THE UNIVERSITY OF MANITOBA

FOOD HABITS, FEEDING SELECTIVITY, GASTRIC DIGESTION RATES, AND DAILY RATION OF RAINBOW TROUT, *Salmo gairdneri* RICHARDSON, IN WESTERN MANITOBA WINTERKILL LAKES

by

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ABSTRACT

Food habits, feeding selectivity, digestion rates, and daily rations were determined for stocked rainbow trout in a Western Manitoba winterkill lake. Amphipods, cladocerans, and chironomid larvae were the most important food items with amphipods comprising more than 90% by weight of the food consumed from August to October in 1970 and 1971. Rainbow trout were diurnal in their feeding habits and fed more or less continuously throughout the day and early evening. Peak stomach fullness occurred in late afternoon. Food consumption was reduced or absent from about midnight to 6:00 a.m. The type of food organisms eaten at different times of the day did not change appreciably. Evidence suggested that feeding was limited primarily to the limnetic zone.

Laboratory and field experiments on feeding selectivity indicated that prey availability was the most important factor in determining which foods were eaten while predator preference was of minor significance. Chironomid larvae, although apparently preferred by the trout, were negatively selected because of their inaccessibility. The more easily captured amphipods were positively selected. Terrestrial invertebrates, plant material, and many littoral organisms were avoided entirely.

The relationship between state of digestion and time approximated a negative exponential. The number of hours required for 95% digestion at 5, 12, 17, and 22C was 54, 16, 14, and 9 respectively. Digestion rates were independent of meal size, food type, and fish size for the range of food items and fish weights used in the experiments.

Several methods of determining daily ration were evaluated. Estimates based on the balanced equation of Winberg (1956) were considerably higher than those derived from data on digestion rates and diel feeding intensities. Food consumption rates of 3.8% to 5.9% of body weight per day were calculated by the former method for July, August, September, 1971.

INTRODUCTION

A research program, designed to determine the feasibility of stocking rainbow trout, Salmo gairdneri, in prairie winterkill lakes, was undertaken by the Fisheries Research Board of Canada in 1968. Initial investigations demonstrated that rainbow fingerlings 2 - $3\frac{1}{2}$ in. in length, stocked in early May, would attain a marketable size of 8 or more oz. by October of the same year (Johnson et al. 1970).

During May, 1970, 20 small lakes in the Erickson area of Western Manitoba were stocked with 2 - 3 in. rainbow trout at densities ranging from 25 to 860 per acre. Success was highly variable with some lakes yielding as much as 80 to 110 lbs. / acre while a few others failed completely. The mean yield was 43 lbs. / acre and the mean weight of fish harvested, 7.0 oz. Corresponding data for the 22 lakes stocked in 1971 show a significantly greater degree of success with a mean yield of 64 lbs. / acre and a mean harvest weight of 8.9 oz. (Sunde, pers. comm.).

Before trout farming in pothole lakes can become a viable, commercially successful operation, a management program based on a knowledge of the physical and chemical limnology of the lakes and of the stocking densities required to produce the maximum sustained yield, must be developed. The purpose of this investigation was to evaluate, qualitatively and quantitatively, various aspects of the feeding ecology of the stocked rainbow trout as an initial contribution to this program. The primary objectives were as follows:

1. to assess the daily, seasonal, and annual variations in food habits and to identify the more important food organisms.

2. to determine the diel feeding periodicity.

3. to evaluate feeding selectivity.

4. to experimentally determine the rates of gastric digestion in rainbow trout with respect to differences in water temperature, food type, meal size, and fish size.

5. to estimate the daily ration of a population of rainbow trout at regular intervals throughout the growing season.

DESCRIPTION OF STUDY AREA

The study area is located immediately south of Riding Mountain National Park in Western Manitoba between latitudes 50° 30' - 50° 40' north and longitudes 95° 55' - 100° 30' west. A Fisheries Research Board field station is situated in the southeast corner of the area, near the town of Erickson.

