THE UNIVERSITY OF MANITOBA

Growth, Mortality, Production and Feeding of Yellow Perch Fry, *Perca fluviatilis flavescens* (Mitchill) and Their Effect on the *Daphnia pulicaria* Forbes of West Blue Lake

by

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GROWTH, MORTALITY, PRODUCTION AND FEEDING OF YELLOW PERCH FRY, PERCA FLUVIATILIS FLAVESCENS (MITCHILL) AND THEIR EFFECT ON THE DAPHNIA PULICARIA FORBES OF WEST BLUE LAKE"

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ABSTRACT

Distribution, mortality, growth, production and feeding habits of perch fry and their effect on the *Daphnia pulicaria* population of West Blue Lake was investigated. Perch hatched in the littoral zone in early June and moved into the pelagic zone 7 to 14 days later when they were 9 - 10 mm in length. Perch fry remained in the pelagic zone until they reached a length of approximately 25 - 30 mm in mid-July, and then returned to the littoral area. Instantaneous daily mortality rates ranged from .017 in areas of low perch fry abundance to .140 in areas of high perch fry abundance.

From hatching until mid-August perch fry increased in length and dry weight by a factor of 10 and 2616 respectively. Growth occurred in two distinct stanzas. The first stanza, from hatching until the beginning of the pelagic phase, was characterized by a low level of feeding and a slow growth rate, while the second stanza, lasting for the remainder of the summer, was characterized by a high level of feeding and a fast growth rate. Variation in the energy intake and growth of perch fry in different parts of the lake was directly dependent upon the abundance of *Daphnia pulicaria*.

Changes in the proportion of carbon, nitrogen and water and in the calorific value of perch fry tissues occurred from hatching through metamorphisis. The initial proportion of carbon, 547.9 ug mg dry weight^{-1}, decreased rapidly following hatching while the low levels of nitrogen at hatching, 70.6 ug mg dry weight^{-1}, increased, indicating that growth occurred at the expense of the accumulation of high energy compounds. Throughout the pelagic phase the proportion of carbon and nitrogen in the tissues increased concomitantly and later decreased when the fry returned to the littoral zone. Calorific values declined from 6727 cal mg dry weight^{-1} at hatching to approximately 5000 cal mg dry weight^{-1} at the end of the pelagic period. They gradually increased during the littoral phase to 5760 cal mg dry weight^{-1} by mid-August. Following an initial increase after hatching to 90%, the water content of the tissues decreased to approximately 81% by mid-August.

Perch fry initially fed on copepods and nauplii. On entering the pelagic zone *Daphnia pulicaria* became the dominant food source and remained so in most of the lake for the remainder of the summer. At one location during the littoral phase *Bosmina longirostris* became the dominant food source as the result of the very low abundance of *Daphnia pulicaria*. Size selective feeding was prominent in fish less than 20 mm in length but older fry fed on all size-classes of *Daphnia pulicaria*. Size selective feeding also occurred on a diel basis with the largest *Daphnia pulicari* being consumed at night. Total daily consumption of *Daphnia pulicaria* by perch fry ranged from less than .1% to greater than 5.8% of the standing crop during the pelagic phase. Predation was heaviest in the area with the highest abundance of perch fry and contributed to the collapse of the *Daphnia pulicaria* population at this location and their replacement by *Bosmina longirostris*. Decreases in the abundance of *Daphnia pulicaria* in areas of the lake with low numbers of perch fry indicated that these populations may decline independently of fish predation.

Mean whole lake production of perch fry was .08 mg C m^{-2} day^{-1}.

