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ABSTRACT

Biological investigations were carried out on 2,031 channel catfish caught from June, 1970 to June, 1972. Fish were obtained from a 33 km stretch of the Ottawa River near the cities of Ottawa and Hull.

Most fish (99%) were caught above the cities of Ottawa-Hull, with the remainder below. Chemical tests indicated no major differences in water quality between the two areas. Water preference experiments indicated that channel catfish showed no preference for water obtained from the Ottawa River either above or below these cities.

Growth for either sex was similar. Increase in length with age is represented by log fork length (cm) = 1.1668 + 0.43037 log age. Increase in weight with age is represented by log wt. (g) = 1.540 + 1.405 log age. Length weight relationships are similar for both sexes and are represented by log wt. (g) = -2.081 + 3.138 log fork length (cm).

Female channel catfish attain a fork length of 33 cm and are at least five years of age before 50 percent of the female fish are mature. State of maturity in males is difficult to assess. Spawning occurs at water temperatures ranging from 20.6° C to 23.3° C. The average fecundity is 6,480 eggs. Egg diameter at time of spawning is 3.6 mm.

Feeding habits are related to fish length. Fish having fork lengths up to 30 cm are insectivorous, from 30 cm to 45 cm are omnivorous and greater than 45 cm are piscivorous. Seasonal variation of food consumed is directly related to the availability of that food item.

No definite evidence was found to explain the relative absence of channel catfish immediately downriver of Ottawa-Hull.

RESUME

De juin 1970 à juin 1972 des observations d'ordre biologique ont été faites sur 2,031 barbues de rivière. 99% des spécimens furent capturés en amont de la ville d'Ottawa; les autres furent capturés en aval. Les captures furent réparties sur une distance de 33 kilomètres. Des tests chimiques n'ont pas révélé de différences entre la qualité des eaux en aval et en amont de la ville d'Ottawa. Des tests ont indiqué aussi que les barbues de rivière n'avaient pas de préférence pour les eaux en amont ou en aval de la ville.

Le taux de croissance pour les individus mâles et femelles est le même. L'accroissement de la longueur du poisson (mesurée à partir de la fourche) s'exprime comme suit:

log longueur (cm) = 1.1668 + 043037 log âge

L'augmentation en poids est exprimée par:

log poids (g) = 1.540 + 1.105 log âge

La relation poids-longueur est la même pour les deux sexes et s'exprime comme suit:

log poids (g) = -2.081 + 3.138 log longueur (cm).

Les barbues femelles atteignent une longueur à la fourche de 33 cm et 50% d'entre elles n'atteignent pas la maturité avant l'âge de 5 ans. La maturité chez les mâles est plus difficile à établir. Les barbues frayent dans des eaux dont la température varie de 20.6°C à 23.3°C. La fécondité moyenne est de 6,480 oeufs dont le diamètre est de 3.6 mm au moment de la ponte.

Les habitudes alimentaires varient suivant la taille des individus. Ceux-ci sont insectivores s'ils mesurent moins de 30 cm. Ils sont omnivores s'ils mesurent entre 30 et 45 cm et sont piscivores s'ils mesurent plus de 45 cm. Les variations saisonnières des habitudes alimentaires sont

en relation directe avec la disponibilité des aliments.

Aucune explication précise n'a été apportée pour expliquer l'absence des barbues de rivières immédiatements en aval de la cité d'Ottawa.

INTRODUCTION

The main purpose of this study was to obtain information on the age, growth, food, fecundity and maturation of channel catfish in the Ottawa River near the cities of Ottawa and Hull, Canada.

Data obtained were used to see what biological differences there might be between fish living at the northern limit of their distribution and those inhabiting waters from more southerly latitudes. Suggestions can also be made regarding possible management of this species at these northern latitudes.

Another purpose of the study was to try to determine the cause of its local distribution and to establish if water quality was a factor.

Biological investigations were carried out from June to late October, 1970, from May to late October, 1971, and May and June, 1972. A total of 2,031 channel catfish caught in a 33 km (20 mile) stretch of the Ottawa River were analyzed.

The Ottawa River has been the subject of several biological investigations. Earlier reports have been concerned with water quality, primarily from a chemical point of view (Piché 1954, LeSauteur 1965). Only in recent years have studies from a more biological point of view been undertaken. The recent report put forth jointly by the Ontario Water Resources Commission (O.W.R.C.) and the Quebec Water Board (Q.W.B.) in 1971 indicated water quality characteristics. These were based on both chemical and biological factors for all sections of the Ottawa River that lie along the interprovincial boundary. Mackie (1971) and Stobo (1971) carried out studies on the distribution and ecology of macrobenthos and the distribution and growth of the yellow perch, Perca

flavescens, respectively, in polluted and non-polluted parts of the Ottawa River. At the present time, several biological investigations on this river are being carried out by other researchers.

Previous investigations have indicated that a fairly large channel catfish population exists upriver from the cities of Ottawa, Ontario and Hull, Quebec, whereas, few fish of this species are found immediately downriver from the above mentioned cities (Stobo ibid, S.U. Qadri unpublished data). Commercial catch records furnished by the Ontario Ministry of Natural Resources, Kemptville Branch, indicate that from approximately 50 km downriver from these cities, the channel catfish population is of sufficient size to be economically important.

Channel catfish found in the Ottawa River represent the northern limit of their distribution (Scott 1967, Trautman 1957). Most ecological research on this species has originated from the central and southern United States. Limited biological investigations of channel catfish in eastern Canada have been from the Saint Lawrence River (Magnin and Beaulieu 1966). Cuerrier (1951) aged a few channel catfish from the Ottawa River but undertook no further studies. It is evident that there exists in eastern Canada a lack of knowledge pertaining to this species.

