THE LIFE HISTORY AND ECOLOGY OF THE NORTHERN LAKE CHUB (*Couesius plumbeus*) IN THE LA RONGE REGION OF SASKATCHEWAN

A

Thesis

Submitted to

the Faculty of Graduate Studies

in Partial Fulfilment of

the Requirements for

the Degree of

Master of Science*

in the

Department of Biology

University of Saskatchewan

Saskatoon, Saskatchewan

by

JOSEPH HARRY BROWN

April, 1969

* According to the convocation programme, the degree awarded was M.A.

ACKNOWLEDGEMENTS

I wish to express my most sincere gratitude to my supervisor Dr. U.T. Hammer. His encouragement, guidance, patience, and understanding were of immeasureable importance to me.

Mr. G.D. Koshinsky, Saskatchewan Fisheries Branch, merits special acknowledgement as he was ever available with helpful advice and assistance which included data and a critical review of the manuscript.

The assistance of the following persons during the course of this study is gratefully acknowledged: Dr. W.B. Scott, Royal Ontario Museum, identified specimens; Dr. C.C. Lindsey, University of Manitoba, Dr. D.E. McAllister, Natural Museum, Ottawa, Messrs. R.E. Jenkin, Roanoke College, Virginia and Mr. K.M. Muth, Fisheries Research Board of Canada, contributed information and suggestions; Dr. J.R. Allen, University of Saskatchewan, identified parasites; Mr. J. Waddington helped with photographs and illustrations; Miss E. MacKenzie typed the thesis; Messrs. R.H. Jamieson, J. Whitaker, and D. Stout aided a great deal in the field work.

Thanks are due Drs. R.S. Miller, J.G. Rempel, W.J. Maher, R.J.F. Smith, and C.C. Gillott for encouragement and advice. Messrs. F.M. Atton and R.P. Johnson, Saskatchewan Fisheries Branch, deserve thanks for their co-operation and interest in this study. It was the interest and assistance of the numerous friends and acquaintances, most of which are not listed here, that helped make this study a most gratifying experience. To these people I express my sincere thanks.

Laboratory facilities and equipment at La Ronge were supplied by the Department of Natural Resources, Fisheries Branch.

The research for this thesis was supported by a scholarship from the Institute for Northern Studies and National Research Council Grant No. A1412.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

1. INTRODUCTION

Very little has been published pertaining to the life history and ecology of the lake chub (*Couesius plumbeus* (Agassiz), at present equal to *Hybopsis plumbea* (Agassiz)), and the purpose of this study was to gain some knowledge in these areas. References to *C. plumbeus* are common in the literature but they mostly comprise incidental remarks. Life history studies are confined to an unpublished B.A. thesis undertaken in some small British Columbia lakes by Geen (1955). Data on the life history of *Couesius* in Michigan are being collected by Dr. V.C. Applegate.

C. plumbeus is common throughout northern North America and ranges farther north than any other cyprinid. In certain areas fishermen report that larger individuals take hooks and flies and although it is edible, it is not considered to be a game fish. Like most members of the cyprinid family its main value is believed to be as a forage fish. This could be particularly beneficial in the north where the species actively incorporates insect fauna into the food chain and its presence presumably relieves predation pressure on young game fishes.

The problem of defining *Couesius* subspecies and the direct involvement of *C. plumbeus* in the present controversy over the validity of the genus *Hybopsis* made this project more interesting. Before these problems can be satisfactorily resolved, it is necessary that the variation of taxonomic and behavioral characteristics of the species be clearly established throughout the geographical range. Studies such as the present one help provide such information.

2. INTRODUCTORY BACKGROUND

2.1 General Description of *C. plumbeus*

The lake chub is an elongate, slightly compressed cyprinid that reaches up to 7 inches in length. In bright light, fresh specimens are dark olive along the back and upper parts of the body but appear dusky when preserved. The belly is pearly white. Prominent on younger fish and generally present on older fish is a purplish lateral band along the body, continuous as a dark band on the opercle, through the eye, and onto the snout. On the body this band is bounded below by the lateral line and above by a thin gilt stripe. The mouth is terminal and oblique, the eyes are moderately large, the scales are small, and the fins are plain.

Identification keys and general descriptions are given by Eddy and Surber (1943); Hubbs and Lagler (1947 and 1958); Moore (1957); Eddy (1957); and Carl, Clemens and Lindsey (1959). Morphological descriptions are also found in Jordan and Evermann (1896), and Dymond (1926 and 1936).

Key distinguishing characters of the lake chub are generally agreed to be the following: dorsal fin of eight rays with a preceding rudimentary ray inserted above or slightly behind the front of the pelvic insertion; flattened hooked pharyngeal teeth, 2,4-4,2, with no grinding surfaces; short intestine; barbel that is not terminal but rather placed anteriad to the posterior end of the anterior surface of the maxilla; scales in the lateral line more than 55.

2.2 Distribution

During the time that most of northern North America was covered by Pleistocene glaciation, living organisms were forced to retreat to the unglaciated Alaska-Yukon (Bering), Pacific, Mississippi Valley, or Atlantic Coastal Plain refugia. Throughout the phases of the ice retreat these areas are believed to have served as distributional centers for surviving species. It has been suggested that the lake chub was one of these post-glacial reinvaders because of its wide distribution throughout Canada from the Atlantic to the Pacific drainages and also because of its presence in completely isolated lakes as, for example, in the Huron mountains (Hubbs and Lagler, 1947).

Radforth (1944) implies that the lake chub of Ontario is derived from both the Mississippi Valley and the Atlantic Coastal Plain refugia. Miller (1958) concurs with this point of view. He lists the lake chub among the primary fauna of the Columbia River complex, presumably having invaded this area by crossing the Continental Divide from the east no earlier than the latter part of the Pleistocene. Walters (1955) believes that the Yukon-Alaska Valley did not serve as a glacial refugium for the lake chub because the species is not broadly distributed in the unglaciated portions of it. He suggests that the presence of lake chub in the MacKenzie and upper Yukon River systems (but not in those of Alaska) is due to headwater transfer which has occurred subsequent to to migration of chubs from south of the ice sheet.

The known distribution of the lake chub in North America is depicted in Figure 1. Northern post-glacial dispersal has been extensive. This is the only minnow known from the western Arctic and the northeastern limits are beyond the northern limits of cyprinid distribution given by Miller (1958). According to Walters (1955), "the lake chub is just barely able to survive arctic life".

Records of northern distribution from Quebec include the Hudson Bay drainage (Bajkov, 1928), George River drainage (Legendre and Rousseau, 1949) and the Ungava Bay area (Dunbar and Hildebrand, 1952). Labrador records include the Hamilton and Northwest River drainages (Backus, 1951). K.M. Muth, Fishery Scientist with the Fisheries Research Board of Canada, has collected specimens in the smaller lakes east of Great Slave Lake and as far north as Chesterfield Inlet at latitude 64° (personal communication). Specimens have been taken from Great Bear and Great Slave lakes (Dymond, 1926). The north-western portion of the range includes the Peace and Laird River drainages of British Columbia (Lindsey, 1956) and extends northward to upper parts of the Yukon and the MacKenzie Delta (Wynne-Edwards, 1952).

The present southern limits of the lake chub range can be deduced from a number of investigations. In the east, lake chub are reported common in Maine (Dymond, 1926), and in the northern part of New Hampshire (Bailey, 1938). They are

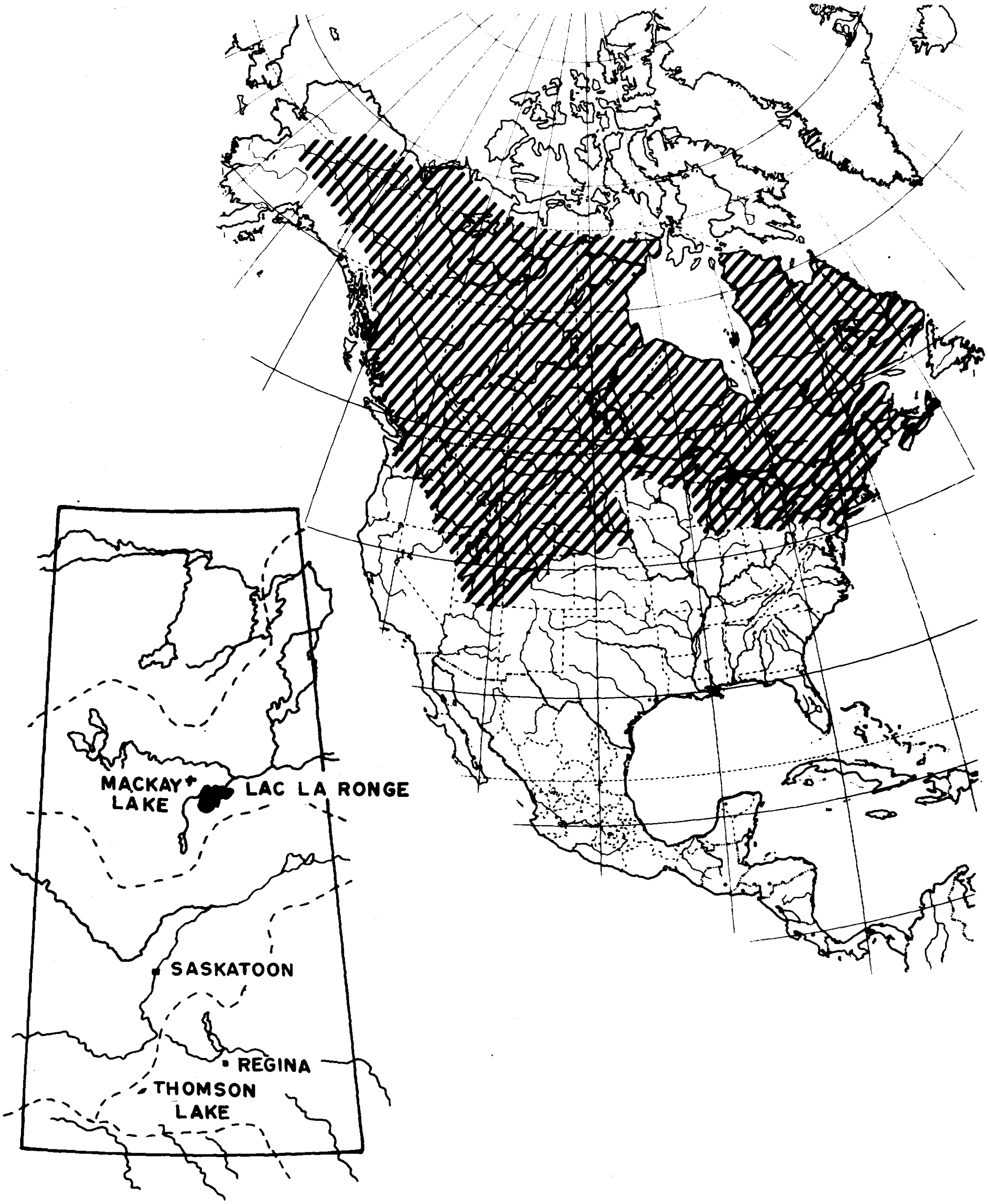


Figure 1. North American distribution of C. plumbeus. The inset map of Saskatchewan shows the location of lakes from which the species was collected for the present study.

present in the Hudson and Delaware River drainages of the other New England states (Eddy, 1957). South of the Great Lakes, lake chubs are recorded from Michigan (Taylor, 1954), are rare in Indiana (Gerking, 1945), are south of the main range when present in Iowa (Bailey, 1956), are not listed from Illinois (O'Donnell, 1935), and in Wisconsin and Minnesota are found only in the tributaries of the Great Lakes and Hudson Bay (Eddy and Surber, 1943). The Mississippi drainages of the central states have no records of lake chub (Eddy and Surber, 1943). On the Western plains, the range includes the Black Hills and Upper Missouri River drainage (Schultz, 1941) and extends south into Colorado (Carl, Clemens and Lindsey, 1959). On the western slopes of the Continental Divide the range includes only the Columbia River drainage and not the other endemic centers of fish evolution in the Colorado, Sacramento, Klamath and Great Basin drainages (Miller, 1958).

2.3 Taxonomy

Agassiz, in 1850, using specimens taken from Lake Superior, first described the lake chub as *Gobio plumbeus* (Dymond, 1926). Other writers of the period not only confused names but also confused species when referring to the lake chub. Early synonymies listed by Jordan and Evermann (1896) include *Ceratichthys prosthemius* from the Montreal River in Ontario (Cope, 1866); *Nocomis milneri* from Lake Superior (Jordan, 1877); *Ceratichthys plumbeus* (Gunther, 1868); *Couesius dissimilis* and *Couesius prosthemius* (Jordan and Gilbert, 1883). The pearl dace (Margariscus margarita; now Semotilus margarita) was referred to as Couesius plumbeus in a series of papers by Dr. Cox in 1896, 1899, 1901 and 1921 (Scott and Crossman, 1959) and by Hankinson in 1915 (Hubbs, 1926).

After publication of Jordan and Evermann's North American Fishes in 1894, accepted nomenclature for the lake chub became Couesius plumbeus (Agassiz). Couesius is derived from the name of an early collector, the American ornithologist, Dr. Eliott Coues.

The three subspecies which have been recognized, Couesius plumbeus plumbeus (Agassiz), C.p. dissimilis (Girard), and C.p. greeni Jordan, were originally assigned specific status. Distinguishing characteristics were relegated to slight descriptive modifications of body shape, eye size, size and shape of fins and the number of scales along the lateral line.

C.p. plumbeus (Agassiz) was supposedly a lake form that was distributed in northern New England states and throughout that portion of the range which includes the drainages of the MacKenzie, Hudson Bay, and the Great Lakes (Hubbs and Lagler, 1947). As the name implies, it represented the original form described by Agassiz.

C.p. dissimilis (Girard) was believed to occur mostly in creeks and to range south of C.p. plumbeus along the eastern slopes of the Rocky Mountains from the MacKenzie River east to Michigan (Hubbs and Lagler, 1947). It was very close to C.p. plumbeus and was separated from it on the basis of a smaller eye and a smaller, more rounded (as opposed to falcate) dorsal fin. The number of lateral line scales ranged from 64 to 72, as compared to 60 to 70 for C.p. plumbeus.

C.p. greeni Jordan was described from specimens taken from Stuart Lake, British Columbia. This form was also found in Lake Pend d'Oreille, Idaho, and in northern British Columbia (Dymond, 1947). It has been erroneously described as a small-eyed, short-finned form by Taylor (1954). Lindsey (1956) reported that the number of lateral line scales ranged from 54 to 65 for the British Columbia specimens which he examined.

Confusion pertaining to Couesius subspecies was indicated when these were still considered separate species. In 1926, Hubbs stated that he was unable to distinguish C. plumbeus from C. dissimilis and the striking similarity between C.p. plumbeus and C.p. dissimilis was also reported in 1954 (Taylor). In the Great Lakes region, C.p. plumbeus and C.p. dissimilis were reported to occur together and all three subspecies were reported present in the Northwest Territories (Wynne-Edwards, 1952).

Couesius persisted as a monotypic genus until placed in the genus Hybopsis by Bailey in 1951. Within Hybopsis, Bailey has also included the former genera Erimystax, Hybopsis, Macrhybopsis, Nocomis, Oregonichthys, Platygobio and Yuriria. Jordan had removed many of these genera from Hybopsis in

1924. Re-expansion of the genus *Hybopsis* thus groups a confusing and taxonomically troublesome assemblage of fishes.

The present systematic status of the subspecies needs further study and possibly for this reason the subspecies have recently been dealt with collectively as *Hybopsis plumbea* (Agassiz) in checklists and keys (Scott, 1954; Eddy, 1957; Moore, 1957; Bailey *et al*., 1960).

The usage of *Couesius* since Bailey's proposed change is still common (Walters, 1955; Keleher and Kooyman, 1957; Slastenenko, 1958). Hubbs and Crowe (1956) contend that the basis for *Hybopsis* is unsteady. Lindsey (1956) retains the genus *Couesius* in the interest of nomenclatorial stability and what he considers an insufficient assessment of the proposed generic lumping. Following Lindsey's stand, *Couesius* is used in this study.

3. STUDY AREA

The main study area was Lac la Ronge and its tributaries. Lac la Ronge covers an area of 500 square miles and is the fourth-largest lake in Saskatchewan. It is situated in forest area near the center of the province at latitude 55° N (Figure 1). The lake is in the Churchill drainage on the southern edge of the Precambrian Shield. This is an important position as it divides the lake into a southern region characterized by glacial drift and a northern region of rugged, rocky shores and islands (Figure 2).

Details of the chemical and physical aspects of Lac la Ronge were reported by Rawson and Atton (1953), and Atton (1955). Lac la Ronge is generally ice-free for a six month period from the end of May to the middle of November. Since the deepest portions of the lake reach 42 meters, warming following break-up results in thermal stratification which is usually evident by the end of July. The water is clear and Secchi disc readings as deep as 9 meters have been recorded. The pH is slightly alkaline and increases during the summer. The oxygen content measured at the bottom does not go below 3 cc. per liter.

Shapiro (1952) has done a study of the plankton of Lac la Ronge from which a list of species present and their abundance may be obtained. Bottom fauna was studied by Oliver (1954). Fish species investigated to date are the walleye (Rawson, 1957), the lake trout (Rawson, 1961), the

Figure 2. Rocky shoreline of the northern part of Lac la Ronge. This is typical of lakes on the Precambrian Shield.

Figure 3. Shoreline of Thomson Lake illustrating the emergent vegetation and surrounding terrain.

lake whitefish (Qadri, 1961 and 1968), and the slimy sculpin (Van Vliet, 1964). The pike are at present being studied by Saskatchewan Fisheries Biologist, G.D. Koshinsky.

Field headquarters for this study was the Department of Natural Resources Fisheries Laboratory at La Ronge, Saskatchewan. Most of the work on lake chub spawning was done in the Montreal River which enters Lac la Ronge west of the townsite approximately 2 miles from the Fisheries Laboratory. The drainage consists of a lake-stream complex originating in the Prince Albert National Park and forms one of the major tributaries to Lac la Ronge. Physical, chemical, and faunal characteristics of this system were examined by Cushing (1961).

Lake chubs for comparative purposes were collected in MacKay Lake on the Precambrian Shield area north of Lac la Ronge, and in Thomson Lake on the plains area at latitude 50° N (Figure 1). MacKay Lake, lined by rock and surrounded by forest, is an oligotrophic lake in the Churchill drainage. Limnological characteristics were reported by Koshinsky (1965). Thomson Lake, which is exposed and lined with emergent vegetation, is characteristic of the southern lakes (Figure 3). A biological survey conducted by Royer (1960) described the lake.

4. METHODS AND MATERIALS

4.1 Duration of Field Study

The study commenced in 1966. Residence at the La Ronge Fisheries Laboratory extended from 25 April until 16 September. Investigations were carried out continuously during this period and one trip was made to MacKay Lake on 20 June. Two additional trips were made to Lac la Ronge on 12 October and 4 November 1966. The lake froze over on 6 November and nets were regained with difficulty.

In 1967 a trip to the Montreal River was made on 26 March and residence at La Ronge started on 3 May. Trips were made to MacKay Lake on 29 May and 19 August, and to Thomson Lake on 12 June during 1967. Field work was terminated on 26 August 1967 but a lake chub spawning sample was collected for purposes of this study by G.D. Koshinsky on 10 May 1968.

4.2 Field Methods

Successful capture methods at Lac la Ronge involved seines, gill nets, rotenone, and a modified type of minnow trap used on the spawning grounds. Standard minnow traps, hoop nets, and piscivore stomach analyses were unsuccessful for obtaining study material. Electric shockers and trawls were unfortunately not available. Indications are that these could be a great asset for the study of this species. Fry were captured using an aquarium net and, later, a dip net.

Habitat and activity studies relied on seines and gill nets. Two hundred and eighty-four gill net sets and 208 recorded seine hauls were made during the study. Seines used were 30 feet long, of 1/4 inch bar mesh and had liners sewn into the bag. The specifications of the gill nets are given in Table 1. Plastic quart-sized outboard oil containers were utilized to buoy up the float lines for surface gill net sets. In June 1967, 50 yards of a 2-inch stretch-mesh nylon gill net was often set in an arc approximately 10 yards from the lake chub nets as a guard to protect the fine mesh from damage by large fish.

Seining and gill net locations throughout the study area covered a broad area (Figure 4). Trips across Lac la Ronge were made with the pike study crew in the 28-foot inboard-outboard powered DNR Fisheries boat. With cooking and sleeping arrangements on board, no time was wasted setting up camps so that each trip involved several full days on the lake. By towing and carrying smaller boats and canoes, netting and investigations were carried out as conveniently as in the areas around the laboratory.

Capture of fish on the spawning grounds proved challenging, particularly when live specimens were sought for marking. The swift current, the rocky bottom, the migrating suckers and walleyes, and the native children prevented use of seines, gill nets, poison, and trap nets. In the absence of an electric shocker, small traps constructed from window screen proved to be the most efficient method of obtaining samples.

The traps (Figures 7 and 8) were 12 x 6 x 8 inches in

Table 1. Specifications of gill nets used for the study of C. plumbeus at Lac la Ronge, 1966 and 1967.

Type of Material	Length in Feet	Depth in Feet	Stretch-m. in Inches
Monofilament	60	6	5/8
Monofilament	70	6	3/4
Cotton (Gang of four portions)	26	5	5/8
	26	6	13/16
	22	7	1
	30	8	1 1/4

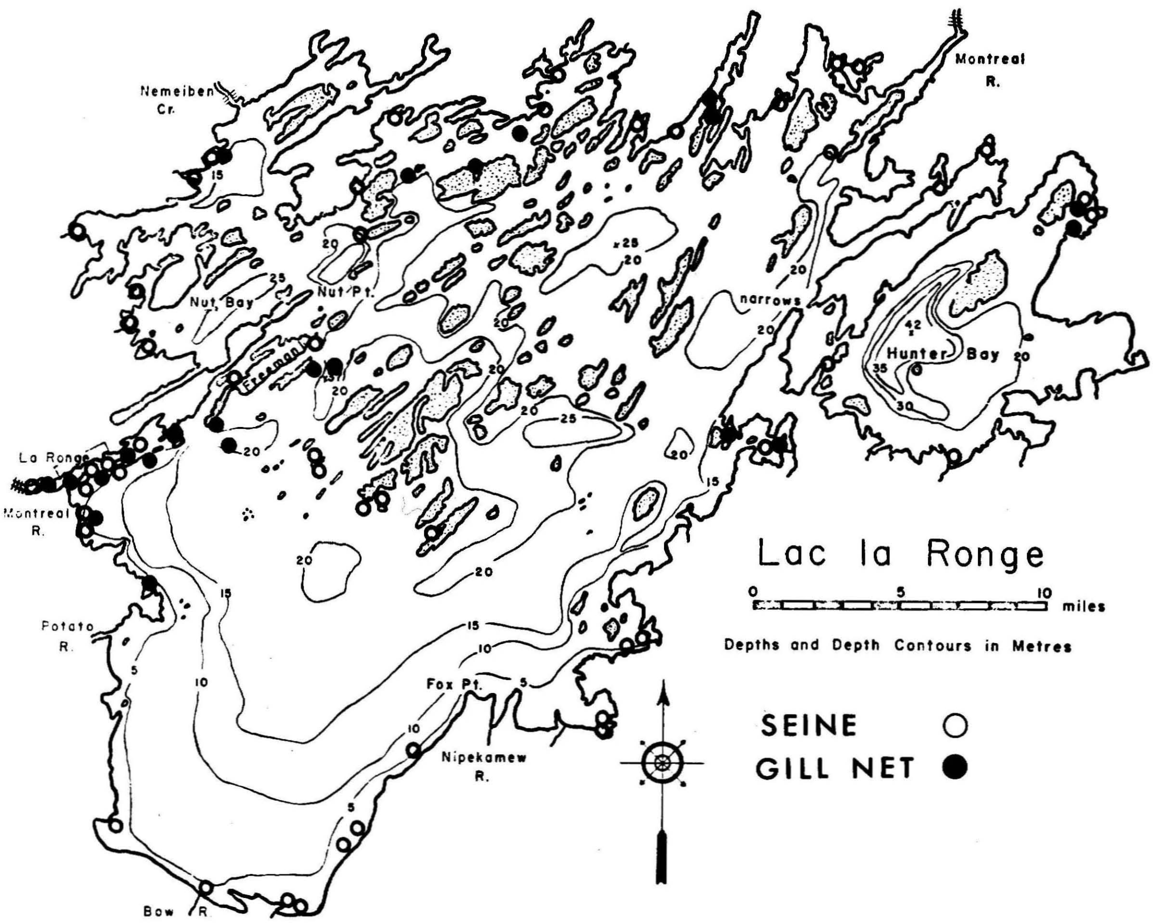


Figure 4. Sampling locations on Lac la Ronge.

dimension and one end formed a funnel with an opening of 1 inch by 2 inches leading into the closed compartment. The lake chubs that moved onto the spawning area could be induced to congregate under boards and flat rocks, set up as in Figure 5, where they had less confinement but were still concealed. They also moved into areas with naturally formed channels between willow clumps and the river bank as in Figure 6. By rearranging the rocks in the immediate areas of congregation, escape routes leading to deeper water or darker concealment were established. The flexible nature of the wire screen traps allowed them to be forced into any type of opening between rocks thus blocking off escape. Removal of the set-out boards, stones, and other cover resulted in the lake chubs dashing into the traps. Each trap area was run exactly the same way each time the spawning area was visited so that daily capture numbers would be comparable. The 1968 spawning sample at the termination of the project was taken by poisoning with rotenone.

Temperature was measured with a rod and electric thermometer. Dissolved oxygen was measured using the Miller method and pH was determined using a Hellige Pocket Comparator.

