the appendix.

Sex Ratio - Young of the Year

The sex ratio of young of the year fish was approximately 1:1. (Table 13). The sex ratios of S. fontinalis in other localities in Newfoundland are in agreement with this value (Wiseman, 1969).

Sex Ratio - Older than 0

The sex ratio by age for fish older than age 0 is presented in Table 14. The data show that over the 5-year lifespan of S. fontinalis there were approximately equal numbers of males and females. This is similar to the data for age 0 S. fontinalis (Table 13). There was, however, a difference in the sex ratios over the lifespan of the fish. The most rapid decline in numbers was for males beginning at age 2+, whereas the decline was more apparent after age 3+ for the females. This effect was noted during most years of the study. Table 14 also demonstrates that both sexes were capable of reaching the maximum age of 5+ in this habitat.

Table 13: Sex ratios of young of the year *Salvelinus fontinalis* by month for year in the outlet stream of Big Northern Pond.

	May		June		July		August		Totals	
	F	M	F	M	F	M	F	M	F	M
1983	5	2	8	12	4	8	4	12	21	34
1984	2	2	7	7	9	9	-	-	18	18
1985	-	-	16	9	1	8	6	6	23	23
1986	3	6	7	5	6	6	2	2	18	19

Table 14: Sex ratio by year for age of <u>Salvelinus</u> <u>fontinalis</u> from Big Northern Pond.

		AGE					
YEAR	Sex	1	2	3	4	5	Total(N)
1982	F	6	27	15	3	9	60
	M	4	21	9	3	0	37
1983	F	2	12	34	5	2	55
	M	8	17	14	3	0	42
1984	F	7	21	7	2	2	39
	M	11	17	3	4	0	35
1985	F	12	3	5	4	2	26
	M	13	28	3	8	5	57
1986	F	4	4	16	3	0	27
	M	9	9	8	3	1	30
Totals	F	31	67	77	17	15	207
	M	45	92	37	21	6	201

Maturity

Maturation of charr started in the second year of life for both sexes (Table 15) and no precocity of males was seen during the study period. The ratio of reproductive males to females was approximatley 2:1. The rate of gonad development was relatively slow in early summer and increased after August. The composition of the population in terms of maturity during late October and early November was 6% for stage 4 and 94% for stage 5 which indicates that most of the population was in full reproductive condition at the same time. Spawning activity in the pond tended to be about 2 weeks later than in the stream (Cowan and Baggs, 1988). The data for reproductively active (maturity >3) and non-active charr is shown in Table 16.

Food Analysis

Young of the Year

Feeding by young of the year fish in the stream outlet of Big Northern Pond was restricted to the stream fauna and any invertebrate drift carried downstream through the slow moving water. The date of commencement of feeding in these fishes was variable, due to times of emergence, and took place before yolk sac resorbtion is complete. The data (Table 17 a,b) show commencement of feeding in May of 1983, 1984 and 1986. These fish had large yolk sacs and very few food items in the digestive tract. The sample taken in May 1984 demonstrates the rather limited variety of the food utilized as the fish began exogenous

Table 15: Mean numbers of reproductivl· active *Salvelinus fontinalis* from Big Northern ·ond for all years.

Age	(N)	%
2	29	43.3
3	18	26.9
4	14	20.9
5	6	9.0

SEX	(N)	%
F	21	31.3
M	46	68.7

Maturity	(N)	%
4	4	6
5	63	94

Table 16: Yearly comparison of reproductively active vs non active *Salvelinus fontinalis* in Big Northern Pond by length (cm) for age

		Active		Non-Active	
Year	Age	Length (cm) Females	Length (cm) Males	Length (cm) Females	Length (cm) Males
1983	2	-	16.94 (3)	17.65 (12)	14.80 (14)
	3	21.23 (6)	20.00 (1)	20.38 (28)	20.17 (12)
	4	24.82 (3)	23.20 (1)	23.38 (2)	22.40 (2)
	5	-	-	23.79 (2)	-
1984	2	17.81 (1)	17.38 (2)	16.05 (20)	16.06 (15)
	3	18.46 (1)	19.12 (2)	18.29 (6)	20.00 (1)
	4	-	-	22.82 (2)	25.08 (4)
	5	-	-	26.99 (2)	-
1985	2	17.42 (2)	16.25 (16)	18.69 (1)	16.23 (12)
	3	20.07 (2)	20.08 (1)	19.69 (3)	19.25 (2)
	4	21.77 (3)	21.94 (6)	22.08 (1)	23.04 (2)
	5	25.00 (1)	24.40 (5)	27.42 (1)	-
1986	2	-	19.71 (5)	16.37 (4)	16.33 (4)
	3	23.65 (1)	23.66 (4)	20.20 (15)	20.97 (4)
	4	30.45 (1)	-	21.94 (2)	24.72 (3)
	5	-	-	-	29.20 (1)

Table 17a: Percentage of Salvelinus fontinalis stomachs containing specific food items for young of the year fish in Big Northern Pond by year and by month. () = Number in sample

Group	1983 May (15)	1983 June (13)	1983 July (12)	1983 Aug (17)	1984 May (4)	1984 June (14)	1984 July (18)	1985 June (17)	1985 July (9)	1985 Aug (11)	1985 Oct (4)	1986 May (9)	1986 June (18)	1986 July (12)
Gastropoda														
Pelycepoda														
Cladocera	13.3	7.7	-	35.3	-	50.0	38.9	88.4		33.3	45.5	-	11.1	-
Amphipoda	6.7	-	-	5.9	-	7.1	-							
Isopoda												11.1	-	
Copepoda														
Archinida					-	7.1	-							
Hydracarina	6.7	-	-	5.9	-	14.3	22.2	-	22.2	18.2	-			
Diplopoda														
Ephemeroptera	-	-	-	11.8	-	-	5.6	-	-	9.1	-			
Odonata	-	30.8	33.3	17.6	-	42.9	55.6	-	66.7	81.8	25.0	33.3	-	33.3
Plecoptera	-	-	25.0	5.9	-	7.1	-	-	11.1	-	-	11.1	23.1	
Hemiptera	-	-	16.7	5.9				-	11.1	-	25.0			
Coleoptera	26.7	23.1	25.0	5.9	-	28.6	22.2	29.4	22.2	36.4	-	11.1	15.4	8.3
Trichoptera	33.3	61.5	41.7	11.8	-	50.0	33.3	-	66.7	36.4	-	11.1	30.8	33.3
Unidentified Diptera	80.0	76.9	83.3	29.4	-	57.1	66.7	29.4	77.8	63.6	75.0	77.8	92.3	83.3
Chironomidae	86.7	92.3	91.7	82.4	-	71.4	94.4	100.0	-	81.8	50.0	-	84.6	75.0
Ceratopogonidae	26.7	15.4	-	17.6	-	21.4	44.4	16.8	11.1	27.3	-	-	15.4	16.7
Hymenoptera					-	-	16.7		-	36.4	25.0			16.7
Fish Eggs														

STOMACH

Table 17b: Percentage of Salvelinus fontinalis stomachs containing specific food items for young of the year fish in Big Northern Pond by year and by month. () = Number in sample

	1983				1984			1985				1986		
Group	May (15)	June (13)	July (12)	Aug (17)	May (4)	June (14)	July (18)	June (17)	July (9)	Aug (11)	Oct (4)	May (9)	June (18)	July (12)
Gastropoda														
Palycepoda	-	7.7	-	11.8								33.3	7.7	25.0
Cladocera	6.7	15.4	-	11.8	25.0	57.1	38.9	94.1	44.4	36.4	-			
Amphipoda												11.1	7.7	
Isopoda														
Copepoda														
Arachnida														
Hydracarina	6.7	-	-	-	-	7.1	5.6					-	7.7	
Diplopoda														
Ephemroptera	6.7	-	-	-										16.7
Odonata	13.3	30.8	41.7	-	-	28.6	61.1		44.4	72.7	-			
Plecoptera	6.7	-	-	-										
Hemiptera	-	-	16.7	11.8								-	15.4	8.3
Coleoptera	6.7	38.5	33.3	5.9	-	21.4	22.2	17.7	11.1	9.1	50.0			
Trichoptera								17.7	-	9.1	-	11.1	23.1	
Unidentified Diptera	73.3	76.9	8.3	41.2	-	71.4	66.7	17.7	77.8	54.5	50.0	22.2	-	8.3
Chironomidae	66.7	46.2	-	76.5	50.0	42.9	83.3	180.0	77.8	72.7	50.0	77.8	84.6	66.7
Ceratopogonidae	33.3	-	8.3	17.6	25.0	21.4	55.6		22.2	-	-	88.9	76.9	33.3
Hymenoptera	13.3	-	-	-	-	14.3	11.1		11.1	9.1	-	11.1	15.4	16.7
Fish Eggs														

feeding. Fish which had just emerged in late May-early June of 1985 had pronounced yolk sacs and few food items in the digestive system.

The data show the diet to be relatively similar to that of the adults (Tables 18 a,b), the exception being fish eggs which are too big for consumption by these fish and the gastropods which are pond inhabitants and not likely to drift into the stream environment.

The only terrestrial food type not encountered were the millipedes which are suspected of being too large to be easily swallowed.

Table 18a: Percentage of Salvelinus fontinalis stomachs containing specific food items from Big Northern Pond by year and by month for ages 1+ through 5+. () = Numbers in sample

	1982			1983					1984					1985					1986					
Group	Aug	May (16)	June (22)	July (14)	Aug (29)	Oct (18)	May (17)	June (1)	July (8)	Aug (11)	Nov (13)	May (3)	July (9)	Aug (13)	Oct (60)	Feb (5)	Apr (9)	May (1)	June (7)	July (9)	Aug (6)	Oct (17)	Nov (2)	Dec (2)
Gastropoda	13.0		4.5	7.1	24.1		12.6					66.7							14.3	11.1	16.7			
Pelycopoda		6.3	22.7	21.4	37.9		11.8					100.0		7.7	1.7	40.0	11.1		42.9	55.6		17.6	100.0	50.0
Cladocera	34.8	18.8	4.5	14.3	41.4			100.0	12.5	9.1	38.5		33.3	38.5	8.3	20.0			71.4	55.6	50.0	17.6	100.0	
Amphipoda	39.1	18.8	31.8	2^.6	58.6	11.1	35.3		12.5	36.4	53.8	100.0	22.2	23.1	1.7		11.1		14.3	55.6	33.3		100.0	50.0
Isopoda							29.4																	
Copepoda																						5.9		
Arachnida																	22.2					11.8		
Hydracarina	2.2		4.5		10.3		5.9		12.5					7.7										
Diplopoda							11.8																	
Ephemeroptera							5.9						22.2		1.7	40.0	33.3		57.1			17.6		50.0
Odonata	60.9	75.0	63.6	78.6	72.4	11.1	17.6		50.0	72.7	84.6	100.0	88.9	69.2	41.7	80.0	88.9		100.0	77.8	66.7	23.5	50.0	100.0
Plecoptera							11.8					100.0					11.1							
Hemiptera				7.1		5.6									6.7							17.6		
Coleoptera	8.7	37.5	13.6	21.4	6.9		29.4		25.0	18.2			11.1	7.7	11.7			100.0	57.1	33.3		35.3		
Trichoptera	6.5	56.3	4.5	14.3	37.9	38.9	70.6	100.0	37.5	18.2	46.2	33.3	22.2	7.7	28.3	60.0	44.4		57.1	33.3		58.8		50.0
Unid. Diptera	34.8	37.5	68.2	100.0	27.6	5.6	64.7		50.0	81.8	53.8		66.7	7.7	6.7	20.0	88.9	100.0	57.1	44.4	16.7	58.8		50.0
Chironomidae	8.7	56.3	40.9	14.3	6.9		41.2			9.1	23.1		11.1	7.7	3.3		22.2		14.3	11.1				
Ceratopogonidae													11.1	7.7										
Hymenoptera	2.2						5.9				7.7		11.1	7.7	53.8	25.0				11.1		41.2		
Fish Eggs		6.3				83.3										43.3						64.7		