MATERIALS AND METHODS

Description of Study Area

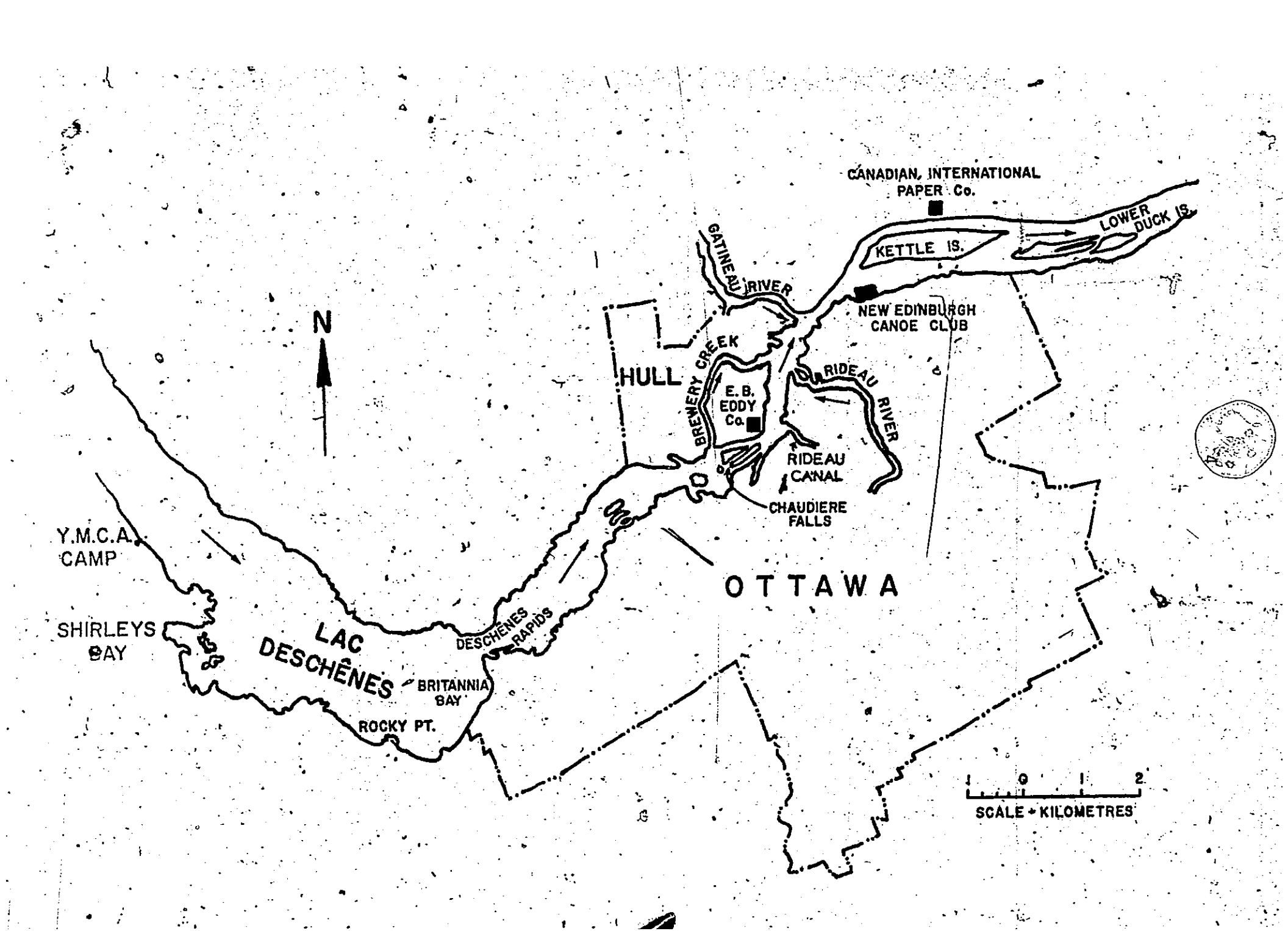
The Ottawa River extends approximately 1,113 kilometres (696 miles) from the drainage system of Lake Temiscamingue (81° 22' longitude west, 48° 42' latitude north) to the St. Lawrence River (73° 30' longitude west, 44° 34' latitude north). Total drainage area for this basin is 145,000 square kilometres (56,000 square miles).

Channel catfish examined for this study were obtained from a 33 km (20 mile) stretch of the Ottawa River. The study area extended from the YMCA camp to the middle of Lower Duck Island and included the cities of Ottawa, Ont., Hull and Gatineau, Que. (Fig. 1). The study area was further divided into three sectors: upper, middle and lower river.

The upper river, extending from the YMCA camp to the Deschênes Rapids (Fig. 1), is part of Lac Deschênes, a widening of the Ottawa River. At the time of this project, Shirleys Bay was being transformed into a sewage lagoon. A maximum depth of 16.7 metres for this sector was found at approximately two thirds of the width of the river opposite Shirleys Bay. The main flow of the river follows the northern (Quebec) shore. Currents found along the southern (Ontario) shore east of Shirleys Bay are probably wind generated. Depths along this southern shore range from one to nine metres. Mud and sand are the predominant substrates along this shore. The littoral zone at Rocky Pt. and upriver from Shirleys Bay is composed of rock. No information on depths and substrate of the northern (Quebec) shore was recorded.

The mid river section lies between the Deschênes Rapids and the Chaudière Falls (Fig. 1). Swift current, rocky shoals, log sorting

Fig. 1. The Ottawa River study area.


CANADIAN, INTERNATIONAL PAPER Co.
LOWER DUCK IS.
KETTLE IS.
GATINEAU RIVER
NEW EDINBURGH CANOE CLUB
N
HULL
BREWERY CREEK
E.B. EDDY Co.
RIDEAU RIVER
RIDEAU CANAL
CHAUDIERE FALLS
Y.M.C.A. CAMP
SHIRLEYS BAY
LAC DESCHÊNES
DESCHÊNES RAPIDS
BRITANNIA BAY
ROCKY PT.
OTTAWA
0 1 2
SCALE - KILOMETRES

and booming are characteristic of this region.

The lower river includes that part of the river between the Chaudière Falls and Lower Duck Island (Fig. 1). This sector can be best described as having quite swift currents and very rapid drop offs. Depths ranging from 6 to 16 metres throughout most of this area are not uncommon. Depths of three metres are found in a few locations such as Governors Bay, located one third of a kilometre down river of the Rideau River, a bay at the mouth of Brewery Creek and waters on the north side of Lower Duck Island. Two main tributaries entering the Ottawa River are the Rideau and Gatineau Rivers having mean annual flow rates in 1968 and 1969 of 39,642 l/s and 370,940 l/s respectively (O.W.R.C. and Q.W.B. 1971). Waters from the Rideau River cascade over the Rideau Falls, a drop of 11.3 metres, into the Ottawa River.

Brewery Creek, a part of the Ottawa River which courses through the city of Hull, deserves special mention. At the beginning of this project, this creek received non-chlorinated raw sewage from the city of Hull as well as wastes from Canada Packers, a meat processing and packaging plant. In the spring of 1971, slaughter house operations ceased. In August, 1971, Brewery Creek was temporarily dammed and remained so for the duration of the study period. Consequently, water below the dam stagnated causing changes in its chemistry in the immediate area.

Major industries operating along the lower river include two paper mills - the E.B. Eddy Company of Hull, Quebec and the Canadian International Paper Company (C.I.P.) of Gatineau, Quebec.

Statistical Methods

Statistical tests used to determine similarities or differences are indicated where applicable in the thesis. The Student's t-test and linear regression by the method of least squares are used primarily for analyzing data. Unless otherwise stated, the 0.05 probability level is used as my criterion for significance.