4.3 Fin Clipping Methods

Five release sites for marked lake chubs were established in the area of the lake approximately 2 miles from the mouth of the Montreal River (Figure 9). Each of these sites represented locations where capture of lake chubs proved to be

Figure 5. On the spawning grounds, *C. plumbeus* congregated beneath this board and flat rocks. Traps set to prevent escape were concealed as above under rock A and exposed as in Figure 7.

Figure 6. Spawning site of *C. plumbeus* in the Montreal River. The channel formed by the small island on the left was utilized to capture *C. plumbeus* by blocking off one end with traps as in Figure 7.

Figure 7. Traps set to intercept the escape of C. plumbeus disturbed on the spawning grounds.

Figure 8. C. plumbeus captured on the spawning grounds in a window screen trap.

more successful than other areas of the lake. The marking code corresponding to release sites is also given in Figure 9.

In 1966, clips were administered without the use of anaesthetic. In 1967, marking fish and recording without assistance was facilitated through the use of the anaesthetic M.S. 222 Sandoz. Ordinary dissecting scissors were used successfully for clipping. Clipped fish were retained overnight and those that did not appear fully recovered were not released.

In 1967, fifteen fish with clipped fins were retained in a 10 x 3 x 2 1/2 foot galvanized tank in order to follow fin regeneration. Fresh water was pumped into the tank from the lake and food was supplied from seine catches of fry and bottom fauna captured with a dip net.

4.4 Laboratory Methods

Length and weight measurements and relationships, growth, age, K factor and maturity were determined using standard methods outlined by Lagler (1950), Rounsefell and Everhart (1953), and Ricker (1958). Methods for scale counting and meristic measurements are given by Hubbs and Lagler (1958). Laboratory equipment utilized included a Unimatic C.L.1 analytical balance, a Mettler K 7 top loading balance, a torsion balance, dissecting instruments, and binocular and dissecting microscopes fitted with ocular micrometers.

Weights for fry were measured to the nearest 0.001 of a gram and weights for adult fish were to the nearest 0.1 of a gram. Total length measurements to the nearest half

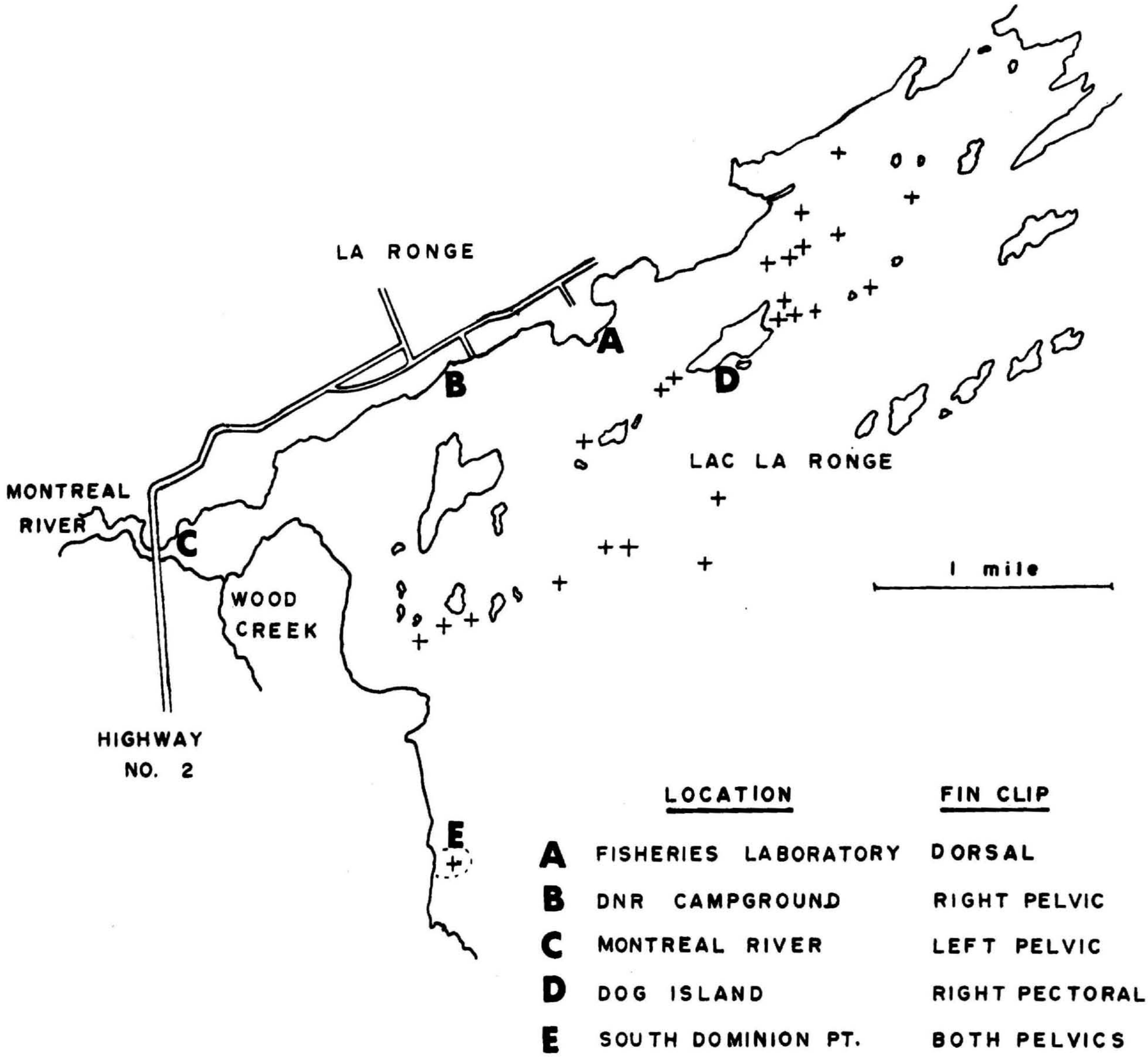


Figure 9. Release sites of C. plumbeus marked by fin clipping.

millimeter for fry and to the nearest whole millimeter for adults were utilized for this study (Carlander and Smith, 1945). The larger fish were measured on a specially constructed measuring board consisting of an inlaid millimeter rule with a perpendicular section at zero. Three hundred and ninety-five specimens were used to calculate conversion factors for standard and fork length so that other studies using these measurements could be compared. Calculations were done with an IBM 360 computer.

Fish captured in the field were preserved in 10% formalin. After one year the fish had gained in weight and shrunk in total length. Fifty fresh specimens were weighed and measured before preservation so that a conversion formula could be determined (Crossman, 1962). The relationships when graphed were found to be linear. The correction formulae calculated from the ratio of sums for total lengths over the range from 79 to 134 mm was

Total length before preservation = Total length after preservation (1.0360);

and for weight over the range from 3.9 to 16.3 g was

Weight before preservation = Weight after preservation (0.9217).

Lake chubs captured green in 4 C water in the Montreal River were taken to the laboratory where they were held for observation in five aquaria and two plastic tanks. Three of the aerated aquaria were 5 1/2 gallon capacity and two were 8 gallon capacity. Ripening of the chubs was hastened in 12-15 C water temperature and aspects of spawning behavior were observed two weeks before spawning occurred naturally.

Fecundity was determined gravimetrically and checked by counting. Eggs were fertilized by hand stripping ripe adults and the eggs were hatched in pint jars. The fry survived and grew on a diet of plankton collected from the end of the dock, with a Number 20 bolting silk plankton net (68 meshes/cm).

Digestion rate experiments involved feeding various organisms at given temperatures, followed by dissections at selected times.

Pharyngeal teeth were cleaned of soft tissue with KOH-NaOH solutions with care not to leave them immersed too long or the complete arch was eaten away. Javex was also used successfully on preserved specimens. Using a binocular dissecting scope, partially dissolved tissue was easily teased away with Number 2 insect pins embedding in glass rod handles. Most of the arches were taken from fresh specimens that were usually allowed to decompose for two or three days so that arches could be removed with greater ease and less chance of damage.

5. RESULTS

5.1 Taxonomic Characteristics

Dr. W.B. Scott of the Royal Ontario Museum kindly identified lake chubs from Lac la Ronge, MacKay Lake and Thomson Lake as Hybopsis plumbea (equal to Couesius plumbeus). To reiterate, the number of lateral line scales, the size and shape of the dorsal fin, the size of the eye, and the pharyngeal tooth formula are characteristics considered important in classifying and keying the lake chub and its subspecies. Investigation of these characters is dealt with below.

5.1.1. Pharyngeal Teeth

Cyprinids have rows of teeth on a modified fifth gill arch and the number of teeth in the rows forms a species-specific dental formula. The lake chub typically has two teeth in an outer row and four teeth in an inner row of each arch. Reading to the right from the outside of the left arch, the dental formula for the lake chub is thus 2,4-4,2 (Figure 10).

Counting pharyngeal teeth is a very delicate procedure. The ease or difficulty with which teeth were broken away from the basal bone of the pharyngeal arch varied with each individual case. At times a slight touch of a dissecting needle removed a tooth and at other times considerable force was required to accomplish this. Teeth purposely broken off with a dissecting needle often left no evidence of their initial presence in the form of stumps or craters in the

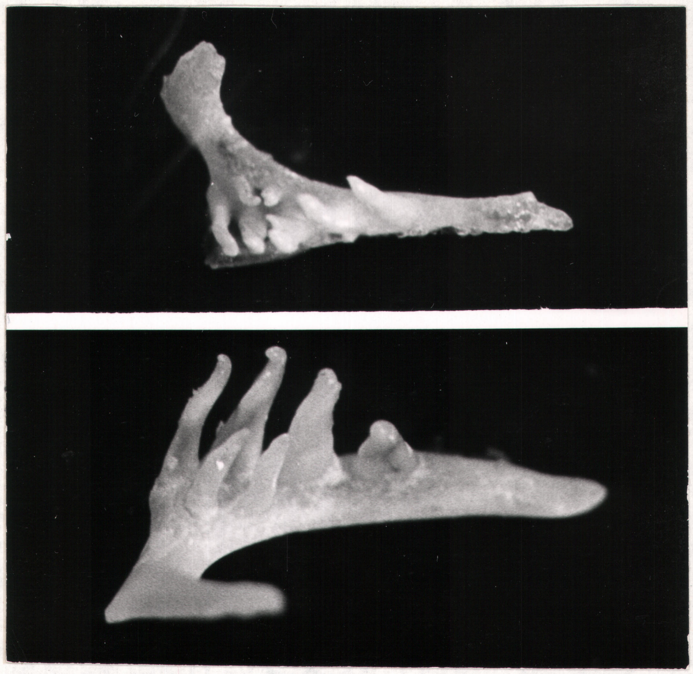


Figure 10. Pharyngeal teeth of C. plumbeus from Lac la Ronge. Top: an atypical 2,5 arch. Bottom: a typical 2,4 arch.

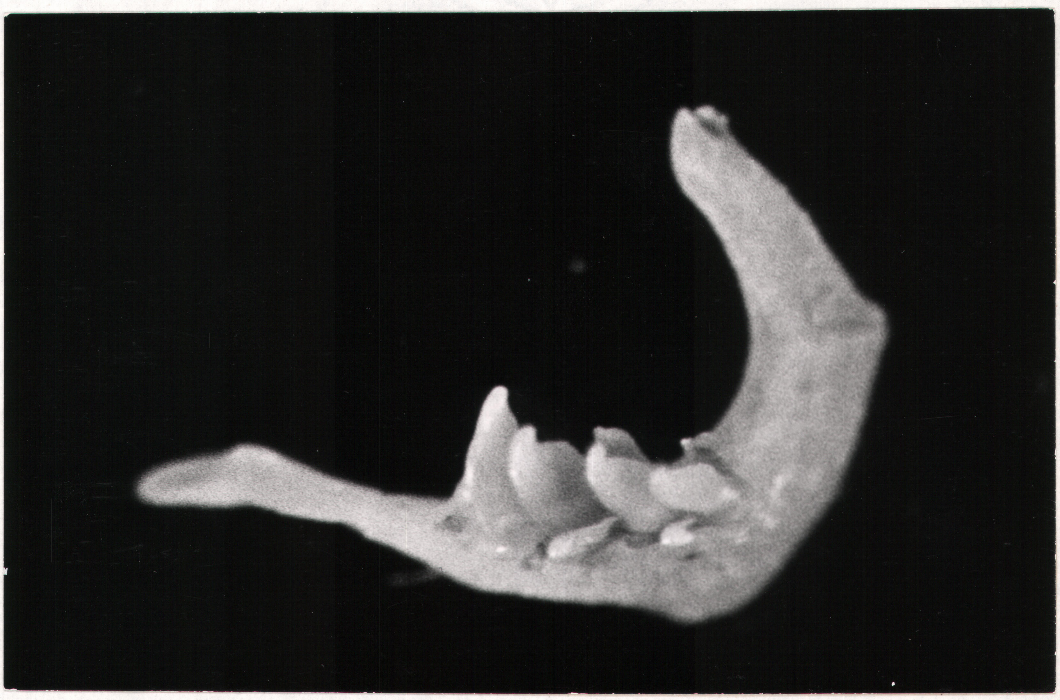


Figure 11. Pharyngeal arch of C. plumbeus from Lac la Ronge, with two accessory denticles attached to soft tissue inside the four teeth of the inner row.

basal bone. Teeth in the outer row were much more difficult to count than those in the inner row because they were smaller and in most cases more delicate. Approximately one-half of the arches to be counted were discarded because dissecting instruments came in contact with teeth before the soft tissue was satisfactorily removed from the arch.

Pharyngeal teeth counts are summarized in Table 2. The typical 2,4-4,2 arch formula was present in 71% of the specimens examined and 86% had inner rows of 4-4.

Variation of the inner rows included 7% with the formula 2,5-4,2 characteristic of the pearl dace (Semotilus margarita). Because of the ease with which teeth can be accidently removed during the cleaning process, only two individuals with inner rows of 3 could be recorded with certainty. In other words, the presence of extra teeth (i.e., 5) is certainly a valid observable variation whereas the presence of fewer teeth (i.e., 3) is more readily questioned.

The variation 1,4-4,1, constituted 9% of the sample. Random variations of missing or extra teeth accounted for 13% of the sample. Included with the variation formulas is one of 1,5-4,2 which may have been 2,4-4,2 with one tooth of the left outer row out of line. Counts for arches that were separated during cleaning are included in Table 2. These are in reasonable agreement with the counts taken from the intact arch pairs.

Table 2. Pharyngeal teeth formulas of C. plumbeus from Lac la Ronge.

A. One hundred intact paired arches.

Formula	Percentage Occurrence
2,4-4,2	71
1,4-4,1	9
2,5-4,2	7
* other	13
4-4 Inside rows	86

B. Seventy-three single arches.

Number of Teeth		Percentage Occurrence	
**Inside Row	Outside Row	Left Arch	Right Arch
4	2	72.5	84.8
5	2	15.0	0.0
4	1	12.5	9.1
4	0 to 3	0.0	6.1

* Includes 2,5-5,2; 2,3-4,2; 1,4-5,1; 0,4-4,1; 1,4-4,0; 1,5-4,2; 1,3-4,1 and 0,4-4,0.

** 90.6% had inner row of 4.

Accessory denticles which appeared to be typical enamelled pharyngeal tooth tips merely attached to the soft tissue and not attached to the modified fifth gill arch were observed in many specimens. At first these caused concern when arches were being cleaned because it appeared that they were pharyngeal teeth knocked loose. While such were frequently observed no attempt was made to record their incidence because a more sophisticated procedure such as whole mount sectioning would be necessary for this. Two such denticles attached to the soft tissue of one arch are shown in Figure 11. As many as three have been observed on a single arch.

5.1.2. Lateral Line Scales

Lateral line scale counts were essentially identical for a sample of 102 males ($\bar{x}$ = 62.31 ± 3.40) and 100 females ($\bar{x}$ = 62.06 ± 2.99) from the Montreal River population in 1968. Both sexes are treated collectively for the other population samples listed in Table 3.

The Montreal River population at Lac la Ronge shows stability of mean number of lateral line scales from 1966 to 1968 when the respective means were 62.39 ± 3.18 and 62.18 ± 3.20. The lake sample includes fish captured in both the mesotrophic rocky island portion of Lac la Ronge and in oligotrophic Hunter Bay. These constitute populations distinct from the Montreal River population but the mean number of lateral line scales (61.67 ± 3.37) is not significantly different. Another sample of 13 lake chubs (total lengths

Table 3. Number of lateral line scales for C. plumbeus sampled in Saskatchewan.

Location	Sample Size	Range	Mean	Standard Deviation
I. Lac la Ronge				
A. Montreal River 1966, males plus females	462	52-72	62.39	± 3.18
B. Montreal River 1968				
(i) Males	102	54-72	62.31	± 3.40
(ii) Females	100	56-72	62.06	± 2.99
(iii) Total	202	54-72	62.18	± 3.20
C. Main lake, 1966 and 1967, males plus females	94	53-70	61.67	± 3.37
II. MacKay Lake 1966 and 1967, males plus females	59	61-71	65.08	± 2.58
III. Thomson Lake 1967, males plus females	30	60-78	66.63	± 4.27
IV. British Columbia specimens*	53	54-65	59.40	

* From Lindsey, 1956.

89 to 107 mm.) was taken in a rocky portion of a predominantly muskeg creek tributary to Lac la Ronge and this sample had a range of lateral line scales from 55 to 74. The range of lateral line scale counts for Lac la Ronge specimens completely overlaps all of the ranges given in the literature for the three subspecies. The means fall between the eastern C. plumbeus and the British Columbia specimens examined by Lindsey in 1956.

Although the sample sizes are small, the material from MacKay and Thomson Lakes suggests considerable variation in numbers of lateral line scales among lake chub populations even within the province. MacKay Lake specimens have lateral line scales ranging from 61 to 71 with a mean of 65.08 $\pm$ 2.58; this is near the definition of C. plumbeus. The Thomson Lake lateral line scale range extends into the high seventies and with a mean of 66.63 is similar to C. dissimilis.

5.1.3. Eye Size

Lake chubs from Lac la Ronge, Thomson Lake and MacKay Lake all had large eyes with the diameter greater than two-thirds the length of the snout. According to Hubbs and Lagler (1958) this is characteristic of C.p. plumbeus.

5.1.4. Dorsal Fin Ratio

The ratio of depressed dorsal fin length to the distance between the occiput and the base of the dorsal was used by Hubbs and Lagler (1958) to distinguish Couesius plumbeus plumbeus from *Couesius plumbeus dissimilis*. For the present study, the dorsal fin ratio was determined for a small sample of preserved lake chubs from MacKay Lake, Thomson Lake, and various locations in Lac la Ronge. The ranges of these ratios for each location are given in Table 4. These ratios do not differ significantly. Some of the ratios were greater than 1.7, above which Hubbs and Lagler chose to distinguish *C.p. dissimilis*. In Lac la Ronge only some females exceeded the 1.7 ratio while in MacKay and Thomson Lakes it occurred also among males.

Since the pectoral fins of the male lake chubs grow larger than those of the females, an effort was made to determine whether the dorsal fin ratio also exhibits sexual dimorphism. Ratios for sample groups of total lengths between 80 and 90 mm, 100 and 110 mm, and over 125 mm are plotted for both sexes in Figure 12. The difference in ratios between sexes is seen to exist before the lake chubs reach 90 mm total length. The difference in ratio among the large and small fish is marked.

5.1.5. Vertebrae and Caudal Peduncle Scales

A new proposal for two morphological forms of lake chub is based on vertebrae number and the number of scales around the caudal peduncle (McPhail, 1963). Counts for Lac la Ronge specimens along with ranges for the two proposed forms are given in Table 5. As with the other characters examined, an overlap exists.

Table 4. Ratio of depressed dorsal fin length to the distance between the occiput and the dorsal fin origin for C. plumbeus from several Saskatchewan locations.

Location	Sex	Number	Range of Total Length in mm.	Range of Ratios
I. Lac la Ronge				
A. Montreal River, 1968	♀	30	82-142	1.33-1.81
	♂	20	78-113	1.29-1.68
B. Montreal River, 1966	♀	2	113-122	1.64-1.84
	♂	8	85-108	1.38-1.55
C. Murphy Island	♀	7	111-127	1.56-1.81
	♂	3	111-113	1.33-1.56
D. Hunter Bay	♀	6	106-125	1.55-1.72
	♂	1	110	1.58
E. Kinosao Creek	♀	5	89-107	1.57-1.71
	♂	5	91-101	1.43-1.58
II. MacKay Lake	♀	2	120-123	1.60-1.69
	♂	4	82-105	1.46-1.71
III. Thomson Lake	♀	3	77-126	1.58-1.86
	♂	6	82-106	1.56-1.70

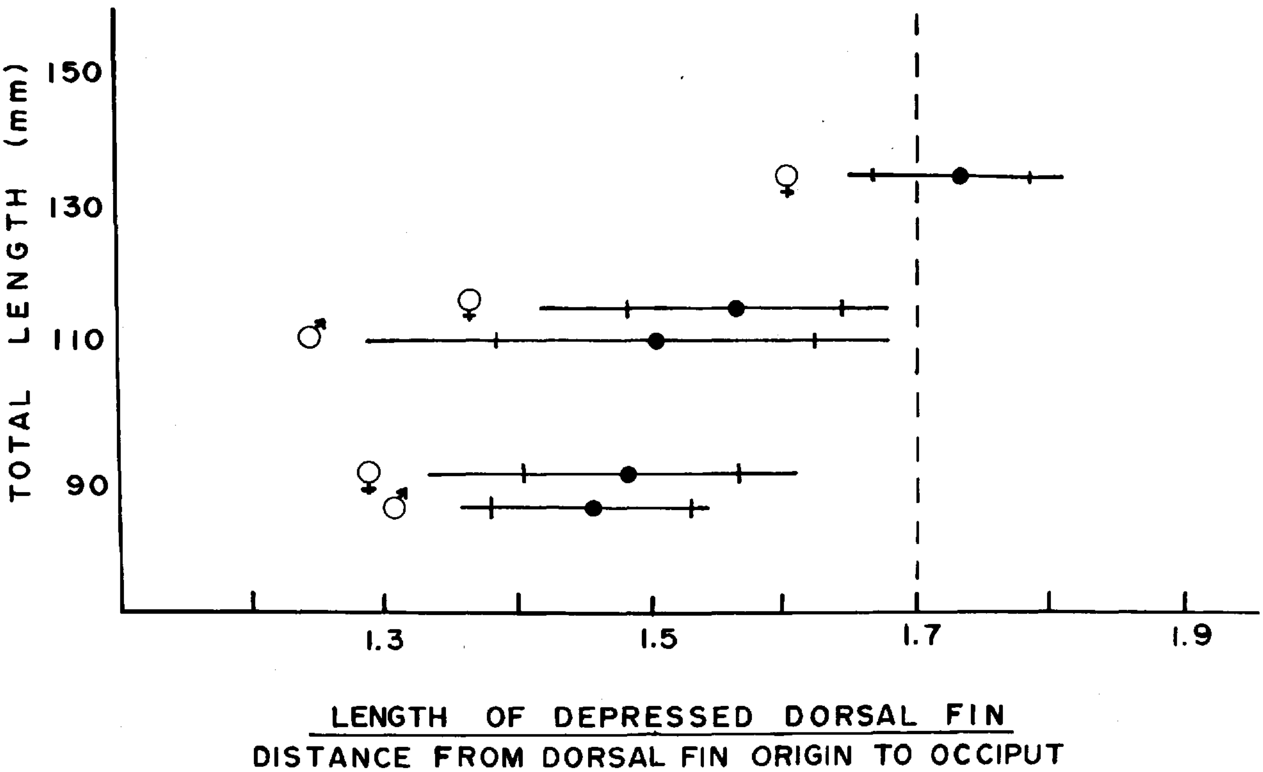


Figure 12. Sexual dimorphism in C. plumbeus illustrated by dorsal fin growth. The mean, standard deviation and range of the ratio for each group were determined from ten specimens captured in the Montreal River in 1968.

Table 5. Number of vertebrae and number of scales around the caudal peduncle of Lac la Ronge C. plumbeus as compared to proposed morphological forms.

Location	Mean Number	
	Vertebrae	Caudal Peduncle Scales
Eastern Form*	41.5 to 42.4	21.5 to 23.6
Western Form*	40.5 to 40.7	18.8 to 20.8
Lac la Ronge**	41.4 ± 0.8	20.9 ± 1.1

* Range of means from McPhail (1963).

** Number of specimens for vertebrae = 86 and for caudal peduncle scales = 93.

Range of number of vertebrae was 39 to 43 and range of number of caudal peduncle scales was 19 to 24.

5.2 Reproduction

5.2.1. Spawning Areas

Lake chubs in spawning condition were first captured in the 2-mile series of rapids and marshy areas of the Montreal River between Bigstone Lake and Lac la Ronge on 9 May 1966. An extensive search carried on continuously during the spawning period indicated that the majority of the spawning lake chub were concentrated in the shallow, rocky areas near the mouth of the river. These areas were well out of the main stream current and the water passed slowly among the protruding rocks. This rocky spawning habitat (Figures 13-15) was also the site of spawning observations conducted in 1967.

Lake chubs passed through marsh and rapids sections of the Montreal River enroute to the spawning grounds, but no evidence was found to indicate that spawning areas other than rocky shallows were utilized. Wood Creek enters Lac la Ronge near the Montreal River mouth. This is a marshy muskeg creek that affords excellent pike spawning grounds. In addition to pike (*Esox lucius*), investigations in Wood Creek throughout the 1966 and 1967 spawning seasons yielded white suckers (*Catostomus commersonii*), northern suckers (*Catostomus catostomus*), burbot (*Lota lota*), perch (*Perca flavescens*), and spottail shiners (*Notropis hudsonius*), but lake chubs were never captured.