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TABLE OF CONTENTS

TABLE OF CONTENTS cont'd

LIST OF TABLES

LIST OF TABLES cont'd

TABLE PAGE

LIST OF FIGURES

LIST OF FIGURES cont'd

LIST OF FIGURES cont'd

LIST OF FIGURES cont'd

LIST OF APPENDICES

INTRODUCTION

Yellow perch, *Perca fluviatilis flavescens* (Mitchill), are found throughout much of Canada, and combined with the Eurasian perch, have an almost circumpolar distribution in freshwaters of the northern hemisphere (Scott and Crossman 1973). As a result of their commercial and recreational importance there is a considerable body of literature available on age, growth and production of juvenile and adult forms in Canadian habitats (Harkness 1922, Carlander 1950, Lawler 1953, Coble 1966, Sheri and Power 1969, Falk 1971). Yet, little is known about the role of the 0+ age group beyond their general ecology (Keast and Webb 1966, Wong 1972).

The most important energy source for perch fry of West Blue Lake is the cladoceran, *Daphnia pulicaria* which comprises over 90% of their daytime energy intake (Wong 1972). In turn, perch fry are a major forage for juvenile and adult walleye of West Blue Lake (Glenn and Ward 1968, Kelso 1973) and account for approximately 30% of annual production in the walleye population (Ward and Robinson 1974). Annual variations in growth of young perch in Oneida Lake during their demersal stage is highly correlated with *Daphnia* sp. abundance (Noble 1975) and growth and production in the walleye population is directly related to abundance and production of young perch (Forney 1965).

Qualitative aspects of the impact of predation by planktivorous fish on zooplankton populations have been well documented by Brooks and Dodson (1965) and Galbraith (1967). In both cases, changes occurred to the genus *Daphnia* which is a common and important food source for most freshwater planktivorous fish (Ivlev 1961). Both studies indicated that the presence of a planktivorous fish population affected size and species composition of local zooplankton populations. More recently, Noble (1975) has shown that young yellow perch in their demersal stage have little effect on the *Daphnia* sp. population of Oneida Lake.

In West Blue Lake the theme of the research is to describe the trophic relationships and ecology of the dominant components of the ecosystem and to evaluate the importance of these relationships in defining the productivity of the major components. The objectives of the present study are (1) to quantify patterns of growth, mortality, feeding and production in young perch and (2) to determine their effect on the *Daphnia pulicaria* population of West Blue Lake.