Physical and Chemical Parameters of Water Examined

Water samples were collected from five stations at approximately three week intervals from early June to late October for the years 1970 and 1971. Stations were as follows: Britannia Bay, mouth of Brewery Creek, New Edinburgh Canoe Club, in the channel between Kettle Island and the C.I.P. mill at a point 1.50 km upriver of the mill and another location 0.75 km below the mill. These last two stations hereafter are referred to as upper and lower C.I.P. respectively.

Samples were collected from both the surface and bottom of the water column, the latter being obtained approximately 30 cm above the substrate with a 4-litre Van Dorn water sampler. A portable Hach kit was used to measure pH, dissolved oxygen and carbon dioxide levels in the field immediately after samples were collected. Water destined for laboratory analyses was kept at 5° C until tested. In the laboratory, a Direct Reading E.L. Hach Chemical "Engineers" Kit with the 4th edition instruction manual was used to measure the following parameters: alkalinity, chloride (Cl), hardness (Ca and total), iron, nitrate, phosphate (PO_4) and sulphate (SO_4).

Testing for the presence of chlorine in the water was

started in July 1971. Turbidity measurements (J.T.U.) were also recorded by using the above kit. Water temperatures were recorded in the field by a mercury bulb thermometer. Average monthly water temperatures at a depth of 7.6 m from Jan., 1970 to Dec., 1971 as recorded at the Britannia Purification Plant were obtained.

Collection and Measurement of Fish

The data and fish were collected between June to October, 1970 and May to October, 1971. In 1971, netting was done once every two weeks, except in October when only one sample was collected. In 1972, limited netting was done to supplement previous years data.

Samples were collected at approximately the same intensity in the upper and lower river. Negligible fishing was carried out in the middle sector for reasons explained later.

Fish were collected by using a 1.8 m trap net and 61 m long gill nets. The trap net, constructed of 5.1 cm stretched nylon mesh has a 36.6 m long lead of similar mesh size. Gill nets were composed of four 15.2 m sections, 1.8 m deep, of multifilament nylon having mesh sizes of 3.8, 5.1, 7.6 and 10.2 cm stretched mesh.

A total of 72 gill and 37 trap net sets in 22 different locations were made. Trap net use was restricted to areas where water depths ranged between 1.8 to 3.0 metres at approximately 30 to 40 metres from shore. With depths shallower or deeper than this, the efficiency of this net was greatly reduced. Normal low water levels in 1971 prevented the setting of this net from late June to early September in the upper river. Trap netting in the lower river was not affected by water level fluctuations since there was a greater variety of sites at different depths available. Gill nets were utilized in

both the upper and lower river to sample areas having depths ranging from 1.5 to 17.0 metres. The very nature of the middle river sector as described previously precluded any sampling in this area.

The use of cheese baited and non baited Windemere minnow traps, day and night seining and skin diving in lotic and lentic waters proved unsuccessful in locating and capturing channel catfish having fork lengths less than 21.0 cm.

Field measurements of fish for age and growth were based on the methods outlined by Lagler (1956). The fork and total lengths were recorded to the nearest millimetre on 858 fresh fish. Field weights of 487 channel catfish were obtained from a Chatillon balance, accurate to the nearest 20 grams. An additional 491 fish were brought back to the lab for further analyses. From this number, lengths and weights of 110 freshly caught fish were recorded. Standard lengths were also recorded from 45 fish. A Mettler balance, accurate to the nearest gram; was used to obtain the weight of fish in the lab.

Fish that could not be worked on immediately were placed in plastic bags and frozen.

Preservation and Shrinkage of Fish

Preservation by freezing was chosen for convenience as well as to allow comparison with specimens collected and frozen in 1970. Duration of preservation ranged from two weeks to thirteen months.

In order to see if there were any significant length and weight losses due to freezing, 28 channel catfish of various sizes were selected for a shrinkage experiment which lasted for the above mentioned preservation times. Using the paired Student's t-test, significant differences ($p<0.001$) for lengths and weights between

fresh and frozen specimens were obtained.

To compare length and weight data of preserved fish to those measurements obtained from fresh fish, correction factors were determined (Table 1). Size class intervals for the fish used for these correction factors were determined by using Sturges formula (Sturges 1926). Applying the paired Student's t-test to fresh and calculated fresh measurement (preserved value + correction factor), no significant differences were obtained ($p>0.10$) and the measurements were comparable. Determination of size class interval using Sturges formula and consequent derivation of the correction factor are given (Appendix 1).

Tagging

In order to study local movements, 530 channel catfish were tagged (430 in June, 1971, and 100 in June, 1972) with numbered "spaghetti" dart tags obtained from the Floy Tag Manufacturing Company of Seattle, Washington. A tagging gun manufactured by the same company was used to fasten these tags to fish. Tags were attached between interneural spines at the base of the dorsal fin (Stott 1968). All fish were anaesthetized in a dilute solution of MS 222 - Ethyl-m-aminobenzoate Methanesulfonate, (Bell 1964) prior to tagging. After anaesthetizing and tagging, quiescent fish were placed in fresh water and were released when they showed recovery from the anaesthetic. The left pectoral spine of all catfish tagged was removed for aging and marking purposes.

Age Determination, Interpretation of Annuli and Validation of Aging Technique

Aging of 851 channel catfish was accomplished by counting

Table 1 Correction factors to be added to measurements of frozen channel catfish.

Range in[1] fork length (cm)	Correction factor (cm)	Range in[1] total length (cm)	Correction factor (cm)	Weight[2] correction factor (grams)
24.7-31.6	0.5	28.9-36.1	0.6	11
31.7-38.6	0.7	36.2-43.4	0.5	41
38.7-45.6	0.9	43.5-50.7	1.1	41
45.7-52.6	1.6	50.8-58.0	1.5	48
52.7-59.6[3]	1.2	58.1-65.3	1.1	67
59.7-66.6[3]	1.1	65.4-72.6	1.1	24

1 - Range in length determined from Sturges formula (Sturges 1926)

2 - Correction factor compensating for weight loss resulting from freezing channel catfish having lengths corresponding to fork and total length ranges.

3 - Correction factors determined from a single fish.

the number of annuli on sections obtained from pectoral spines (Kalman 1934, Sneed 1951, Marzolf 1955).