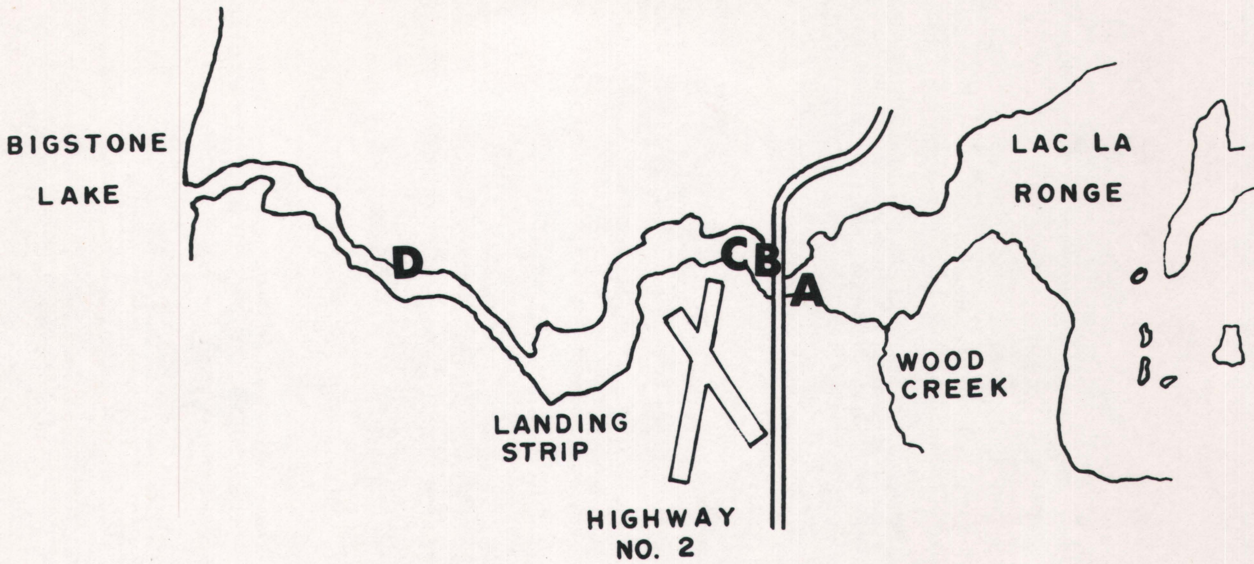


Figure 13. The main spawning locations of C. plumbeus in the 2-mile section of the Montreal River between Bigstone Lake and Lac la Ronge.

Figure 14. Spawning site of C. plumbeus in the Montreal River near the landing strip (location C in Figure 13).

Figure 15. Spawning site of C. plumbeus in the Montreal River near the highway bridge (location B in Figure 13).

Figure 16. Outlet creek of MacKay Lake in which C. plumbeus were abundant in May, 1967.

Lake chubs that did not migrate into the river or creeks spawned extensively in the lake and, as in the Montreal River, ripe adult lake chubs congregated on shallow rocky shoals and along the rocky shores of islands. Spawning as such was not observed in the lake but the subsequent capture of fry at the areas of congregation of ripe adults indicates that spawning did occur.

The rocky creek into which spawning migration was observed at MacKay Lake is shown in Figure 16. The creek habitat includes areas of sharp jagged rocks interspersed with areas of rounded rocks such as occur in the larger and swifter Montreal River. Such variability of rocky spawning substrate is also evident throughout the Precambrian Shield area of Lac la Ronge. Rocky habitat is absent in some lakes inhabited by lake chubs. Versatility in this regard is exhibited in Thomson Lake where fry were found along marshy shorelines.

5.2.2. Montreal River Spawning Run

5.2.2.1. Integrity of the Run

Throughout the summer and fall of 1966 and 1967, various traps, seines, and rotenone poisoning of the spawning grounds and other portions of the Montreal River yielded only one lake chub. No lake chubs were observed or captured by rotenone poison on 26 March 1967. The presence of the lake chub in the Montreal River during May and June represented a spring spawning migration from the lake which was later verified by fin-clipping. The adult lake chub returned to the lake after spawning and the fry followed the current into the lake shortly after hatching.

Lake chubs were initially marked by fin-clipping so that some estimate of movement on the spawning grounds could be made. It was also hoped to determine whether lake chubs merely moved into the Montreal River to spawn or whether separate populations occurred in the lake and in the river as was demonstrated for slimy sculpins by Van Vliet (1964). Recovery success and apparent hardiness of the lake chub prompted a continued marking program at seining areas within the lake to determine how far the spawners migrated.

The portion of Lac la Ronge where marking was undertaken included the Montreal River and that portion of the shoreline extending 2 miles northeast from the river mouth (Figure 9). Lake chubs captured on the spawning grounds in 1966 were marked by removal of the left pelvic fin. Marking in the lake involved the removal of the dorsal, the right pectoral, the right pelvic, or both pelvic fins, depending on the release site (Figure 9). In 1967 the same release point marks were used and a partial right pectoral clip was included to designate the year. The partial clip did not include the first three fin rays thus minimizing the ill effects of the multiple clip. The clips appeared to have no effect on spawning drive as 34 chubs were recaptured on the spawning grounds after being marked and released at the mouth of the river.

The number of days that the lake chubs remained on the spawning grounds was also inferred from fin-clip recaptures, summarized in Table 6. Of the recaptures listed for 1967, only three were females. These females were green when marked and ripe when recaptured. Two were recaptured the day after marking and the third was recaptured three days after marking.

It appears that the females remained on the spawning grounds while they were green and left once they had spawned. Indications are that males partake in spawning activity for a number of days since they were recaptured on the spawning grounds up to 6 days after marking. This type of behaviour was observed in the aquarium and is also indicated by the drop in the proportion of females in the daily catches towards the end of the spawning run (Figure 17).

The Montreal River current flows along the north shore and ice breakup occurs first in this area. The early spawning in the river was probably a response to temperature increase in the area of the river mouth. Those in the main part of the lake commenced spawning a month later when they were subjected to higher temperatures. Ripe females were captured throughout June and July in the lake area beyond the islands adjacent to the river mouth. During these months only one ripe female captured 18 July 1967 in front of the field

Table 6. Duration of recaptured C. plumbeus spawning activity.*

Number of Days After Release	Number of C. plumbeus Recaptured 1966	1967	Total
1	13	20	33
2	10	4	14
3	0	4	4
4	7	1	8
5	0	0	0
6	4	2	6
7	0	0	0

* In many cases recaptured chubs may have been on the spawning grounds longer than indicated. The total length relating a recaptured chub to a release date was often recorded for a number of chubs in daily marking and the above Table was made assuming that a recaptured chub represented the last chub released with a similar total length.

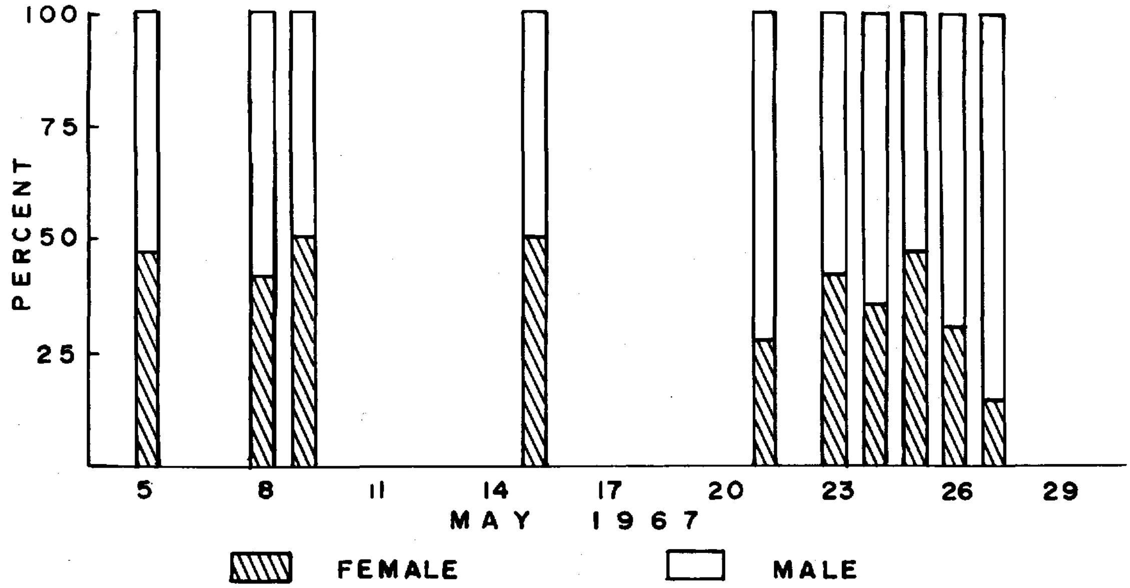


Figure 17. Per cent contribution by sexes to daily catches of C. plumbeus on the Montreal River spawning grounds, 1967.

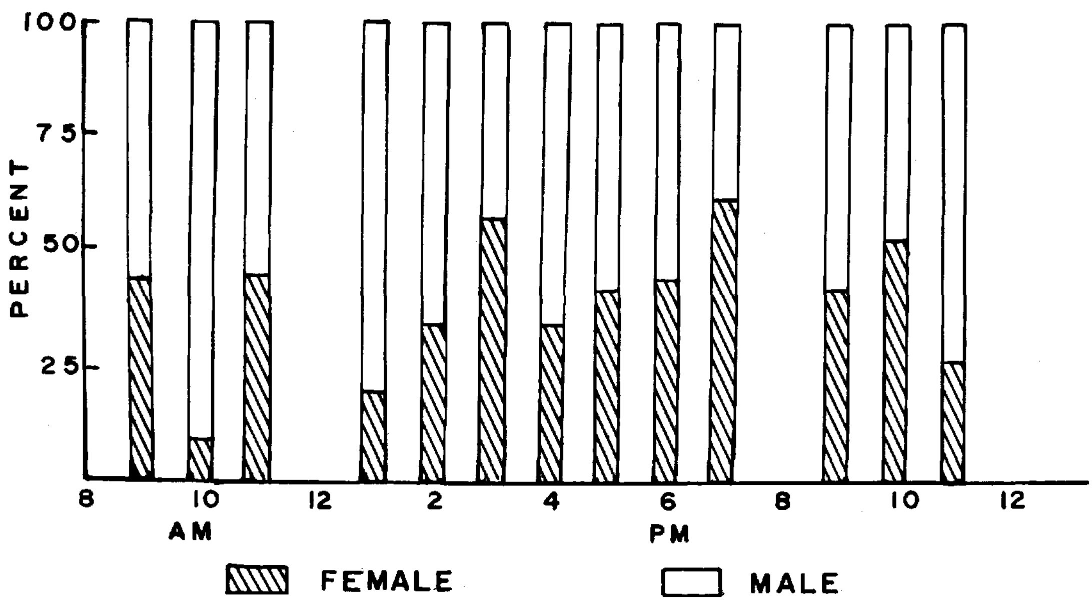


Figure 18. Diurnal variation in sex composition of C. plumbeus on the Montreal River spawning grounds, 1967.

laboratory and one collection of abnormally small fry at the campground beach 14 July 1966 indicated prolonged spawning in the area of the river mouth.

Fin-clip recaptures on and off the spawning grounds are summarized in Table 7. Capture gear was used extensively throughout the area illustrated in Figure 9. Apart from one recapture at Dog Island however, recaptures were made exclusively in the river and along portions of the north shore. None were made beyond the islands to the south, or beyond the bay north of the Fisheries Laboratory. The failure to recapture chubs originally captured, marked and released at Dog Island and south of Dominion Point suggests that these fish belong to lake breeding populations which did not intermingle extensively with the Montreal River spawning population.

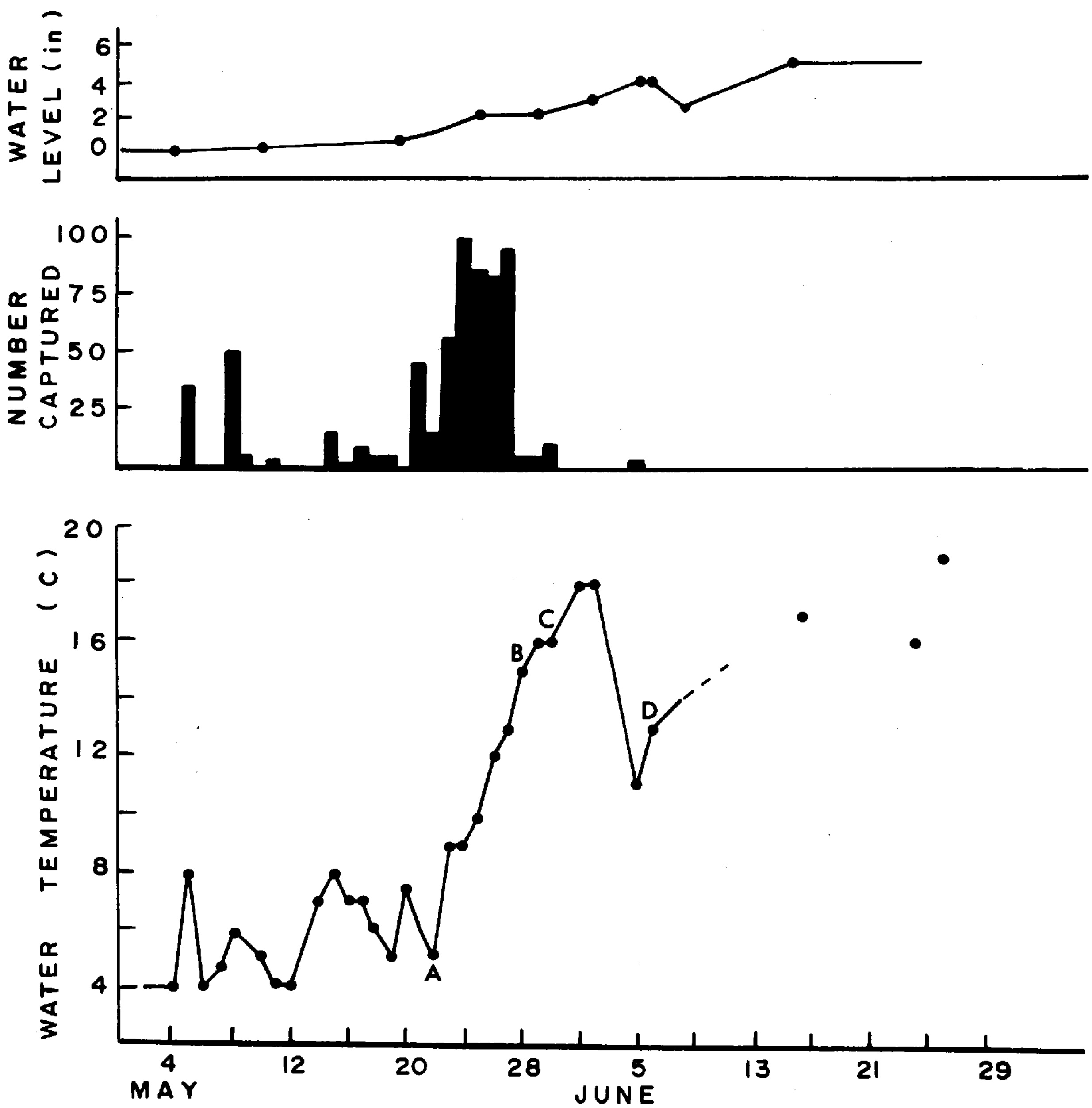
5.2.2.2. Time and Duration of Spawning

In 1967, lake chubs were on the spawning areas at the mouth of the Montreal River by 5 May. The river was free of ice by mid-April, but only 100 yards of open water existed in the lake beyond the mouth of the river at this time. Ice breakup upstream, rain, snow, and variable air temperatures caused fluctuations in water temperature of the river throughout May (Figure 19). Lake chub migration onto the spawning grounds appears closely related to water temperature. Breakup on Bigstone Lake (Figure 13) occurred on 22 May. This was followed by a warming trend in the Montreal River which corresponded

Table 7. Location of all C. plumbeus fin clip releases and recaptures during 1966, 1967 and 1968.

			Number of Recaptures									
Release Site	Year	Number Clipped	Montreal River, 1966	D.N.R. Campground, 1967	Laboratory, 1966	Montreal River, 1967	Laboratory, 1967	D.N.R. Campground, 1967	Montreal River, 1968	Dog Island, 1966	Dominion Point, 1966	TOTAL
Montreal River	1966	539	34	1	2	10	0	1	2	0	0	50
D.N.R. Campground	1966	189		18	2*	1	1	1	0	1	0	24
Laboratory	1966	1727		0	152**	5	14	4	1	0	0	176
Montreal River	1967	489		0		34	1	2	6	0	0	43
Laboratory	1967	354		0			43	0	1	0	0	44
Dog Island	1966	657		0	0	0	0	0	0	5	0	5
Dominion Point	1966	71		0	0	0	0	0	0	0	0	0

* 1 was captured at NorCanAir Dock
** 3 from RCMP Dock, 3 from Stonehocker Bay



A. Ice broke up on Bigstone Lake. White sucker spawning run began.
B. Schools of spottail shiners ascended the river.
C. Large numbers of longnose dace in breeding condition were first captured.
D. First chub fry were captured.

Figure 19. The relationship of temperature to the entry of C. plumbeus onto the Montreal River spawning grounds, 1967.

with increased migration onto the spawning areas and seemed to trigger spawning activity. At this time the ice on the main part of Lac la Ronge had not broken up but open water extended 2 miles along the bay at the mouth of the Montreal River.

When the first lake chubs were captured, the water was 4 C. Large female perch were abundant throughout the rocky shallows and the native people were snaring walleyes farther up the river. The white sucker spawning run in the Montreal River began with the warming trend on 22 May, and coincided with the increase in lake chub spawning activity. Some lake chubs were captured on the spawning grounds in June but spawning was essentially completed and the chubs had returned to the lake by 30 May when the water temperature reached 16 C. At this time large numbers of longnose dace (Rhinichthys cataractae) invaded the same areas to spawn.

Green females taken from the river in early May and placed in an aquarium in the laboratory at temperatures up to 15 C became ripe within two days and often released eggs on the aquarium bottom. This observation, along with the field data (Figures 19 and 20), suggests that the final triggering mechanism for spawning is temperature.

Actual spawning time as compared to arrival at the spawning grounds can be inferred from the progression of the spawning condition of the females (Figure 20). Until 23 May, all of the females captured on the spawning grounds were in

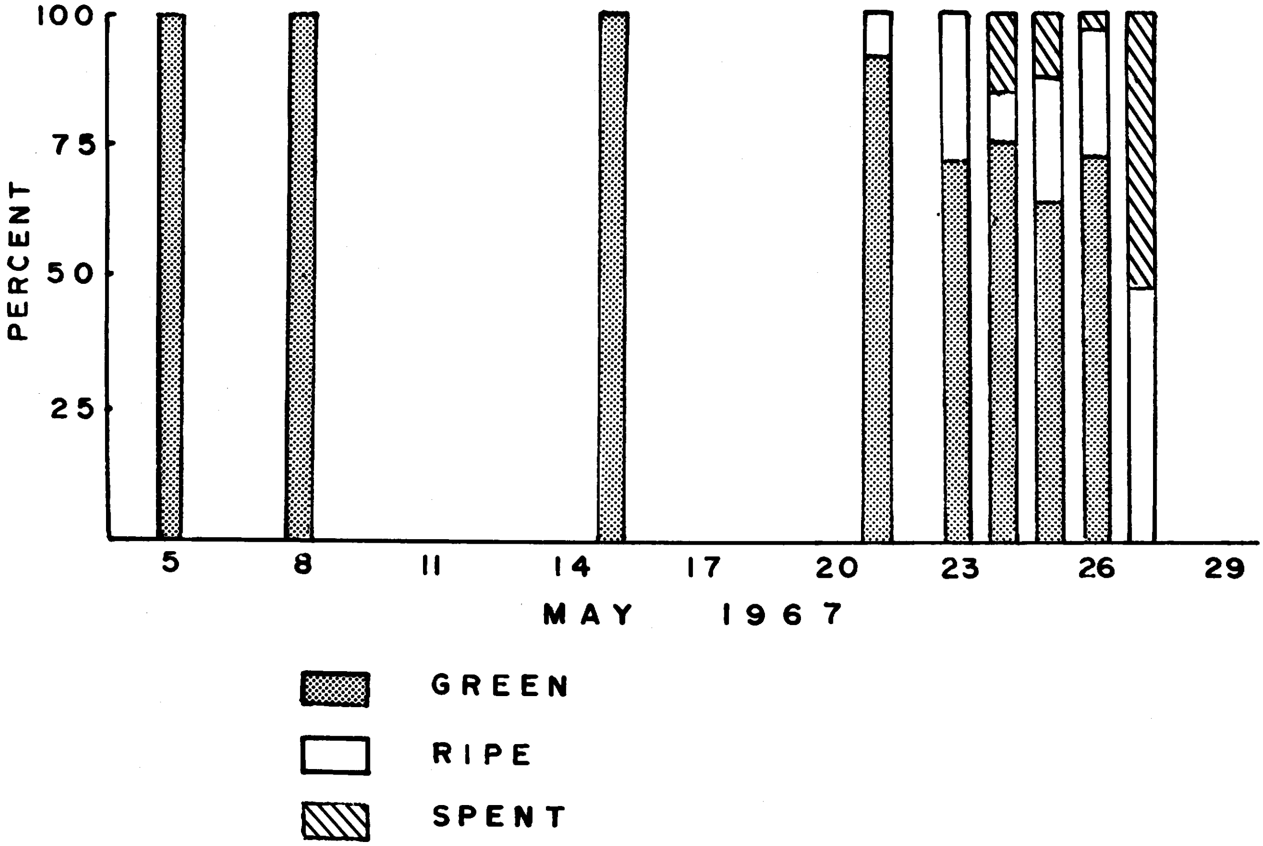


Figure 20. Spawning condition of female C. plumbeus captured on the Montreal River spawning grounds in 1967.

green condition except for one ripe female captured on 21 May. The percentage of green females captured decreased from 23 to 26 May. Only ripe and spent females were captured on 27 May after which no spawning activity was observed.

In Lac la Ronge proper, ripe lake chubs were first captured by gill netting on 13 June 1966 and 16 June 1967 when the surface water temperature was 10 C. Some gravid females were captured throughout both summers and the latest date of capture was 13 September 1966. The eggs appeared in near-ripe condition, unlike the atretic eggs that two aquarium-held females retained rather than releasing. It is possible that some of the captured females had attained an 'over-ripe' condition but size variability of fry captured throughout the summer indicates a prolonged spawning period in the lake.

Investigations at two other lakes revealed that spawning activity had occurred shortly after ice break up. Fry in Thomson Lake reached 16 mm by 12 June 1967, while spawning at MacKay Lake creek was completed on 29 May 1967.

5.2.2.3. Pre-Spawning Behavior

While the water temperature fluctuated between 4 - 8 C, early arrivals at the spawning grounds were observed where water varied from 0.5 to 2 feet in depth. At times they appeared sluggish and reluctant to flee, but normally when disturbed they proved excellent at hiding under rocks and, because o their mobility, were much more elusive than sculpins. This cryptic behavior proved advantageous as it was possible to discern their presence by setting out boards or flat rocks for them to hide under. A thorough search of an area necessitated a crow bar to jar and over-turn large rocks. Their ability to remain hidden is well exemplified by an experience of G.D. Koshinsky, who collected a large spawning sample by poisoning a small area of the river in 1968. He reported not seeing a single chub until the rotenone was applied and stricken individuals began drifting into the net.

Temperature had (Figure 19) an important influence on migration to the spawning grounds and it also appeared to influence daily activity. Diurnal water temperature variation of the Montreal River generally corresponds to the air temperature variation; thus a warming trend in the morning and cooling at night results in at least a 2 C discrepancy between morning and afternoon water temperature. By noon, temperature variation of the river itself often exhibited a gradation of as much as 3 C from the main current to the extreme shallows. Capture numbers were always low in the morning, high during the afternoon and gradually declined during the late evening. The chubs appear to move onto the spawning grounds and into the warmer water of the shallows by late afternoon and return to deeper water during the evening and night. Consequently few are present on the spawning grounds in the morning.

It was discovered that males became rather aggressive during spawning season. Rather than fleeing a dip net or other object poked at them while in an aquarium, they most often faced the object and held their position. In doing this, they seemed nervously excited and went through a series of twitches or body jerks involving quick movements of the pectorals accentuated by movement of the dorsal, pelvic and caudal fins. After males had been held a number of days at 12 to 15 C, their aggressiveness and spawning drive wore off and they again assumed the timid nature of the lake chubs held captive throughout the year. Females remained timid throughout the spawning season and were extremely elusive and difficult to capture in the aquarium.

Territorial behavior was demonstrated by only three of the 14 observed aquarium groupings of males in spawning condition. In each instance only two males were involved and a boundary dividing the aquarium was strictly adhered to. Aggressive chases occurred in virtually all groupings of males as they milled about the aquaria. The aggression seemed to be initiated by movement of another male rather than by establishment of territory in preferred rock cover or the darker portion of the aquarium. In all three instances of territorial behavior, the males were of nearly identical size. In groupings involving males of disparate sizes, aggressive behavior was reduced. When three or more males were placed together no territorial behavior was exhibited and the fish remained quiet, milled about the aquarium, or randomly pursued each other.

In aggressive encounters, it appeared that a male seldom actually rammed the side of another male. Instead the aggressor would press his snout just behind the eye region of another male and swimming vigorously would force him across the aquarium. Once the pair had traversed the aquarium the situation was generally reversed by a tight arc resulting in the original pursuer now being pursued. In the territorial instances this behavior usually involved five or six chases and at times lasted as long as 30 minutes before the fish were content to remain on their holding. If one of the males wandered, if the aquaria were disturbed, or if the room lights were turned on at night, the aggressive pursuit behavior would be initiated and the fish would again chase each other back and forth until they had redefined their positions.