The physiography of the region has been described by Goodwin (1930), Munro (1963), Princic (1971), and Fedoruk (1971). A mantle of unconsolidated material, deposited by the receding Wisconsin glacier, overlies a sedimentary shale bedrock of Cretaceous origin. The characteristic "knob and kettle" topography results from the uneven deposition of till in the form of moraines. The till is a heterogeneous mixture of boulders, gravel, sand, silt, and clay. Soil types are grey wooded, black, or variations of the two (Jenkins 1970). The natural vegetation reflects the transition from grassland to boreal forest which occurs here with broadleaf forest predominating in uncleared areas (Jenkins 1970).

Pothole or kettle lakes are extremely abundant in the study area. Most are relatively small in size; those between 2 and 5 acres account for about 50% of the total water area, while lakes of 20 acres or more constitute only 15% (Fedoruk 1971). They are characteristically shallow (15 ft. or less) and self-contained. Water levels are maintained by precipitation, run-off, and groundwater seepage. They are also highly productive with substantial concentrations of dissolved salts (primarily magnesium sulphate and sodium bicarbonate) and high levels of phosphate and nitrate nutrients (Sunde et al. 1971). Winterkill, the gradual reduction of dissolved oxygen to lethal levels resulting from oxidation reactions beneath the ice cover, is an annual phenomenon in all but the deeper lakes and accounts for the absence of indigenous fish populations.

Partial or complete summerkill occurred in some stocked lakes as a result of oxygen depletion during July and August. Decaying algal blooms probably account for this depletion.

Lake 3 (Plates 1 and 2), located adjacent to the Erickson field station, was used extensively during the ice-free seasons of 1970 and 1971 for investigations of rainbow trout food habits, feeding selectivity and feeding periodicity. Physical and chemical features of this lake and of other experimentally stocked lakes are described in Table 1. Weekly oxygen and temperature data are illustrated in Fig. 1. Several authors, including Greenbank (1945), Rozkowska and Rozkowski (1969), and Nickum (1971), provide more detailed information on the limnological characteristics of winterkill lakes.

Flora and fauna lists of the study area lakes are as yet incomplete. A partial list for Lake 3 is given in Table 2. The most abundant invertebrates are the crustacean amphipods, *Gammarus lacustris lacustris* and to a lesser extent, *Hyalella azteca*. Tiger salamanders, *Ambystoma tigrinum* are relatively abundant throughout the area. Population estimates of this species in two small lakes yielded densities of 127 and 282 individuals per hectare (Macklem, pers. comm.). Fathead minnows, *Pimephales promelas* and brook stickleback, *Culaea inconstans* are also commonly found. Heavy blooms of the blue-green alga *Aphanizomenon flos-aquae* occur regularly during the warm summer months in many study area lakes.

Figure 1. Weekly oxygen concentrations (ppm) and mean weekly water temperatures at a depth of 1 m. on Lake 3.