Pruning shears were used to cut the spine from as close to the body wall of the fish as possible. Spines were air dried for at least three days and then fixed in 10% non-buffered formalin for a minimum period of 48 hours. Fixed spines were next placed in 2-dram vials to which the decalcifying fluid, Decal[1] (Scholl 1968) was added. After a decalcification period of approximately three days (length of time varied with size of spine being decalcified), the spent Decal was discarded and the spines were washed in water for three hours. A single edged razor blade was used to cut sections of one to two tenths of a millimetre thick from the distal end of the basal groove (Sneed 1951) of the decalcified spine. A dissecting stereomicroscope at a magnification of 25X was used to examine sections which were immersed in water to give better contrast. Sections were read a minimum of two times before a final age was assigned to a fish. Spines and their respective sections were stored in a 10% glycerin water solution in a cool place (Scholl pers. comm. 1972). A few crystals of thymol were added to each vial containing spines and sections in order to prevent mould growth (Miller 1966).

Many difficulties were encountered before a technique for age determination from pectoral spines was found. Prior to selecting decalcification as a way of preparing spine sections for cutting, a method involving the use of a jeweller's saw (Scidmore and Glass 1953, Pycha 1955) was attempted but was abandoned because of too thick and/or shattered sections. Decalcification solutions such as sodium citrate

[1]Decal - A product of Omega Chemical Corporation. Distributed by Science Products, Division of American Hospital Supply Corporation, Evanston. In Canada, distributed by Can Lab.

and formic acid (Perry 1967) and E.D.T.A. - disodium (ethylenedinitrilo) tetra-acetate, (Jande pers. comm. 1972) were also tried but were discarded because of the long period of time required for decalcification to take place. Decal (Scholl 1968) proved to be a satisfactory, fast acting decalcifying agent. Spines not fixed in 10% non buffered formalin decalcified much faster than those that were but the edges of these non fixed sections had a tendency to curl, making counting of outer rings difficult. Consequently, most spines were fixed prior to decalcification. Rings were clearly visible on these decalcified spine sections. Interpretation of annuli was based primarily on experience gained from reading several hundred ages since there is virtually no literature available explaining the rings found in decalcified spine sections.

Annuli were distinguished from accessory rings in the following way. The distance between successive annuli was greatest near the centre of the spine section and smallest on the outside (Fig. 2). Any ring which did not conform to this description was considered to be an accessory check. Annuli were distinct rings which encircled the lumen of the spine. Unfortunately, accessory rings also gave this same appearance. These, however, could be distinguished as they always seemed to parallel the annulus that they were near.

Validation of aging technique was accomplished by two methods. First, 13 decalcified spines and their sections were sent to Mr. Russel Scholl for verification of ages read by myself. Complete agreement and to within one year occurred 46% and 77% of the time respectively. For the second verification method, the fifth vertebra of 25 channel catfish was removed and placed in a warm 1%

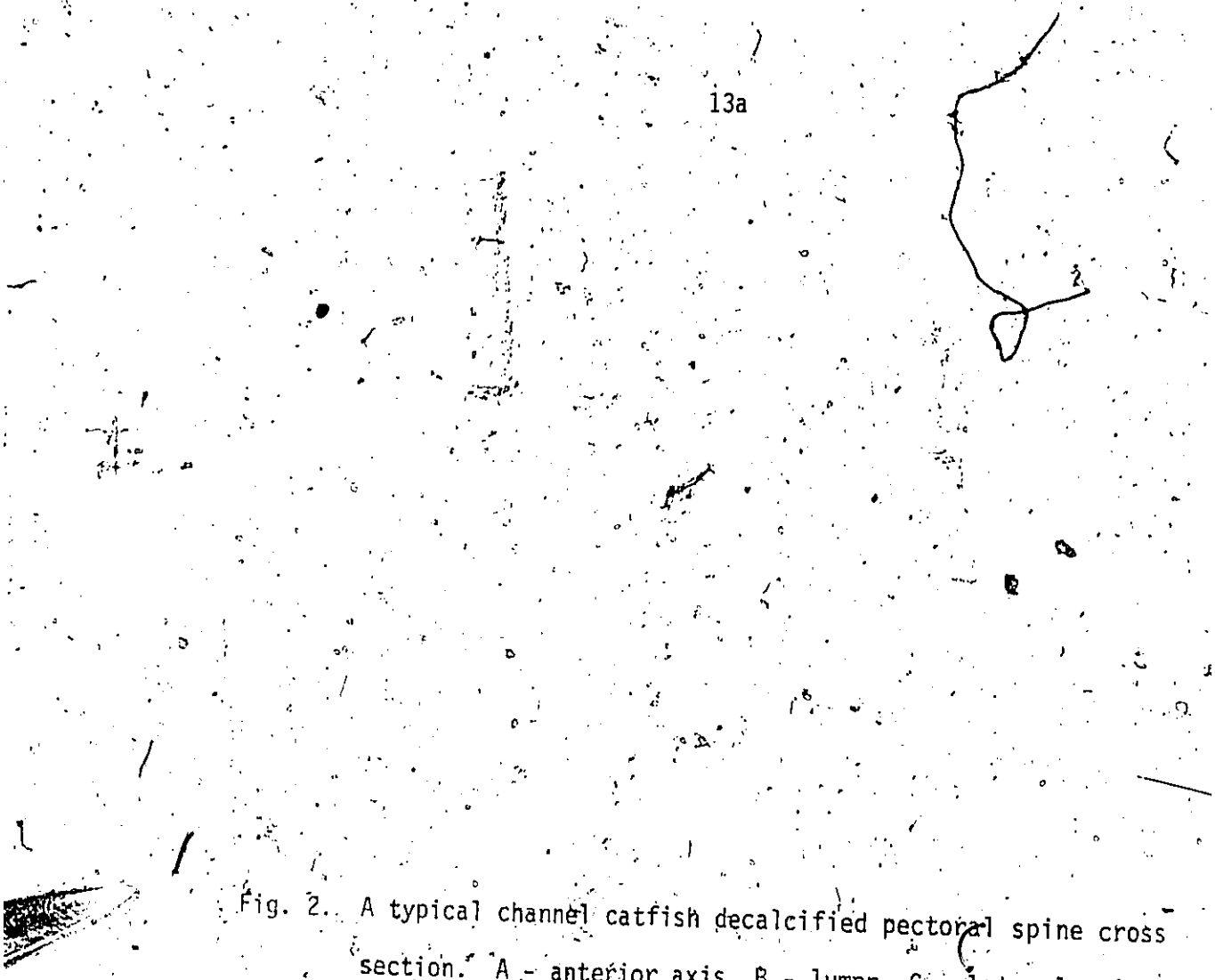
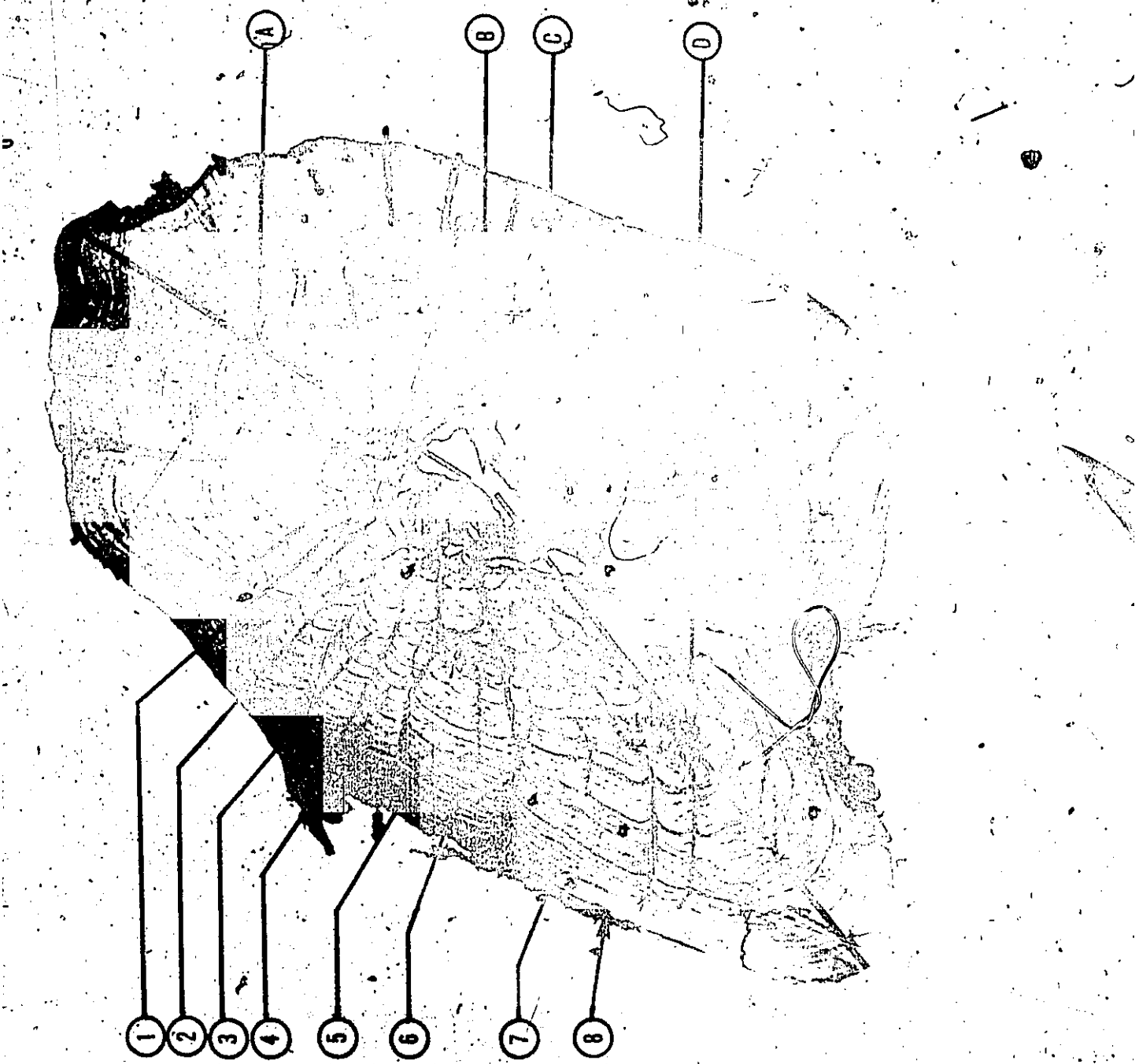