Table 18b: Percentage of <u>Salvelinus fontinalis</u> intestines containing specific food items from Big Northern Pond by year and by month for ages 1+ through 5+. () = Numbers in sample

Group	1982	1983					1984					1985				1986								
	Aug (46)	May (16)	June (22)	July (14)	Aug (29)	Oct (18)	May (17)	June (1)	July (8)	Aug (11)	Nov (13)	May (3)	July (9)	Aug (13)	Oct (60)	Feb (5)	Apr (9)	May (1)	June (7)	July (9)	Aug (6)	Oct (17)	Nov (2)	Dec (2)
Gastropoda	6.5		9.1		27.6		12.6			9.1		66.7		7.7		20.0	11.1		28.6	22.2	16.7	17.6	50.0	100.0
Pelycopoda	10.9		9.1	7.1	44.8					45.5	23.1	66.7				80.0	66.7	100.0	85.7	55.6	16.7		50.0	100.0
Cladocera	13.0	12.5	4.5	7.1	48.3			100.0	37.5	9.1	23.1		11.1	46.2	5.0									
Amphipoda	6.5		27.3	21.4	27.6				12.5		23.1	33.3		15.4					5.0	44.4	50.0	5.9	100.0	
Isopoda							5.9																	
Copepoda											7.7									33.3	16.7		100.0	50.0
Arachnida											7.7													
Hydracarina					3.4																			
Diplopoda							11.8																	
Ephemeroptera			4.5				5.9										55.6		42.9		16.7	29.4		50.0
Odonata	41.3	62.8	50.0	50.0	72.4		11.8		12.5	18.2	53.8		55.6	53.8	26.7							17.6		
Plecoptera												33.3					44.4		57.1			17.6		
Hemiptera				7.1						9.1	7,7								14.3			5.9		
Coleoptera	2.2	37.5	13.6	7.1	10.3		22.5		12.5	9.1	7.7			7.7	3.3					11.1				
Trichoptera	6.5	37.5	4.5		37.9		29.4		25.0	9.1	46.2	66.7			20.0					11.1				
Unid. Diptera	26.1	50.0	50.0	85.7	13.8		41.2		37.5	45.5	38.5		55.6	15.4	1.7									
Chironomidae		6.3	9.1				17.6				7.7		22.2		8.3		77.8			14.3	55.6	16.7	17.6	
Ceratopogonidae											7.7		11.1	7.7			11.1							
Hymenoptera	4.3				3.4						23.1			46.2	16.7									
Fish Eggs					3.4	5.6	5.9				7.7				8.3								5.9	

The most important foods consumed by young fish were chironomids, which were utilized to a relatively constant degree, followed by dipterans (most probably larvae of simulids and tipulids), and members of the Coleoptera and Odonata.

Other items occurred less often. The data are, however, comparable as samples were taken at approximately the same time for each year and the handling was similar in all cases.

Fish of age greater than 0

The food in the diet tended to be larger as the bigger fish tended to eat larger prey items, notably Odonata. However, the opportunistic nature of the brook charr allowed for utilization of smaller prey items, ie Copepoda, Chironomidae and the Gastropoda. The differences in food items (occurrences) seen in monthly data reflect the seasonal changes in number and size of emergent prey species. There is, however, an apparent reliance in terms of frequency of occurrence on the Odonata, members of the Diptera, Coleoptera and Amphipoda, respectively (Table 19). There does not appear to be any difference in the occurrence of food items by year and no empty stomachs were encountered for fish during the period studied.

One food item seen in the digestive tracts of older S. fontinalis is fish eggs. It showed up in May and/or October-November samples in most years. The eggs seen in the August 1983 sample showed the type of resistance to breakdown that fish eggs display. The eggs were not identified as to species but it is

Table 19: Occurrence (%) of food items in the digestive tract of Salvelinus fontinalis from pooled data.

Stomach		Intestine	
Food Type	%	Food Type	%
Odonata	48.9	Diptera Sp.	30.7
Diptera Sp.	47.0	Odonata	30.1
Chironomidae	35.1	Chironomidae	29.2
Trichoptera	30.9	Cladocera	18.0
Cladocera	23.8	Trichoptera	14.7
Amphipoda	18.2	Pelecypoda	12.8
Coleoptera	17.3	Ceratopogonidae	9.9
Fish Eggs	12.1	Coleoptera	9.5
Hymenoptera	8.9	Amphipoda	8.6
Pelecypoda	8.6	Hymenoptera	7.1
Ceratopogonidae	6.5	Gastropoda	5.2
Gastropoda	4.3	Ephemeroptera	4.5
Ephemeroptera	4.3	Fish Eggs	2.6
Hydracarina	3.9	Plecoptera	2.2
Plecoptera	3.0	Hemiptera	1.9
Hemiptera	2.6	Copepoda	1.5
Arachnida	1.3	Hydracarina	0.7
Isopoda	0.9	Diplopoda	0.4
Diplopoda	0.4	Arachnida	0.4
Copepoda	0.4	Isopoda	0.2

suspected that eggs from S. fontinalis and S. salar are equally susceptible to predation because they are of similar size and co-occur.

One aspect lost when pooling data is that of individuality within the population in respect to feeding. There were numerous examples of what can be referred to as "binge feeding" whereby an individual fish will feed on one food item to the exclusion of all others. This behaviour has implications in terms of parasite transmission and is discussed elsewhere in the thesis.

Parasitism (Onset)

The results of five consecutive years of instream evaluation of larval development showing the onset and incidence of parasitism are presented (Table 20).

These observations indicate that for the periods studied only two helminth parasites of the digestive tract were established in the young-of-the-year host during the first four months of postemergent life. These parasites are Metechinorhynchus lateralis and Metabronema salvelini. The earliest presence of parasitism seen occurred in May 1983 when a 13% incidence was recorded for M. lateralis in female S. fontinalis. This parasite occurred in the stomachs and intestines of the young-of-the-year fish whereas M. salvelini, which was observed one month later, was found only in the stomach. M. lateralis was encountered on twice as many sampling dates as M. salvelini. There was a trend in the data such that most cases of parasitism were represented by a single parasite. Statistical analysis of prevalence data for

Table 20 : Onset and Incidence (%) of M. salvelini and M. lateralis in age 0+ S. fontinalis for 1982 through 1986 by month for sex.

Year	MO.	(N) F/M	Stomach (%) F/M M. salvelini	Stomach (%) F/M M. lateralis	Intestine (%) F/M M. salvelini	Intestine (%) F/M M. lateralis
1982	08	(4) 2/2	100/100	0	0	0
1983	05	(13) 8/5	0	0	0	13/0
	06	(12) 5/7	0	0	0	0
	07	(12) 3/9	0	0	0	67/11
	08	(18) 5/1	20/0	0/8	0	0/23
1984	05	(4) 2/2	0	0	0	0
	06	(15) 8/7	13/0	0	0	50/14
	07	(18) 9/9	11/0	0/11	0	33/33
1985	06	(16) 9/7	0	0	0	0
	07	(10) 1/9	0	0	0	0/13
	08	(12) 6/6	0	0	0	33/0
1986	05	(9) 3/6	0	0	0	0
	06	(12) 7/5	0	0	0	48/0
	07	(12) 6/6	1[illegible]/[illegible]	0	0	0/17

year, month and sex revealed no significant differences ($P \geq .05$). Differences could, however, be masked by the small sample sizes. Pooling of the data also failed to demonstrate any significant trends.

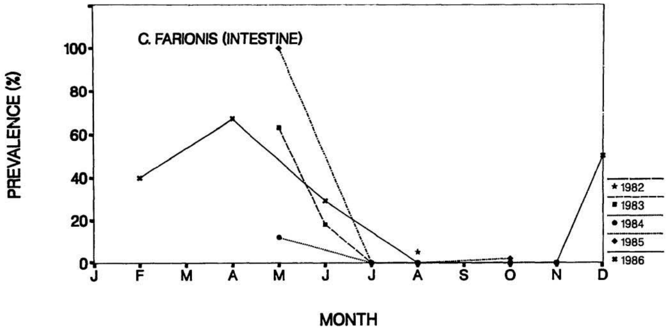
Examination of the food for young-of-the-year S. fontinalis revealed that ephemeropterans were encountered with M. salvelini in the samples of August 1983 and July 1984. The parasite was seen without the presence of the ephemeropterans and vice versa. The limits placed on the study by sample size and frequency, the amount of food eaten, and the intensity of infection within the intermediate hosts all would have an effect on the onset of M. salvelini in the brook charr.

Prevalence and seasonality of the parasites of the intestinal tract of S. fontinalis, age greater than 0^+.

Samples of the enteric parasites which may, physically or nutritionally, cause physiologic stress to the fish was studied. The samples of fish obtained from Big Northern Pond showed the presence of only four species of parasite in the digestive tract; a digenean, Crepidostomum farionis, a cestode, Eubothrium salvelini, a nematode, Metabronema salvelini, and an acanthocephalan Metechinorhynchus lateralis. The data for prevalence, intensity and abundance are seen in Tables 12 a and b of the appendix.

The comparison of five years of data for the prevalence of parasites in S. fontinalis is shown in Figs. 12 (a-f).

Figure 12a: Prevalence of *C. farionis* in the intestines of *S. fontinalis* (1982-6).