MATERIALS AND METHODS

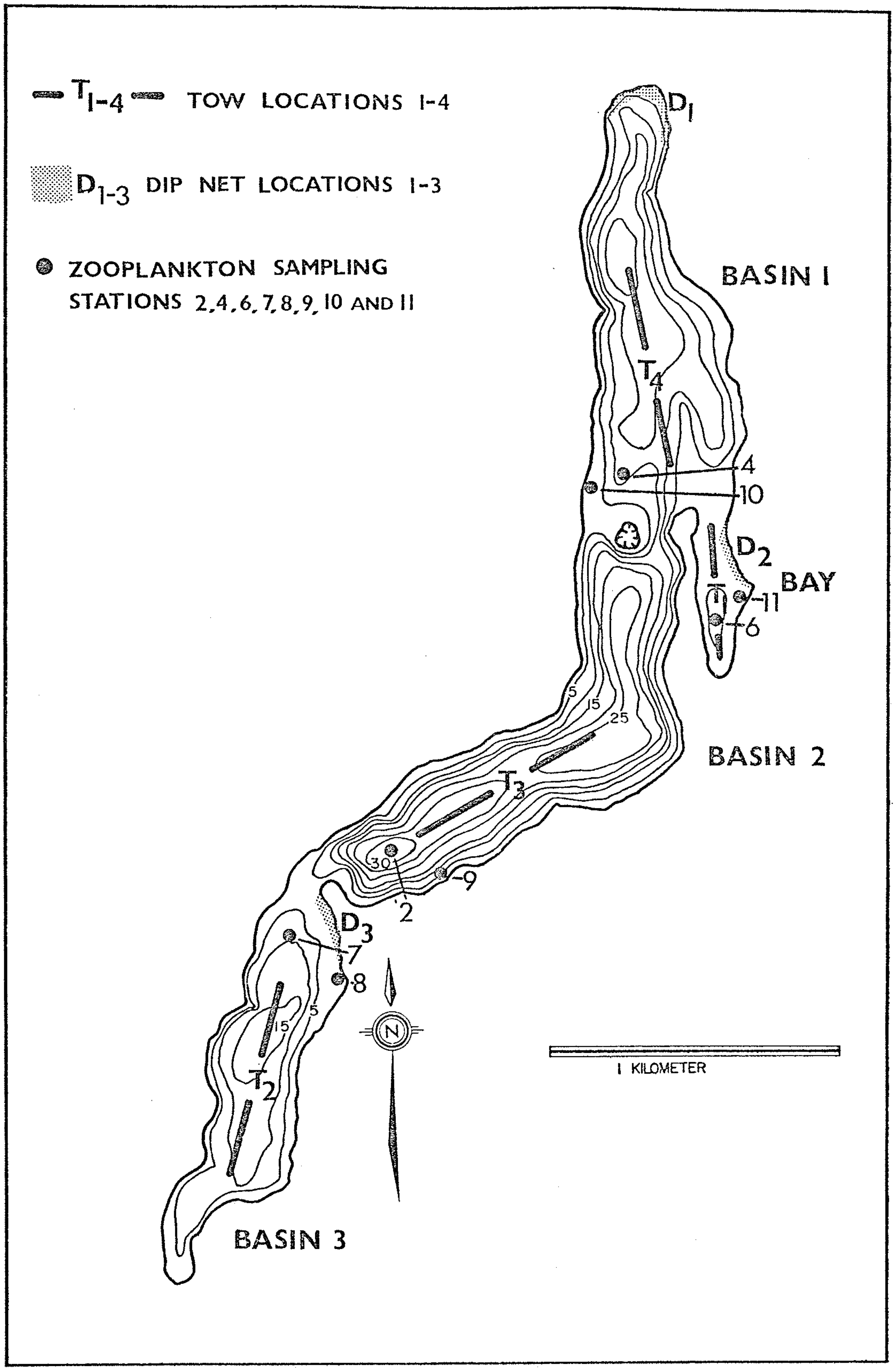
Description of Area

West Blue Lake, situated in the Duck Mountain Provincial Park in west central Manitoba (latitude 51°36', longitude 100°55' and altitude 670 m) is a channel lake with a multibasin configuration (Fig. 1). It is essentially a closed lake with a maximum depth of 31 m, a mean depth of 11.3 m, and a total area of 160 ha (Bell and Ward 1970).

The zooplankton is composed of three dominant species, *Daphnia pulicaria*, *Cyclops bicuspidatus*, and *Diaptomus siciloides* and associated species *Mesocyclops edax*, *Epischura lacustris*, and *Bosmina longirostris*. The Rotifera are represented by *Keratella cochlearis*, *Keratella quadrata*, *Felinis longiseta* and *Asplanchna* sp. (Wong 1972).

The fish community of the lake consists of yellow perch, *Perca fluviatilis flavescens;* walleye, *Stizostedion vitreum vitreum;* five-spined stickleback, *Culea inconstans;* northern pike, *Esox lucius*; and lake trout, *Salvelinus namycush*. Also, two minnows, *Pimephales promelas* were caught in 1966 and two common white suckers, *Catostomus commersoni*, were caught in 1974.

Figure 1. A contour map of West Blue Lake showing sampling sites (depths in metres).



T1-4 TOW LOCATIONS 1-4
D1-3 DIP NET LOCATIONS 1-3
ZOOPLANKTON SAMPLING STATIONS 2,4,6,7,8,9,10 AND 11
D1
BASIN I
T4
4
10
D2
BAY
T1
11
6
5
15
25
BASIN 2
T3
30
9
2
D3
7
8
15
5
N
1 KILOMETER
T2
BASIN 3

Sampling of Perch Fry

Date of initiation of spawning by adult perch, spawning locations, water temperatures at spawning sites, number of spawning sites over defined areas of the lake and date at which eggs became eyed were recorded in 1975.