Fig. 2. A typical channel catfish decalcified pectoral spine cross section. A - anterior axis, B - lumen, C - lateral axis, D - expanded posterior axis; 1-8 - annuli.


A
B
C
D
1
2
3
4
5
6
7
8

KOH solution to loosen the attached flesh. Following removal of flesh, vertebrae were air dried and then aged (Appelget and Smith 1951). Comparisons were then made with ages read from corresponding spines. This method indicated more accuracy since 48% of ages read were in complete agreement and 96% were within one year. Validation of an aging technique is an estimate of one's accuracy. Since great difficulty is often encountered in aging fish, it is almost impossible to achieve 100% accuracy. For this project, age determination can be considered as being accurate to within one year of the actual age.

Back calculations of ages of 216 channel catfish were accomplished by first attaching a cameralucida to the microscope (Chuganova 1963). The distance from the center of the spine section to each annulus along the lateral field was then recorded. Growth was calculated at different ages by assuming direct proportions between growth of spine radius and growth in length of the fish.

Growth determinations were made from measurements along the lateral axis as opposed to the expanded, posterior edge (Sneed 1951, Muncy 1959) or the anterior radius (Marzolf 1955) of spine cross sections. The lateral axis was chosen since annuli were more uniformly spaced and distinct and because a line drawn from the center of the spine to its outer edge would meet the rings perpendicularly. The distal end of the basal groove was used as a reference point for taking cross sections of spines (Sneed ibid, Marzolf ibid, Muncy ibid). During spine growth the basal groove lengthens. For this reason the point of sectioning in older fish is actually more distal along the spine than in younger fish (Marzolf ibid). The elongated posterior portion of the spine cross section is very pronounced at the proximal end but because of the tapering nature of the spine, it

decreases in size distally until the cross section gives a very rounded appearance. In this study, cross sections at the distal end of the basal groove, particularly in larger fish, yielded posterior lobes ranging from very pronounced to almost negligible. A line drawn from the center to this outer edge often would not meet the rings perpendicularly and consequently would make the validity of the back calculated ages doubtful. For these reasons, the expanded posterior edge was rejected for growth measurements. Annuli along the anterior axis were very crowded and were often difficult to distinguish. Consequently, use of this axis for growth measurements was rejected.

Several sources of error are apparent in growth calculations from using pectoral spines. The distal movement of the basal groove as fish increase in size, as previously mentioned, introduces error in that the location where sections are taken changes with the size of the fish. Considering that spines also taper, then for a fish n years old, the distance from the focus of the cross section to the x^{th} annulus (where $x<n$) would be less than the distance to the same annulus when the fish was x years old. The lumen found in the center of the spine section increased in size as the fish grew, to the extent that the first annulus was often eroded away. Scholl (1968) made the same observations. With increased lumen size, difficulties arose in determining exactly where the focus was for taking measurements for growth calculations. Similar findings have also been reported by Muney (1959).

The above mentioned sources of error involved in measuring the radii and annuli of larger cross sections were not constant for

all fish sizes. Consequently, the body-spine relationship and subsequent mathematical corrections were not determined because this would introduce further error into the calculations. An approximate growth rate for each fish was calculated based on the theory that growth in the cross section of the spine was directly proportional to growth in length of the fish. Muncy (ibid) made a similar assumption.