C. FARIONIS (INTESTINE)
PREVALENCE (%)
0
20
40
60
80
100
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
1982
1983
1984
1985
1986

Figure 12b: Prevalence of <u>E. salvelini</u> in the intestine of <u>S. fontinalis</u> in (1982-6)

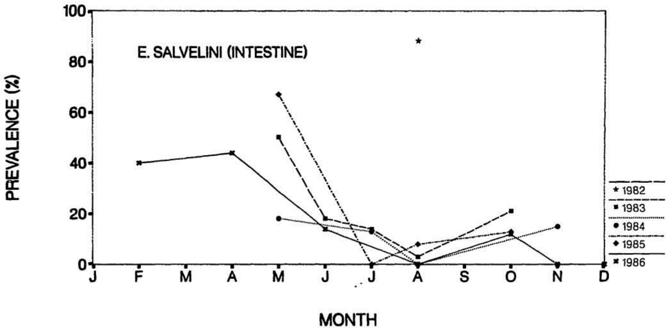

E. SALVELINI (INTESTINE)
PREVALENCE (%)
100
80
60
40
20
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
1982
1983
1984
1985
1986

Figure 12c: Prevalence of <u>M. lateralis</u> in the stomachs of <u>S. fontinalis</u> (1982-6)

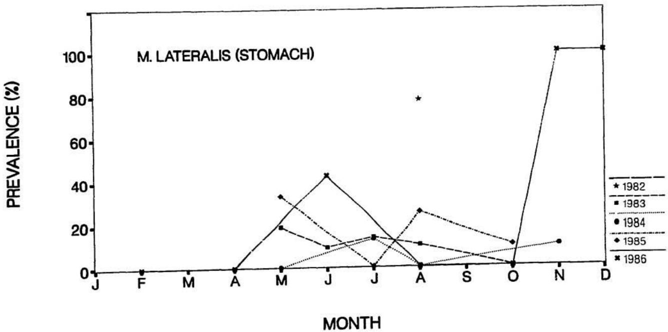

M. LATERALIS (STOMACH)
PREVALENCE (%)
100
80
60
40
20
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
1982
1983
1984
1985
1986

Figure 12d: Prevalence of M. lateralis in the intestine of S. fontinalis (1982-6)

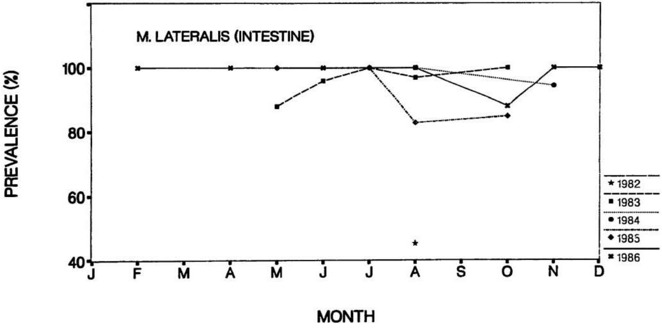

M. LATERALIS (INTESTINE)
PREVALENCE (%)
100
80
60
40
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
1982
1983
1984
1985
1986

Figure 12e: Prevalence of *M. salvelini* in the stomach of *S. fontinalis* (1982-6)

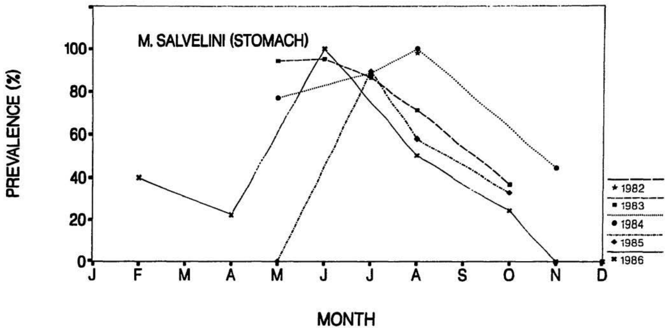
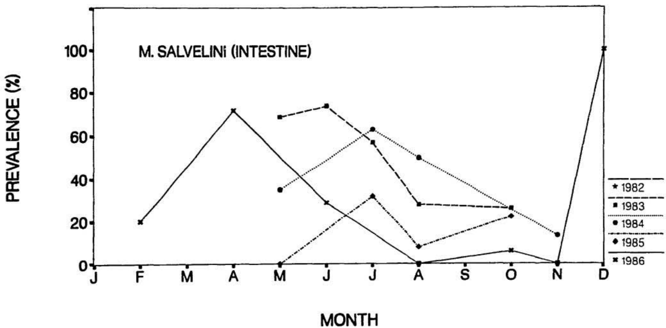

M. SALVELINI (STOMACH)
PREVALENCE (%)
100
80
60
40
20
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
1982
1983
1984
1985
1986

Figure 12f: *Prevalence of* M. salvelini *in the intestines of* S. fontinalis (1982-6)



M. SALVELINI (INTESTINE)
PREVALENCE (%)
100
80
60
40
20
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
1982
1983
1984
1985
1986

C. farionis, a small enteric trematode, occurred in the intestines of the fish during late fall through late spring. The number of fish carrying this parasite was lowest during August of all years under investigation. Low numbers were recorded for June through October for years other than 1982. However, the samples of February through April and November and December 1986 showed marked increases in parasite incidence ($\geq$ 40%). Samples examined for May showed elevated levels, the exception being 1986, which showed a decrease.

E. salvelini, except for August 1982, showed for the years 1983 through 1986 a relatively low prevalence during most of the year. The highest level of parasitism was noted in the spring.

Based on May-June samples, which would indicate the normal periods of high incidence, it can be seen that in 1983 the rate was approximately 50%, dropping to 15% in 1984 with a rise to 75% and 50% for 1985 and 1986, respectively. The period of maturation of these worms has been demonstrated to be May - June as this investigator observed the release of eggs from the parasite when handling them for preservation. This release coincided with the blooms of cyclopid copepods in the system. Sandeman and Pippy (1967) report mature and gravid worms for both spring and summer in Newfoundland. The high number of infections noted for *E. salvelini* during 1982 in the present study is the exception rather than the rule. The minor peaks seen in figure 12b for 1985 and 1986 were not found to be significant statistically.

The August 1982 fish sample showed a 100% prevalence of M. salvelini. There were no nematodes seen in the intestines at that time. A similar prevalence was noted in 1984. However, in this instance a 70% prevalence was also noted in the stomachs. Fish samples taken over a series of months in the years following 1982 showed high prevalences for stomachs and intestines during summer and a low prevalence for both regions of the gut during late winter.

M. salvelini infections are highly variable but do illustrate a seasonal fluctuation corresponding to seasonal changes in water temperature. S. fontinalis is an active feeder with a catholic dietary regime. However, it is a binge feeder in Big Northern Pond and takes advantage of emergent insects to the exclusion of all other species of food. The increase in prevalence during summer coincides with the exploitation of ephemeropterans (the intermediate host of many species of nematode) which emerge in late May to early June.

The loss of M. salvelini from S. fontinalis during December is illustrated by the large increase in the prevalence of the nematode in the intestines. It is felt that this is not due to handling or postmortem migration, as these fish were immediately frozen at the site of capture, but rather to maturity of the nematodes and natural cyclical events.

The parasite which attracts one's attention immediately upon extraction of the viscera of S. fontinalis is M. lateralis. These parasites were readily visible through the intestinal wall and are often seen dropping and/or hanging from the vent of the fish. This acanthocephalan is the most numerous (some samples containing over 400 worms) and persistent (maintained prevalence) of the four parasites encountered in the digestive system of the fish.

An examination of the data to investigate differences in prevalence of the parasites by year showed that in 1983 intestinal trematode prevalence was significantly higher than 1984 and that 1985 was higher than 1984 and 1986. The prevalence of stomach nematodes for May samples was significantly lower in 1985 than in 1983, 1984 and 1986 while the intestinal nematodes were significantly higher for 1983 over 1984 and 1985.

Evaluation of data for August, all years, revealed that for stomach nematodes 1982 and 1984 were higher than 1983, 1985 and 1986. The 1982 data indicate a higher percentage of infections for stomach acanthocephalans than did 1983 - 1986, while 1985 was found to be greater than 1984. Stomach trematode prevalence for 1985 was greater than that of 1982-3. Intestinal nematode prevalence for 1984 was greater than that of 1982, 1983, 1985 and 1986 while 1983 was greater than 1982. The intestinal acanthocephalans showed greater prevalence in all years over 1982, while 1982 showed a greater prevalence of cestodes than for other years studied. The prevalence of these two species appears to be negatively correlated.

There is a general trend seen in the data but there is great variability in prevalence when months are ranked. This may be due to gear selection and low numbers of fish samples examined for some months.

Evaluation of the data for 1982 through 1986 based on age, sex and maturity showed that an effect of age was demonstrated for intestinal cestodes and trematodes. Fish aged 1+ and 2+ had lower infections than those aged 3+, 4+ and 5+. The mean ages ranked 1+ through 5+. The intestinal trematodes showed 4+ and 3+ respectively to be higher than 1+ and 2+. The other two parasites, M. lateralis and M. salvelini, showed no significant differences due to age and this can be explained by the early onset of these parasites and the nature of the seasonality of E. salvelini and C. farionis.

There were significant differences noted for sex of fish in the cases of stomach nematodes, intestinal cestodes and trematodes, these showing a greater prevalence in female fish. When maturity is taken into account, the effect of gonadal development and related hormonal changes may account for the differences seen. Stomach nematodes were significantly greater in ages 2,0 and 1 than for 5, and stomach acanthocephalans were greater at 0 than 5. The intestinal nematode prevalence for maturity level 1 was higher than for 2 while prevalence of the intestinal trematode was higher at level 1 than for levels 2,5, and 0 respectively.

The data for age and maturity parallel each other in some respects. Fish maturity and age are not synonymous as some fish show reproductive maturity at different ages and demonstrate different levels of maturity within an age group due to season.

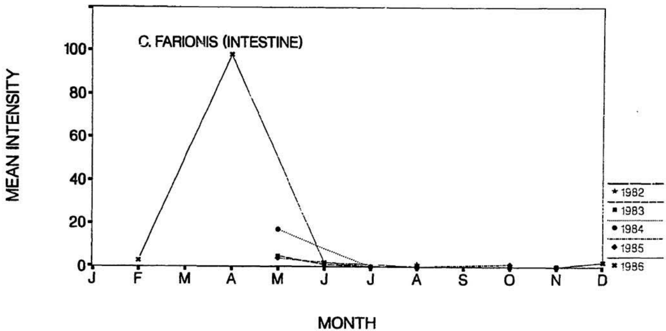
The age of first maturity of S. fontinalis for both sexes in Big Northern Pond was 2+ and the largest percentage of spawners was represented by this group.

Parasite Burden

The changes with time for parasite burden are presented in Figures 13 (a-f).

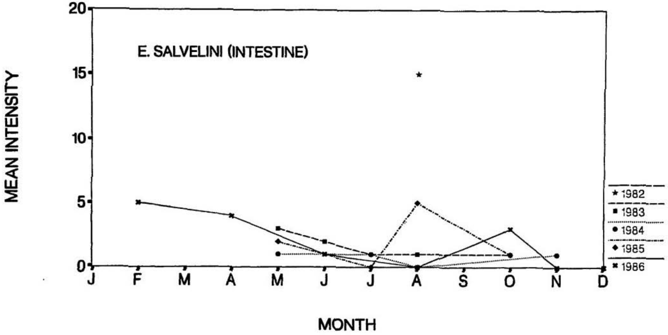
C. farionis, (Fig. 13a) which were located only in the intestine of S. fontinalis, was seen in low numbers throughout most of the study period. The extension of sampling periods in 1986 indicates the possible burden which may be reached in late winter and is indicated by the higher levels seen in May samples of other years.