Samples of perch fry were collected from different parts of West Blue Lake at regular intervals from early June until mid-August in 1974 and 1975. Perch fry used for determining lengths and weights were collected from basins 1, 2 and 3 and the bay. Those used for gut analysis were collected from basin 2 and the bay. Carbon, nitrogen and calorific estimates were based on samples collected from basins 1, 2 and 3 and the bay in 1974 and from basin 2 in 1975. These samples were collected using dip nets, half metre tow nets and seine nets.

In 1975 samples of perch less than 1 h old were collected from aquaria in which fertilized eggs had been reared. The aquaria, equipped with a flow-through water system, were kept at natural temperatures by supplying them with lakeshore water.

During the first days after hatching, perch fry were collected near shore (Fig. 1) at night by hanging an artificial light source over the side of the boat and dipping them out as they rose to the surface. Later, when they became pelagic, a half-metre tow net was the main sampling method. The sampling procedure was the same as that described by Wong (1972).

In the middle of the summer, when the perch fry returned to the littoral zone, collections were made using a seine net with .63 cm (stretched measure) mesh. The seine net was set about 7 m offshore and pulled in slowly. Fish trapped were then removed with a dip net. All seining was done during daylight hours.

Pelagic perch fry were also sampled using Miller high-speed trawls (Miller 1961) between June 25 and July 15, 1975 to quantitatively estimate their abundance. The translucent trawls, constructed with 1000 um Nitex screening and plexiglass, were pulled at speeds of 11-12 kmh^{-1} using a towing cable attached to the transon of a 4.9 m fibreglass boat (Noble 1970). Trawls were made in basin 2 and the bay with four samples being taken at each depth of 0, 2 and 4 m. All sampling was done between 23:00 and 01:00 h and the distances over which the trawls were made was determined using an Isurumi-Seiki-kosakusho flow meter.

Samples were washed from the catch buckets and immediately killed and preserved in 5% formalin. In the laboratory the samples were placed in sorting pans where perch fry were separated from zooplankton and counted.

Perch fry were collected at 2 h intervals over a 24 h period in basin 2 and the bay on June 28-29 and July 8-9 and in the bay on July 15-16. All samples were collected with a half-metre tow net at depths of 3-5 m during daylight and at the surface from dusk until dawn. A minimum of 10 perch fry were collected in each sample and immediately killed and preserved in 5% formalin for later gut analysis.

Experiments were conducted at the same time the 24 h sampling was in progress to determine the passage rate of food through the guts of the perch fry. Twenty to 30 perch fry were collected at each of four equal time intervals over the 24 h period using a half-metre tow net. The perch fry were immediately placed in feeding chambers containing zooplankton at natural concentrations. After 30 min the fry were transferred to chambers containing zooplankton stained with Bismark Brown Y. Through serial sacrifice the median time from initiation of feeding to initiation of evacuation of the stained food source was determined.

Sampling of *Daphnia pulicaria*

Daphnia pulicaria were collected at eight stations (Fig. 1) at weekly intervals from May 14 to August 13, 1975, using a 15 l Schindler-Patalas trap (Schindler 1969).

Station 2 was sampled at 0, 1, 3, 5, 7, 12, 17, 20, 25 and 30 m; station 4 at 0, 1, 3, 5, 7 and 12 m and station 6 and 7 at 0, 2, 4, 6 and 8 m. Stations 8, 9, 10 and 11 were located within 3 m of the shoreline and sampled at the surface in 1.0-1.5 m of water. Station 2 was always sampled first, at 10:00 h, with the remaining stations being completed by 14:00 h. Samples were immediately killed and preserved in formalin. They were counted at a later date using a Zeiss inverted microscope to determine the number of *Daphnia pulicaria* present. The number of *Daphnia pulicaria* present at intermediate depths was obtained by interpolation and results were converted into the number under 1 m^2 of water. The number of *Bosmina longirostris* under 1 m^2 of water was determined for stations 2 and 6 at bi-weekly intervals from July 3 to August 13 using the same samples and counting procedure. At each station on each sampling date a temperature profile was obtained.