Both sexes appeared on the Montreal River spawning grounds simultaneously (Figure 17). During the day, neither sex preceded the other to the shallow spawning areas (Figure 18). From the close proximation of lake chubs congregated under the set out boards and flat rocks, it appears highly improbable that any pre-spawning territories are maintained by either sex before spawning. If pre-spawning territorial behavior did exist in natural conditions, it certainly broke down during spawning. There was no evidence of nest building by either sex.

5.2.2.4. Courtship and Spawning Behavior in Aquaria

The most common aquarium observation involved a male nosing the anal region of a female as he approached her or pursued her from beneath as in Figures 21 and 23. When a number of males were involved, they would swim side by side

Figure 21. Beginning of C. plumbeus courtship as a male approaches a female and nudges her anal region with his snout.

Figure 22. A male C. plumbeus vigorously forcing himself against a female after having approached her as in Figure 21.

Figure 23. Pre-spawning behavior of C. plumbeus in which a male pursues the female from beneath.

and appeared to compete intensely to stay closest to the female. At times a pursuing male would swim alongside a female keeping his head just behind her operculum as in Figure 22. Females were pursued relentlessly in an aquarium. They often acted annoyed by the persistent males and would turn sharply, eluding the pursuers who continued in the original direction preoccupied with each other. The female would then move to the bottom and remain quiet but the respite would only be momentary as the males, discovering their error, quickly located the female and again took up the pursuit. The male pursuit from beneath seemed to force a female upward and often caused her to break the surface.

When a female was introduced into an aquarium, never more than 25 seconds elapsed before the males recognized her presence and began pursuing her. When one male made a quick motion or approached a female, the other males present would immediately rush over and join him. Males in adjoining aquaria, when attracted by the activity, attempted to reach it by swimming frantically against the glass.

Other observations following introduction of a female into an aquarium containing males, included the darkening and increased distinctness of the lateral body stripe on the males (Figures 21 to 25). Also noted was the rapid opening and closing of the mouths of the chubs as if they were exhausted and gulping for oxygen.

Often before pursuit a male would swim the length of a female's body, vibrating as he pressed against her. During these observations, no eggs were released by the female. Twice a male was observed to swim within 2 inches of a female and vibrate before he began nosing beneath and pursuing her. The vibrations lasted approximately 2 seconds and were similar to those observed during the spawning act.

Pursuit lasted until the female could be forced beneath or against a rock as in Figure 24. A male then aggressively forced himself against the female and as he vibrated vigorously and she appeared to struggle, the spawn was released. When a female was underneath a large stone, a male would swim against her and vibrate along the length of her body. Arcing away, the male would circle and repeat the procedure if another male had not rushed in ahead of him. The rough, male approach was most often from the female's tail but approaches from the head were also observed. The locking of pectoral fins characteristic of many cyprinid spawning acts was not observed. Often after prolonged spawning periods in an aquarium the females became lethargic and stayed beneath a large rock. Removal of the males allowed the females to rest and they always recovered.

In one instance, a large male and a small female spawned over gravel. The male, arcing his body, forced himself alongside the female so that the pelvic regions were together and the ensuing violent tail action dispersed spawn for at least 3 inches.

Spawning vibrations generally occurred several times

Figure 24. A male C. plumbeus forcing a female against a rock where a portion of her eggs were released.

Figure 25. After the spawning act (Figure 24), the female struggled free and attempted to escape from the male.

per minute with each instance lasting for about one second. The number of eggs released each time would represent only a small portion of the total eggs that a female originally carried. At times spawning behavior was interspersed with feeding activity and both sexes were observed to devour eggs.

Introduction of a spent female into an aquarium initiated the typical response described for the males but it rarely lasted more than 3 minutes. The female generally ignored a male's approach and would refuse to swim away when males nosed beneath her. After the initial excitement the males most often lost interest in the female. On some occasions, they would mill about her or lie alongside her, nosing her from time to time but no longer attempting to spawn.

5.2.2.5. Courtship and Spawning Behavior in the Field

Although spawning was not observed while it was dark, flashlight investigation of splashing on the spawning ground at 11:30 p.m. on 25 May 1967, revealed a large female lake chub attended by many smaller chubs most of which were males. Later that night, two similar observations were recorded along the edge of the river beneath overhanging trees where the bottom was covered with silt and old leaves. Light stopped all spawning activity and the chubs quickly dispersed. Fresh eggs scooped out with a dip net revealed that the chubs were definitely spawning.

It was not determined what percentage of spawning took place in the dark, but the egg collections and lake chub congregation beneath large stones in the rocky shallows indicates that a great deal occurred in the afternoon and it was at this time that most spawning behavior was observed.

The first observation of spawning in the field was made at the spawning area adjoining the airfield (Figure 14) on 27 May 1967. At 3:00 p.m. splashing was noticed alongside a clump of willows. The use of willows as cover permitted the observation of lake chub spawning from a distance of 3 feet. It was a bright sunny day, the water was only 2 inches deep and with no wind effect on this portion of the spawning area, conditions for observation were excellent.

Initially one large female and three small males were involved but other males were milling about in the rocks and joined the spawning activity. Behavior was very similar to that observed in the aquaria. The female swam slowly, avoiding the males that followed her and continually tried to force her against or beneath rocks where they could come alongside her and vibrate.

Males that discontinued the spawning activity or were eluded by the female continuously searched among the rocks and dashed towards other chubs that were involved in any type of activity. The female would disappear among the rocks for as long as 5 minutes before returning to where she could be observed. Throughout the observations, this female was easily identified by a white fungus-like patch above her left pelvic fin. Recording was abruptly terminated at 3:40 p.m. when school was out and native children came to the rocky shallows to chase the suckers and 'little fishes'.

The second observation of spawning in the field was made at 5:00 p.m. on 27 May 1967, at the mouth of the Montreal River. Again it was splashing that attracted attention to the spawning activity, but this time it came from among rocks where there was very little water. When a large rock (Figure 26) was turned over, chubs dispersed from beneath it. Observations were made from a position above the overturned rock shown in Figure 27. Three males were observed to dart across the opening during the first 15 minutes. Subsequently two females, each pursued by three males swam from among the rocks. Chubs suddenly began appearing from all directions and they were simultaneously milling about, chasing each other and spawning. No new behavioral characteristics were noticed.

A trap was set to cut off an escape route to deep water and as this was being done, the chubs remained completely hidden. Removal of the rocks that the chubs were hiding under resulted in the capture of 32 males and 6 females. Similar sex ratios of chubs had been captured in rocky shallows previously in both 1966 and 1967 but actual spawning had not been observed beforehand.

It might be noted that two males with recent fin-clips were observed at night on 25 May 1967 and another was observed on the afternoon of 27 May. The activity of these fish did

Figure 26. C. plumbeus were discovered spawning among these rocks at the mouth of the Montreal River on 27 May 1967.

Figure 27. Spawning site of C. plumbeus revealed by removal of some of the protective rocks in Figure 26. Eggs and fry were collected at this location. Note wrist watch at top left of figure.

not appear to be hampered by the clips.

5.2.2.6. Sex Ratio on the Spawning Grounds

The sex composition of lake chubs captured each year on the spawning grounds is given in Table 8. None of the marked fish that were recaptured are included in the percentage determinations. The percentage of males was found to be higher than that of the females in each year. This might have been expected as males always outnumbered females when spawning was observed in the field.

Table 8. The sex ratio of lake chubs captured on the Montreal River spawning grounds in 1966, 1967, and 1968.

Year	Total captured	Total sexed	Number ♂	Number ♀	Per cent males	Per cent females
1966	773	234	149	85	63.7	36.3
1967	617	602	401	201	66.6	33.4
1968	1285	1285	732	553	56.9	43.0

The percentage of spawning males and females captured daily in 1967 has been illustrated in Figure 19. There appears to be no tendency for one sex to precede the other to the spawning grounds to distort the overall sex ratio in the run.

5.2.2.7. Sexual Dimorphism

Male nuptial coloration consists of a distinct lateral stripe and bright orange markings, the most prominent of which appear at the base of the pectoral fins. Orange markings also appear above and behind the operculum and at the corner of the mouth, often extending up to the eye. On some chubs orange markings were found at the base of the pelvic fin. Great variation in the number of breeding marks and the amount of color per breeding mark exists throughout the breeding population. Many of the larger males captured on the spawning grounds had nuptial coloration similar to that shown in Figure 28. Younger males most often have only three breeding marks, the patch at the base of the pelvic fin seldom being present. Females often have patches at the base of the pectoral fin and at the corner of the mouth and these are often particularly well developed in older females.

Some fish had little coloration but they were ripe and their spawning activity appeared no different or in the case of males, less aggressive than that of the brightly marked individuals. Throughout the summer and fall periods chubs were captured with orange markings at the base of the pectoral fins but appeared to be no more sexually developed than others.

During the breeding season, sexual dimorphism is exemplified not only chromatically but also by the obvious

Figure 28. Male C. plumbeus in breeding condition.

gravid appearance of the females. Males may also be distinguished by the development of nuptial tubercles on the head and often on the body scales. The size and number of these tubercles vary with each individual and seem to be positively correlated with the intensity of orange breeding marks. The tubercles are fine and there appear to be no prominent ones developed and no pattern formed. Up to six tubercles on the periphery of each scale appear on some of the males that develop tubercles along their bodies. The dorsal surface of the first pectoral fin rays develops a serrate appearance from tubercle-like swellings. The other fins of many males appear unchanged but on the dorsal surface of the first few pelvic fin rays some males develop regular swellings as on the pectorals. Close examination revealed very fine tubercles on some females but none of the other developments were noticeable.

5.2.2.8. Age and Size Composition of the Spawning Population

Length frequency of the 1967 and 1968 lake chub spawning samples are given in Figure 29. The 1966 spawning sample was not included as it was biased by selectively preserving larger individuals. Examination of Figure 29 suggests that the 1967 male and 1968 female samples are probably the only ones large enough to reliably represent the age composition of the lake chub population.

Lake chubs appearing on the spawning grounds for the first time constitute the major portion of the spawning fish. These fish are classified as group III and are actually 2 years and 11 months old. After spawning, they will become group IV at the time the fry hatch. The smallest representatives of this group captured were a mature male 77 mm total length in 1967 and a mature female 81 mm total length in 1968. The percentage of spawning fish that were age group III is estimated in Table 10 after taking into account the year class overlap. Mean total length of the group III females in 1967 was calculated to be 95.3 mm as compared to 95.1 mm in 1968.

Recapture of fish marked in previous years indicates that the group IV females constituted 26.3% of the spawning females in 1968. Year class overlap (Figure 29) and recapture of fewer marked fish makes it difficult to define group IV for the other samples.

In 1968, groups over 125 mm total length constituted only 5.92% of the spawning females captured and examination of the 1967 female data indicates a similar percentage for this sample. Yearly maximum total lengths of captured spawning fish are given in Table 9 and illustrate the greater growth and probably the greater longevity of the females. Indications are that the larger females are at least group VI and quite possibly older.

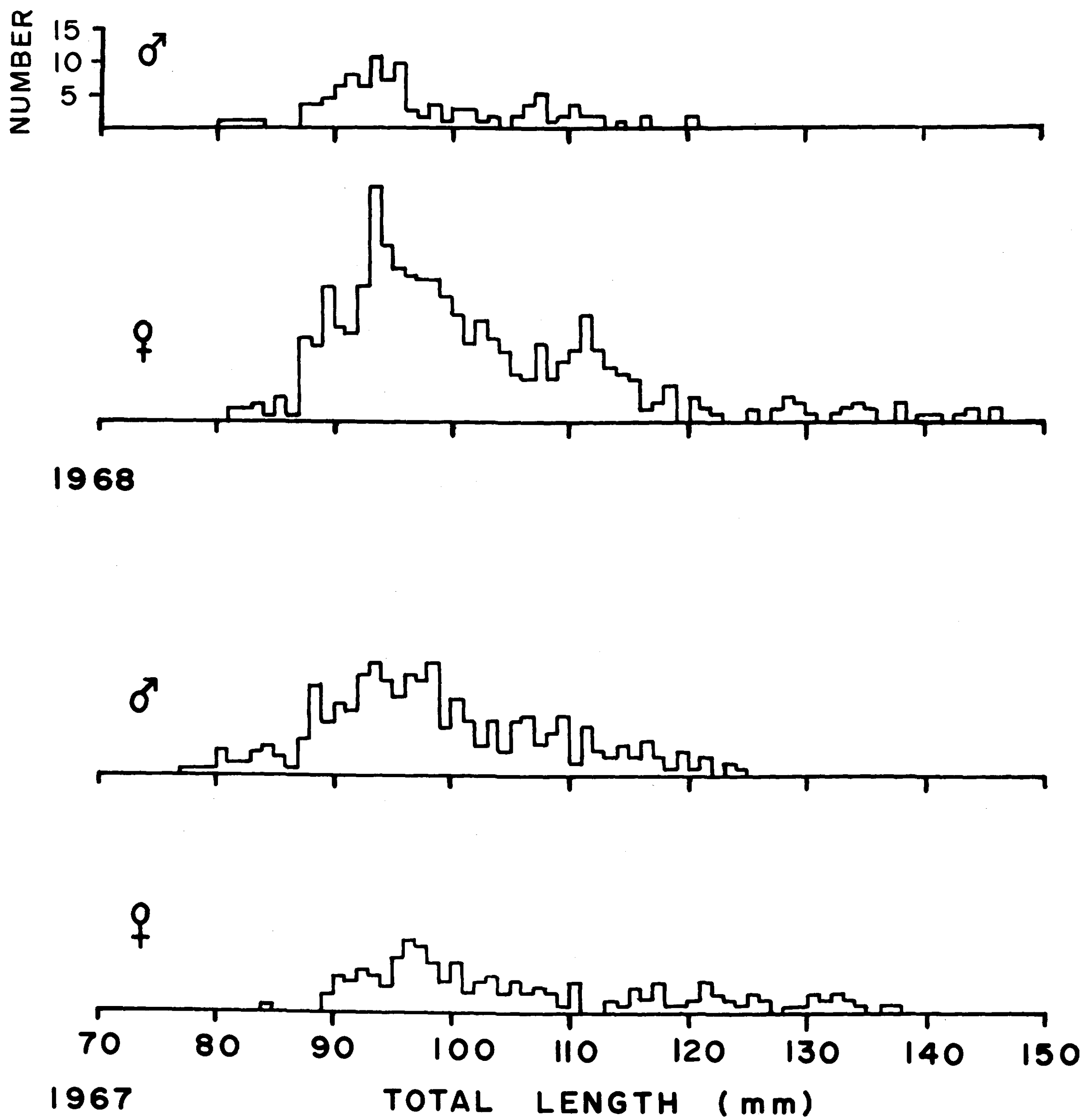


Figure 29. Length frequencies by sex of *C. plumbeus* spawning samples from the Montreal River, 1967 and 1968.

Table 9. Minimum and maximum size of mature _C. plumbeus_ captured on the spawning grounds in the Montreal River, 1966-68.

	Total Length in Millimeters			
	Minimum		Maximum	
Year	Male	Female	Male	Female
1966	80	80	134	143
1967	77	84	124	146
1968	80	81	121	147

5.2.2.9. Fecundity

Ripe females released eggs when they were handled so green females captured early in the spawning season were used to determine fecundity. Egg numbers of females ranging from 90 to 132 mm total length are shown in Figure 30. The egg number was determined by gravimetric estimation that was found to vary not more than 6% from actual counts. Eggs developed in both ovaries and though 70.6% of the females examined had more eggs in the left ovary than in the right, no significant difference was found.

The recruitment potential of each age class of spawning females in the Montreal River run in 1968 is given in Table 10. This is actually relative recruitment potential as the absolute numbers of each age class in the run is not known. Despite the fact that the larger females carry more eggs, the group III females that constitute 67.8% of the spawning females outnumber the other age groups to such an extent that 53.6% of the potential recruitment is attributable to them. Age group IV, constituting 26.3% of the spawning females, was calculated to contribute 33.2% of potential recruitment. Greater longevity of the females does not appear to play as great a role in recruitment as one would expect since the age groups V and older only made up 13.2% of the potential recruitment.

Throughout the year, two types of eggs present in the ovaries could be classed as maturing eggs or recruitment

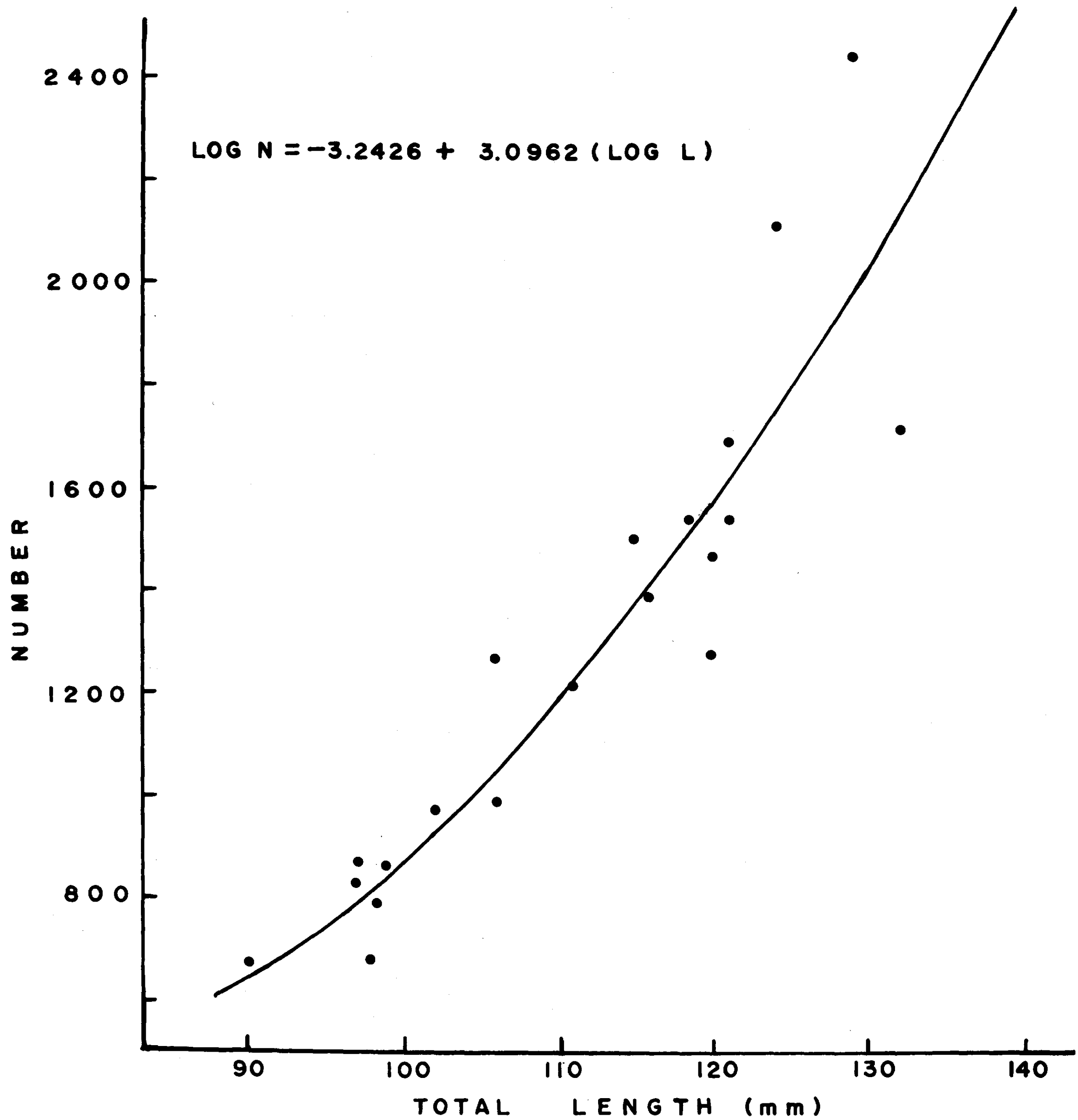


Figure 30. Relationship between mature egg number and total length for 20 green *C. plumbeus* females from the Montreal River spawning run, May, 1967.

Table 10. Potential recruitment contributions of each age class of C. plumbeus in the Montreal River, 1968.

Spawning Age Class	Number f	Mean Total Length	Calculated Number Eggs Per Mean Total Length N	Number Eggs Per Age Group fN	Percentage Recruitment
group III	366	95.08	762.1	278928.6	53.63
group IV	142	110.50	1214.0	172388.0	33.15
group V	19	126.39	1841.0	34979.0	6.73
females over 134 mm T.L.	13	141.27	2597.0	33761.0	6.49
Total	540			520056.6	

eggs. The yellow maturing eggs were found to increase in diameter and decrease in number until they are ready to be spawned so that an unidentified atretic type of egg must also be present in the ovary. Examination of ovaries from spent females revealed varying numbers of large residual eggs that were not spawned. The opalescent recruitment eggs vary in size and indicate clearly that lake chubs spawn in successive years.

Diameters of water hardened eggs averaged 2.3 mm. Just before spawning, the eggs were yellow and ranged from 1.29 to 1.67 mm. The pale recruitment eggs and translucent oocytes also present in the ovary during spawning are much larger than they are later in July (Figure 31). Possibly hormonal control of egg development causes these eggs to increase in size during spawning. Cessation of spawning activity may then result in a type of resorption.

Reference to Figure 31 shows that egg development did not occur until mid-August at which time the eggs turned yellow and growth proceeded. Egg diameter increased rapidly until October and further increase up to spawning season the following May was slight. Corresponding to the lack of egg development in July was the presence of large amounts of fatty tissue along the ovaries and other internal organs. When egg development commenced the fat appeared to be utilized as little was present in late August and September.

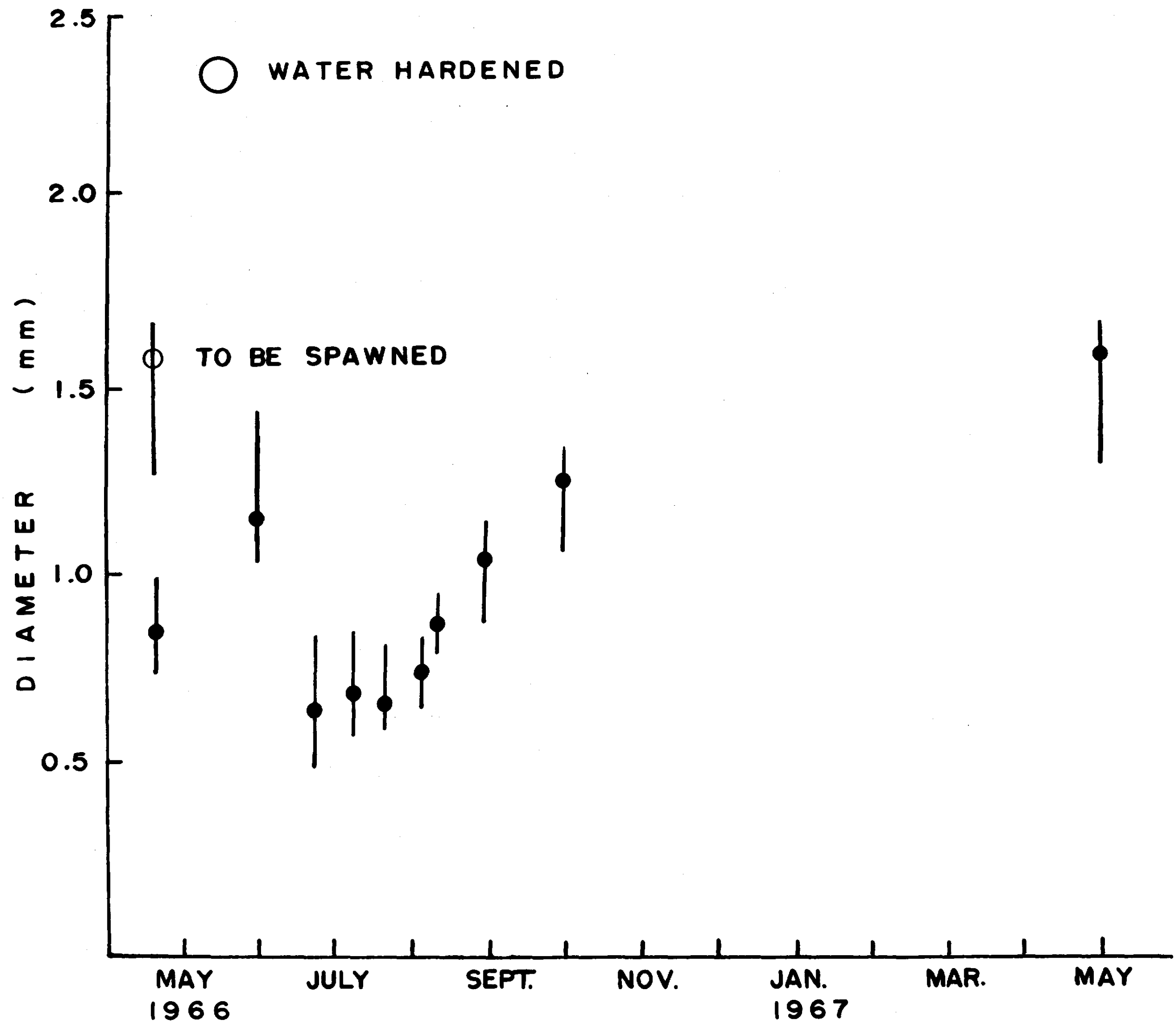


Figure 31. Egg diameter of C. plumbeus from Lac la Ronge illustrating the seasonal development of recruitment eggs until they are spawned. Average diameter of eggs after spawning are labelled as water hardened.