Figure 13a: Mean intensity of <u>C. farionis</u> in the intestine of <u>S. fontinalis</u> (1982-6)



C. FARIONIS (INTESTINE)
MEAN INTENSITY
100
80
60
40
20
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
1982
1983
1984
1985
1986

Figure 13b: Mean intensity of *E. salvelini* in the intestines of *S. fontinalis*



E. SALVELINI (INTESTINE)
MEAN INTENSITY
MONTH
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D
1982
1983
1984
1985
1986

Figure 13c: Mean intensity of _M. lateralis_ in the stomachs of _S. fontinalis_ (1982-6)

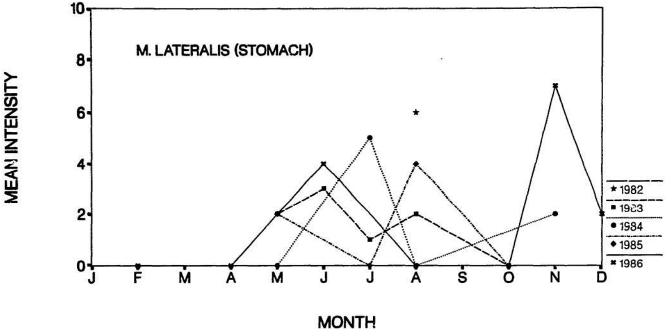
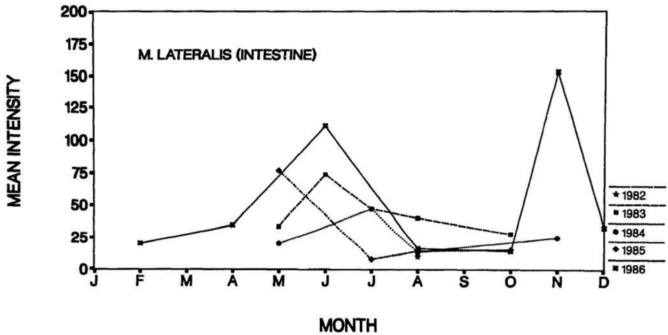

M. LATERALIS (STOMACH)
MEAN INTENSITY
10
8
6
4
2
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
1982
1983
1984
1985
1986

Figure 13d: Mean intensity of M. lateralis in the intestines of S. fontinalis (1982-6)



M. LATERALIS (INTESTINE)
MEAN INTENSITY
200
175
150
125
100
75
50
25
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
1982
1983
1984
1985
1986

Figure 13e: Mean intensity of *M. salvelini* in the stomachs of *S. fontinalis* (1982-6)

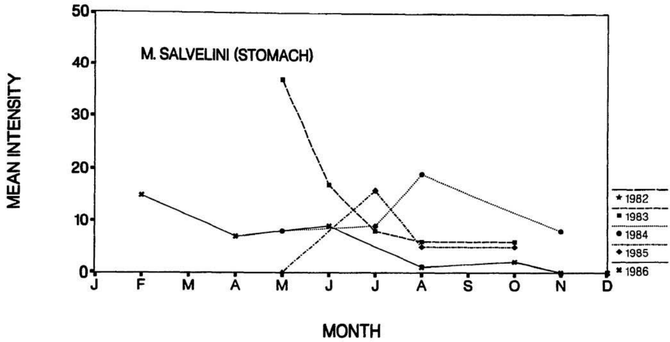
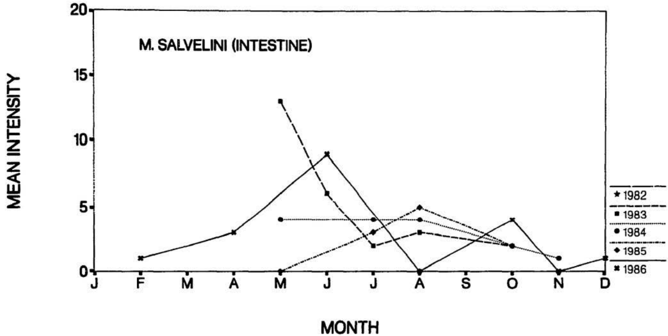

M. SALVELINI (STOMACH)
MEAN INTENSITY
50
40
30
20
10
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
1982
1983
1984
1985
1986

Figure 13f: Mean intensity of *M. salvelini* in the intestines of *S. fontinalis* (1982-6)



M. SALVELINI (INTESTINE)
MEAN INTENSITY
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH
1982
1983
1984
1985
1986

E. salvelini (Fig. 13b) was located in the intestine in most cases with the scolex of each worm inserted within the pyloric caecae. Only two cases were seen in the stomach and this is thought to be due to postmortem migration or pressure on the gut when the fish were being removed from nets.

The mean intensity of M. lateralis in stomachs was relatively low. Samples taken in February and April show no instances of the acanthocephalan. However, May and June samples contained worms which could not be associated with amphipods (Hyalella azteca) which are known to be the intermediate hosts. The samples taken in November 1984 and November and December in 1986 contained H. azteca with the cystacanth in the haemocoel of the amphipods. Some individuals of M. lateralis could well have been forced into the stomach while the fish were in nets and during handling. The burden for the intestines is indicative of the parasite load. The charr of Big Northern Pond, when infected, had a mean burden of no less than 10 acanthocephalans and this can reach numbers in excess of 150 worms. The data illustrated in Figs. 13 c and d show that there were two possible periods when infection was taking place. The first was May through July and the second was during November. These periods were coincident with increased numbers of H. azteca and took place when the water temperature was rising in the spring and falling in autumn.

The parasite M. lateralis, when in large numbers, were located along the entire intestine from the pyloric caecae to the anus. In many cases the parasite was seen hanging from the vent. Newly acquired parasites were found near the anus and were not attached. The shedding of these juvenile parasites into the environment can be a major source of parasites in fish and may be responsible for the maintained prevalence seen in these charr.

The nematode M. salvelini occupied a prominant position in the stomach with mean numbers reaching 38 parasites per individual. The numbers for the intestine were sowewhat less and indicative of the migration of the worm downwards through the digestive tract as they mature. The graphs of the stomach and intestine burden (Fig. 13e and 13f respectively) show a trend whereby large numbers of the nematode were found in late spring and early summer and then dropped off towards early winter. This is in line with the seasonal growth patterns of the intermediate host, the ephemeroptera.

Effect of parasitism on condition factor

A comparison of the data when all parasites were pooled and then compared to fish condition failed to show any significance.

The only parasite that showed significant results when condition factors and parasite numbers were considered were the acanthocephalans. There was a signficant difference between fish which contained M. lateralis and those that didn't (SNK test).

The differences seen in cases where fish were parasitized by M. lateralis showed a trend whereby fish containing 11-20 acanthocephalans were generally in better condition than those with 10 or less parasites (excepting fish not having *M. lateralis*). There is a loss of some information in this analysis as seasonal effects were masked by pooling of data and some sample sizes were regrettably but unavoidably small.

Discussion

Physical, Chemical and Microbiological Water Quality

Temperature

The thermal stability and chemical quality of an aquatic ecosystem dictates the life forms which may inhabit it. The physiological ability of S. fontinalis allows it to survive in Big Northern Pond where temperatures have been recorded as high as 20°C with daily swings of 4°C.

Chemical Water Quality

The chemical composition of water is often included in studies dealing with fish growth and it is accepted that the more alkaline waters support a greater diversity of organisms (Howells et al., 1983). It is now increasingly obvious that the more acidic waters in the eastern North American continent are sensitive to lowered pH levels (Beamish, 1976; Schofield, 1976). Big Northern Pond is the most acidic of the ponds evaluated to date in the Topsail-Manuels system and it demonstrates well the changes which take place in the physical (ionic) parameters over the period of a year. The depression in the pH of the water during spring is also documented in other areas and is thought to be the cause of mortality of young fish and failure of eggs to hatch (Trojnar, 1977; Menendez, 1976).

Microbiological Water Quality

Bacteriological water quality is important when assessing the possible effects of agricultural development on watersheds. An investigation into the water quality of Big Northern Pond revealed that the water remains in a pristine state unlike that of the water quality lower in the watershed. The levels of E. coli further down the system do reflect human activity and are a reflection of the intensity of the activity surrounding their respective water bodies (Cowan, Baggs and Hollohan, in press).

It would appear that water quality in Big Northern Pond (excepting acid precipitation) is not influenced greatly by man.

Biological Parameters

The initial sample collection of S. fontinalis taken in 1982 contained only four specimens of 0+ fish, two male and two female. The paucity of this age group within the sample was due in part to the type of gear utilized and the locations within the pond where the fish were obtained. The movement of fish from the pond down to the stream was later determined when mature specimens were entrapped in surber sampling equipment left to collect drift organisms. Redds used in this area were small and dispersed amongst larger rocks, totalling no more than 10-12 during the period of observation. The actual recruitment to the pond population of S. fontinalis from the stream area is small as the pond is known to be the main area for spawning (Cowan and Baggs, 1988). It is of interest to note that at no time were S.

salar ever seen to utilize the stream area for spawning purposes and over seven years of sampling only two 1+ S. salar were seen in this habitat.

The effect of water depth and flow rates on redd selection by S. fontinalis have been investigated (Witzel and MacCrimmon, 1983). These authors found that water velocity separated the brook charr from the brown trout in terms of redd selection. The brook charr utilized slower waters which were supplemented by some upwelling or seepage of ground water. This would appear to be similar to the situation in Big Northern Pond except that S. salar, the cohabiting species, is relegated to the upwelling areas of the pond (Cowan and Baggs, 1988).

Fry Emergence

The variability in the date of emergence for various fish species has been documented by Braum (1978). He states that effects of photoperiod, temperature, oxygen and other factors (eg. physiological) all play a role in the emergence of larval stages. The effect of temperature on egg development for brook charr was described by Polyanouskaya (1949). He found that the early stages of egg development, cleavage to gastrulation, were less sensitive to increasing water temperatures. The later stages of development were suppressed by lowered temperatures and, as a result, the time required for hatching increased.

The temperature regimes of the Avalon Peninsula of

Newfoundland are varied and no two winters are ever the same. The temperature effects on the eggs in the outflow of Big Northern Pond are unknown but the changes in environmental conditions are known, and if these are averaged for the year the effect of temperature from one year to another may well be the same. There is, however, one aspect which has a greater influence on the time of emergence and that is the time of spawning in this system. The stream in which the eggs are deposited is extremely shallow and until the depth of water and the temperature are tolerable, fish do not enter the area. Depending on the nature of the summer and early fall the spawning occurs from late October to early December.

It was apparent that water levels and, secondarily to it, temperature were mediating factors for fish in this system as they determine not only the time of spawning and time of emergence but also when the young move into the pond in late August (see Table 4; presence/absence). It is, however, interesting to note that spawning in the pond occurred several weeks later than in the stream (Cowan and Baggs, 1988).

One important factor which affects egg survival and larval development is pH. Acidity of ecosystems has been much publicized in recent times as it is now known that aerial pollution has decimated large tracts of land, devoiding these areas of both terrestrial and aquatic species of plants and animals. Many authors have produced work to show the effects of pH on eggs and larvae (Gunn and Noakes 1986; Rogers 1984; Hulsman *et al.*, 1983) and it is generally accepted that survival of eggs at low pH is reduced when there is an increase in some toxic metal which becomes biologically available due to an increase in leaching. Hulsman *et al.* (1983) report in a study concerning walleye eggs and rainbow trout larvae that when survival of both were considered in relation to whether or not the water had a humic content, the mortality was high for walleye eggs at pH 5.4. Mortality for rainbow larvae was 100% in 5 days at pH of 4.6 and 5.4 in the clear water. However, in cases where there was a humic content the rainbow larvae had a mortality of only 3% at pH 5.5.

The H^+ toxicity was not the sole reason for mortality of rainbow trout yolk-sac larvae (Hulsman *et al.*, 1983) but was associated with increased presence of toxic metals, particularly aluminum. There was only one occasion when the pH compared to those of Big Northern Pond, recorded by Hulsman *et al.* (1983) during April-May, 1981 for the Ruth-Roy stream in Ontario where the pH was 4.6. A comparison of the other elements indicates that the levels are considerably lower in this study and any toxic effects that may cause mortality are unclear. Gunn and Noakes (1986), in a study of avoidance of low pH and elevated aluminum, showed that *S. fontinalis* alevins were able to detect and avoid toxic H^+ levels. The alevins actively avoided pH values less than 5.0 when exposed to a variable environment with a pH range of 4.0 to 5.5.

The brook charr in Big Northern Pond do survive, reproduce and grow in an area of low pH and the growth does not appear to be reduced due to acidity. The deformities reported by Beamish (1975) in his study of white suckers (*Catastomus commersoni*) were not seen in Big Northern Pond fish even though pH values reported by him mimic those for this pond.

The effect of temperature is tied to the actual time of spawning as the onset and duration of spawning activity may be early or late depending on water depths and velocity in the stream environment.