Length-frequency distributions of the *Daphnia pulicaria* population were determined at weekly intervals from May 13 until August 15, 1975, for stations 2 and 6. Vertical tows were taken at station 2 from 30-0 m and at station 6 from 8-0 m using a Birge net constructed of 72 µm Nitex screening. Discrete samples were collected weekly at station 2 at 2.5, 8, 15 and 20 m using a 15 h Schindler-Patalas trap. Samples from both stations were collected at 10:00 h except on July 10 at station 2 and July 11 at station 6 when additional samples were taken at 2.5 m at 24:00 h. In most cases a minimum of 200 *Daphnia pulicaria* were collected and measured as described by Wong (1972).

Seasonal Growth of Perch Fry

Perch fry used to estimate growth in 1974 were collected from June 9, when they were 1-3 days old, until August 19. In 1975 they were collected from May 31, when they were 1 day old, until August 12. In 1975 lengths and weights were obtained for perch within 1 h of hatching from aquaria reared eggs. Lengths and wet weights were determined as described by Wong (1972). Dry weights were obtained by placing perch fry in a drying oven set at 100 C for 24 h. Mean lengths and weights were calculated for all samples and used to estimate seasonal growth (Chapman 1967) and length-weight relationships (Tesch 1968). Instantaneous growth rates (Ricker 1975), measured as change in dry weight, were estimated for both years.

Calorific, carbon and nitrogen estimates for perch fry were obtained for a series of dates in 1974 and 1975.

Fry used for calorific work were measured and dried at 100 C for 24 h. The remains were ground into a fine powder and frozen in a sealed container. At a later date, samples were burned in a Phillipson Microbomb Calorimeter.

Perch fry used for carbon and nitrogen estimates were treated in a similar manner except care was taken to ensure that all surfaces touching the fry contained no residual carbon. All instruments used in the manipulation of perch fry and containers used to store their remains had previously been soaked in dichromate acid for 30 min and rinsed six times in distilled water. Carbon and nitrogen determinations were made on a Perkin-Elmer 240 Elemental Analyzer.

Perch fry production in terms of carbon and calories was estimated during the pelagic period using the method described by Allen (1951). This is a method for estimating production graphically in which mean carbon or calorific content of the perch fry is plotted against population numbers at given times over the pelagic period. The area beneath the resulting curve was measured to estimate production.

Stomach Analysis of Perch Fry

Perch fry were collected over the spring and summer of 1974 and 1975 to determine number, type and size of prey being consumed. Guts of perch fry were examined using a binocular microscope. For fry with undifferentiated guts (total length < 23 mm), the entire digestive tract was examined. When the stomach became differentiated (total length > 23 mm), it alone was examined. The main taxonomic groups of prey were copepods and cladocerans. Copepods were classified as nauplii or adults (copepodids and mature adults) while the dominant cladoceran, *Daphnia pulicaria* was classified into one of 28 length classes (.1 mm intervals). The number of *Bosmina longirostris* and *Chaoborus flavicans* was also recorded. Calorific values of the prey species were based on the work of Snow (1972) for *Daphnia pulicaria*, Patrick (Department of Zoology, University of Manitoba, Winnipeg, Man., unpublished) for *Cyclops bicuspidatus*, Lysack (1976), for *Chaoborus flavicans* and Schindler, et al. (1971) for *Bosmina longirostris*.