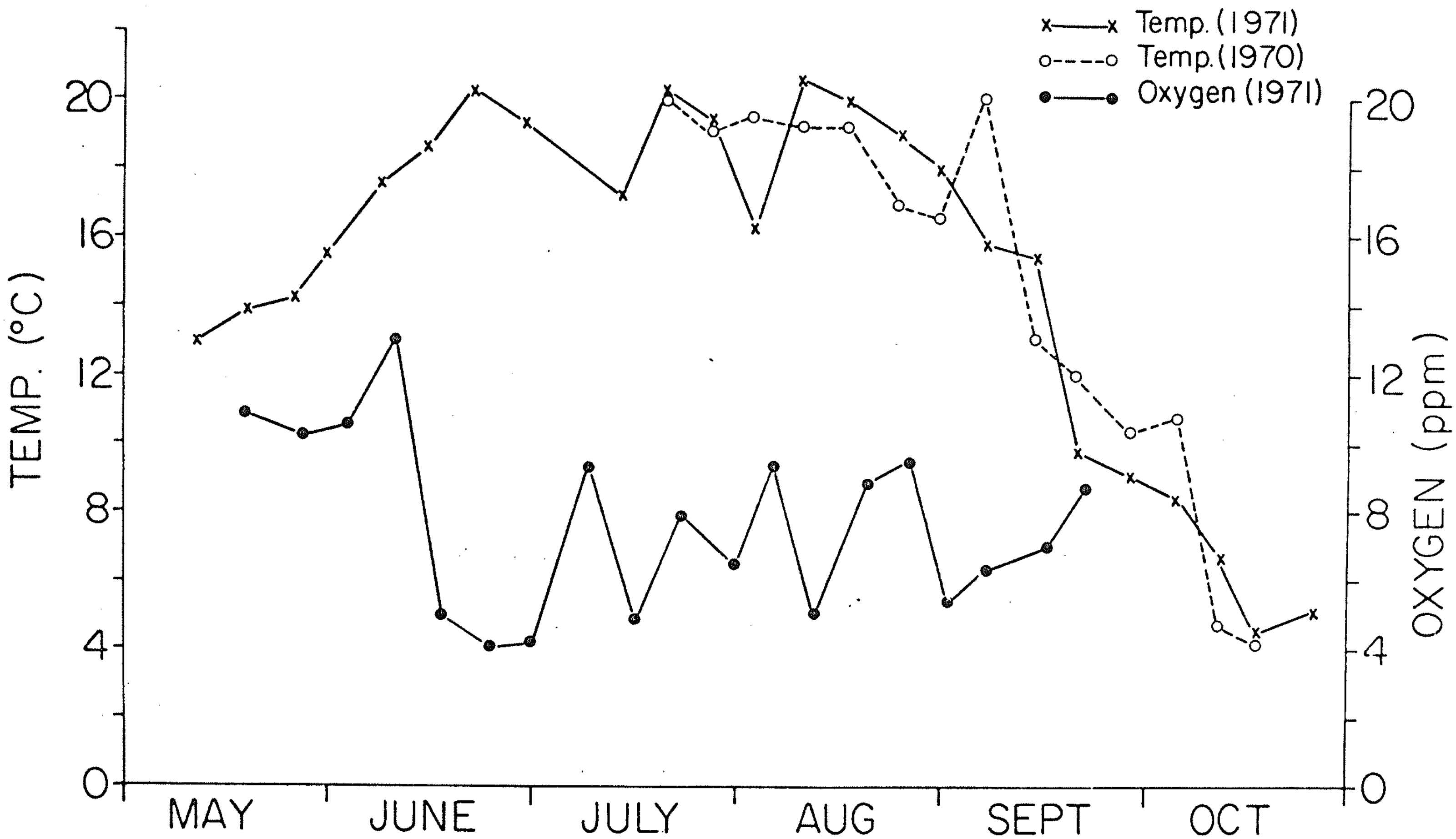
Temp. (1971)
Temp. (1970)
Oxygen (1971)
TEMP. (°C)
OXYGEN (ppm)
0
4
8
12
16
20
MAY
JUNE
JULY
AUG
SEPT
OCT

Table 1. Physical - chemical data from a series of study area lakes compared with those of lake 3.

Feature	Time of year	Lake 3	Other lakes Min.	Max.
Lake area (hectares)		10	1	28
Max. depth (m.)		1.5	1	8
Spec. cond.(μmho/cm^2)	March	2160	700	4100
	July	1000	-	-
Total diss.solids(μmho/cm^2)	March	1790	1170	3960
	July	810	-	-
Calcium (mg/l)	March	97	31	215
	July	90	-	-
Magnesium (mg/l)	March	180	60	747
	July	55	-	-
Sodium (mg/l)	March	269	15	496
	July	53	-	-
Sulphate (mg/l)	March	745	72	2065
	July	285	-	-
Total phosphorus (μg/l)	March	2172	33	310
	July	900	-	-
Total nitrogen (μg/l)	March	3740	1465	4205
	July	860	-	-
pH	July	-	8.5	9.2

Table 2. A partial list of fauna and flora of Lake 3.