5.2.2.10. Egg Mortality

By scooping among the rocks with an aquarium net, egg samples were taken from two locations in the Montreal River. One area had a slow current and the eggs were collected from among silt, leaves, and wood fragments along with white sucker eggs and numerous caddis and mayfly nymphs. Only 519 of the 919 chub eggs collected were viable. Collections from a gravel bottom beneath a flat rock yielded only 53 viable chub eggs of the 99 collected so that it would appear that the silt at the first collection site had no special adverse affect on the developing eggs. The reason for the low percentage of viable eggs was not investigated but often eggs fertilized by hand stripping ripe males and females produced only 65% viable eggs.

The amount of silt and debris that gathered among the rocks with the eggs was dependent on fluctuations in the water level. In both 1966 and 1967 the water level increased after spawning and increased water flow removed silt and debris from where the eggs were deposited. Eggs observed along the depressions and crevices of the rocks would disappear after a few days and it is not known whether the disappearance was due to predation. Possibly movement of fry within the egg or fungus could cause the current to catch the eggs and move them into deeper depressions or downstream.

5.2.2.11. Incubation Period and Hatching

During 1966, eggs were first collected from the river on 21 May and the first fry were captured on 6 June. The amount of spawning that had occurred before the spawning grounds were discovered is not known so that any estimation of incubation period from the above data would be minimal. To determine the incubation period, eggs were retained in wire baskets in both the river and the lake but the native children prematurely terminated each experiment.

In 1967, eggs were successfully hatched in the laboratory in pint jars and aquaria. Hatching occurred ten days after fertilization in a temperature environment that fluctuated from 8 to 19 C. During the intensive investigation of the spawning grounds, eggs were first collected on 24 May and fry on 2 June, indicating a natural incubation period of ten days. River temperature fluctuation during this time is illustrated in Figure 19 and is not unlike the laboratory temperature fluctuation.

Biological development has been related to temperature by summation of the difference between mean daily temperature and biological zero (Belehradek, 1930). The temperature at which no biological development occurs was not known for lake chub eggs so the freezing point was substituted in an attempt to apply the rule of thermal summation to incubation. Estimated thermal unit values between 121 and 142 for the various laboratory hatchings are in reasonable agreement with the 145.5 thermal units based on observations of first spawning and first fry capture in the river.

5.3 Growth

5.3.1. Fry

Newly hatched fry from the aquaria averaged 5.5 mm in total length. Growth proceeded immediately after hatching. The yolk sac was barely discernable after four days and after nine days the mean total length had increased to 8.3 mm. In the field, fry were first captured in early June in both 1966 and 1967. Comparison of total length and yolk sac condition with the fry hatched in aquaria indicated that the captured fry were recently hatched.

Rapid growth of fry hatched in 1967 is indicated in Figure 32. By 24 August 1967 the mean total length was 41.3 mm. Over this same period the weight had increased from a mean of 0.007 g on 24 June 1967 to a mean of 0.52 g.

Fry captured throughout Lac la Ronge vary in size. The fry from the Montreal River mouth were generally larger than fry from the lake as spawning took place a month before it did only 2 miles beyond the river mouth at Dog Island. Early spawning took place in other locations on Lac la Ronge as on 26 July 1967 fry were captured at Waden Bay which were similar in size to those at the Montreal River.

5.3.2. Age and Growth of Adults

Lake chub age proved difficult to determine using scales or bony structures and was inferred using the length-frequency method. Growth of the year class that hatched in

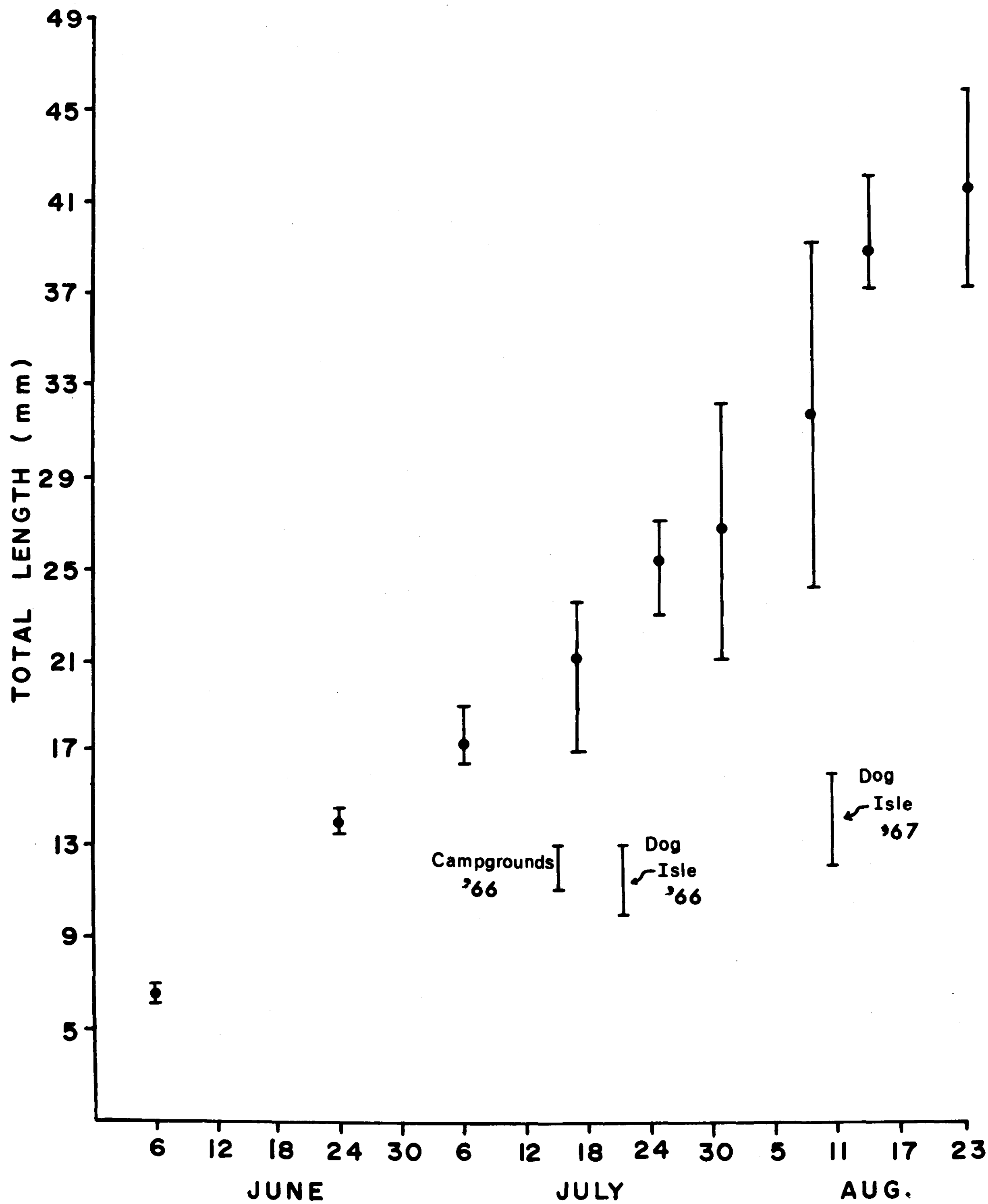


Figure 32. Growth of C. plumbeus fry hatched in the Montreal River, 1967.

June of 1965 is illustrated in this manner in Figure 33. As chubs increase in age the slowing down of growth causes the year classes to overlap to such an extent that it becomes difficult to distinguish ages beyond group IV. If sexes are not treated individually, further overlap is introduced because the females grow faster than the males.

The mean total lengths of lake chub age groups given in Table 11 were inferred from a Walford plot (1946). The Walford plot is based on decrease of yearly growth increments at a constant percentage rate. Using arithmetic graph paper, body length is represented along both the x and the y axis. Length at age 2,3,4...n is plotted on the x axis against length at ages 3,4,5...n + 1 respectively on the y axis. These points fall along a straight line for the lake chub as they do for most animal species.

Recapture of lake chubs marked in previous years verified interpretations of the lower year classes in Figure 33 and validated construction of a Walford plot.

Table 11. Age group sizes of Lac la Ronge *C. plumbeus* for July 1968. These were determined from a Walford plot.

Age Group	Mean Total Length mm
I	58
II*	77
III*	95
IV*	110
V	124
VI	137
VII	148

* Calculated from length frequencies in Figure 33.

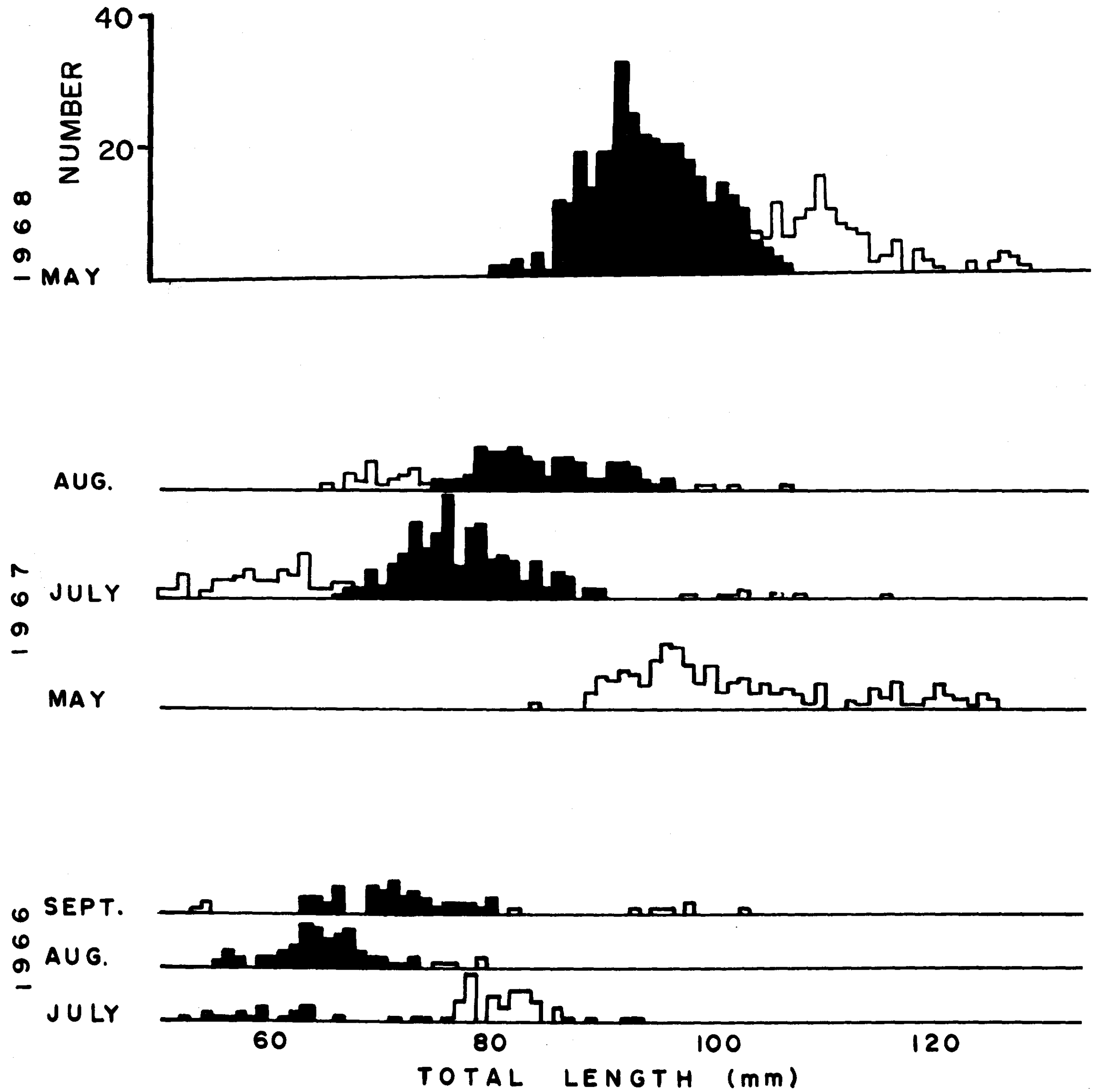


Figure 33. Growth rate of the female C. plumbeus year class that first spawned in the Montreal River in May, 1968.

5.3.3. Relation of Total Length to Standard and Fork Lengths

Relation of total length to standard and fork length as determined with an IBM 360 computer for 395 lake chubs from Lac la Ronge is represented in Figure 34. The relationships for fish ranging from 60 to 146 mm total length are expressed by the equations:

$$\text{Standard Length (mm)} = -1.6404 \text{ mm} + 0.8171 \text{ (Total Length)}$$

and

$$\text{Fork Length (mm)} = -0.6143 \text{ mm} + 0.9177 \text{ (Total Length)}$$

Correlation between empirical and calculated values is 0.99 for both equations.

5.3.4. Length-Weight Relationship

The length-weight relationship in Figure 35 is expressed by the equation $W = CL^N$, where W = weight, L = total length and C and N are constants. The IBM 360 computer was used to calculate C and N for 285 lake chubs from Lac la Ronge. Lake chubs in spawning condition were not included in the sample. The length-weight relationship for the males ($W = 2.6774 \times 10^{-6} L^{3.2373}$) as compared to that for the females ($W = 4.4713 \times 10^{-6} L^{3.1097}$) shows that for a given length, males are heavier than females. Greater bone development of the male (i.e., the larger pectoral fin) may be responsible for the increased density. Correlation between empirical and calculated values for the males was 0.98; for the females was 0.99; and for both sexes together was 0.98.

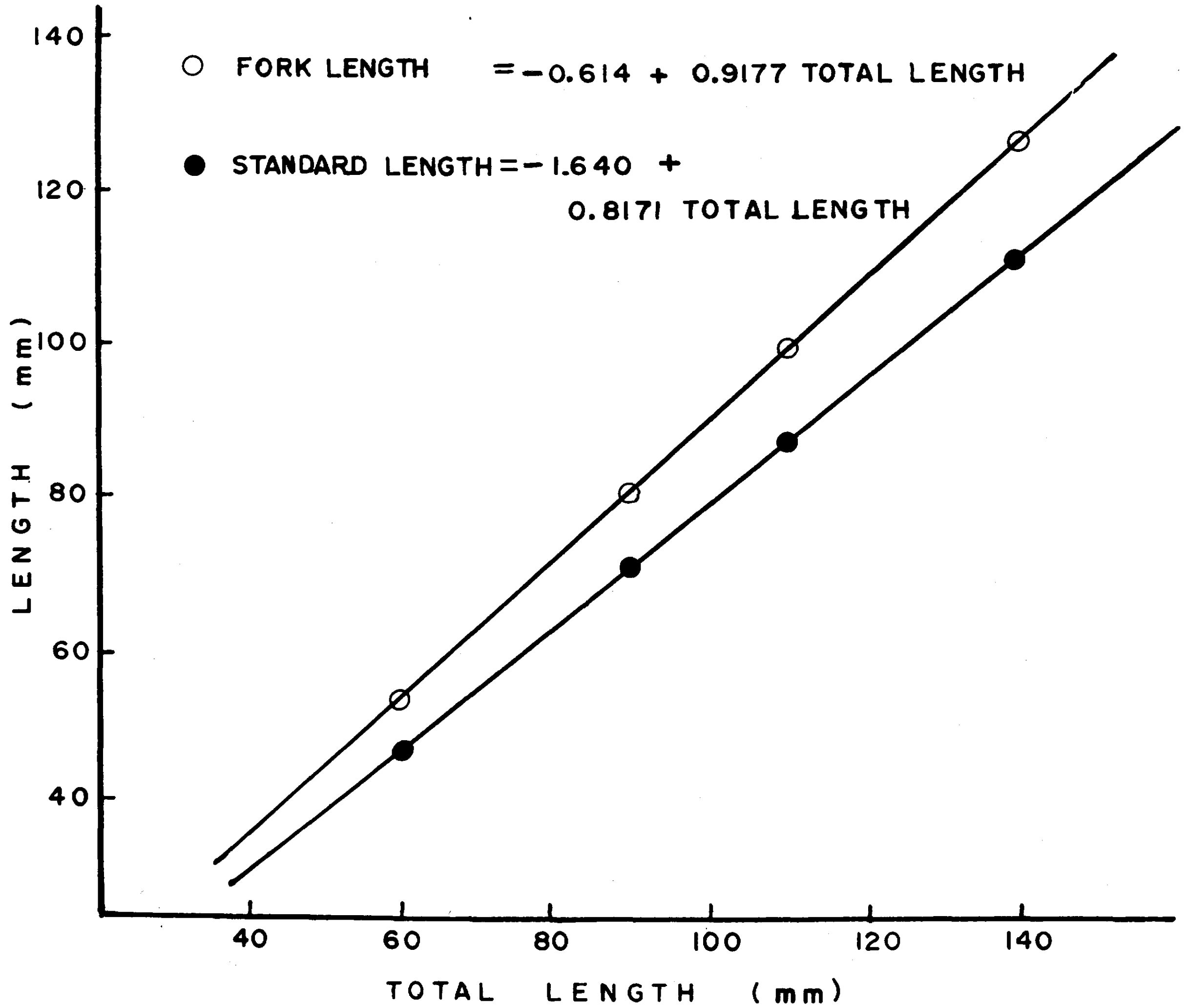


Figure 34. Relationship of total length to fork length and standard length for 395 C. plumbeus collected at Lac la Ronge, 1966.

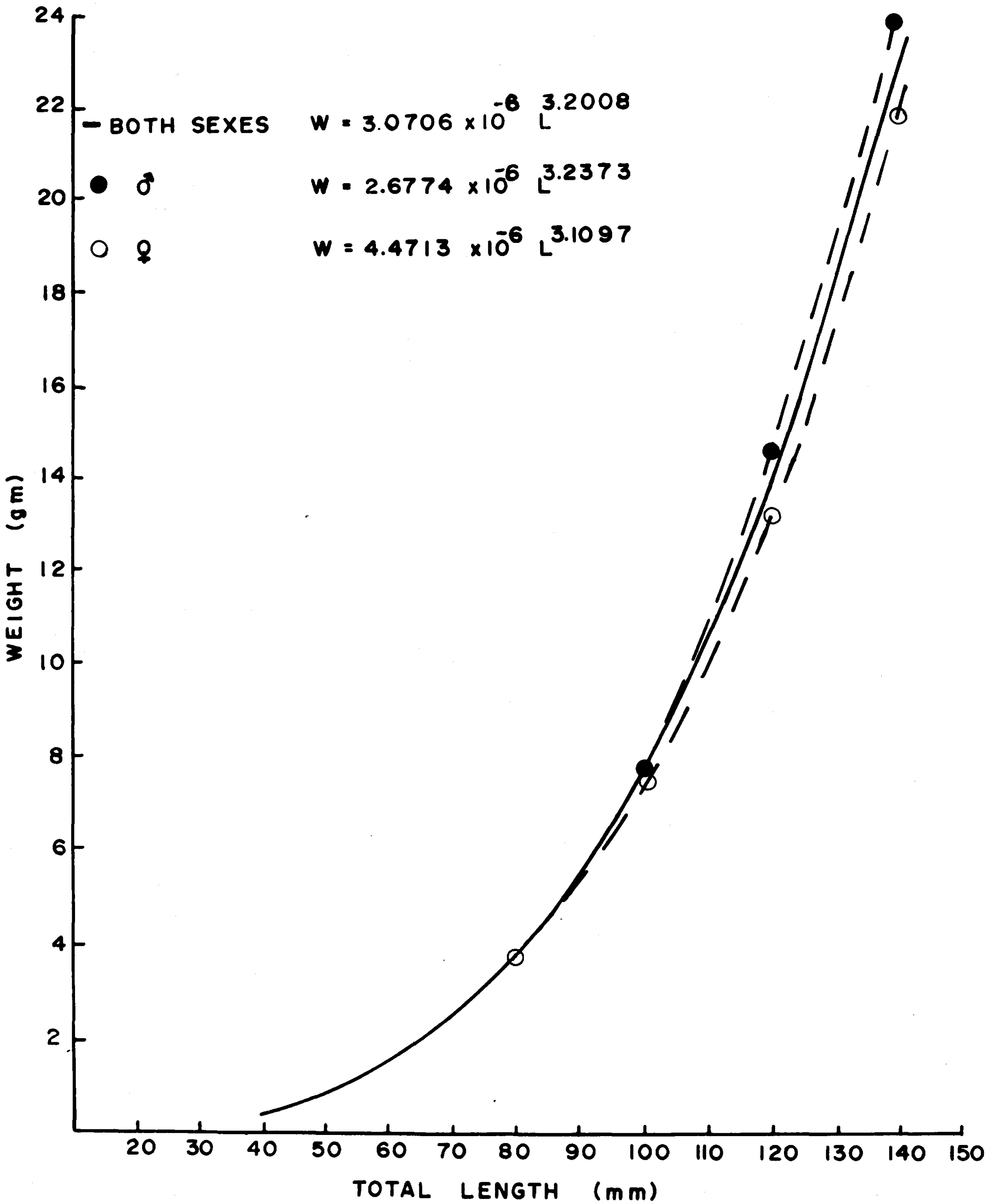


Figure 35. Length-weight relationship of 285 C. plumbeus collected at Lac la Ronge, 1966. Samples from the spawning season were not included.

5.3.5. Condition

The coefficient of condition is represented by K and expressed by the equation $K = \frac{W \times 10^5}{L^3}$, W = weight and L = length. Mean K values for 395 lake chubs captured throughout the field season at Lac la Ronge are given in Table 12. The mean K values were found to be high during the spawning season, low in July and to increase through August and September. This appears closely related to the development of ovaries and testes as indicated by egg development in Figure 31.

Table 12. Seasonal change in *C. plumbeus* condition*.

	Age Group						
	Females				Males		
Month	II	III	IV	V	II	III	IV
May		1.64	1.63	1.63		1.58	
July	1.46	1.41	1.47		1.46	1.43	
Aug.	1.55				1.55		
Sept.	1.60	1.62			1.60	1.71	

* Coefficients of condition = $K = \frac{W \times 10^5}{L^3}$

5.4 Habitat

In the Montreal River where the water was not more than 2 inches deep and the current was slight, newly hatched fry were captured with an aquarium net but it was only with great difficulty that any could be observed. Movement resembled that of a tadpole as they swam for a few seconds and again settled out of sight into the Cladophora. It is probable that this undirected swimming activity combined with increased water level resulted in the current moving the fry downstream to the lake.

On 24 June 1967, fry with a mean total length of 14 mm were first collected at the mouth of the Montreal River. They were out of the main current in about 18 inches of water. The fry remained in this area for the next month and by 17 July had attained a mean total length of 20 mm. During this time they congregated by themselves in mid-depth apparently feeding on material carried by the current. They remained completely segregated from the groups of spottail shiner fry that remained in the Carex and Scirpus beds and from the longnose dace fry on the flat rocks beneath them. By 10 August the fry had reached a mean total length of 31 mm and were associated with sucker, perch and spottail fry moving about freely in the deeper water and amid emergent vegetation. Fry activity in the lake was similar to that observed at the mouth of the Montreal River. The fry captured in mixed schools were 32 mm mean total length.

Two hundred and eight seine hauls were recorded but satisfactory seining areas in Lac la Ronge are limited by deep water, rocky substrate, and muskeg. Older age group lake chubs were not captured on the sand beaches or around the creek mouths where footing was solid and seining was convenient. They were successfully seined only from the rocky bottoms in front of the laboratory and beside the DNR campgrounds. In these areas the seine could be set out over the rocks in 4 to 6 feet of water and pulled onto a cleared beach area where it could be dragged up without snagging. Thus study of the habitat of larger lake chubs was not as convenient as that for the fry and younger age groups. Due to the large size of Lac la Ronge, much of the 1966 field work was directed towards finding locations where samples of adult lake chub could successfully be obtained independent of the type of gear.

Lake chub age groups II, III and IV were found at various times in most of the habitats throughout the lake. During July and August large schools of small fish were attracted to exposed rocky shoal areas with moderate vegetation consisting of Scirpus, Carex and Phragmites. Adjoining flooded shallows contained mostly Sium, Potamageton, Ceratophyllum, Polygonum, Juncus and Ranunculus. Associated with the lake chubs were perch, spottail shiners, both longnose and white sucker fry and, on occasion, longnose dace. Lake chubs were observed congregated in rocky bays and inlets that contained little vegetation. Large schools of small fish were observed milling about sluggishly in 4 C water at the sand beach of Waden Bay before freeze-up. Ninespine sticklebacks (*Pungitius pungitius*) and fathead minnows (*Pimephales promelas*) were also associated with the lake chubs at this time.

Seine hauls at muskeg creek mouths with a great deal of emergent vegetation yielded Iowa darters (*Etheostoma exile*), pike and various fry, but not lake chubs. Lake chubs also were often not found among the islands in sheltered bays. On numerous occasions small fish with dark lateral stripes were observed but they proved to be fathead minnows or black-nosed shiners (*Notropis heterolepis*) rather than lake chubs. In each case the water was very clear and a moderate amount of aquatic vegetation grew from a firm clay bottom.

Gill net effort, broadly categorized according to habitat, is summarized in Table 13. The most successful catches were made with the 3/4 inch monofilament mesh net along rocky shoreline and offshore over rock bottom. This net selectively captured only large lake chubs. Smaller chubs were captured most successfully with the 5/8 inch monofilament mesh net when it was set along the shore. Both nets caught lake chubs poorly in weedy environments.