Lengths of fish at each age were determined from back calculations (Table 2). The sample size for each age group, although somewhat small, was considered large enough to be representative of all fish within a respective age group. Comparison of the last calculated length given for each age (Table 2) to the average length found for each age (Appendix 5), indicates that calculated lengths were both less than corresponding average lengths of fish of the same age and greater than the average length for a fish a year younger. Thus, the last calculated length given for each age (Table 2) can be considered as being a very close approximation of the actual value.

Rosa Lee's phenomenon (Tesch 1968), in which calculated lengths at a given age are smaller the older the fish from which they are computed, was apparent for all age groups in this study. In channel catfish, this phenomenon can probably be attributed to the distal movement of the point of sectioning with increasing size of fish as previously mentioned. Consequently, it was felt that more accurate growth increments could be found if only the increase in length from the last season, for each age group, was considered (Table 2). Muncy (1959) determined his growth rates in a similar manner.

Gonad and Body Weight Relationship

Gross examination of the gonads of 491 channel catfish was

Table 2 Calculated length of Ottawa River channel catfish at end of each year of life.

Age Group	N	Calculated fork length (cm) at end of year															Growth increment
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
III	9	11.3	17.1	21.5													4.4
IV	17	10.3	16.1	20.7	24.6												3.9
V	14	10.1	15.6	20.1	23.9	27.2											3.3
VI	19	9.9	15.7	20.3	24.1	27.4	30.1										2.7
VII	22	9.9	15.2	20.6	24.7	27.9	30.7	33.1									2.4
VIII	21	10.2	15.7	19.6	22.8	26.0	29.1	32.0	34.6								2.6
IX	20	9.4	15.1	19.3	22.9	26.1	29.1	31.8	34.4	36.6							2.2
X	21	9.8	15.2	19.4	23.2	26.5	29.4	31.9	34.5	36.9	39.1						2.2
XI	20	10.4	15.4	19.7	23.6	26.4	28.9	31.1	33.6	35.9	38.0	39.9					1.9
XII	20	10.3	15.1	19.3	22.7	25.4	28.0	30.3	32.6	34.9	37.0	39.2	41.4				2.2
XIII	20	10.2	15.5	19.1	22.4	25.4	28.1	30.5	32.8	35.0	37.1	39.6	41.8	43.9			2.1
XIV	11	9.2	13.7	17.7	21.0	23.7	26.3	28.9	31.2	33.7	36.0	38.5	40.9	43.1	45.3		2.2
XV	2	8.6	15.6	19.8	23.5	26.5	28.8	31.8	34.3	36.4	38.8	40.4	42.4	44.7	47.1	49.1	2.0

made to determine their sex and maturity. Immature fish had poorly developed gonads which were almost indistinguishable from the ventral surface of the kidney. All fish whose gonads were distinguishable were considered mature. A more detailed classification of maturity stages based on Kesteven's (1960) work was attempted but was abandoned when difficulties arose in identifying the various stages of development according to his classification. Age and length at first maturity and the proportion of immature and mature fish were determined.

Gonad wet weights, recorded to the nearest 0.1 gram, of 302 channel catfish obtained from May to October, 1971 were used in determining the monthly gonadosomatic index or coefficient of maturity $\left(\frac{\text{gonad wt.} \times 100}{\text{total body wt. of fish}}\right)$ (Nikolskii 1963).

Both fresh and preserved fish were used in determining gonadosomatic indices. I assumed that as a result of freezing, gonad weight loss was directly proportional to total body weight loss. If fresh and preserved gonad weights are compared with respective total body weights, then the ratio used in determining the gonadosomatic index remains unchanged. Consequently, indices of preserved fish are assumed to be comparable with those of fresh fish.

Fecundity and Egg Size

Ovaries from 16 mature channel catfish caught close to the spawning time during May and June, 1971 and 1972, were found to be suitable for fecundity studies and for determination of egg size. Ovaries were preserved in Gilson's fluid (Bagenal 1968) so that ovarian tissue would be broken down and ova hardened.

Counting of eggs followed the procedure of Kandler and Pirwitz (1957). All clean eggs were poured into a graduated cylinder

containing a minimum amount of water. The total volume of eggs in each fish was noted. From these eggs, a random sample was selected and the number of eggs required to give a volume of 20.0 ml was determined. Three replicates were taken. The average of each set of replicates was then used in determining the fecundity of each fish.

A Vernier Micrometer[1] was used to determine the ova diameters of 20 eggs per fish for each of the above mentioned fish.

Stomach Content Analysis

Channel catfish were removed from the nets early in the day and killed in order that stomachs with food organisms in an undigested state might be obtained.

Out of the 491 channel catfish brought back to the lab, 267 had food in their stomachs. Stomach contents were fixed in 10% formalin for at least four days after which they were stored in 70% ethyl alcohol.

Analysis of stomach contents follows in part some of the methods described by Windell (1968) and Lagler (1956). The number and frequency of each food item as grouped broadly under the headings of insects, crustaceans, molluscs, fish, vegetation, miscellaneous vertebrates and invertebrates and unidentifiable debris were tallied. The volume of each group of food organism was measured to the nearest 0.1 ml by volume displacement in a graduated cylinder. Frequencies and volumes obtained were converted to percentages for different sizes of fish and for each month from May to October. Percent frequency of occurrence and percent volume of each of the above mentioned groups were also found for the total sample of fish examined without reference

[1] Vernier Micrometer No. 11, Instrument No. 1953, HB manufactured by the Precision Tool and Instrument Co. Ltd., England.

to size of fish or time of year. With the aid of the Insect Identification Service of the Canada Dept. of Agriculture and Mr. G. Mackie, many of the insects and bottom fauna which formed a predominant part of channel catfish diet were further identified to the generic level. Vegetation was identified when possible. Classification of algae, however, was not undertaken.

Water Preference Experiments

The design of the tank used in this experiment resembled in a number of ways the channelled avoidance trough used by Whitmore, Warren and Doudoroff (1960). In their experiment, as well as in this one, fish were initially placed in a common area from which they could elect which chamber to enter. Where the above mentioned researchers gave four choices, I presented two.

The water preference tank was constructed from a horse trough and modified to form five areas(Fig. 3). Each partition was made of 1.9 cm (3/4 inch) plywood which was coated with epoxy resin to make the wood waterproof. Each reservoir held up to 427 litres of water. Water from each reservoir was moved by means of two pumps[1] to the respective receiving chamber. To each pump intake hose was attached a plastic vial to which one layer of cheese cloth was stretched over the open end. These acted as filters to prevent debris from entering and fouling the pumps. Diameter of all tubing was constant. Flow rates were set at three litres per minute since this was the minimum rate that would prevent a backwash from one receiving chamber to the other via the common area. Each receiving chamber was connected to the common chamber

[1] Pump model #D-6, manufactured by Eastern Industries of Hamden, Conn., U.S.A.