Phyllum/Division	Class, Order	Family	Scientific Name	Identification[1]
Mollusca	Gastropoda		*Gyraulus*	C. Holmstrom
			Helisoma	"
			Lymnaea	"
Annelida	Hirudinea			"
Arthropoda	Amphipoda	Gammaridae	*Gammarus lacustris*	J. Flannagan
		Talitridae	*Hyalella azteca*	"
	Copepoda		*Diaptomus sicilis*	K. Patalas
			Cyclops vernalis	"
			Cyclops bicuspidatus	"
			Diaptomus siciloides	"
			Mesocyclops edax	"
	Cladocera		*Bosmina longirostris*	A. Salki
			Daphnia pulex	"
			Daphnia magna	"
	Odonata	Lestidae	*Lestes*	C. Holmstrom
		Coenagrionidae	*Ischnura*	"
	Hemiptera	Gerridae	*Gerris*	"
		Corixidae		"
		Belostomatidae	*Belostoma*	"
		Notonectidae	*Notonecta*	"
	Coleoptera	Dytiscidae	*Dytiscus*	"
		Haliplidae		"
		Gyrinidae	*Gyrinus*	"

Table 2. Cont'd.

Phyllum/Division	Class, Order	Family	Scientific Name	Identification[1]
	Trichoptera	Hydrophilidae		C. Holmstrom
		Limnephilidae		"
	Diptera	Culicidae	Chaoborus	"
		Tendipedidae		"
		Tipulidae		"
		Syrphidae		"
Cyanophyta	Myxophyceae		Microcystis flos-aquae	H. Kling
			Aphanizomenon flos-aquae	"
Chlorophyta	Chlorophyceae		Pandorina	"
			Pediastrum Boryanum	"
			Pediastrum duplex	"
			Oocystis lacustris	"
			Oocystis crassa	"
			Oocystis submarina	"
			Nephrocytium limneticum	"
			Nephrocytium Agardhianum	"
			Scenedesmus quadricauda	"
			Quadrigula closteroides	"
			Ankistrodesmus falcatus	"
			Crucigenia quadrata	"
			Coelastrum microporum	"
			Dictyosphaerium pulchellum	"
			Dictyosphaerium Ehrenbergianum	"
			Dimorphococcus lunatus	"

Table 2. Cont'd.

Phyllum/Division	Class, Order	Family	Scientific Name	Identification
Euglenophyta	Euglenophyceae		Euglena Ehrenbergii	H. Kling
			Lepocinclis ovum	"
			Phacus	"

[1]With the exception of the author, all of the personnel listed below are members of the staff of the Freshwater Institute and are qualified in the taxonomy of the invertebrate group with which their name is associated.

MATERIALS AND METHODS

Sampling

Rainbow trout were stocked in Lake 3 on May 15, 1970 and May 5, 1971 at a mean initial size of 3.1 g. and 1.5 g. respectively. The stocking density in both years was approximately 750 fish/hectare.

Although information on food habits and growth rates was obtained from samples of trout collected in several stocked lakes, only Lake 3 fish were used in studies on feeding periodicity, feeding selectivity and food consumption rates. During 1970, 24 hour gill netting experiments were conducted on Lake 3 on the following dates: July 28-29, August 25-26, and September 27-28. In 1971 the sampling was extended to cover a broader period and was carried out on May 25-26, June 2-3, June 21-22, July 14-15, August 9-10, August 30-31, September 20-21, and October 19-20. All fish were taken with graduated mesh, nylon gill nets since the submergent vegetation and soft, silty bottom precluded the use of other types of fishing gear. For each diel sampling two joined 50 m. nets were set perpendicular to shore at consecutive 3 hour intervals and left for not more than 15 minutes. This very brief fishing time was usually sufficient to catch the preselected quota of 10 trout. In May and June nets were left in for the entire 24 hour sampling period and checked every 3 hours. Data from the May 25-26 and June 2-3 experiments were combined to provide a sufficiently large sample for that time of year. If less than 7 fish were caught at any given interval the set was repeated the following day. When more than 10 fish were taken, a random selection of 10 was used for stomach analysis and, for the remainder, only length-weight information was recorded. It was assumed that the data obtained were representative of the total population and that regurgitation of stomach contents did not occur.

Complete records of water temperature fluctuations were essential in estimating digestion rates and daily ration of the trout. These were obtained with a continuous recording thermometer (Wekslar, model 06MN1) stationed near the centre of Lake 3 with the probe fixed at a depth of 1m. Weekly oxygen profiles were taken with an oxygen meter (YSl, model 54) and Hach kit.