Lake chub preference for a rocky bottom was demonstrated in Kinesao Creek 21 July 1967. The creek consists of rocky rapids and meanders through a muskeg flat before opening into Lac la Ronge. A seine was set across the creek at the foot of the last rocky rapids and another was set across the creek

Table 13. Summary of gill net fishing effort for lake chub in Lac la Ronge, 1966 and 1967.

Type of Habitat	3/4 inch mesh			5/8 inch mesh		
	Total Hours Set	Chubs Captured	Fish Per Net Hour	Total Hours Set	Chubs Captured	Fish Per Net Hour
Rocky Shore, Rock Bottom	639.5	182	0.285	449.5	28	0.062
Rocky Shore, Ooze Bottom	521.0	43	0.083	476.0	69	0.145
Weedy Shore, Ooze Bottom	41.0	1	0.021	36.0	0	0.000
Offshore, Rock Bottom	35.5	37	1.042	35.5	1	0.028
Offshore, Ooze Bottom	314.0	11	0.035	308.0	1	0.003
Surface Set	128.0	1	0.008	105.0	1	0.009
Total	1679.0	275	0.164	1410.0	100	0.071

in the muskeg area 30 yards below the first. Upstream application of rotenone resulted in the capture of lake chubs, longnose dace, and white suckers in the first seine, and white suckers, pike, spottail shiners, and Iowa darters in the second seine.

At MacKay Lake (29 July 1967), elusiveness of the lake chub in a boulder environment was observed. A group of lake chubs were milling about a creek mouth when a pike suddenly dashed towards them. The lake chubs immediately disappeared among the boulders and the larger pike was unable to pursue them. For a few minutes the pike remained with his head between two boulders. It then moved back approximately 6 feet and remained quietly in a position facing the boulders and about a foot off the bottom. After approximately 5 minutes a lake chub moved out of the rocks and the pike again unsuccessfully tried to follow the chub in among the rocks. The pike then patrolled the area for a number of minutes and slowly moved away. The chubs then commenced to move about as they did before the interruption.

Sampling at Thomson Lake demonstrates that the lake chub is capable of utilizing a variety of habitats. Thomson Lake, located on the southern plains area of Saskatchewan, has a typically ooze bottom, was turbid and the shoreline was weedy creating a situation in which one would not expect to find lake chubs. Contrarily, they were present in large numbers and after 5 hours, six standard minnow traps set in the weeds along the shore captured 54 lake chubs, 721 fathead minnows and 10 five-spine sticklebacks (*Culaea inconstans*). The success of the standard minnow traps in capturing lake chubs was also in direct contrast to the completely unsuccessful attempts to use them in Lac la Ronge. Factors such as clarity of the water and population numbers may have been responsible.

5.5 Movement

5.5.1. Seasonal

Small fish were not observed in the shallows in early June and seining was unsuccessful at that time. The lake chubs came into shallower water in July, August, and early September and they were relatively easy to sample. In the later part of September they again moved offshore and seining became futile. Even gill net success was poor during this period, suggesting that the fish dispersed throughout the lake or became inactive.

Percentage recaptures of fin-clipped fish (Table 14) seems high considering the large size of Lac la Ronge. A high incidence of recapture in the first week following release of fin-clipped fish indicates that daily movement is not extensive.

Conversely, indications from fin-clip returns throughout the year, are that the adult lake chubs moved about freely in the 2 mile area of the lake where fin clipping was done (Table 6). The spawning migration also revealed movement of at least 2 miles. One male marked at the laboratory beach in 1966, was recaptured on the Montreal River spawning grounds in May 1967 and was recaptured again at the laboratory beach 28 July 1967. Lake chub movement within a month included distances of a mile along the shoreline, and one recapture had moved across the bay to the islands in 20 days. Marked lake chubs were never captured in other areas of the lake including those adjacent to the

Table 14. Recaptures of fin-clipped <u>C. plumbeus</u> in Lac la Ronge, 1966, 1967 and 1968.

Release Site	Number Clipped	Percent Recaptured 1966	1967	1968	Total
Montreal River 1966	539	6.9	2.0	0.4	9.3
D.N.R. Campground 1966	189	11.1	1.6	0.0	12.7
Laboratory 1966	1727	8.8	1.3	0.1	10.2
Dog Island 1966	657	0.8	0.0	0.0	0.8
Dominion Point 1966	71	0.0	0.0	0.0	0.0
Montreal River 1967	489		7.6	1.2	8.8
Laboratory 1967	354		12.2	0.3	12.4

marking area at the mouth of the Montreal River. It is not known whether populations can also be associated with spawning areas in the lake proper.

5.5.2. Diurnal Activity

At Lac la Ronge during 1966 and 1967, sunrise and sunset times each changed by 2 hours during the summer and from 10 May until 3 August, astronomical twilight existed all night. For this reason running nets on a rigid schedule every 2 or 3 hours for certain periods each month was not practical. Nets were run according to the light conditions. A summary of netting results for 22 netting days in which gill nets were cleaned continuously every 2 or 3 hours throughout each set period is given in Table 15. The period of greatest catch was after sunset and before sunrise throughout the study months of June, July, August, and September. In June and July when astronomical twilight was not followed by darkness, lake chubs were caught throughout the night. In August and September astronomical twilight is followed by a period of darkness. During these months some chubs were captured in daylight and darkness but by far the greatest catch success occurred between sunset and dark.

Diurnal movement of a number of other species captured in the lake chub nets is shown in Table 16. The spottail shiner and the trout perch (Percopsis omiscomaycus) were the only small fish captured in large numbers. Like the lake chub, they were also captured poorly in daylight. Indications

Table 15. Diurnal movement of C. plumbeus indicated by gill net success at depths up to 2.5 m in Lac la Ronge, 1966 and 1967.

Date	Number of 24 Hour Sets*	Number Captured During Light Period	Number Captured During Dark Period**
June 1966	3	2	28
Aug. 1966	5	6	66
Sept. 1966	5	8	42
June 1967	2	2	9
July 1967	4	0	44
Aug. 1967	3	0	6
Totals	22	18	195

* Nets were run every 2 or 3 hours for each of the 22 sample days.

** Includes sunset and sunrise.

are that of the larger fish, the walleye is active at night and the white sucker, perch and pike are active throughout the day. Walleye and white sucker captures agree with activities reported by Carlander (1953). Carlander (1953) found that pike and perch were only relatively inactive for a few hours at night. His activity periods for these two species overlaps the time division used in Table 16 so the results are not contradictory.

Observations of small fish rising to the surface were usually made in the evening. The slight surface disturbances were hard to detect. They were similar to disturbances created by lake chubs feeding in aquaria, as they most often barely broke the surface when seizing insects floating on the water. Also noted in the aquarium was the restless swimming that began in the late afternoon and continued throughout the evening. Both of these observations support the period of lake chub activity determined by gill net catches.

Seine hauls taken at various times of the day and night varied considerably in catch numbers of all fish species. Wind, sunlight, temperature, and turbidity all appeared to be involved in seine haul success and contributed to inconclusive results. Peterson (1958) found wave action was one of the factors which affected the diurnal movement of minnows.

Table 16. Fish species captured in gill nets set for *C. plumbeus* at Lac la Ronge, 1966 and 1967.*

Fish Species	Number of Fish Captured	
	Light Period	Dark Period**
Perca flavescens	180	192
Catastomus commersoni	31	39
Stizostedion vitreum	1	19
Esox lucius	18	19
Notropis hudsonius	12	145
Percopsis omiscomaycus	3	302
Coregonus artedii	12	34
Coregonus clupeaformis	21	40
Lota lota	0	4

* Netting period is the 22 day period in Table 15.
** Includes sunset and sunrise.

5.6 Food

5.6.1. Fry

The fry began eating plankton within a week of hatching and were rarely found with empty stomachs. Identification of stomach contents from fry of 11 mm total length showed food consisted mostly of phytoplankton. Recognized in the stomach samples were *Scenedesmus*, *Navicula*, *Dinobryon*, and *Tabellaria*. A copepod was identified in one individual.

By the time the fry had reached 18 mm total length, the stomachs contained mainly zooplankton. The stomach contents were not macerated and *Diaptomus*, *Daphnia*, *Bosmina*, *Cyclops* and nauplii were easily identified. Phytoplankton present may have originated from the digestive tracts of the zooplankton. One fry contained what appeared to be the remains of a small aquatic insect.

At 26 mm total length the stomach contents of the fry were unidentifiable masses of minute insect parts. Fry of this size and upwards appear to prey upon the smaller insects and the early instars of the same organisms that adult lake chub utilize for food.

5.6.2. Adult

Working with stomach samples of the adult lake chub proved most discouraging. Stomach contents were always so macerated that identification of food items in Table 17 had to be done by undigested chitinous parts such as tarsal

Table 17. Food items identified from adult *C. plumbeus* stomachs, Lac la Ronge, 1966 and 1967.

Food Organism	Month of Capture: May	June	July	Aug.	Sept.	Oct.
Annelida						
Hirudinea		+				
Insecta	+	+	+	+	+	+
Plecoptera	+					
Ephemeroptera	+	+		+		
Hemiptera						
Corixidae		+			+	+
Trichoptera		+				
Coleoptera			+			
Diptera	+	+	+	+	+	
Culicidae				+	+	
Tendipedidae		+		+	+	
Simuliidae	+					
Crustacea						
Amphipoda		+				
Decapoda		+				
Arachnida						
Acarina		+			+	
Araneida				+		
Vertebrata						
Pisces			+		+	
Eggs (Pisces)	+	+				
Scales (Pisces)		+				
Plant Material	+	+		+		

claws, wings, and mouth parts. Corixids, for example, were macerated after ingestion but the wavy lines on hemelytra sections and the double tarsus and spatulated front legs rendered them identifiable. A collection was made of the food organisms present so that the parts found in the stomach samples could be identified by comparison. This was particularly useful in the Montreal River for the month of May. Probably because of their size, amphipods were one of the few organisms that were not completely destroyed during ingestion.

Throughout the summer the percentage of empty stomachs increased steadily from 18% in June to 92% in September. This compounded the problem of food analysis. When the first portion of the digestive tract was empty, undigested remains from beyond the first and second loops were used for identification.

Much of the insect fauna in the food samples was adult forms of aquatic insects or terrestrial insects that had apparently fallen onto the water. Other insects commonly eaten by lake chubs in the aquaria but not identified from stomach analysis included Gerridae, Notonectidae, Neuroptera, Lepidoptera, Tipulidae, and a variety of dipterans. By placing a light over an aquarium to attract insects it was convenient to watch the lake chubs surface feed on insects that fell from the light onto the water's surface. It appears that the lake chubs can utilize whatever type of food is available. During the spawning season, the lake chubs that migrated into the Montreal River fed on the abundant Simuliidae and Plecoptera.

It should be noted that during May and June fish eggs were common in stomach samples. In June ripe trout perch and longnose dace were found and their egg sizes corresponded to the eggs found in the lake chub stomach samples. Various fish fry were also identified food items and aquarium-held chubs were fed on fry all summer.

5.6.3. Feeding Experiments

Movement of potential food organisms plays an important part in food selection by lake chubs. The organisms swimming around in an aquarium were the first to be eaten. Swimming mayfly nymphs were quickly devoured in preference to other food organisms while those that remained quietly on the bottom or on rocks were ignored. It seemed that the lake chubs preferred to surface feed. They would ignore corixids swimming near the surface and jump out of the water trying to capture corixids that had crawled onto the side of the aquarium and were an inch above the water's surface.

Digestion rate was found to be faster at higher temperatures than at lower ones and it did not vary with the type of food consumed. Digestion rates in Table 18 indicate that during the summer when lake temperatures reach 17 C, it may take less than 15 hours for food to pass completely through an adult lake chub. Having fed in the evening, chubs

Table 18. Temperature effect on the rate of movement of various food organisms through the digestive tract of C. plumbeus. Presence of food material marked by +.

Temp. °C	Food Organism	Hours After Ingestion	Digestive Tract Divided by Loops: 1st Portion	2nd Portion	3rd Portion	Fecal Matter
16		3	+	+		
	Corixids	6	+	+	+	
	Mayflies	9		+	+	+
	Chironomids	12			+	+
		15				+
17	Corixids	5	+	+		
22		3	+	+		
	Corixids	6		+	+	
		9			+	+
		12				+
22	Chironomids	7		+	+	
	Mayflies					
	Caddis flies					
23	Water striders	3	+	+	+	
		6		+	+	

captured and analyzed the next afternoon would be recorded as empty.

5.7 Parasites, Abnormalities and Disease

During spawning in the Montreal River the lake chubs were found to have more parasites than during any other time of the year. Large leeches resembling Piscicola sp., myxosporidia and copepods of Ergasilus sp. were commonly found.

The Ergasilus sp. was found on 57% of 185 lake chubs examined. The copepods were common on the gills and often attached at the base of the pectoral fins. Dogiel, Petrushevski and Polyanski (1961) report that cyprinid infestation by this parasite is generally comparatively light and that pike is one of the main hosts.

The myxosporidia were common on slimy sculpins in Lac la Ronge (Van Vliet, 1964). According to Dogiel, Petrushevski and Polyanski (1958) these infect all organs of the fish with the exception of the lumen of the alimentary canal. They were most noticeable as white spots on the scales or under the skin along the backs of the Lac la Ronge lake chubs. They were probably Myxobolus sp. (Dr. J.R. Allen, Veterinary Medicine, University of Saskatchewan; personal communication).

Metacercariae were also identified on the air bladder of many of the lake chubs. The host cycle includes gastropods and molluscs, cyprinids and the final hosts are mammals, including man, or piscivorous birds.

Diseases were rarely encountered and the multitude of other available parasites were seldom found. Ligula sp., was found commonly in the spottail shiner at Lac la Ronge, but was found in only two lake chub specimens. Some livers contained yellow cysts and these may possibly have been *Triaenophorus* sp. Unfortunately they were not identified. Black spot was noticed on a few fish. Nematodes were found in some digestive tracts, and popeye, usually caused by a parasite, was observed periodically. Although two lake chubs were captured with badly rotted caudal peduncles and fins, only once was an aquarium population infected by a fin rot. *Saprolegnia* sp. was not a problem and was never observed.

Infrequently encountered abnormalities which are common to the fish species of Lac la Ronge were also rarely found in the lake chub populations. What appeared to be congenital fin deformity was observed on only one lake chub. A number of specimens were captured with deformed caudal vertebrae so that the caudal peduncle region had a wavy form as is common with many hatchery-raised fish. A pugnose condition was observed twice and deformity of the lower jaw once. Large swellings relative to the body size were also observed on a small number of lake chubs.

6. DISCUSSION

6.1 Habitat

Early references indicated that the lake chub was restricted to clear, cold, natural trout waters and to preferred bottoms of sand, gravel, rubble, and boulders in exposed situations rather than protected bays supporting vegetation (Dymond and Hart, 1927; Bailey, 1938). The habitat preference as indicated by capture success in Lac la Ronge and MacKay Lake essentially agreed with this. However the bottom substrate and vegetation appeared less critical than the amount of exposure. Large numbers of lake chubs were captured over ooze bottoms where only the shoreline was rocky and young fish were found in exposed weedy environments but not in protected ones. Conversely, lake chubs were abundant throughout the weedy, ooze bottom areas of Thomson Lake. Other examples of the variety of environments in which lake chubs are established are irrigation canals (Simon, 1946) and outlets of hot springs (Carl, Clemens and Lindsey, 1956). This ability to utilize a wide variety of habitats is probably one of the contributing factors to the extensive North American distribution.

The two most successful gill net sets were made on rocky bottoms at depths of 12 and 16 feet. Capture of larger lake chubs proved nearly futile with standard seining procedures and this is understandable since gill nets were consistently successful at depths between 6 and 17 feet. Surface sets were unsuccessful and it appears that the lake chub in Lac la Ronge remain near the bottom. This is similar to the results of Geen's (1955) study of lake chubs in some British Columbia lakes. Hubbs and Lagler (1949) reported adult chubs taken by gill net in 20 to 30 feet of water, and Dymond, Hart and Pritchard (1929) reported that they captured chubs from the surface to 36 feet and that two specimens were taken at 100 feet.

6.2 Food Relationships

The lake chub is often referred to as a forage fish and, according to Scott (1954), is sold by bait dealers for lake trout and walleye fishing. There was no evidence of the lake chub being utilized as a forage fish during the study period at Lac la Ronge. The tourist fishing camps were visited periodically throughout June, July and August and stomach contents of game fish were analyzed. No lake chubs were found in the 89 lake trout, 59 walleye, and 463 pike examined. Twelve hundred and forty pike stomachs were analyzed for the pike project that was running concurrently with the lake chub project and from these stomachs only two lake chubs were identified. Lake chubs entangled in the gill nets attracted predators as did other fishes but none of the 127 pike, 207 walleye, 22 burbot, or several hundred large perch captured in the small mesh nets contained lake chubs. All stomach contents of piscivores captured by seine and poison were also examined and two lake chubs were found in a burbot. Lake chubs are rarely found listed as food items in published piscivore life history studies. It is of particular interest that the lake chub is not mentioned as a food item in the life history studies of the Lac la Ronge walleye (Rawson, 1957) and lake trout (Rawson, 1961).

Fishermen in the Thunder Bay area of Ontario argue that the creek northern chub (C.p. dissimilis) having recently become established in brook trout areas has ruined the fishing (K. Denis, Thunder Bay Field Naturalist's newsletter editor; personal communication). That introduction of the creek chub into a lake can upset balances that previously existed was suggested by Allin (1953) but this statement like that of Denis' is not substantiated with any data. Investigation of this type of interspecific competition would be interesting and valuable. The apparent utilization of whatever food is available along with predation on other fish eggs and fry make the lake chub a strong potential competitor. Contrary to their timid nature in the aquarium, undisturbed lake chubs were aggressive feeders. They competed among themselves for food and were observed taking food from other species of comparable size.

The aquatic insect diet of the lake chub is one aspect of the life history that is commonly referred to. In Lac la Ronge this was found to be the case and it must be emphasized that the food consists of terrestrial forms as well as aquatic nymphs, larvae and adults. The ability to surface feed was well demonstrated and in the evenings observations were made of lake chubs rising for insects that fell onto the water.

In the aquarium lake chubs were observed feeding by sight. This was suggested by Davis (1966) from a study of brain development and sense organs. Sight feeding at Lac la Ronge was indicated by the relationship of lake chub activity and food availability as the seasonal light changed. The peak of lake chub activity implied by gill net catches was after sundown. Mundie (1959) found that in Lac la Ronge, the activity of larger invertebrates also began after sundown and continued for periods varying with the species, some activity periods lasting until sunrise. Lake chub activity coincides with the emergence of chironomids and diurnal migrations of *Mysis relicta* and *Pontoporeia affinis*. In June, astronomical twilight lasts throughout the night. Lake chubs were active throughout the night during June and had a high percentage of full stomachs. In August and September, sunset is followed by a short period of dusk and then darkness. During this time there was a decrease in lake chub activity after dark and a sharp increase in percentage of empty stomachs.

Utilization of insects for food may also explain the more northerly distribution of the lake chub as compared to that of other cyprinids. In this capacity the lake chub is potentially valuable as a forage fish in the northern lakes.

Although predation on the lake chub at Lac la Ronge appears to be very slight, numerous forage species that are probably less elusive than the lake chub are readily available here. It is possible that the lake chub may play an important role as a forage species during a restricted portion of the year or during restricted stages of another species' life cycle. This study covered only the ice-free period and no data were obtained during the winter. Food and stomach content analysis restricted to older individuals would not reveal the complete role played by the forage species.

6.3 Fin Clipping

The results of fin clipping have been most useful in evaluating age and movement. The recapture rate was much greater than was expected in a lake of this size. Unfortunately, by the time the effectiveness of fin clipping was realized, too many fins had been utilized for location marks and a more comprehensive marking code could not be incorporated.

The small size of the lake chub precluded marking by tagging. In the future it is anticipated that small fish will be successfully marked using a vast array of materials such as radioactive isotopes, latex and liquid plastics, metallic compounds, tetracycline antibiotics, dyes, and stains that will be applied by injection, tattooing, daubing or feeding (Arnold, 1966). Assuming that immersion dyeing did not affect behavior, it possibly could have been used successfully on the spawning grounds but the short duration of visibility would limit the value. Fin clipping was chosen for this project as most of these new methods are still being tested and perfected for larger fish. It was also not necessary to rely on inexperienced observers such as fishermen to recognize the fin clips.

There are possible drawbacks to fin clipping and these include missing fins that could have been caused by injury or disease. When the recapture rate is low or only a small portion of the population is marked, fish with missing fins, misinterpreted as fin clips, would cause large errors in conclusions. Congenital fin deformity was noted on only one of the 5065 large chubs handled. This involved the left pectoral fin which was not one of those used as a marking clip.

Contrarily, fin regeneration could play an important role in interpretation as regenerations may be too complete to be identifiable. According to Ricker (1956) regeneration is generally a greater problem for small fish than for large fish, in warm water than in cold water, and for median fins than for paired fins. Regeneration with the lake chubs seemed more dependent on how deep and how well the clip was made. Both median and paired fins showed varying amounts of regeneration. Partial clips made in 1967 were found to be almost completely regrown by the end of the summer and recognizable only by slight ray deformity. Eipper and Forney (1965) claim that all partial clips can be clearly recognized when viewed between two polarizers. The polarizers must be aligned at 90 degrees to each other and have a good light source behind them. The rapid regeneration that occurred in one year indicates that had the study continued for another summer, this technique would have been valuable.

Recaptured fin-clipped lake chubs were not used to estimate the size of the Montreal River spawning population (Krumholtz, 1944; Rounsefell and Everhart, 1953) as the amount of population dispersal and recruitment from the main lake were unknown.

Dispersal and recruitment could have been crudely estimated following a more intensive netting program in the regions connecting the marking area and the main lake, but mortality and other related effects of fin clipping would be more difficult to determine. One or more missing fins may increase vulnerability to predation, create a competition disadvantage with unmarked individuals, alter physiological processes and behavior, and possibly facilitate invasion of pathogens (Coble, 1967). All of these factors may reduce survival and growth of the marked fish. The loss of fish with fin-clip marks would result in over-estimation of the population size.

Lake chubs retained in hatchery tanks and aquaria showed no adverse effect of fin clipping and this was reported as a consistent observation for other species by

Parker *et al*. (1963). However, a number of studies have shown increased mortality after release of marked salmon (Cope and Slater, 1957; Fry, 1961) and lake trout (Ricker, 1949; Shetter, 1951).

Even with limited recapture of a marked minnow species in a lake the size of Lac la Ronge, the marking program must be considered successful. The results were most valuable for illuminating matters of growth, movement, and spawning. Studying aspects of adult ecology and life history with a well planned marking program would be more convenient and comprehensive in a small lake. It was relatively easier to obtain lake chub samples in Thomson and MacKay Lakes than it was in Lac la Ronge.

6.4 Reproduction

Early literature records of lake chub spawning activities indicate knowledge of the lake chub entering creeks to spawn (Hubbs and Brown, 1929; Dymond, 1947) and that the males developed orange breeding marks (Greeley, 1931). Spawning dates in June and July for the Lake Ontario region (Dymond, Hart and Pritchard, 1929) and throughout the summer in Montana (Schultz, 1941) were also known and yet nothing has been written concerning the breeding habits of *Couesius plumbeus*. The shy nature of the lake chub and the cryptic spawning sites make observations very difficult and it is understandable why the spawning activity was not described in the absence of a deliberate attempt to study it. It would be interesting to compare the adaptations in spawning behavior of lake chubs in lakes such as Thomson where no rocky spawning grounds are available.

There is a striking similarity between the pre-spawning activity of the lake chub and the courtship described for *Notropis longirostris* by Hubbs and Walker (1942). The males of both species persistently pursue females and were continuously observed to approach the female from beneath and to nudge the vent region. At times the male lake chubs involved in pursuit gave the impression that the intent was egg-eating rather than courtship. It was demonstrated by Hunter and Hasler (1965) that fish milt and ovarian fluid attract shiners (*Notropis umbratilis*) and stimulate them to spawn. It is possible that aspects of male lake chub spawning behavior are related to attraction by ovarian fluid as spent females did not initiate the male spawning drive to the same extent as ripe females.

The close relationship between temperature and lake chub spawning activity demonstrated at Lac la Ronge was verified experimentally for lake chubs from British Columbia (Ahsan, 1966b). Ahsan showed that the effect of photoperiod on spermatogenetic activity was small and it was temperature which exercised the dominant regulating role. Higher post-spawning temperatures cause a rapid disappearance of spermatids and sperm and induce a rapid post-spawning regression of the testis which is followed by a very slow proliferation of the prespermatocytal stages.

The true sex ratio is probably nearer 1 to 1 than captures of spawning lake chubs indicated. The proportion of females captured on the spawning grounds in 1968 increased greatly over the 1966 and 1967 proportions. The 1968 sample was captured early in the spawning season by poisoning an area that extended into deeper water than that in which the 1966 and 1967 samples were collected. Thus the 1968 sample is a closer representation of the proportion of lake chubs which migrated into the river during spawning season and remained in deeper water until they ripened. The 1966 and 1967 captures represent ripe chubs that went into the shallows to spawn. Spawning lake chubs would have a greater proportion of males as fin-clip recaptures indicate that the females became spent and left the spawning grounds before the males. Supporting evidence comes from work by Ahsan (1966a) who showed that spermiogenesis continues during spawning and repeated sperm discharges are possible.

6.5 Taxonomy

The inclusion of Couesius along with other genera under the nominal genus Hybopsis by Bailey (1951) has resulted in a reappraisal of relationships by a number of taxonomists. The controversy involves the fact that although certain characteristics are shared by all members of the proposed Hybopsis expansion, many members also share characters with other genera. Recent proposals are that Couesius plumbeus might be more closely related to Rhinichthys or Semotilus than to Hybopsis

(Dr. D.E. McAllister, National Museum, Ottawa; personal communication). Aspects of the groups placed in Hybopsis are presently being compared by R.E. Jenkins (Biology Department, Roanoke College, Salem, Virginia; personal communication) with a view to determining phyletic lines of the assemblage. Although this project is not complete, Jenkins has firm conclusions, based on morphology and coloration, that Couesius is more closely related to Semotilus, particularly S. margarita, and should be removed from Hybopsis.