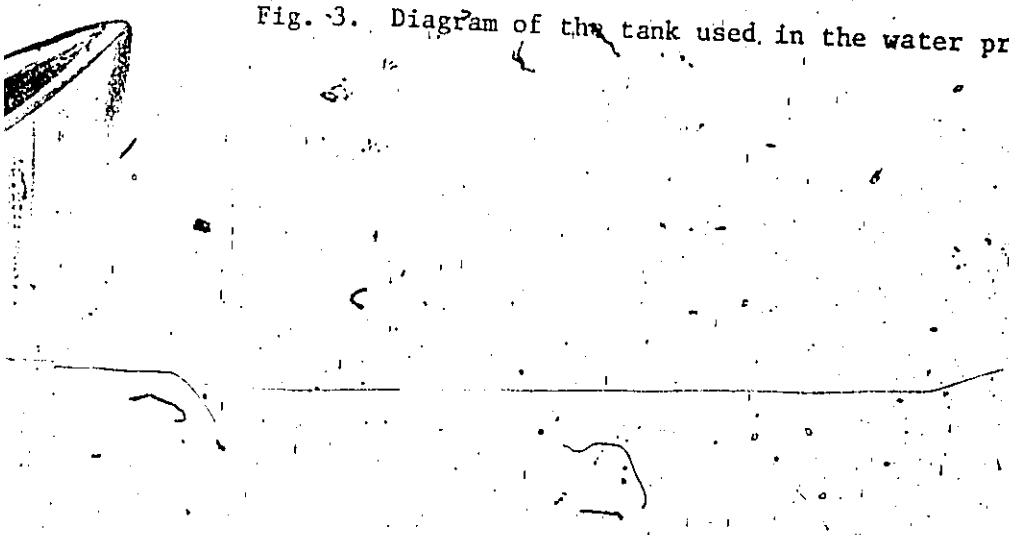
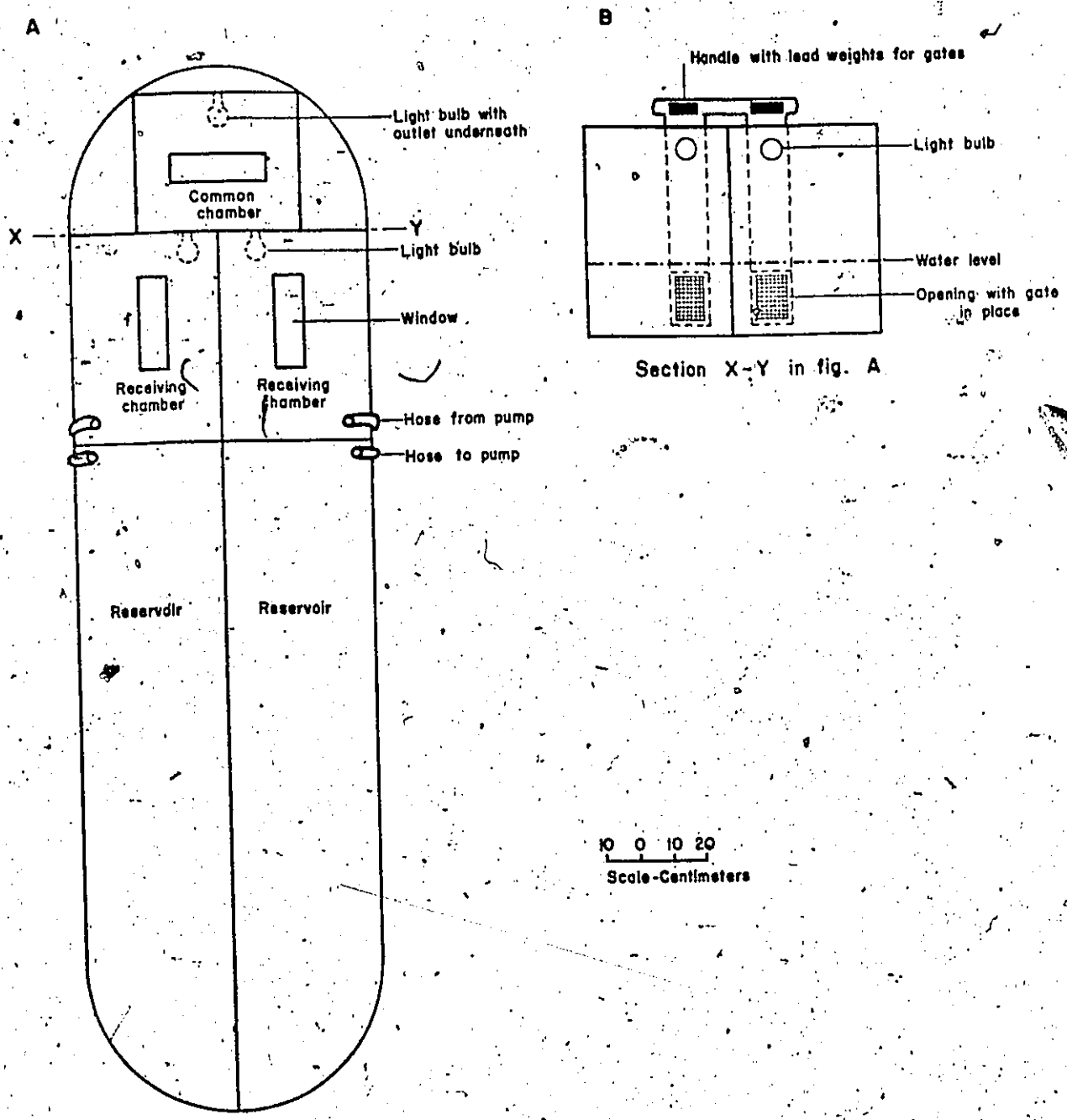


Fig. 3. Diagram of the tank used in the water preference experiments.


A
Light bulb with outlet underneath
Common chamber
X
Y
Light bulb
Window
Receiving chamber
Receiving chamber
Hose from pump
Hose to pump
Reservoir
Reservoir
B
Handle with lead weights for gates
Light bulb
Water level
Opening with gate in place
Section X-Y in fig. A
10 0 10 20
Scale-Centimeters

by an opening 12.5 cm x 16.7 cm. Gates composed of fibre glass screening which allowed passage of water could be lowered into the openings. The drain outlet was located in the common chamber opposite the two openings. Water level in these three chambers was kept at 22 cm. Volumes of water in each receiving chamber and the common area were 52.2 and 38.0 litres respectively. To equalize the lighting and to make fish visible, three 25 watt red lights were installed as indicated (Fig. 3). Removable covers with 30.0 cm x 8.3 cm plexiglass windows were placed over each receiving and common chamber. Fish were viewed from above in a darkened room through these windows.