The invertebrate fauna of Lake 3 was sampled during the summer of 1971. Although quantitative determinations were taken with the original intention of estimating secondary production of amphipods, these determinations are presented here only in so far as they pertain to the feeding selectivity of stocked rainbow trout. Two perpendicular transects were established, each traversing the breadth of the lake. Stakes were driven into the bottom at contour intervals of 0.3 m. along the transects and these served as sampling stations (Plates 1 and 2).

To obtain adequate samples of the substrate, water column, and inshore zone of dense vegetation, 3 separate sampling devices were used. A multiple corer, described by Hamilton et al. (1970) and employed successfully by Flannagan (1970), was used for the benthic fauna (Plate 3) and a 28 l., self-activating plexiglass trap, described and tested by Schindler (1969), was used for the water column samples (Plate 4). Dense vegetative growth posed special problems in sampling the littoral zone. An apparatus designed by J. Whitaker of the Fisheries Research Board was an effective alternative to other available gear (Plate 5). It consisted of a cylindrical iron tank, 152 cm. by 30 cm. with a serrated bottom edge and handles welded at the top. The sampling procedure was as follows: At each sampling station the tank was lifted about 0.5 m. above and perpendicular to the water surface and released thereby sealing off a volume of water proportional to the tank diameter and the water depth.

In tall stands of *Scirpus* the emergent vegetation was clipped prior to dropping the tank. By twisting the handles the tank was securely anchored and the enclosed substrate well separated from its surroundings. As much vegetation as possible was removed by hand, each piece being rinsed thoroughly within the confines of the tank before discarding. A diaphragm pump, bolted to a plywood base and clamped to the stern of the boat, quickly extracted the water, loose pieces of vegetation, and the surface layer of substrate. All material was pumped into an adjacent sieve net, washed, emptied into a large plastic bag, and fixed in formalin. The paucity of organisms observed from repeated fillings suggested a high recovery rate on the first extraction. The tremendous number of invertebrates present necessitated sub-sampling. Consequently only one-sixth by volume of the actual sample was analyzed.

Plate 1. Aerial view of Lake 3 facing north. Transects with sampling stations are indicated.

Plate 2. Aerial view of Lake 3 facing west. Note dense mats of submergent vegetation and partial ice cover. (Photographs taken late October, 1971.)

Plate 3. F.R.B. Multiple corer used for sampling Lake 3 benthos.

Plate 4. Schindler trap used for taking zooplankton samples in Lake 3 limnetic zone.

Plate 5. Cylindrical iron tank, diaphragm pump, and sieve net used for sampling Lake 3 littoral zone.

Treatment of Samples:

Trout caught during the diel netting experiments were immediately returned to the field laboratory where length and weight information was recorded and stomachs removed for preservation. Fish weights were recorded to the nearest 0.1 g on a top loading balance (Mettler, P 1200). Stomachs plus contents were placed in vials containing 10% formalin and stored for future analysis.

Food analysis initially involved the determination of number and weight of various food organisms present in individual stomachs. Although basic identification was relatively simple, absolute counts became difficult when food was in an advanced state of digestion. Consequently it was often necessary to count head capsules or eyes rather than whole food items. When cladocerans were the predominant food organism the sorting dish was divided in quarters and the contents sub-sampled. Food samples were distributed in small aluminum dishes and dried in a vacuum oven for 48 hours at a temperature of 100C and a pressure of 15 p.s.i. The dried material was weighed to the nearest 0.01 mg on an analytical balance (Mettler, H6T).

To facilitate the expression of stomach content weight as a percentage of fish body weight, the dry weights of various size rainbow trout were taken. Since it was not possible to dry all the fish caught, dry weight information is based on a sample of 79 trout ranging in size from 3.8 to 256 g wet. An equation based on the linear regression analysis of the resultant data was used for all subsequent determinations of dry fish weight (Appendix A-3).