According to Dr. C.C. Lindsey (Zoology Department, University of Manitoba, Winnipeg; personal communication), reproductive habits may serve as strong indicators of phyletic relationship. In the literature assembled by Breder and Rosen (1966) on the modes of fish reproduction, Hybopsis males were reported to guard the nests that they built of small stones. Observations of the free broadcast of non-adhesive eggs by the polyandrous lake chub (at Lac la Ronge) is not similar to the Hybopsis breeding activity. Neither does it enhance the relationship of this population to Semotilus or Rhinichthys, however. Published observations (Breder and Rosen, 1966) reveal that spawning behavior of members of these genera also differs from that of the lake chub. Spawning habits of Semotilus species such as S. atromaculatus and S. nachtriebi involve nest building or strong territorial holdings. Some Rhinichthys species such as R. meleagris have well defined territories although others such as R. atratulus do not.

Jenkins (personal communication) refers to unpublished information from Dr. V.C. Applegate in which the latter claims that Couesius builds a pit-like nest. This of course is contrary to the findings of this study. The discrepancy may be due to the fact that Dr. Applegate's study was done in the Lake Huron drainage of lower Michigan. It is in this area that Hubbs and Lagler (1964) suggest that the former C.p. dissimilis may be truly distinct.

Natural hybridization between Couesius plumbeus and Rhinichthys cataractae has been reported by Hubbs and Lagler (1949) and by Nelson (1965). Whereas hybridization between C. plumbeus and Margariscus margarita (now Semotilus margarita) reported by Schultz (1941) was shown to be a case of misinterpretation of sexual dimorphism (Hubbs, 1942), the characteristics of the longnose dace and the lake chub are such that misinterpretation of hybrids is improbable.

In the present study, longnose dace in full nuptial dress and ready to spawn were observed to swarm into the lake chub spawning areas in the Montreal River when the water temperature reached 16 C. Lake chub spawning was essentially finished by that time but the few ripe individuals which remained afforded some opportunity for hybridization to occur. However, none of the specimens captured appeared intermediate between the 5065 adult lake chub and 273 longnose dace examined.

If reproductive habits are indeed strong indicators of phyletic lines, one would conclude from this study that the form of _C. plumbeus_ in Lac la Ronge should be separated from _C. dissimilis_ as proposed by Hubbs and Lagler (1964). This also supports the removal of _Couesius_ from _Hybopsis_ as proposed by Jenkins, but his linking of _Couesius_ to _Semotilus_ certainly needs further appraisal. It appears that Jenkins bases the relationship of _Couesius_ to _Semotilus_ partly on the nest building of _C. dissimilis_ which is not similar to the _C. plumbeus_ reproductive behavior observed at Lac la Ronge. To draw conclusions, it is obvious that geographic variation of spawning activity needs further study. Other considerations are the demonstration of some territoriality in the aquarium, and the observation of one spawning act over gravel, indicating that in different habitat the Saskatchewan form of _C. plumbeus_ may have different spawning behavior.

Nomenclatorial history of the lake chub indicates that subspecies confusion might have been expected as it appears that only two specimens were utilized by Jordan to describe _C. greeni_ (Green, 1893). It is also probable that subspecies appeared in print based on personal conviction (W.B. Scott, personal communication) and without any formal declaration or description. Hubbs (1942) described _C. greeni_ and _C. dissimilis_ as subspecies of _C. plumbeus_ without explanation even though he had previously described all of the forms as distinct species (Hubbs and Lagler, 1939).

An example of flippant shuffling of lake chub taxonomy without justification is the suggestion made by Taylor (1954) pertaining to the re-expansion of the genus Hybopsis (also proposed without sufficient assessment by Bailey in 1951). When the spotted chub, formerly Erimystax dissimilis (Kirtland), and C. dissimilis were concurrently placed in Hybopsis this created the homonym H. dissimilis taking precedence to, and thus making a new species name necessary for, the former C. dissimilis. Taylor (1954) was prepared to solve the nomenclatorial problem by treating C. dissimilis as C. greeni. Lindsey (1956) refuted this using British Columbia specimens while emphasizing the lack of sufficient systematic knowledge with which to deal conclusively with the subspecies problem.

Designation and use of the subspecies appears to have been made under the old assumption that species were composites of uniform subtypes and the subspecies could be defined as those individuals that conformed to the type of subspecies. This led to the subjective approach taken by many authors who tried to force natural populations into a preconceived framework of artificial taxonomic or ecological units. Thus an unsubstantiated attempt to categorically list particular province and state distributions of lake chub species as done by Halkett (1913) and duplicated for subspecies by Slastenenko (1958) serves no real purpose and ignores modern systematics. Subspecies are now defined as aggregates of local populations of a species inhabiting a geographic subdivision of a range of species and differing taxonomically from other populations of the species (Mayr, 1966).

Wilson and Brown (1953) cite four characteristics of geographic variation that contribute to the difficulty of delimiting subspecies. One of these, the arbitrariness of the degree of distinction selected as justifying subspecific separation is well exemplified in the case of the lake chub. The lateral line scale counts of the populations studied overlap all three recognized subspecies. The depressed dorsal fin length is also a very poor characteristic because of sexual dimorphism which is expressed by greater male fin growth, the more forward insertion of the dorsal fin in male cyprinids (Hubbs, 1942), and the larger growth of the females.

Morphological differences of subspecies may be compared by the determination of the Coefficient of Difference (Mayr, Linsley and Usinger, 1953). The Coefficient of Difference is expressed by the equation:

$$\text{Coefficient of Difference} = \frac{\text{Mean}_B - \text{Mean}_A}{\text{Standard Deviation}_A + \text{Standard Deviation}_B}.$$

A Coefficient of Difference of 1.71 indicates that 95% of one population is different from 95% of another population and 1.28 represents 90% non-joint overlap. The choice of a Coefficient of Difference value for indicating that a population is worthy of subspecific recognition must include biological and biogeographical considerations. However, applying the Coefficient of Difference to lateral line scales there was no significant difference between each lake chub population studied. The ratio of the length of the dorsal fin to the distance between the dorsal insertion and the occiput indicates that large older females and smaller males and females captured on the same spawning grounds could be classed as separate subspecies when the Coefficient of Difference is applied. The range of this ratio was also found to overlap the three defined subspecies. Most of the large females had ratios higher than 1.7 and thus fell into the range used by Hubbs and Lagler (1958) to distinguish C.p. dissimilis.

Recent investigations of a number of northwestern lake chub populations indicate that there are at least two allopatric morphological forms most easily identified by mean number of scales around the caudal peduncle and mean number of vertebrae (McPhail, 1963). One form is found on the Barren Grounds, throughout the Yukon River system and most of the MacKenzie River system, and extends into the Great Lakes and the New England States. The other form is found in the Fraser and Columbia river systems and part of the MacKenzie River above the Peace River Canyon (Dr. C.C. Lindsey, personal communication). Lindsey also reports that the males of the two forms differ in the mutually exclusive formation of a rough patch of breeding tubercles in front of the pectoral fin by the western form and development of a distinct orange patch at the base of the pectoral fin by the eastern form.

Implications following these observations are that postglacial dispersion may have come from a Pacific refugium as well as from the Mississippi refugium. The result is a secondary type of integration in which the two forms now connected by steeply sloping character gradients were once separated completely and after evolving differences have again come into contact. This is good evidence to refute Miller's (1958) view that the lake chub crossed the Continental Divide from the east no earlier than the latter part of Pleistocene but it does not explain the restricted distribution of Couesius within the Columbia River system.

Comparing the two recently proposed morphological forms with the Lac la Ronge sample leads one to question the validity of the two forms. As was the case with the lateral line scales and dorsal fin ratio, the Lac la Ronge specimens are variable and overlap the characteristics used to distinguish the two proposed forms. The mean of the number of caudal peduncle scales is at the upper range of the western form and the mean of the number of vertebrae is at the lower range of the eastern form.

Thus the Lac la Ronge material brings up the questions of clinal variation, hybrid belts, and geographical isolates that must be assessed for the two proposed forms before subspecies may be validly designated. More intensified study where both forms are reported to exist in the MacKenzie River drainage will be helpful if investigations can reveal sympatric coexistence. For without interbreeding they would not be subspecies, but good species, and if they are merely arbitrary segregates within a single interbreeding population they would not be true distinct subspecies.

In dealing with the taxonomic aspects of the Lac la Ronge lake chub it must be remembered that the new approach to systematics is based on the population structure of species. Modern application of the polytypic species concept has already resulted in the reorganization of species classification of well-studied organisms such as birds, but has lagged behind in application to the fresh-water fishes. Clarification of the *Couesius* confusion will involve investigation of the degree of difference among neighbouring populations, the presence or absence of discontinuities between populations, and the characteristics of those populations that are intermediate between phenotypically distinct populations. The results of this study represent progress towards this end and should not be used as a proposal of subspecies but rather as an indication that further investigation is necessary.

7. SUMMARY AND CONCLUSIONS

1. Aspects of the ecology and life history of *Couesius plumbeus* were studied at Lac la Ronge, Saskatchewan during 1966, 1967, and 1968.
2. After preservation for one year, fish were found to gain weight and shrink in total length. The correction formula for total length was found to be

   Total length before preservation = Total length after preservation (1.0360)

   and for weight was

   Weight before preservation = Weight after preservation (0.9217).

3. The pharyngeal tooth formula 2,4-4,2 occurred in 71% of the population.
4. The number of lateral line scales, vertebrae and caudal peduncle scales overlap with all proposed morphological variations of *C. plumbeus*.
5. Fin clipping was successfully utilized to mark *C. plumbeus*. This aided interpretation of spawning migration, seasonal movement and growth. Recovery of marked fish varied from nil in the lake to 12% at the Montreal River mouth.
6. Spawning occurred during May in the Montreal River while in Lac la Ronge proper, spawning lasted into July. Spawning activity correlated with temperature in both the river and the lake. In the Montreal River spawning started

at 8 C and was finished when the temperature reached 15 C. In the lake ripe females were only captured where the water was 10 C or higher.

7. C. plumbeus migrated into the Montreal River to spawn from as far as 2 miles out in the lake.
8. In the Montreal River, preferred spawning area was the rocky shallows. Versatility in the use of other habitats for spawning is exhibited in other lakes.
9. On the spawning grounds C. plumbeus most often were concealed beneath the rocks.
10. Males become aggressive during spawning season but territorial acquistion was not observed in the field.
11. Pre spawning behavior included the male nudging his snout against the vent region of the female. This was followed by the male pursuing the female and attempting to spawn.
12. Spawning was polyandrous as a number of males pursued each female coming onto the spawning ground. Males were attracted by spawning activity.
13. Eggs were released when males forced females against or beneath the rocks on the bottom and vibrated alongside them. Only a small portion of a female's total eggs were released during each spawning act and eggs were thus dispersed throughout the spawning grounds.
14. Males remained ripe for a number of days and remained on the spawning grounds longer than females. The sex ratio of C. plumbeus captured on the spawning grounds therefore

indicates a greater percentage of males.

15. The male has a larger pectoral fin than the female so that sexual dimorphism exists throughout the year. The females grow larger and live longer than the males.

16. During the spawning season, sexual dimorphism is emphasized by orange markings and development of tubercles on the male. The female becomes gravid.

17. C. plumbeus spawned for the first time at the age of 2 years and 11 months. Mean total length for this age group III female sample was 95.3 mm in 1967 and 95.1 mm in 1968. The smallest mature female captured on the spawning ground was 81 mm total length and the smallest male was 77 mm total length.

18. The number of eggs carried per female was found to increase with body size increase. The relationship is expressed by the equation

$$\text{Log Number of Eggs} = -3.2426 + 3.0962 \text{ (Log Length)}$$

Age group III females made up 62% of the females captured on the spawning grounds and contributed 53% of potential relative recruitment.

19. Natural incubation period in the Montreal River was 10 days when the temperature fluctuated between 8 and 18 C. Fry were first captured on 6 June 1966 and on 2 June 1967.

20. Fry reached a mean total length of 41 mm by the end of August.

21. Relationships of total length to standard and fork lengths for fish ranging from 60 to 146 mm total length are expressed by the equations:

$$\text{Standard Length (mm)} = -1.6404 \text{ mm} + 0.8171 \text{ (Total Length)}$$

and

$$\text{Fork Length (mm)} = -0.6143 \text{ mm} + 0.9177 \text{ (Total Length)}.$$

22. Length-weight relationship for C. plumbeus captured after the spawning season is represented by the equation:

$$\text{Weight} = 3.0706 \times 10^{-6} (\text{Length}^{3.2008})$$

23. Coefficient of condition (k) was found to be high during spawning season, low in July and to increase to the spawning level through August and September.

24. C. plumbeus fry were not found in mixed schools of spottail shiner, perch and white sucker fry until they attained a mean total length of 32 mm.

25. C. plumbeus were relatively easy to sample in July, August, and the first part of September when they were found close to shore. During the rest of the year they were difficult to capture.

26. Capture of large C. plumbeus with seines and gill nets was most successful over rock bottom while the same gear in weedy environments yielded the least number.

27. Throughout the season, movement was extensive in the

area of fin-clip marking. Daily movement as indicated by recapture of marked fish was found to be limited during July and August.

28. Peak of diurnal activity was during dusk between sunset and darkness.

29. Fry commenced feeding on phytoplankton by the time they were 11 mm total length. At 18 mm total length stomach contents consisted mostly of zooplankton and at 26 mm insects became the predominant food organisms. Adult stomach contents consisted mainly of macerated insect material.

30. In aquaria, adult C. plumbeus preferred feeding on organisms that were active or floating on the surface.

31. Digestion rate increases with temperature. At 17 C food passes through the digestive tract of C. plumbeus in 15 hours.

32. Parasites were most prevalent on the C. plumbeus in the Montreal River during spawning. Most common parasites at this time were leeches, copepods of Ergasilus sp., and myxosporidia.

33. Assuming reproductive habits are valid indicators of phyletic lines it appears that the Lac la Ronge form of C. plumbeus should be removed from Hybopsis and separated from C. dissimilis.

34. The morphological characters of the Saskatchewan form of C. plumbeus overlap all proposed forms indicating that more

investigation of geographical variation is necessary before subspecies are assigned or eliminated.

8. LITERATURE CITED

Ahsan, S.N. 1966a. Cyclical changes in the testicular activity of the lake chub, Couesius plumbeus (Agassiz). Can. J. Zool. 44(2):149-159.

___________ 1966b. Effects of temperature and light on the cyclical changes in the spermatogenetic activity of the lake chub, Couesius plumbeus (Agassiz). Can. J. Zool. 44(2):161-171.

Allin, A.E. 1953. Records of the Northern Creek Chub from Ontario. Can. Field-Naturalist 67(3):128-130.

Arnold, D.E. 1966. Marking fish with dyes and other chemicals. U.S. Dept. of the Interior Fish and Wildlife Service. Technical Paper 10. 44 p.

Atton, F.M. 1955. Thermal studies of Lac la Ronge, 1949-52. M.A. Thesis, Univ. of Sask. 95 p.

Backus, R.H. 1951. New and rare records of fishes from Labrador. Copeia 4:288-294.

Bailey, R.M. 1938. The Fishes of the Merrimack Watershed. New Hampshire Fish and Game Department Survey Report 3:149-185.

___________ 1951. A checklist of the fishes of Iowa, with keys for identification, p. 192. In: J.R. Harlan and E.B. Speaker (ed.), Iowa fish and fishing. State Conservation Commission of Iowa.

___________ 1956. A revised list of the fishes of Iowa, with keys for identification, p. 327-377. In: J.R. Harlan and E.B. Speaker, (ed.), Iowa fish and fishing. State Conservation Commission of Iowa.

___________, E.A. Lachner, C.C. Lindsey, C.R. Robins, P.M. Roedel, W.B. Scott and L.P. Woods. 1960. A list of common and scientific names of fishes from the United States and Canada. Special publication No. 2, Am. Fish. Soc. (2nd ed.). 102 p.

Bajkov, A. 1928. A preliminary report on the fishes of the Hudson Bay Drainage System. The Canadian Field-Naturalist 42(4):96-99.

Belehradek, J. 1930. Temperature coefficients in Biology. Biol. Rev. 5:30-38.

Breder, C.M., Jr. and D.E. Rosen. 1966. Modes of reproduction in fishes. The Natural History Press, Garden City, New York. 941 p.

Carl, G.C., W.A. Clemens and C.C. Lindsey. 1959. The fresh-water fishes of B.C., 3rd ed. B.C. Prov. Museum, Dept. of Ed. 192 p.

Carlander, K.D. 1953. Use of gill nets in studying fish populations, Clear Lake, Iowa. Iowa Academy of Science 60:621-625.

_______________, and L.L. Smith, Jr. 1945. Some factors to consider in the choice between standard, fork or total lengths in fishery investigations. Copeia 1: 7-12.

Coble, D.W. 1967. Effects of fin-clipping on mortality and growth of yellow perch with a review of similar investigations. J. Wildl. Mgmt. 31(1):173-180.

Cope, O.B., and D.W. Slater. 1957. Role of Coleman Hatchery in maintaining a king salmon run. U.S. Fish and Wildl. Serv. Res. Rept. 47. 22 p.

Crossman, E.J. 1962. The grass pickeral (Esox americanus vermiculatus Le Sueur) in Canada. Royal Ont. Museum, Life Sciences Division, Contribution 55. 29 p.

Cushing, C.E. 1961. Ecology of a lake-stream system. Ph.D. Thesis., U. of Sask. 134 p.

Davis, B.J. 1966. Brain patterns in fishes of the genus Hybopsis in relation to feeding habits and habitat. Ph.D. thesis, Oklahoma State University. 109 p.

Dogiel, V.A., G.K. Petrushevski, Yu.I. Polyanski. 1961. Parasitology of Fishes. Oliver and Boyd, Edinburgh and London. 348 p.

Dunbar, M.J., and H.H. Hildebrand. 1952. Contribution to the study of the fishes of Ungava Bay. Jour. Fish. Res. Board Canada 9(2):83-128.

Dymond, J.R. 1926. The fishes of Lake Nipigon. Univ. of Tor. Studies, Biol. Series Publ. Ont. Fish. Res. Lab. 27:1-108.

____________ 1936. Some fresh-water fishes of British Columbia. Contribution of the Royal Ont. Museum of Zoology 9, 13 p.

Dymond, J.R. 1947. A list of the freshwater fishes of Canada east of the Rocky Mountains with keys. Roy. Ont. Mus. Zool., Misc. Publ. 1, 36 p.

__________, and John L. Hart. 1927. The fishes of Lake Abitibi (Ontario) and adjacent waters. Publications of the Ont. Fish. Res. Lab. 28, 19 p.

__________, J.L. Hart and A.L. Pritchard. 1929. The fishes of the Canadian waters of Lake Ontario. Publications of the Ontario Fisheries Research Laboratory 37, 35 p.

Eddy, S. 1957. How to know the freshwater fishes. Wm.C. Brown Co. Dubuque, Iowa. 253 p.

________, and T. Surber. 1943. Northern Fishes. University of Minnesota Press. 252 p.

Eipper, A.W., and J.L. Forney. 1965. Evaluation of partial fin clips for marking large mouth bass, walleyes and rainbow trout. New York Fish and Game Journal 12(2):233-240.

Fry, D.H. 1961. Some problems in the marking of salmonids. Pac. Mar. Fish. Comm., Bull. 5:78-83.

Geen, G.H. 1955. Some features of the life history of the lake chub (Couesius plumbeus greeni Jordan) in British Columbia. B.A. Thesis, Dept. Zoology, Univ. of Br. Columbia. 33 p.

Gerking, S.D. 1945. The distribution of the fishes of Indiana. Investigations of Indiana Lakes and Streams 3(1):1-137. Indiana Dept. of Conservation, Indianapolis.

Greeley, J.R., and C.W. Greene. 1931. Fishes of the area with annotated list, p. 44-94. In: A Biological Survey of the St. Lawrence Watershed (including the Grass, St. Regis, Salmon, Chateaugay Systems and the St. Lawrence between Ogdensburg and the International Boundary). Suppl. 20th Ann. Rept. New York St. Cons. Dept. 1930. 261 p.

Green, A.H. 1893. Notes on occurrence of new and rare fish in British Columbia. Bull. Nat. Hist. Soc. B.C.1893:9-10.

Halkett, A. 1913. Checklist of the fishes of the Dominion of Canada and Newfoundland. Ottawa, C.H. Parmelee, Printer. 138 p.

Hubbs, C.L. 1926. A checklist of the fishes of the Great Lakes and tributary waters, with nomenclatorial notes and analytical keys. University of Michigan Museum of Zoology, Misc. Pub. 15, 85 p.

Hubbs, C.L. 1942. Sexual dimorphism in the cyprinid fishes, Margariscus and Couesius, and alleged hybridization between these genera. Occ. papers of the Museum of Zoology, Univ. of Michigan 468, 6 p.

__________, and D.E.S. Brown. 1929. Materials for the distribution study of Ontario fish. Trans. Roy. Can. Inst. 17(1):1-56.

__________, and W.R. Crowe. 1956. Preliminary analysis of the American cyprinid fishes, Seven New, Referred to the genus Hybopsis, Subgenus Erimystax. Occasional papers of the Museum of Zoology, University of Michigan 578, 8 p.

__________, and K.F. Lagler. 1939. Fishes of the Great Lakes region. Cranbrook Inst. Sci.

__________, and __________. 1947. Fishes of the Great Lakes region. Cranbrook Inst. Sci., Bull. 26, 186 p.

__________, and __________. 1949. Fishes of Isle Royale, Lake Superior, Michigan. Reprint from papers of the Michigan Academy of Science, Arts, and Letters 33, 1947:73-133.

__________, and __________. 1958. Fishes of the Great Lakes region. Cranbrook Inst. Sci., Bull. 26.

__________, and __________. 1964. Fishes of the Great Lakes region. Cranbrook Inst. Sci., Bull. 26.

__________, and B.W. Walker. 1942. Habitat and breeding behavior of the American cyprinid fish Notropis longirostris. Copeia 2:101-104.

Hunter, J.R., and A.D. Hasler. 1965. Spawning association of the red-fin shiner and the green sunfish. Copeia 3:265-281.

Jordan, D.S. 1924. Concerning the Genus Hybopsis of Agassiz. Copeia 130:51-52.

__________, and B.W. Everman. 1896. The fishes of North and Middle America, Vol. 1, Washington Gov't printing office. 954 p.

Keleher, J.J., and B. Kooyman. 1957. Supplement of Hink's "The Fishes of Manitoba". Dept. of Mines and Natural Resources, Province of Manitoba. 12 p.

Koshinsky, G.D. 1965. Limnology and fisheries of five Precambrian headwater lakes near Lac la Ronge, Sask. Fisheries Rept. 7, Sask. Dept. of Nat. Res. 52 p.

Krumholtz, L.A. 1944. A check on the fin-clipping method for estimating fish populations. Papers of the Michigan Academy of Science, Arts, and Letters 29:281-291.

Lagler, K.F. 1950. Studies in fresh-water fishery biology, 3rd ed. rev. J.W. Edwards - Ann Arbor, Michigan. 231 p.

Legendre, V., and J.J. Rousseau. 1949. La distribution de quelques-uns de nos poissons dans le Quebec Arctique. Annales de l'Ass. Can. Franc. pour l'Advancement des Sciences 15:133-135.

Lindsey, C.C. 1956. Distribution and taxonomy of fishes in the MacKenzie Drainage of British Columbia. J. Fish. Res. Bd. Canada 13(6):759-789.

McPhail, J.D. 1963. The postglacial dispersal of freshwater fishes in northern North America. Ph.D. thesis, Department of Zoology, McGill University, Montreal. 167 p. and Appendices I, II and III, 64 fig.

Mayr, E. 1966. Animal species and evolution. The Belknap Press of Harvard University Press. Cambridge, Mass. 797 p.

_______, E.G. Linsley and R.L. Usinger. 1953. Methods and principles of Systematic Zoology. McGraw-Hill Book Co., Inc. New York, Toronto, London. 328 p.

Miller, R.R. 1958. Origin and affinities of the freshwater fish fauna of Western North America. Zoogeography, American Association for the Advancement of Science 51:187-222.

Moore, G.A. 1957. Fishes, p. 33-210. In: Vertebrates of the United States by W.F. Blair, A.P. Blair, P. Brodkorb, F.R. Cagle and G.A. Moore. McGraw-Hill Book Co., Inc., New York. 819 p.

Mundie, J.H. 1959. The diurnal activity of the larger invertebrates at the surface of Lac la Ronge, Saskatchewan. Can. J. Zool. 37:945-956.

Nelson, J.S. 1965. Effects of fish introductions and hydro-electric development on fishes in the Kananaskis River System, Alberta. J. Fish. Res. Bd. Can. 22(3):721-753.

O'Donnell, D.J. 1935. Annotated list of the fishes of Illinois. Bull. Natural History Survey 20(5):473-500.

Oliver, D.R. 1954. An ecological study of the macroscopic bottom fauna of Lac la Ronge (with special reference to the Tendipedidae). M.A. Thesis. Univ. of Sask. 100 p.

Parker, R.R., E.C. Black, and P.A. Larkin. 1963. Some aspects of fish-marking mortality. p. 117-122. In: Internatl. Comm. N.W. Atlantic Fish. Spec. Pub. 4. N. Atlantic Fish-Marking Symp., May, 1961.