The use of degree-days for determination of possible incubation periods is not applicable in determining post-spawning dates as spawning areas which are subject to diurnal temperature fluctuations and flow changes often experience temperature variations of 10^0C (Braum, 1978). This would compound the variability already introduced by the differences in the times of spawning.

Any post-embryonic development may be further delayed or even accelerated due to temperature changes and the development of an appropriate food resource which must coincide with the onset of exogenous feeding.

Cunjak (1982) showed in experiments involving *Salmo gairdneri* and *Salvelinus fontinalis* that the brook charr was most competitive at a temperature of 13^0C when there was no limit of food in an experimental tank. However, when temperatures were raised to 19^0C the brook charr demonstrated a higher weight loss than *S. gairdneri*. This weight loss, although not demonstrable in the present study, may well be a reason for the abandonment of the redd sites and stream environment, as food supplies in this area would certainly be limited due to demands of a growing fish population as well as the normal depletion of prey due to seasonal variations. The intra-specific studies of behaviour amongst brook charr (Cunjak, 1982) demonstrated a lowered antagonistic behaviour at higher temperatures suggesting that the physiological strain placed on brook charr by high temperatures leaves little reserves or vitality for behaviours other than the minimal ones required for survival. Hence, in an environment where escape to a less stressful environment is possible, abandonment of one habit for another would be expected. It would also appear that the temperature affects all age classes of S. fontinalis in this stream.

Morphological characteristics

The morphological relationships of fish can vary depending on species, age, sex, diet and maturity (Baganel and Tesch, 1978). The length-depth relationship of 0+ S. fontinalis in Big Northern Pond showed little variation. The few cases that showed variation are thought to be the result of late emergence or slow absorption of the yolk sac.

The length-depth relationship for older fish also showed little variation.

The length-weight relationships of S. fontinalis and other salmonids has been approximated at a value of 3 (Wiseman, 1966) and this value is appropriate for isometric growth (Bagenal and Tesch, 1978). Upon calculation of the slopes of year class data it was found that the values for the length-weight relationship of 0+ fish were significantly greater than 3, indicating allometric growth. This had a significant effect on the condition factor values for this age group.

The length-weight relationship for older fish did not, however, differ significantly from 3 and this value was used in the calculation of the condition factor for older fish.

Condition factors of Age 0^+ fish.

Condition factors have been used for expressions of relative robustness of fish and are of use when indications of environmental suitability for a species are being considered (Lagler, 1956). Changes in condition can be expected when looking at factors such as age, sex and season.

A seasonal decrease in condition factors of S. fontinalis in Ontario streams has been demonstrated (Cunjak and Power, 1987) from August onward for forklength ranges of 5.9 to 17.1 cm. Their data, however, was pooled and no comparisons of young of the year and older fish were made. Pooling of data masks information which may be used to describe the effect of season and a review of the literature did not demonstrate the effect of winter on young of the year fish. As a result, comparisons could not be made.

An examination of mean air temperatures for the Topsail-

Manuels watershed (Table 1) does not indicate that water temperatures would have had an effect on growth and well being of the young of the year fish and no differences in the level and flows of the stream were noted. One factor which may play a role is the quality of the diets. No data were collected on the relative abundance of food but, however, notable differences in yearly abundances of emergent insects were observed during the study.

Cunjak and Power (1987) related changes in condition to temperature and not food supply as the caloric intake remained equal throughout the study. As there was no attempt to quantify the food of the young of the year in Big Northern Pond no such assumption can be made. However, lowered temperatures are not felt to be the cause as the temperatures up to August are in what is considered to be the optimal range (Cunjak, 1982; Scott and Crossman, 1973).

The prolonged sampling of 1986 indicated the rapidity with which brook charr respond to the environment. The decline in the condition of the July, 1986 sample is not thought to have been directly caused by temperature as the mean temperatures were still rising. It may have been a decline in food due to pulses or periods of prey emergence followed by lower emergent activity that is responsible for the decline in condition. These pulses can be species specific (Larson, pers. comm.) and may change dietary habits and hence nutritive gain. The differences in condition are probably due to seasonal effects such as temperature, parasitism and food supply which would cause decreases in overall growth.

Age Composition

The age structure of *S. fontinalis* of Big Northern Pond was the same with both sexes reaching the age of 5+. This is in agreement with Wiseman (1969). There are areas in the Topsail-Manuels watershed where isolated populations of *S. fontinalis* reach the maximum age of 3+ (Baggs and Cowan, unpublished data).

Mortality

Mortality in a fish population can arise from various sources ie., (1) natural mortality where hatching failure due to egg predation, disease and pollution may affect recruitment, (2) angling mortality where selected age groups are targeted by management policies or personal size choice concomitant with damage during hook and release strategies and other deliberate or unintentional catching practices. A further list of factors influencing angling mortality has been published (Wiseman, 1969; Lagler 1961). The size limits (length of fish) on catches of *S. fontinalis* are no longer used to regulate the fishery as the enforcement of a 15 cm limit would restrict catches where stunted populations of fish exist. The situation was further exacerbated when stunted populations of fish occurred within watersheds containing populations of larger growing members of the population. The situation of having a length limit on fish has changed since the work of Wiseman (1969) and, barring extremely small fish, the effort is spread out over the age profiles of the species concerned.

No attempt to establish natural or angling mortality was made for Big Northern Pond. However, it is thought that angling mortality is low for this pond due to its relative isolation and inaccessibility. It is felt that the location of the pond is not common knowledge to most of the fishing enthusiasts and this is backed up by the low numbers of anglers encountered there over the last 8 years. When encountered, the anglers tended to be the same people and information supplied by them about the pond tended to be borne out by this investigation. An interesting aspect to angling efforts and resulting mortality is that the catch per unit effort, if computed, would probably be very low as efforts to augment sample sizes using various angling gear had dismal results. This is most likely due to the fact that these fish, when caught by other means, appear to be well fed and not actively searching for food.

Kennedy (1954) states that 'mortality rates in fish populations can be estimated if the ages of random samples are known.' If the least vulnerable fish to fishing gear, ie. age 0 and 1, in the Big Northern Pond study are ignored the number remaining in any year class is less then the preceding year class. Year class fluctuations can obscure this in some cases.

Mortality curves do show fluctuations which may be due to year class strengths or weaknesses. However, overall the data would indicate that the fish populations are not being affected greatly by environmental changes or fishing efforts during the study period.

Sex and Maturity

Sex Ratios

Wiseman (1969) in his review of the literature indicates that there are a large number of papers reporting deviations in the 1:1 sex ratio of fish populations which are dependant on the species examined. Wiseman (1969) also shows that within Newfoundland there are deviations from the 1:1 sex ratio for S. fontinalis depending on locality, fishing pressure, and whether or not the life history involves periods of sea life. The overall 1:1 sex ratio applies to Big Northern Pond.

The mean age of S. fontinalis in Thomas Pond was approximately 2.5 for both male and female brook charr (Wiseman, 1969) whereas the mean age for Big Northern Pond was 1.6 years. A difference in mean ages would suggest some differential mortality .

The variation in this data may be due to sampling techniques, behaviour (social or feeding) or sex specific mortality. It is felt that pooled data best describe the actual situation for the pond and this is supported if the data obtained from collections of young of the year from the redds are compared.

Maturity

The age of maturation of fish is important as it can be used to indicate possible recruitment to the habitat. This is done by recording the percent of the population which reaches full reproductive potential within any year. It is generally accepted that the older (and hence bigger) the fish the more eggs that will be generated. The effect of stress (physiological/ environmental) may also affect the onset of maturation, advancing it in an attempt to deal with this stress (Wiseman, 1969). This present study did not deal with this aspect but recorded only the proportions of the population that may be involved in reproduction. The data obtained compare with the data of Wiseman (1969) but differ from data on S. fontinalis downstream in the Topsail-Manuels watershed where the age of first spawning is 1+ (Baggs and Cowan, unpublished data). There were very few cases of atretic eggs in non-active members of the population which would indicate previous or multiple spawning events.

Food Analysis

The diets of brook charr have been determined from gross examination of various sections of the digestive tract. Power (1980) states "unfortunately the effort devoted to the study of natural diets has provided few insights into the fundamental ecology of energy flux through brook charr populations." A review of the literature concerning Newfoundland fish shows the data on feeding to be primarily of a qualitative, semi-seasonal nature which tends to lump food items into phylogenetic categories (Wheeler, 1977; Chinniah, 1977), frequency (Tilley, 1984) or percent weights of dietary items as compared to total stomach weight (Keats, 1986). Wiseman (1971, 1972) evaluated the diets of brook char in the Topsail-Manuels system with a view to quantifying and qualifying the dietary components. Wiseman's study of 1971 was based on a sample of fish taken in June from Thomas Pond and the study done in 1972 reports the quantitative and qualitative nature of the fish diets of Paddy's Pond during May.

There are few studies dealing with diets of fish on an age basis and only one (Tilley, 1984) which deals with feeding of juvenile fish in the Topsail-Manuels system. Studies of feeding of adult fish on a seasonal basis are lacking completely for the Topsail-Manuels system and such data are limited on the island.

Studies of the dietary habits of brook charr which have been carried out elsewhere provide limited baseline data (Power, 1980) when attempting to evaluate the food preference, relative availability, and nutritional value of natural diets. Many studies are limited by accessability, ie. remoteness or seasonal restrictions due to ice cover or migratory behaviour, and limits placed on sample sizes do not allow, for the most part, adequate numbers to assess the effects of age or size on prey selectivity. A problem which also occurs when looking at the effect of diet on fish growth is that caused by stock exploitation and changes in the predator-prey ratios. This particular situation is further exacerbated when natural ecosystems are subjected to arrivals of exotic predator species which may, through behavioral and competitive advantages, upset the natural balance of the aquatic ecosystem.

Nyman (1970) describes a situation for the Waterford River system in Newfoundland where brown trout, S. trutta, an exotic fish species, have displaced the resident brook charr due to the similarity of diets for the two fish species and in part to the more aggressive and competitive nature of the larger, longer lived brown trout. Where brook charr and brown trout co-existed there was partitioning in respect to size of prey eaten, with the larger prey items being consumed by the larger brown trout. He suggests that in a lacustrine environment, for fish that are indiscriminate feeders (Wiseman, 1969), there may well be food segregation coupled with habitat segregation. Big Northern Pond is inhabited by two salmonids. The main competitor for food in this environment in respect to S. fontinalis is the ouananiche, Salmo salar. S. salar provides a lacustrine situation comparable to the fluvial brown trout - brook charr study of Nyman (1970), as in this situation S. salar is also longer lived and bigger than S. fontinalis.

Wurtsbaugh et al. (1975) in their study of the food preference of under yearling brook charr and rainbow trout in Castle Lake, California found that there was a high preference for benthic organisms. Their ranking of food items showed a 5 and 10% occurrence by weight of chironomid larvae and pupae, respectively, followed by a 60% component of Ephemeroptera. There was a 10% total weight component allocated to unidentified benthic material. The other items, of limnetic and terrestrial origin, made up the remainder of the diet (approximately 5% each). The diet of the young of the year fish was somewhat different in Big Northern Pond. The Castle Lake study lists the major food preferences in descending order to be Ephemeroptera, Chironomidae, Cladocera, Copepoda and lastly mixed terrestrial items, whereas the situation in Big Northern Pond showed a relative preference for Chironomidae, various Diptera, Coleoptera and lastly the Odonata.