Howmiller (pers. comm.) reported substantial weight losses of aquatic invertebrates preserved in 70% alcohol and in 10% formalin. An effort was made to compensate for this potential error in stomach content weights by preserving 20, 10.0 g. (wet wt.) samples of amphipods in 10% formalin and determining dry weights at regular intervals over a 21 week period. The results obtained (Appendix A-2) were used to correct dry weights of the stomach samples taken from Lake 3 trout.

Multiple corer and tank samples were sorted in white enamel trays containing a sugar solution of specific gravity 1.12, as recommended by Anderson (1959). Each water column sample was analyzed by emptying the contents into glass petri dishes and counting the invertebrates directly. Although individual counts have been recorded for each sampling device and for each station, the results used in the selectivity study represent pooled data.

Food Habits and Feeding Periodicity.

Percent frequency of occurrence, total number, and total dry weight were determined for each type of food organism consumed by Lake 3 trout. These data were separated according to the sampling interval, date, and year. Individually, numerical and gravimetric presentations of food habit results can often produce biases in the interpretation of the relative importance of a particular food item. Consequently a consumption index, similar to that proposed by Godfrey (1955), was calculated for all Lake 3 fish. The index was calculated by taking the square root of the product of the number of fish in the sample that have consumed the organism in question and the average weight of that organism in the stomachs of all the fish in the sample and converting this value to a percentage of the total stomach contents for the interval under consideration. The combination of numerical and gravimetric data into a single consumption index eliminates the bias which is otherwise introduced when fish consume a few very large food organisms or conversely when they consume many small ones. It therefore provides a more acceptable measure of the importance of a given food item in a fish's diet.

An index of stomach fullness was also determined for each interval of the 1970 and 1971 diel netting experiments on Lake 3. This index is simply the dry stomach content weight expressed as a percentage of dry body weight. When plotted for each of the 8 sampling intervals over a 24 hr. period these indices provide a graphic expression of the diel feeding rhythm of Lake 3 trout.

Feeding Selectivity.

Both laboratory and field studies were carried out on the feeding selectivity of rainbow trout. Selectivity is expressed as an index with values from -1 to +1, an index of 0 indicating that the food organism under consideration is consumed in about the same proportion as it is available. This index, used initially by Ivlev (1961) and more recently by Starostka and Applegate (1970) is calculated using the equation,

$$S = (r_i - p_i)/(r_i + p_i)$$

where S = index of selectivity, r_i = the abundance of a given food item in the ration, expressed as a percentage of the total ration, and p_i = the abundance of the same food item in the lake, expressed as a percentage of the total food complex. It should be emphasized that this index is a measure of the selectivity shown for a food item in relation to its particular abundance and does not necessarily indicate the importance of that food item in the trout diet.

Selectivity is actually a function of two closely related factors: (1) the preference (P) shown by a fish for a particular food item, and (2) the accessibility (A) of the food organism itself. Differences in prey size, mobility, and habitat prevent the absolute separation of these factors under natural conditions. The purpose of the laboratory experiments was to obtain some understanding of the relative contribution of each factor to the observed feeding habits of the stocked trout.

Laboratory Experiments

A 100 l. aquarium, connected to an adjacent 500 l. holding tank by a small water pump and siphon, was used for the laboratory experiments. This arrangement provided a continuous flow-through with a constant water temperature of 17 $\pm$ 0.5 C. In the first series of experiments a clear, concealment-free aquarium was used while in the second series a natural situation was duplicated by introducing a 5 cm. layer of silt and organic debris as well as several aquatic plants. Theoretically the clear aquarium afforded equal accessibility of food items to the fish and subsequent measures of selectivity were a function of preference only. With concealment available to the prey, as in the latter arrangement, selectivity was a function of both preference and availability. A comparison of selectivity indices obtained using both set-ups provides at least a superficial assessment of the importance of availability and preference as components of feeding selectivity.

For each experiment a single trout, ranging in size from 17 to 45 g., was introduced into the aquarium 15-20 min. after 75 of each of the following organisms had been added: amphipods, corixids, *Chaoborus* larvae, chironomid larvae, zygoptera naiads, and small gastropods. After feeding for two hours the fish was removed, autopsied, and its stomach contents enumerated. Eight replicates were run for each series of experiments.