The number of *Daphnia pulicaria* consumed by perch fry m^{-2} day^{-1} during the pelagic phase in basin 2 and the bay was determined in 1975. These estimates were obtained by multiplying the number of perch fry under 1 m^2 of water by the daily consumption of *Daphnia pulicaria* per perch fry.

Daily consumption of *Daphnia pulicaria* per perch fry was estimated by apportioning the average frequency distribution of *Daphnia pulicaria* found in perch fry stomachs, determined from samples collected at 2 h intervals over a 24 h period, into intervals equal to the time required for one *Daphnia pulicaria* to pass through the digestive system of a perch fry. The midpoint of each interval was determined and the corresponding number of *Daphnia pulicaria* in the gut. These estimates were summed over the 24 h period to determine daily consumption of *Daphnia pulicaria* by a perch fry. In equation form:

$$C_T = C_F \times F$$

and $$C_F = \Sigma\,(D_{1-X})$$

where C_T = total number of *Daphnia pulicaria* consumed m^{-2} day^{-1} by perch fry

C_F = number of *Daphnia pulicaria* consumed per perch fry day^{-1}

F = number of perch fry m^{-2}

D = number of *Daphnia pulicaria* in guts of perch fry at the midpoint of each evacuation interval

and X = number of evacuation intervals day^{-1}.

Estimates for dates between the 24 h samples were obtained by interpolation. Daily consumption of *Cyclops bicuspidatus*, *Bosmina longirostris* and *Chaoborus flavicans* by perch fry was estimated using the same procedure. Elevtivity indices for different size-classes of *Daphnia pulicaria* were calculated according to Ivlev (1961).

RESULTS

Perch Fry Distribution and Abundance

Adult perch began to spawn on May 13 in 1975 in water temperatures of 7.1 C (Table 1). The duration of spawning activity varied in different parts of the lake, but did not exceed 13 days from the initiation of spawning. Heaviest spawning activity occurred in the bay at dip net location 2 (Fig. 1). The first eggs became eyed on May 28 when embryos had a mean length of 4.37 mm. The time required for hatching of perch eggs at dip net location 2 was 20 days when the mean daily water temperature was 10.9 C. During this time water temperature varied from 7.1 - 13.0 C.

The first hatching of eggs reared in aquaria occurred on June 2 in 1975 when the fry had a mean length of 5.49 mm. The first fry were caught in the lake on June 9 in 1974 and June 2 in 1975 with mean lengths of 5.60 mm and 5.96 mm respectively.

Observations made on hatching perch fry in aquaria showed that on emerging from their eggs they passively sank to the bottom of the aquarium and laid on their side. At 2-3 min intervals during the first 3 h they would point their head towards the surface and wiggle vigorously, moving 3-5 cm off the bottom of the aquarium. At this point they would stop moving and sink to the bottom of the aquarium, resting on their side. Within 5 h of hatching the fry were able to

Table 1. Observations of perch spawning sites in 1975.

Date	Dip Net Location 1			Dip Net Location 2			Dip Net Location 3		
	Temp (C)	No. of Spawning Sites	Eggs Eyed	Temp (C)	No. of Spawning Sites	Eggs Eyed	Temp (C)	No. of Spawning Sites	Eggs Eyed
May 13	+*	0		7.1	3	NO	+	0	
May 15				11.8	17	NO	10.8	1	NO
May 16	9.3	0							
May 18	8.3	3	NO	9.5	26	NO	9.5	4	NO
May 20	10.0	5	NO	11.0	32	NO	9.5	13	NO
May 26	10.5	5	NO	10.5	33	NO	10.0	18	NO
May 28	10.5	5	NO	12.5	29	YES	12.0	14	NO
May 30	10.0	4	YES	11.0	26	YES	10.5	12	NO
June 1	10.5	4	YES	12.0	31	YES	12.0	13	YES
June 2	10.5	4	YES	13.0	24	YES	12.0	11	YES

*+ temperature not available.