There have been investigations regarding feeding and growth in sympatric populations of salmon, S. salar with brook charr, S. fontinalis (MacCrimmon et al., 1983; Gibson, 1973) and brown trout, S. trutta with S. fontinalis (Nyman, 1970).

These authors show various degrees of aggression between species when feeding which can lead to reduced growth of one or both species depending upon the species involved. In all cases a certain amount of habitat shift takes place as a result of competition. There are no stream resident S. salar in the outlet stream of Big Northern Pond and the only competition is of an intraspecific nature. Young S. fontinalis hatched in the lacustrine habitat live sympatrically with S. salar but the degree of interaction between them and the resultant dietary selection of these two species of fish is presently unknown. They do, however, occupy similar lacustrine spawning areas (Cowan and

Baggs, 1988).

It has been suggested that there may be shifts in diet where sympatric populations exist (Hanson and Leggett, 1986). In Big Northern Pond, diets of S. fontinalis and S. salar showed S. salar consumed no fish eggs, and relied less on the Coleoptera, Amphipoda, Gastropoda and Pelecypoda than did S. fontinalis. Conversely, S. salar relied more on the Odonata, Cladocera, Ephemeroptera and Chironomidae (Cowan, unpublished data). This would suggest some partitioning of food resources due to behaviour or resources utilization.

Parasitism

S. fontinalis has been extensively studied with respect to parasitism. The lists of type and number of parasites harbored by this animal are long (Power, 1980) and a review of the literature shows that the parasite-host interactions are dependent on geographical location, species interactions, age, intermediate hosts, water quality, and density of both the host species and their exposure to various vectors. The specific intermediate hosts for many of the parasites and the route of infection has been established for many species of parasite. As more work is done in those areas different routes of infection are being uncovered.

An examination of local information shows that the host diversity of parasites within insular Newfoundland and Labrador is as variable as it is throughout other geographical areas of

North America. The information on parasites for local areas is comprehensive and covers most of the freshwater fish species within the province (Hicks and Threlfall, 1973; Sandeman and Pippy, 1967; Pippy, 1965).

The great majority of information compiled has, however, been related to occurrences and intensities of infections using limited numbers of samples. It does not address the onset of parasitism and seasonality in terms of parasite burden. No studies were found regarding parasitism of larval fishes in Newfoundland and Labrador, probably due to the fact that there are few studies of any aspect of larval development on S. fontinalis.

Onset of Parasitism

The onset or establishment of parasitism in the wild is generally not well known for S. fontinalis.

The present study, in its examination of some aspects of growth and feeding of young of the year fish, evaluated parasites in developing young and provided some insight into the onset of some parasites of S. fontinalis in Newfoundland waters.

The intermediate host of M. salvelini is an ephemeropteran (Pippy, 1965; Awachie in Chubb, 1982).

The data in this study would suggest that there are two periods of high infection and low periods of low infection, the highs occurring in mid-summer and again in early winter. The early fall decrease may be due to several factors such as a lowered availability of intermediate hosts for the nematodes, cessation or reduction of feeding by S. fontinalis, and/or by changes in hormonal levels brought on by maturation of the host. These findings have been paralleled for the same parasite in studies of other hosts (Chubb, 1982). Chubb (1982) also shows that for M. salvelini there exists several ephemeropteran species which carry the infective stage of this parasite. The number of different species of ephemeroptera are not known for Big Northern Pond. It can be reasonably expected that there are two periods during the year when parasite egg release occurs causing an increase in the number of infected intermediate hosts.

The onset of M. lateralis at an early age raised some interesting questions as to the possible routes of infection.

The occurrence of this parasite in the stomach of the fish collected in August 1983 and July 1984 indicated that the parasites were being actively picked up. This was further parallelled by the larger numbers seen in the intestine (the site of preference of the parasite) of the same fish.

The intermediate host of M. lateralis in Newfoundland is the amphipod, Hyalella azteca (Pippy, 1965). This was also demonstrated in this system by the author. However, this infective route for parasitism in young of the year fish is questionable. The amphipods which have been isolated from the stomachs and intestines of these fish are extremely small and for the most part intact. The presence of an infective cystacanth has not been demonstrated in any small amphipods in this system.

There are two other possibilities for the transmission of this parasite. The first is that of a paratenic host, and while this cannot be discounted, there is no evidence to date that this is the case. The second possibility is much more demonstrable, that being the direct ingestion of the parasite by young fish. It is accepted that parasites are passed on through ingestion of one fish by another (Noble & Noble, 1976) but only where activation of the parasite from its larval or egg state has not occurred.

The possibility of a direct route (host to host) was raised when a fish caught in May 1983 contained an adult acanthocephalan. This fish had only just begun exogenous feeding and the developmental stage of the parasite it contained takes approximately 80 days (Nickol, 1985). Other specimens of acanthocephalans were found to be well developed in subsequent samples taken a month later.

Brook charr are indiscriminate, opportunistic carnivores (Nyman, 1970; Swift, 1970). A great majority of studies list unintentionally obtained material in the stomach and intestinal contents which is ingested while feeding. Young fish, when beginning heterotrophic exogenous feeding, can be expected to experiment with food items and they usually are easily attracted to a variety of items. This author has seen fish grab at and/or attempt to swallow the mucoid fecal strings from another fish as it hangs from the anus or floats through the water column. This can be seen in aquaria. Furthermore, in instances where the parasite burden is high, many parasites may be passed with the feces. These would receive some protection due to the mucoid nature of the feces allowing an active adult parasite to survive for some time.

Coprophagy can be expected amongst fishes, given the nature of their foraging. The availability of parasites is enhanced in the stream habitat under study as the area contained other members of the species up to the age of 3+, and these older members have been seen to have 100% infection rates and parasite numbers of M. lateralis in excess of 250. Fish of this older group have also been seen to pass acanthocephalans from their digestive tracts, and this would provide an ongoing supply of worms to the young fish.

The ability of parasites to survive changes from one definitive host to another host of the same species has been demonstrated (Hnath, 1969) and physiological factors which may influence cystacanth development for some species of parasites has been shown (Graff and Kitzman, 1965). Furthermore, the digestive ability of some fish is reduced during the initiation of exogenous feeding (Kawai and Ikeda, 1973 a,b) which would enhance the transfer of parasites and subsequent passage through the digestive tract.

The factors that influence cystacanth activation have been studied for Moniliformis dubius (Graff and Kitzman, 1965), and it was found that bile salts were obligatory for activation of cystacanths in vitro. This in turn was dependent on pH, with a pH of 8.5 being optimal. This activation was further enhanced by high CO_2 levels. It was also noted that, depending on temperature and the previously mentioned factors, the activation period could run from a few minutes up to several hours.

Adult fish, when feeding actively, are known to increase the rate at which food will pass through the digestive tract. This can result in inactivated or partially activated parasites being released to the environment in a stage which is resistant to mortality.

The survivorship of cystacanths and juvenile worms is also enhanced due to the relatively inactive stomachs of the young fish. Kawai and Ikeda (1973a,b), in two studies on the digestive enzymes of carp, sea bream and rainbow trout, report that tryptic, maltase and amylase activity developed with age shortly after hatching while peptic activity did not. Furthermore, it took from 40-60 days post-hatching for proteolytic activities of larval rainbow trout to reach the levels of older trout. These activities paralleled growth.

Hnath (1969) transferred live acanthocephalans from coho salmon by force-feeding adult worms to hatchery reared S. fontinalis. The experimental trout were examined over a twelve-week period and all were found to harbour the parasite. Transfers of parasites through cannibalism or predation are also recognized (Noble and Noble, 1976) and the effect of icthyophagy or cannibalism is supported by work done (DeBuron and Maillard, 1987) on gobies, labrids and anguillids.

Parasites, through evolution, have been able to maintain viable populations of themselves in a wide variety of habitats by using various strategies.

This study demonstrated that adult or developing acanthocephalans can be ingested without being part of the regular diet and that coprophagy, another possibility for transmission, may be an important route by which larval fish become infected in Big Northern Pond.

Prevalence and Seasonality of the parasites of the digestive tract of S. fontinalis of age greater than 0.

The data collected in August 1982 produced information that seemed somewhat inconsistent with observations made on S. fontinalis in the years preceding the initiation of this study. The number of cestodes in this sample suggested an abundance of this parasite during a period when a lack of cestodes would normally be seen. A review of the literature for Newfoundland (Hicks and Threlfall, 1973; Threlfall and Hanek, 1970; Sandeman and Pippy, 1967) lists Eubothrium salvelini but does not indicate the dates on which the fish containing the parasites were caught. The lack of local information on the number and seasonal variations in parasite prevalence and seasonality indicated an area of research which required further investigation if some insight as to parasite effect on fish growth was to be determined for Big Northern Pond.

Pippy (1965) recorded C. farionis from several species of fish in Newfoundland. He also described a mollusc-ephemeropteran route for this parasite. Chubb (1979) suggested a route via the mollusc through a crustacean, Gammerus pulex to the brown trout, Salmo trutta. The possibility of two routes of transmission of C. farionis in Big Northern Pond exists as there is a co-existence of at least two species of mollusc, various species of ephemeropteran and two species of amphipod. There was a relationship between the rise in parasite occurrence and change in the spring and fall diets of the brook charr. A high incidence of ephemeropterans occurred in the diet of the fish in the spring whereas an increase in the incidence of amphipods in the diet occurred in the fall.

A low prevalence of C. farionis has been attributed to water movement (Chubb, 1979). He also attributed the decrease in parasite prevelance to lowered water temperatures. Water movement other than that caused by wind was not a factor in Big Northern Pond and this aspect cannot be compared to Chubb's study. However, his observations on the onset of colder temperatures do agree with the findings of this study. The data collected for 1986 would suggest two periods of increased prevalence for C. farionis. The initiation for changes in intermediate hosts could well be directional changes in temperature. The advantage to C. farionis of a dual route of transmission would be its continuous existence in the fish population and a reduced reliance on the presence of specific intermediate hosts. This strategy needs further investigation.

The data for August for these years supported the casual observations made prior to the study period. The occurrence of E. salvelini in the stomachs of fish in 1982 and 1985 was probably due to handling the fish when taking them from the nets, or to postmortem migration as the site of preference is known to be the intestine. It would appear that the parasite was obtained during the late fall or early winter and decreased in late spring or early summer. This occurrence of the parasite coinciaed with lower temperatures. The occurrence of E. salvelini in fish found in Newfoundland and Labrador waters has been noted (Sandeman and Pippy, 1967; Hicks and Threlfall, 1973) but no seasonality in prevalence was demonstrated. Chubb (1982) states that there may be years of high prevalence followed by years with lower prevalence.

The effect of season on incidence has been investigated for some parasites (Chubb, 1982). Amin and Burrows (1977) tested for a host-parasite relationship in the rainbow smelt, Osmerus mordax, and found no relationship between season and intensity of infection. Kennedy (1985) stated that generally-speaking the acanthocephalans exist in a state of equilibrium between recruitment and loss of parasites but that exogenous factors, ie. water temperature, availability of infected hosts, and the diet and feeding behaviour of the fish, may cause fluctuations in infection levels.