Peterson, A.R. 1958. Notes on diurnal movement of minnows in shallow waters of a bog lake in north central Minnesota. Proceedings of the Minn. Academy of Science 26:215-221.

Qadri, S.U. 1961. Food and distribution of lake whitefish in Lac la Ronge, Saskatchewan. Trans. Am. Fish. Soc. 90(3):303-307.

__________ 1968. Growth and reproduction of the lake whitefish, Coregonus clupeaformis, in Lac la Ronge, Saskatchewan. Jour. Fish. Res. Bd. Canada 25(10):2091-2100.

Radforth, Isobel. 1944. Some considerations on the distribution of fishes in Ontario. Cont. Roy. Ont. Mus. Zool. 25:1-116.

Rawson, D.S. 1957. The life history and ecology of the yellow walleye, Stizostedion vitreum, in Lac la Ronge, Saskatchewan. Transactions of the Am. Fish. Soc. 86:15-37.

__________ 1961. The lake trout of Lac la Ronge, Saskatchewan. J. Fish. Res. Bd. Canada 18(3):423-462.

__________, and F.M. Atton. 1953. Biological investigation and fisheries management at Lac la Ronge, Saskatchewan. Fisheries Rept. 1, Saskatchewan Dept. Nat. Res., 39 p.

Ricker, W.E. 1949. Effects of removal of fins upon the growth and survival of spiny rayed fishes. Jour. Wildl. Mgmt. 13(1):29-40.

__________ 1956. Uses of marking animals in ecological studies: The marking of fish. Ecology 37(4):665-670.

Ricker, W.E. 1958. Handbook of Computations for Biological statistics of fish populations. Bull. Fish. Res. Bd. Canada 19, 300 p.

Rounsefell, G.A., and W.H. Everhart. 1953. Fishery Science: Its methods and applications. John Wiley and Sons, Inc., New York. Chapman and Hill, Limited, London. 444 p.

Royer, L.M. 1960. Biological survey of Thomson Lake. Manuscript Rept., Fisheries Laboratory, Sask. Dept. Nat. Res. 43 p.

Schultz, L.P. 1941. Fishes of Glacier National Park, Montana. U.S. Dept. Int., Nat. Park Ser., Cons. Bull. 22, 42 p.

Scott, W.B. 1954. Freshwater fishes of eastern Canada. Royal Ont. Museum of Zoology and Paleontology. U. of Toronto Press. 128 p.

__________, and E.J. Crossman. 1959. The freshwater fishes of New Brunswick: A checklist with distributional notes. Contr. of the Royal Ont. Mus. Division of Zoology and Paleontology 51, 45 p.

Shapiro, J. 1952. The plankton of Lac la Ronge, Saskatchewan. M.A. Thesis. Univ. of Sask. 106 p.

Shetter, D.S. 1951. The effect of fin removal on Fingerling Lake trout. Transactions of the American Fisheries Society 80:260-277.

Simon, J.R. 1946. Wyoming fishes. Wyoming Fish and Game Dept., Cheyenne. 129 p.

Slastenenko, E.P. 1958. The distribution of freshwater fishes in the provinces and main water basins of Canada. Bulletin of the Sheuchenko Scientific Society 1(6):1-11.

Taylor, W.R. 1954. Records of fishes in the John N. Lowe Collection from the Upper Peninsula of Michigan. Misc. Publications Museum of Zoology, Univ. of Michigan 87, 50 p.

Van Vliet, W.H. 1964. An ecological study of Cottus cognatus Richardson in northern Saskatchewan. M.A. Thesis, Univ. of Sask. 155 p.

Walford, L.A. 1946. A new graphic method of describing the growth of animals. Biol. Bull. 90:141-147.

Walters, V. 1955. Fishes of Western Arctic America and Eastern Arctic Siberia. Bull. of the American Museum of Natural History 106(5):259-368.

Wilson, E.O., and W.L. Brown. 1953. The subspecies concept and its taxonomic application. Systematic Zool. 2:97-111.

Wynne-Edwards, V.C. 1952. Freshwater vertebrates of the arctic and subarctic. Bull. Fish. Res. Board Canada 94, 28 p.

APPENDIX A.

Fish Fauna

Table 1. The fish fauna of Lac la Ronge and the Montreal River.

Common whitefish	*Coregonus clupeaformis* (Mitchill)
Lake trout	*Salvelinus namaycush* (Walbaum)
Cisco	*Coregonus artedii* (Le Sueur)
Longnose sucker	*Catostomus catostomus* (Forster)
White sucker	*Catostomus commersoni* (Lacépède)
Walleye	*Stizostedion vitreum vitreum* (Mitchill)
Northern pike	*Esox lucius* (Linnaeus)
Burbot	*Lota lota* (Linnaeus)
Yellow perch	*Perca flavescens* (Mitchill)
Trout perch	*Percopsis omiscomaycus* (Walbaum)
Ninespine stickleback	*Pungitius pungitius* (Linnaeus)
Fivespine stickleback	*Culaea inconstans* (Kirtland)
Spottail shiner	*Notropis hudsonius* (Clinton)
Blacknose shiner	*Notropis heterolepis* (Eigenmann and Eigenmann)
Fathead minnow	*Pimephales promelas* (Rafinesque)
Iowa darter	*Etheostoma exile* (Girard)
Lake chub	*Couesius plumbeus* (Agassiz)
Longnose dace	*Rhinichthys cataractae* (Valenciennes)
Slimy sculpin	*Cottus cognatus* (Richardson)
Deepwater sculpin	*Myoxocephalus thompsonii* (Girard)

APPENDIX B. - Summary of gill net catches in Lac la Ronge, 1966 and 1967.

Table 2. Summary of 3/4 inch stretch mesh monofilament gill net catches in Lac la Ronge, 1966.

Habitat: R = rock
O = ooze
V = vegetation

Fish: T = lake trout
B = burbot
S = deep water sculpin

Date	Location	Habitat	Depth (m)	Hours Set	Number of Times Run	lake chub	perch	spottail	percopsis	pike	walleye	white sucker	cisco	whitefish	longnose sucker	miscellaneous
June 9	Potato Point	R	1.5	5	1		12		8	1						
June 10	Professor Bay	R	9.0	2	1		26				1					
June 10	Freeman Isle	R	3.0	3	1		16		1							T-1
June 13	Freeman Isle	R	2.0	12	1	1	8			3						
June 17	R.C.M.P.	R,O	2.5	12	1	2	51		5		1	2	1	1		
June 25	Dog Isle	R	2.5	99	24	49	103		178	4	1	8	3	4	1	B-1
July 13	Laboratory	R,O	3.0	44	3	11	73		5	7	17	3	2	2		
July 22	Laboratory	O	4.0	12	1	1	118			1	3	1	2		2	
July 25	Mitchel Bay	O,V	2.0	12	1		35			1						
July 26	Mitchel Bay	R	4.0	24	1	2	54		1	5				1		
July 29	Stonehocker	R	2.0	12	1	4	33			5		1				
Aug. 8	Dog Isle	R	2.5	60	11	25*	47			3	5	11	2	3	3	
Aug. 10	Temp. Station	R	14.0	12	1	19	21		1							

Table 2. continued.

Date	Location	Habitat	Depth (m)	Hours Set	Number of Times Run	lake chub	perch	spottail	percopsis	pike	walleye	white sucker	cisco	whitefish	longnose sucker	miscellaneous
Aug. 15	Stonehocker Bay	R,O	2.0	60	4	4	61			1	3	10	14			
Aug. 16	Murphy Isle	O	11.0	24	1				1				4			B-1
Aug. 18	Dog Isle	R	2.5	34	2	1	3				3	2	5			
Aug. 19	Four Portages	O	18.0	12	1								27			
Aug. 20	Robertson Creek	R	8.0	19	2		12					2			1	
Aug. 21	Freeman Isle	O	18.0	19	1								7		2	
Aug. 22	Downton Lake	R,O	3.0	32	3	3	51	3		6	11	2	1	6		
Aug. 24	Bear Isle	R	9.0	18	2		15				3					
Aug. 25	Pipestone Bay	O	24.0	24	1								2	6		
Aug. 25	Warne Isle	R	5.0	4	1	7	2								2	
Aug. 26	Downton Lake	R,O	3.0	22	2	5	6			1		1				
Aug. 27	Murphy Isle	R	3.0	26	3	31	16			4	2	1		1	6	
Sept. 5	Laboratory Isle	R,O	2.5	14	1	1	9					3		1		
Sept. 9	Hatchery	R,O	2.5	82	10	4	36			8		17	6	24		
Sept. 9	Temp. Station	O	13.0	9	1		1					1				
Sept. 12	Hatchery	R,O	3.0	70	14	10	38			10	1	3	10	4		B-1
Sept. 16	Laboratory	O	4.5	22	4	7	44		1	2	3	8	9	6		
Oct. 13	Hatchery	R,O	3.0	14	1	1	2			1				3		
Oct. 14	Laboratory	O	4.5	24	3	1	9	1					6	4		B-8
Nov. 5	Laboratory	O	4.5	23	2	1	4		1	1		1	6			
Nov. 5	Dog Isle	O	11.0	6	1		4						1			S-2
Nov. 6**	Laboratory	O	3.0	16	1								1			

* 1 recapture
** Lake froze over

Table 3. Summary of 5/8 inch stretch mesh monofilament gill net catches in Lac la Ronge, 1967.

Habitat: R = rock, O = ooze

Date	Location	Habitat	Depth (m)	Hours Set	Number of Times Run	lake chub	perch	spottail	percopsis	pike	walleye	cisco
Aug. 10	Freeman Isle	O	37.0	12	1							
Aug. 15	Stonehocker Bay	R,O	2.0	60	3	1	2	45				
Aug. 16	Murphy Isle	O	11.0	24								
Aug. 18	Dog Isle	R	2.5	34	2	13	1	26				
Aug. 19	Four Portages	O	18.0	12	1							
Aug. 20	Robertson Creek	R	8.0	19	2			1				
Aug. 21	Freeman Isle	O	18.0	19	1							
Aug. 22	Downton Lake	R,O	3.0	32	3	9	10	115			6	
Aug. 24	Bear Isle	R	9.0	18	2		1	15				
Aug. 25	Pipestone Bay	O	24.0	24	1							
Aug. 25	Warne Isle	R	5.0	4	1	1					1	
Aug. 26	Downton Lake	R,O	3.0	22	2	7	1	42				
Aug. 27	Murphy Isle	R	3.0	26	3	1	1	5				1
Sept. 5	Laboratory Isle	R,O	2.5	14	1	1		1				
Sept. 9	Hatchery	R,O	2.5	82	10	21	1	38		2	1	
Sept. 9	Temp. Station	O	11.0	9	1							
Sept. 12	Hatchery	R,O	3.0	70	14	19*	2	21				
Sept. 16	Laboratory	O	4.5	22	4	1	6	23				2
Oct. 13	Hatchery	R,O	3.0	14	1							
Oct. 14	Laboratory	O	4.5	24	3							
Nov. 6**	Laboratory	O	4.5	45	4		1		1			

* 1 recaptured chub
** Lake froze over

Table 4. Summary of 3/4 inch stretch mesh monofilament gill net catches in Lac la Ronge, 1967.

Habitat: R = rock
O = ooze
V = vegetation

Fish: B = burbot
L = longnose dace

Date	Location	Habitat	Depth (m)	Hours Set	Number of Times Run	lake chub	perch	spottail	percopsis	pike	walleye	white sucker	cisco	whitefish	longnose sucker	miscellaneous
June 2	Dog Isle	R	2.0	15	1											
June 3	Laboratory	R,O	2.5	12	1	2	12		2	2	4	10		3	1	B-1
June 5	Laboratory	O	4.5	12	1		13		11		1	10	1			B-3
June 7	Freeman Isle	R	2.5	15	1	3			2	1	1			4		
June 17	Dog Isle	R	2.5	17	4	5	2		16	1						
June 21	Dog Isle	O	11.0	10	1		2					4		2		B-2
June 27	Dog Isle	R	2.5	145	14	12	11		14	8	5	10	1	16		B-1
June 28	Kitsaki Isle	V,O	3.5	9	1		2							1		
June 29	Montreal River	V,O	2.0	12	1	1	9				11	10				
June 30	Hatchery	R,O	2.5	21	2		15		2	9	2	13				
July 4	Laboratory	R,O	2.5	12	1		8			2	10	3				
July 6	Laboratory Isle	R,O	4.5*	23	2		1		1				56			
July 18	Dog Isle	R	2.5	22	4	3	31		20		13	3	1	3		
July 19	Dog Isle	O	8.0	23	3	1	2		24			1	11		1	
July 21	Dog Isle	O	8.0*	49	3	1	9				2		273	2		
July 25	Laboratory Isle	R,O	3.0	19	2		16		3	4		2				
July 27	Laboratory	O	4.5	57	5		101		14	2	7	40	10	3	1	B-1

Table 4. continued.

Date	Location	Habitat	Depth (m)	Hours Set	Number of Times Run	lake chub	perch	spottail	percopsis	pike	walleye	white sucker	cisco	whitefish	longnose sucker	miscellaneous
July 28	Camp Ground	O	4.5	25	2		28		4	7	4	11				
July 29	Camp Ground	R,O	2.5	12	1		11			1	3	9				
July 30	Murphy Isle	R	3.5	23	2	22			7		1			3		
July 31	Murphy Isle	R	3.5*	7	2							1	1			
Aug. 1	Murphy Isle	R	3.5	37	4	20	4		12		4		14	4		
Aug. 9	Dog Isle	R	2.5	22	1		4		1		7	3				
Aug. 10	Little Dog Isle	R	2.5	25	3	1	6		3	1	8	13			1	
Aug. 11	Kitsaki Isle	V,O	3.0	24	2		31				3	11				
Aug. 14	Dog Isle	R	2.5	69	10	5	86		14	3	4	11				
Aug. 14	Stonehocker Bay	R,O	2.5	12	2	1	24			3		20				
Aug. 19	Laboratory	R,O	2.5	33	2		28			3	7	7	3	2		
Aug. 26	Stonehocker Bay	R,O	2.5	65	4		79			2	9	18	1			L-1
Aug. 23	Nunn Portage	R	3.5	23	2	12	7			1	2	1				

* surface set

Table 5. Summary of 5/8 inch stretch mesh monofilament gill net catches in Lac la Ronge, 1967.

Habitat: R = rock
O = ooze
V = vegetation

Fish: C = cisco
W = white sucker
B = burbot
L = longnose sucker

Date	Location	Habitat	Depth (m)	Hours Set	Number of Times Run	lake chub	perch	spottail	percopsis	pike	walleye	longnose dace	miscellaneous
June 17	Dog Isle Reef	R	2.0	17	4			3					
June 21	Dog Isle	O	6.5	10	1								
June 27	Dog Isle Reef	R	2.0	142	14	6	1	42	4		4	5	
June 28	Kitsaki Isle	V,O	3.5	9	1		1	2					
June 29	Montreal River	V,O	2.0	12	1		4	208		1	1		W-1
June 30	Laboratory	R,O	2.5	21	2		2	11		1			
July 6	Laboratory	R,O	2.5	35	3		5	10		1	3		B-1
July 18	Dog Isle	R	2.5	22	4	5	9	1	3				
July 19	Dog Isle	O	8.0	23	3		32	1					
July 25	Lab. Isle	O	3.0	19	2		2	3		3	1		{L-1
July 27	Laboratory	O	4.5	57	5		6	5					C-3
July 28	Campground	O	4.5	25	2		7	5	3	2	2		
July 28	Campground	R,O	2.5	12	1						2		
Aug. 1	Murphy Isle	R	4.0	67	8	2							
Aug. 9	Dog Isle	R	2.5	22	1		1						

Table 5. continued.

Date	Location	Habitat	Depth (m)	Hours Set	Number of Times Run	lake chub	perch	spottail	percopsis	pike	walleye	longnose dace	miscellaneous
Aug. 10	Little Dog Isle	R	2.5	25	3		1						
Aug. 11	Kitsaki Isle	O,V	3.0	24	2								
Aug. 14	Dog Isle	R	2.0	69	10	1	7	15	3		1		C-1
Aug. 14	Stonehocker Bay	R	2.0	12	2		1						
Aug. 19	Laboratory	R,O	2.5	33	2	4	2				2		
Aug. 23	Nunn Portage	R	3.5	23	2			1					
Aug. 26	Stonehocker Bay	R,O	2.5	65	4	8	4	3					

APPENDIX C. - Summary of seine hauls in Lac la Ronge, 1966 and 1967.

Table 6. Seine hauls at the Fisheries Laboratory beach, Lac la Ronge, 1966 and 1967.

Habitat: Rocky bottom adjacent to sand and gravel beach area.

Date	Number of Hauls	lake chub	lake chub recaptured	perch	spottail shiner	white sucker	percopsis	walleye	longnose dace	slimy sculpin	nine-spine stickleback	miscellaneous
1966												
July 12	8	140		28	3	105	31	2				
July 13	12	501		50	4	366	73		33			
July 14	8	118	32	3	47	32	137		3			
July 15	12	226	22	17	432	53	91	2	3			
July 15	2	163	3	22	1	79	60		1			
July 19	8	195	20	37	13	9	61		2			
July 20	8	93	6	9	85	1	40					
July 21	12	89	26	37	2		24					
Aug. 12	4	19	4	-	-	-	-	-	-	-	-	-
Aug. 13	4	302	3	-	-	-	-	-	-	-	-	-
Aug. 15	4	148	5	-	-	-	-	-	-	-	-	-
Aug. 22	4	40	10	109	7		1			2	2	
Aug. 27	4	46	3	95		30			1			
Sept. 7	4	89	14	-	-	-	-	-	-	-	-	-
Sept. 14	4	13	2		2							Fry
Oct. 13	3	3	2	++								

Table 6. continued.

Date	Number of Hauls	lake chub	lake chub recaptured	perch	spottail shiner	white sucker	percopsis	walleye	longnose dace	slimy sculpin	nine-spine stickleback	miscellaneous
1967												
July 3	12	2		1			6		4	2	2	
July 6	4	30		70	++*		++		15			
July 18	3	4			1		1			2	1	Fry
July 18	1	40		++	4	8	3					
July 19	8	51	1	++		2	6					Fry
July 19	1	6		++			+					
July 20	4	21	1	++	++	4	++	5				Fry
July 25	4	9		12	40		12		1			Fry
July 28	12	238	10	++	++	2	+++		1	1		
July 31	4	37	13	+++	3	1	96					Fry, 1 pike
Aug. 8	4	66	7	++	++	++	26					Fry
Aug. 11	4	46	8	63	265	8	1					Fry
Aug. 24	4	172	18	++	++		++					
Aug. 31	2	56	-	-	-	-	-	-	-	-	-	-

* + = 0 to 10, ++ = 10 to 100, +++ = over 100

Table 7. Seine hauls at the La Ronge campground beach, 1966 and 1967.

Habitat: Rocky adjacent to sand beach.

Date	Number of Hauls	lake chub	lake chub recaptured	perch	spottail shiner	white sucker	percopsis	walleye	fathead minnow	slimy sculpin	nine-spine stickleback	miscellaneous
1966												
July 15	4	148	4	5	5	22	17					
Aug. 27	2	36	3	-	-	-	-	-	-	-	-	-
Sept. 12	2	45		520	6				5			
Sept. 14	2	45	8	-	-	-	-	-	-	-	-	-
Oct. 13	3	8	4	++*		1				2	1	
1967												
July 6	4	39		240	++	110	++					
July 18	2	++		++		++	++					
July 25	3	102	2	++	++	30	++	5				
July 28	2	129	5	++	++	++	++					
Aug. 28	2	43	1	50	10		20	4				

* + = 0 to 10, ++ = 10 to 100, +++ = over 100

Table 8. Seine hauls taken throughout Lac la Ronge for the pike study, 1966.

Habitat: S = sand
R = rock
V = emergent aquatic vegetation
O = ooze

Fish: W = walleye
L = longnose sucker
F = five spine stickleback
S = slimy sculpin
B = blacknose shiner

Date	Location	Habitat	Number of Hauls	lake chub	perch	spottail shiner	white sucker	percopsis	pike	fathead minnow	Iowa darter	nine-spine stickleback	miscellaneous
June 21	Hunter Bay	S,R	3		31	1	40	1		1			L-6, S-1
June 28	Mandel Isle	S,R,V	2		29	6	1					28	S-1
July 6	Abrams Bay	S,V	4		2083	222	1066	5	1	41		17	
July 7	Abrams Bay	S,V	3		585	71	395	1	1	8			
July 8	Meeymoot Bay	S,V	2		257	283	79		5	35			L-4
July 8	Bow River	S,R	3		27	22	4	2		1			
July 8	Sandy Point	O,V	2		1317	1531			7	10			B-5
July 11	English Bay	O,V	6		42	3	3		8		3		F-1
July 11	Waden Bay	S,O,V	6		6	491		2	8	24	7	17	W-1
July 11	Dog Isle	R	1						2				
July 14	Kinesao Creek	O	2		5						2		
July 15	Wapawekka Portage	S,R,V	5		126	1	166		8	1	1	1	W-1
July 15	Nipekamew Bay	S	5		20		176		11				W-1
July 15	Larva Point	S,O,V	3		3	6	60		5		2		
July 15	Reilander Creek	S	1				1		1				

Table 8. continued.

Date	Location	Habitat	Number of Hauls	lake chub	perch	spottail shiner	white sucker	percopsis	pike	fathead minnow	Iowa darter	nine-spine stickleback	miscellaneous
July 16	Murray Isle	S	2	13	200	4		1				4	L-2
July 16	Hamilton Bay	O,V	5		52	29			20	21	19		B-1
July 19	Kenardine Isle	R,S	1								1		
July 20	Arrowhead Bay	S,O,V	9		86	3			7				
July 20	Russel Bay	O,V	9		187				9			1	
July 20	Duck Point	O,V	8		44	1			15		3		L-1
July 23	Jackson Isle	R,S,V	4	1		1	1		6		2	10	L-3
July 23	Long Isle	O	1		13				4		1		
July 23	Reilander Creek	R,S,V	4		25		2		1			6	L-3
July 25	Mitchell Bay	R,S	1		20								Fry
July 29	Hamilton Bay	O,V	11		22	2	1		15		16		
Aug. 5	Pothole Bay	S,O,V	9		31	37	8		12	87	2		Fry
Aug. 12	Thomas Bay	O,V	5		2				4		4		
Aug. 16	Nut Bay	S,V	11		92	1			4		3	3	Fry 1 whitefish
Aug. 16	Nut Bay	O,V	3		5		1				2		Fry
Aug. 16	Ewen Bay	O,R,V	12		39	1			2			1	Fry
Aug. 16	Moore Isle	O,V	2								1		Fry
Aug. 19	Four Portages	S,V	3		8	5			1	6		4	Fry
Aug. 20	Duck Point	O,V	9		39				8		1		Fry
Aug. 26	Nipekamew Bay	R,S,V	17		127		10		8		1		Fry

Table 9. Seine hauls taken throughout Lac la Ronge, 1966 and 1967.

<u>Habitat</u>: S = sand
R = rock
V = emergent aquatic vegetation
O = ooze

<u>Fish</u>: I = Iowa darter
W = walleye
F = fathead minnow
B = blacknose shiner

Date		Location	Habitat	Number of Hauls	lake chub	lake chub recaptured	perch	spottail shiner	white sucker	percopsis	pike	longnose dace	nine-spine stickleback	miscellaneous
1966														
June	10	Freeman Isle	R	2			300	60					600	
June	13	Freeman Isle	S	1	3			6					3	I-1
June	13	Freeman Isle	R,S	1	145			44				10	62	
June	18	Dog Isle	R,V	1	78									
June	25	Dog Isle	R,V	1	73									
July	11	Downton Lake	O,V	3			9				3			
July	11	Isle near Downton	R,V	1							2			
July	11	Dog Isle	R,V	2	26		++*	++						W-1
July	12	Dog Isle	R,V	3	558	5	21	79		2		70	1	
July	15	Kitsaki Isle	R,V	1			++	++			+			
July	28	Little Kitsaki Isle	R	1			3		1		2			Fry
July	28	Dominion Point	S,R,V	2	8		++	++	8	1	4		1	Fry, W-1, I-1
July	28	Dr. Bradley's Creek	R,S,V	1	18		++	++	++		2			F-++

Table 9. continued.

Date		Location	Habitat	Number of Hauls	lake chub	lake chub recaptured	perch	spottail shiner	white sucker	percopsis	pike	longnose dace	nine-spine stickleback	miscellaneous
Aug.	4	Dominion Point	R,S,V	2	71									
Aug.	10	McKee Isle	S,V	2			++	++						F-++
Aug.	17	Anglo Rouyen	R	3				++						
Aug.	25	Pipestone Bay	S,V	1										B-+
Aug.	27	Stonehocker Bay	O,V	1	4	2	++							
Sept.	19	Stonehocker Bay	O,V	1										
Oct.	13	Stonehocker Bay	O,V	1				2	1					Fry
Oct.	14	Waden Bay	S	1	++		+++	+++	++				350	F-++
1967														
June	16	Freeman Isle	S,V	3			++	++					+	F-+
July	19	Stonehocker Bay	O,V	1	2		20		14					
July	20	Dr. Bradley's Cabin	S,V	3			++	++		++				W-11
July	20	Dominion Point	S,V	1	+		++	++		+			3	
July	20	Dominion Point	R,S,V	1								++		Fry
July	20	Dominion Point	S	3	++		++	++	++	++				
Aug.	7	Dr. Bradley's Cabin	S,V				++	++						Fry
Aug.	7	Dominion Point	S,V				++	++						F-+
Aug.	7	Dominion Point	R,S,V				++	++						Fry
Aug.	22	Nunn Portage	S				+	+						

* + = 0 to 10, ++ = 10 to 100, +++ = over 100