An examination of the intestinal prevalence of M. lateralis in S. fontinalis would support the foregoing, as there was for the most part a maintained prevalence of M. lateralis at or about 100% in the fish. However, there were periods when there was an increase in the intake of infective stages. There was a significant rise in the number of small parasites in the stomach and the known intermediate host, the amphipod Hylella azteca, has been seen intact in the stomach of S. fontinalis with the cystacanth visible in the haemocoel. This has previously been reported for Newfoundland fish (Pippy, 1965). The increase in stomach parasites was seen during two periods in 1986, those being early summer (June-July) and early winter (November-December). July of 1983 and 1984 showed slight increases in the incidence of stomach parasites as did August and June of 1985 and 1986, respectively. The change in month for this parasite may be due to changes in environmental factors which can advance or delay the occurrence of suitable intermediate hosts. The presence of two periods would enhance the maintenance of the consistent level of parasitism seen for this organism.

Kennedy (1985) reports that Awachie (1966) found that in Salmo trutta populations of Echinorhynchus truttae were complementary with intermediate and definitive hosts. Awachie (1966) also states that infection rates increased with low temperature and decreased with higher temperatures. In this study the mid-summer peak in parasitism for M. lateralis coincided with increased temperatures. In fact, the highest temperatures in the pond, $21^{0}C$, were reached during this period. It would appear that in Big Northern Pond, a change in temperature rather than a maximum or minimum temperature is what triggered the process.

The intermediate host responsible for the mid-summer peaks of M. lateralis in the stomach is uncertain. Occurrences of H. azteca (the known intermediate host) were seen to occur one month after the mid summer peaks. However, this is not to say that these intermediate hosts were not present during periods of no sampling.

The mid-summer peaks of M. lateralis also coincided with the onset of parasitism of alevins of S. fontinalis by this same parasite. The peaks of 1985 and 1986 were found to be significantly higher (Figs. 12 c,d) than other months sampled except for November and December of 1986. This would further strengthen the contention of a second shorter period of invasion by M. lateralis.

The general trend seen in the data on the interspecific parasite relationships demonstrates that the nematodes and acanthocephalans maximize their numbers during the May-July period while the cestodes and trematodes tend to drop during this period. The exclusion of one parasite by another has been shown (Noble and Noble, 1976) and it can be argued that a surge in metabolic by-products from an increasing parasite presence, ie. M. lateralis, may well be inhibitory to other parasites and result in a reduction in their numbers.

Harris (1972), in Crompton and Nickol, (1985) also speculated that in Leuciscus cephalus (Pisces) antibodies are produced in response to excretory or secretory products of mature acanthocephalans. This situation may well bring on a host response which is selective against parasites other than M. lateralis, thereby excluding them and decreasing the overall burden.

The effect of increasing maturity and the concomitant increase in hormones on parasitism has been recorded (Noble and Noble, 1976; Thomas, 1964). Thomas (1964) postulates increasing levels of estrogens associated with maturation of S. trutta as enhancing parasite resistance and this has been demonstrated for birds and mammals (Haley 1958; Dobson, 1961). Male hormones on the other hand (Haley 1958; Dobson 1961) were found to enhance growth and survival of parasites. There appears to be some related effect of age, sex and maturity when all three aspects are grouped for some of the parasites. The trend would be a reduced prevalence as the fish aged and matured with an increased survival of nematodes, cestodes and trematodes in females. Any effect of reduced prevalence seen in older fish may well be due to residual effects from previous maturity in the individuals concerned but this aspect was not investigated.

Parasite Burden

Parasite burden has some important implications as it can affect the growth and maturity of fish (Noble and Noble, 1976), be responsible for mortality (Pippy, 1965; Lagler, 1956), and make fish undesirable from an angling or eating point of view.

Wiseman (1969) reported that *E. salvelini* in his fish samples occurred with the proglottids protruding in the stomach. It is the feeling of this investigator that this is certainly due to handling as these worms do not have mechanisms which would allow them to position themselves in a direction contrary to gastric flow.

The numbers of *E. salvelini* in infected fish was low and did not reach the numbers seen by this author in the same fish species in other localities, being due most probably to geographical position of the pond and its isolation from migrating species. There was one sample of fish caught in August 1982 which contained a large number of cestodes. This can be attributed to environmental factors which may have allowed an unusually large number of intermediate hosts carrying the cestodes to survive and then be eaten by the brook charr.

Effect of parasitism on condition factor

Parasitism is known to be detrimental to the health and general well-being of animals (Noble and Noble, 1976) and has been implicated in the poor condition of sport fishes to the extent the fish were not appealing to anglers (Wiseman, 1969). Pippy and Sandeman (1967) report fish kills due to acanthocephalan parasites while Frost (1940) reports that the increase in acanthocephalan numbers paralleled an increase in age and condition. The brook charr of Big Northern Pond have been shown to harbour large numbers of parasites and in the cases where a parasite is known to have mechanical structures, ie. the proboscis of acanthocephalans, which may cause tissue damage and the possible depletion of nutrients through competitive absorption of a resource (seen in all cases of parasites reported here), then there may well be an effect on the condition of the fish.

No demonstrable effect of parasitism was seen in regard to condition factor and in the case of acanthocephlan parasite burden there may well be a benefit. However, results were not significant.

Summary

A five-year ecological investigation into the life history of <u>Salvelinus fontinalis</u> (Mitchill) was undertaken to evaluate the effect of an acid, dystrophic, headwater habitat on the seasonal aspects of growth, feeding, reproduction and parasitism.

The water quality of the system seems, with the exception of pH, unaltered by man. The water contains low amounts of ions due to the relatively low solubility of the underlying substrate. The bacteriological quality in terms of coliforms indicates that no contamination from surrounding areas (cattle pastures) is affecting the system.

The pH of the system is low and responds to input of acid precipitation. The low pH may be responsible for the low condition of the young of the year fish relative to the older members of the species. The fish of age greater than 0+ show similar growth to those lower in this watershed where the pH is higher. Comparisons of growth on a year by year basis and by cohort revealed no significant differences, indicating the ability of the fish to compensate to environmental change.

There was a 1:1 sex ratio for young of the year fish. This ratio changes with age, the males having a higher rate of mortality then females. Both males and females mature at the same age and changes in the sex ratios may be due to stress involved with courtship and spawning. The conspicuous coloration of males during spawning may also enhance predation on this sex.

The length-weight relationship for the brook charr (age $\geq$ 1+) closely followed the cube law. The exponent values ranged between 2.92 and 3.05 and were not significantly difference from 3.0. The length-weight relationship for developing young of the year fish was significantly different from the expected value of 3 for salmonids, with exponent values ranging from a low of 3.30 to a high of 3.44. The condition factor for young of the year fish was variable with extremely low for gutted fish condition. Condition factor was higher for adult fish and dropped below 1 only once for the older fish.

The food of all age groups of the population was similar with the exception of fish eggs which were present only in the stomachs of fish age greater than 1+. There were no cases of empty stomachs in any fish.

Parasite species diversity in S. fontinalis in Big Northern Pond was low. Four enteric helminths parasites were encounted consistently over the period of study. These parasites were M. salvelini, C. farionis, M. lateralis and E. salvelini. The parasite numbers for M. salvelini and M. lateralis were high. Parasite burden does not seem to affect the condition of the fish and no pathology suggestive of parasite related mortality was noted.

Seasonal variation in parasite numbers was noted and a new route of infection for M. lateralis, involving coprophagy is proposed.

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APPENDIX

Table: I Weight distributions of the age groups of *Salvelinus fontinalis* from Big Northern Pond in 1982.

Weight (G)	0^+		1^+		2^+		3^+		4^+		5^+	
	F	M	F	M	F	M	F	M	F	M	F	M
0.00 - 9.99	(100.0)2	(100.0)2										
10.00 - 29.99			(33.3)2	(25.0)1								
30.00 - 49.99			(66.7)4	(50.0)2	(7.4)2	(23.8)5						
50.00 - 69.99				(25.0)1	(77.8)21	(33.3)7	(40.0)6	(44.4)4				
70.00 - 89.99					(14.8)4	(42.9)9	(53.3)8	(44.4)4				
90.00 - 109.99							(6.7)1	(11.1)1	(66.7)2	(66.7)2		
110.00 - 129.99										(33.3)1		
130.00 - 149.99									(33.3)1			
150.00 - 169.99												
170.00 - 189.99											(11.1)1	
190.00 - 209.99											(55.6)5	
210.00 - 229.99											(11.1)1	
230.00 - 249.99											(11.1)1	
250.00 - 269.99											(11.1)1	
270.00 - 289.99												
290.00 - 309.99												

Table: 1 Weight distributions of the age groups of Salvelinus fontinalis from Big Northern Pond in 1983.

Weight (G)	0^+		1^+		2^+		3^+		4^+		5^+	
	F	M	F	M	F	M	F	M	F	M	F	M
0.00 - 9.99	(100.0)21	(100.0)34		(12.5)1								
10.00 - 29.99			(50.0)1	(37.5)3		(17.6)3						
30.00 - 49.99			(50.0)1	(50.0)4		(29.4)5		(7.1)1				
50.00 - 69.99					(33.3)4	(41.2)7	(11.8)4					
70.00 - 89.99					(50.0)6	(5.9)1	(14.7)5	(21.4)3				
90.00 - 109.99					(16.7)2	(5.9)1	(26.5)9	(28.6)4				
110.00 - 129.99							(17.6)6	(7.1)1				
130.00 - 149.99							(17.6)6	(35.7)5		(66.7)2		
150.00 - 169.99							([illegible] 8)3		(40.0)2			
170.00 - 189.99							(2.9)1		(40.0)2	(33.3)1	(50.0)1	
190.00 - 209.99									(20.0)1		(50.0)1	
210.00 - 229.99												
230.00 - 249.99												
250.00 - 269.99												
270.00 - 289.99												
290.00 - 309.99												

Table:[1] Weight distributions of the age groups of <u>Salvelinus</u> <u>fontinalis</u> from Big Northern Pond in 1984.

Weight (G)	0^+		1^+		2^+		3^+		4^+		5^+	
	F	M	F	M	F	M	F	M	F	M	F	M
0.00 - 9.99	(94.7)18	(100.0)18										
10.00 - 29.99	(5.3)1		(57.1)4	(54.5)6	(9.5)2							
30.00 - 49.99			(42.9)3	(45.5)5	(33.3)7	(23.5)4						
50.00 - 69.99					(57.1)12	(70.6)12	(57.1)4	(33.3)1				
70.00 - 89.99						(5.9)1	(14.3)1					
90.00 - 109.99							(14.3)1	(33.3)1				
110.00 - 129.99							(14.3)1	(33.3)1	(50.0)1			
130.00 - 149.99							(20.0)1					
150.00 - 169.99										(50.0)2		
170.00 - 189.99									(50.0)1	(25.0)1		
190.00 - 209.99												
210.00 - 229.99												
230.00 - 249.99										(25.0)1		
250.00 - 269.99											(50.0)1	
270.00 - 289.99											(50.0)1	
290.00 - 309.99												

Table: [4] Weight distributions of the age groups of <u>Salvelinus</u> <u>fontinalis</u> from Big Northern Pond in 1985.

Weight (G)	0^+		1^+		2^+		3^+		4^+		5^+	
	F	M	F	M	F	M	F	M	F	M	F	M
0.00 - 9.99	(100.0)18	(100.0)23										
10.00 - 29.99			(66.7)8	(69.2)9								
30.00 - 49.99			(33.3)4	(30.8)4		(50.0)14						
50.00 - 69.99					(33.3)1	(42.9)12	(20.0)1					
70.00 - 89.99					(33.3)1	(7.1)1	(20.0)1		(25.0)4			
90.00 - 109.99					(33.3)1		(20.0)1	(100.0)3		(12.5)1		
110.00 - 129.99							(20.0)1	(12.5)1	(25.0)1	(37.5)3		
130.00 - 149.99							(20.0)1			(37.5)3		
150.00 - 169.99									(50.0)2			
170.00 - 189.99												(80.0)4
190.00 - 209.99										(12.5)1	(50.0)1	
210.00 - 229.99												
230.00 - 249.99												
250.00 - 269.99												
270.00 - 289.99												
290.00 - 309.99												
310.00 - 329.99												
330.00 - 340.99											(50.0)1	

Table : Weight frequency distributions of the age groups of Salvelinus fontinalis for 1986 from Big Northern Pond.

Weight (G)	0+		1+		2+		3+		4+		5+	
	F	M	F	M	F	M	F	M	F	M	F	M
0.00 - 9.99	(100.0)16											
10.00 - 29.99			(25.0)1	(22.2)2								
30.00 - 49.99			(75.0)1	(66.7)6	(50.0)2	(22.2)2						
50.00 - 69.99				(11.1)1	(50.0)2	(33.3)3	(12.5)2					
70.00 - 89.99						(11.1)1	(25.0)4	(12.5)1				
90.00 - 109.99						(22.2)2	(18.8)3					
110.00 - 129.99							(6.3)1	(12.5)1	(33.3)1			
130.00 - 149.99						(11.1)1	(6.3)1	(25.0)2				
150.00 - 169.99							(18.8)3	(37.5)3	(33.3)1			
170.00 - 189.99							(6.3)1			(33.3)1		
190.00 - 209.99							(6.3)1	(12.5)1		(33.3)1		
210.00 - 229.99										(33.3)1		
230.00 - 249.99												
250.00 - 269.99												
270.00 - 289.99												
290.00 - 309.99												
310.00 - 329.99										(33.3)1		(100.0)1
330.00 - 349.99												

Table: 6 Length frequency distributions of the age groups of <u>Salvelinus</u> <u>fontinalis</u> for 1982 from Big Northern Pond.

Length (CM)	0+		1+		2+		3+		4+		5+	
	F	M	F	M	F	M	F	M	F	M	F	M
0.00 - 2.99	(50.0) 1											
3.00 - 5.99	(50.0) 1	(100) 2										
6.00 - 8.99												
9.00 - 11.99			(16.7) 1									
12.00 - 14.99			(66.7) 4	(75.0) 3		(9.5) 2						
15.00 - 17.99			(16.7) 1	(25.0) 1	(100.0) 3	(90.5) 19	(66.7) 10	(78.8) 7				
18.00 - 20.99							(33.3) 5	(22.2)	(66.7) 2	(66.7) 2		
21.00 - 23.99									(33.3) 1	(33.3) 1		
24.00 - 26.99											(88.9) 8	—
27.00 - 29.00											(11.1) 1	
30.00 - 32.99												

Table: 7 Length frequency distributions of the age groups of *Salvelinus fontinalis* for 1981 from Big Northern Pond.

Length (CM)	0+		1+		2+		3+		4+		5+	
	F	M	F	M	F	M	F	M	F	M	F	M
0.00 - 2.99	(28.6)6	(8.8)3										
3.00 - 5.99	(61.9)13	(61.8)21										
6.00 - 8.99	(9.5)2	(29.4)10		(12.5)1								
9.00 - 11.99			(50.0)1	(25.0)2		(11.8)2						
12.00 - 14.99				(62.5)5		(29.4)5						
15.00 - 17.99			(50.0)1		(58.3)7	(52.9)9	(8.8)3	(7.1)1				
18.00 - 20.99					(41.7)5	(5.9)1	(44.1)15	(57.1)8				
21.00 - 23.99							(47.1)16	(35.7)5	(40.2)2	(100)3	(50.1)1	—
24.00 - 26.99									(60.0)3		(50.0)1	—
27.00 - 29.00												
30.00 - 32.99												

Table:8 Length frequency distributions of the age groups of <u>Salvelinus fontinalis</u> for 1984 from Big Northern Pond.

Length (CM)	0^+		1^+		2^+		3^+		4^+		5^+	
	F	M	F	M	F	M	F	M	F	M	F	M
0.00 - 2.99	(1.05)2	(16.7)3										
3.00 - 5.99	(84.2)16	(83.3)15										
6.00 - 8.99												
9.00 - 11.99	(5.3)1		(42.9)3	(36.4)4								
12.00 - 14.99			(57.1)4	(63.6)7	(19.0)4							
15.00 - 17.99					(81.0)14	(100.0)17	(28.6)2					
18.00 - 20.99							(71.4)5	(100.0)4				
21.00 - 23.99									(100.0)2			
24.00 - 26.99										(100.0)4	(50.0)1	—
27.00 - 29.00											(50.0)1	—
30.00 - 32.99												

Table:[9] length frequency distributions of the age groups of <u>Salvelinus fontinalis</u> for 1985 from Big Northern Pond.

Length (CM)	0^+		1^+		2^+		3^+		4^+		5^+	
	F	M	F	M	F	M	F	M	F	M	F	M
0.00 - 2.99	(33.3)6	(30.4)7										
3.00 - 5.99	(55.6)10	(56.5)13										
6.00 - 8.99	(11.1)2	(13.0)3	(8.3)1									
9.00 - 11.99			(41.7)5	(23.1)3								
12.00 - 14.99			(50.0)6	(76.9)10								
15.00 - 17.99					(66.7)2	(96.4)27	(20.0)1					
18.00 - 20.99					(33.3)1	(3.6)1	(60.0)3	(100.0)3	(25.0)1	(12.5)1		
21.00 - 23.99							(20.0)1		(75.0)5	(75.0)6		(20.0)1
24.00 - 26.99										(12.5)1	(50.0)1	(80.0)4
27.00 - 29.00											(50.0)1	—
30.00 - 32.99												

Table: 10 Length frequency distributions of the age groups of Salvelinus fontinalis for 1986 from Big Northern Pond.

Length (CM)	0^+ F	0^+ M	1^+ F	1^+ M	2^+ F	2^+ M	3^+ F	3^+ M	4^+ F	4^+ M	5^+ F	5^+ M
0.00 - 2.99	(18.8) 3	(35.3) 6										
3.00 - 5.99	(62.5) 10	(41.2) 7										
6.00 - 8.99	(18.8) 3	(23.5) 4										
9.00 - 11.99			(25.0) 1	(11.1) 1								
12.00 - 14.99			(25.0) 1	(55.6) 5	(25.0) 1	(11.1) 1						
15.00 - 17.99			(50.0) 2	(33.3) 3	(75.0) 3	(33.3) 3	(6.3) 1					
18.00 - 20.99						(44.4)	(56.3) 9	(25.0) 2				
21.00 - 23.99						(11.1) 1	(37.5) 6	(50.0) 4	(66.7) 2			
24.00 - 26.99								(25.0) 2		(100.0) 3		
27.00 - 29.00												(100.0) 1
30.00 - 32.99									(33.3) 1			

Table 11a. Parasite burden in the Stomach of
S. fontinalis in Big Northern Pond.

		M. salvelini			M. lateralis			E. salvelini		
Yr.	No.	A	B	C	A	B	C	A	B	C
1982	08	97.70	1.05	1.03	78.00	6.00	4.68	4.80	1.00	0.05
1983	05	93.70	37.40	35.04	18.80	1.67	0.31	0	0	0
	06	95.00	17.19	16.33	9.00	2.50	0.23	0	0	0
	07	85.70	8.17	6.95	14.30	1.00	0.14	0	0	0
	08	71.40	6.19	4.41	10.30	1.67	0.17	0	0	0
	10	36.80	6.14	2.26	0	0	0	0	0	0
1984	05	76.50	7.54	5.77	0	0	0	0	0	0
	06	87.50	9.14	8.00	12.50	5.00	0.63	0	0	0
	08	100.00	18.64	18.64	0	0	0	0	0	0
	11	43.60	7.71	3.36	10.30	1.50	0.16	0	0	0
1985	05	0	0	0	33.00	2.00	0.67	0	0	0
	07	88.90	15.5	13.78	0	0	0	0	0	0
	08	58.30	4.63	2.70	25.00	3.50	0.88	0	0	0
	10	33.30	4.75	1.58	0	0	0	1.70	1.00	0.02
1986	02	40.00	15.00	6.00	0	0	0	0	0	0
	04	22.20	7.00	1.55	0	0	0	0	0	0
	05	100.00	3.00	3.00	0	0	0	0	0	0
	06	100.00	9.29	9.29	42.90	4.00	1.71	0	0	0
	08	50.00	1.33	0.67	0	0	0	0	0	0
	10	23.50	2.75	0.65	0	0	0	0	0	0
	11	0	0	0	100.00	6.50	6.50	0	0	0
	12	0	0	0	100.00	1.50	1.50	0	0	0

A = Prevalence (%)

B = X intensity

C = Abundance

Table 11b. The parasite burden of the intestine of S. fontinalis in Big Northern Pond.

		M. salvelini			*M. lateralis*			*E. salvelini*			*C. farionis*		
Yr.	Mo.	A	B	C	A	B	C	A	B	C	A	B	C
1982	08	0	0	0	45.20	9.95	4.50	88.10	15.03	13.24	4.80	1.00	0.05
1983	05	68.70	12.64	8.68	87.50	33.79	29.57	50.00	2.38	1.19	62.50	5.00	3.13
	06	73.70	6.06	4.5	95.50	74.05	70.72	18.20	1.50	0.27	18.20	1.00	0.18
	07	57.10	2.38	1.36	100.00	47.20	47.20	14.30	1.00	0.14	0	0	0
	08	27.60	3.00	0.83	96.60	40.10	38.74	3.40	1.00	0.03	0	0	0
	10	26.30	1.60	0.42	100.00	27.68	27.68	21.10	1.00	0.21	0	0	0
1984	05	35.30	4.17	1.47	100.00	19.71	19.71	17.60	1.33	2.23	11.80	16.50	1.95
	07	62.50	4.20	2.63	100.00	46.50	46.50	12.50	1.00	0.13	0	0	0
	08	50.00	4.00	2.00	100.00	12.91	12.91	0	0	0	0	0	0
	11	12.80	1.00	0.13	94.40	25.32	24.66	15.40	1.17	0.18	0	0	0
1985	05	0	0	0	100.00	77.33	77.33	66.70	1.50	10.00	100.00	39.67	39.67
	07	32.20	2.50	0.81	100.00	7.78	7.78	0	0	0	0	0	0
	08	8.30	5.00	0.42	83.30	14.09	11.74	8.30	5.00	0.42	0	0	0
	10	21.70	1.69	0.37	85.00	15.04	12.78	13.30	1.25	0.17	1.70	1.00	0.02
1986	02	20.00	1.0	0.20	100.00	20.00	20.00	40.00	4.50	1.80	40.00	2.50	1.00
	04	72.20	2.50	1.80	100.00	35.11	35.11	44.40	3.75	1.67	66.70	98.00	65.37
	05	0	0	0	100.00	5.00	5.00	0	0	0	0	0	0
	06	28.60	8.50	2.43	100.00	111.43	111.43	14.30	1.0	0.14	28.60	1.50	0.43
	08	0	0	0	100.00	16.17	16.17	0	0	0	0	0	0
	10	5.90	4.00	0.24	88.20	14.27	12.59	11.80	2.50	0.30	0	0	0
	11	0	0	0	100.00	153.50	153.50	0	0	0	0	0	0
	12	100.00	1.00	1.00	100.00	33.00	33.00	0	0	0	50.00	2.00	1.00

A = Prevalence (%)

B = X inten