Experimental procedure was as follows. Channel catfish with fork lengths ranging from 25.3 cm to 37.7 cm were obtained from Lac Deschênes. All fish were kept in dechlorinated tap water for at least one week before testing. Prior to placing the first fish to be tested in the common chamber, the gates were lowered and lights and both pumps were turned on. After 15 minutes with the pumps on, one fish was placed in the common chamber. Five minutes later, the gates were raised and the movements of the fish were observed and recorded. After another five minutes had elapsed, the pumps were shut off to conserve the water supply. Fish movements were recorded until 30 minutes had passed from the time that the gates were lifted. The experiment was terminated at this point. For the second and successive fish to be tested, the pumps were turned on for ten minutes before a fish was placed in the common chamber. Five minutes after the fish was introduced, the gates were raised and above described procedure was followed.

Following the experiment, the amount of time spent in each chamber was determined. Time spent in the common chamber was halved

and added to each of the times found for the receiving areas. Any fish with its head (from the snout to gill slit) or fraction thereof resting in any of the chambers other than the one in which the rest of its body was located, was considered as being half in each chamber. Consequently, time spent was divided equally between the areas involved. If more than the head of the fish was in one chamber, then the fish was considered to be in that area.

The preference of 21 channel catfish for waters from Britannia Bay and the lower CIP channel was determined. Control experiments were carried out on six fish. Experimentation took place within 24 hours of obtaining the water.

RESULTS

Water Chemistry and Physics

The Student's t-test was applied to the data obtained from bottom and surface samples for each parameter and station during 1970 and 1971. No significant differences were found between bottom and surface values. Consequently, these were grouped and averaged. The mean, range, standard error and number of samples for each station and parameter for the combined years 1970 and 1971 are presented (Table 3). Significant differences and similarities for each parameter at the various stations are indicated.

Brewery Creek was a special case because, as mentioned previously, it was dammed in August, 1971. With the loss of current, many nutrients and other compounds concentrated, resulting in the significantly higher values indicated in Table 3.

Water temperatures recorded at any one time were similar for all stations. Comparison of average water temperatures taken in the field to those obtained from the Britannia Purification Plant for selected months showed no significant differences. Since water temperatures were not recorded consistently in the field over the entire study period, temperatures recorded at the purification plant were accepted as a measure of the temperature of the river. Temperatures ranged from 1.7° C to 23.3° C for 1970 and 1971. Monthly average values for 1970 and 1971 are given (Appendix 2).

Distribution and Movements

Distribution of channel catfish was determined by examining gill and trap netting records. Since gill and trap nets are both selective for different species and sizes of fish, data from each was

Table 3 Chemical and physical characteristics of Ottawa River water at each station for the years 1970 and 1971 combined. Bottom and surface values are averaged. All units are expressed in ppm unless otherwise indicated. For each parameter and station, the range is followed by the mean, standard error and number of samples.

Chemical Parameters	Stations				
	Britannia Bay	Brewery Creek	New Edinburgh Canoe Club	Upper CIP Channel	Lower CIP Channel
pH	6.8-7.5 [1] 7.3 0.081 13	6.6-7.5 [2] 6.9 0.052 17	6.7-7.3 [2] 7.0 0.034 18	6.5-7.1 [2] 6.8 0.055 14	6.5-7.0 [3] 6.7 0.057 11
Dissolved O_2	7.0-13.0 [1] 9.6 0.445 13	0.6-12.0 [1] 8.1 0.751 17	7.0-11.0 [1] 9.0 0.277 18	7.5-10.0 [1] 8.9 0.278 14	5.0-9.5 [1] 7.8 0.532 11
Dissolved CO_2	4.0-10.0 [1] 7.4 0.783 12	5.0-20.0 [1,2] 10.5 0.943 16	5.0-10.0 [1,2] 9.1 0.422 17	5.0-11.0 [1,2] 9.2 0.505 14	10.0-17.5 [2] 11.5 0.829 10
Alkalinity	22.0-55.0 [1,2] 34.1 2.409 14	27.0-89.5 [1] 44.9 4.888 15	21.5-51.5 [1,2] 32.4 2.369 14	20.0-38.5 [2] 27.1 1.424 15	20.5-43.5 [2] 28.7 1.769 15
Chloride	1.6-8.8 [1,2] 4.3 0.556 14	2.3-48.0 [1] 11.2 2.707 16	1.7-8.8 [2] 4.1 0.573 14	1.7-7.0 [2] 3.9 0.441 16	1.9-9.0 [1,2] 4.8 0.626 15
Chlorine	0.001-0.023 [1] 0.009 0.005 4	0.001-0.004 [1] 0.003 0.001 4	0.003-0.004 [1] 0.003 0.000 2	0.001-0.007 [1] 0.003 0.001 6	0.002-0.015 [1] 0.007 0.002 7

Hardness (Ca)	15.0-37.0 [1]	17.5-70.0 [1]	14.5-43.0 [1]	13.5-45.0 [1]	12.0-45.0 [1]
	22.8	31.9	23.8	20.5	24.9
	1.735	4.218	2.290	2.059	2.643
	14	16	13	16	15
Hardness (Total)	22.0-51.3 [1]	25.0-90.5 [1]	20.5-54.5 [1]	20.5-70.0 [1]	24.0-70.0 [1]
	34.4	48.1	37.5	33.2	38.7
	2.838	5.749	3.691	3.805	3.825
	12	14	12	14	13
Iron	0.01-0.28 [1,2]	0.00-0.25 [1]	0.00-0.20 [2]	0.04-0.23 [1,2]	0.02-0.20 [1,2]
	0.08	0.14	0.06	0.10	0.10
	0.023	0.024	0.013	0.018	0.016
	12	14	14	13	15
Nitrite Nitrogen	0.003-0.048 [1]	0.004-0.035 [1]	0.003-0.050 [1]	0.003-0.080 [1]	0.002-0.083 [1]
	0.013	0.017	0.016	0.024	0.023
	0.003	0.002	0.004	0.007	0.007
	14	15	13	14	15
Phosphorus	0.09-0.33 [1]	0.13-2.53 [2]	0.05-0.24 [1]	0.01-0.25 [1]	0.09-0.25 [1]
	0.17	0.80	0.18	0.16	0.16
	0.017	0.255	0.034	0.017	0.013
	15	15	14	15	15
Sulphate	5.5-20.0 [1]	8.0-21.0 [1]	5.5-25.5 [1]	8.0-33.0 [1]	9.5-32.0 [1]
	12.2	16.0	13.5	16.7	17.5
	1.064	1.070	1.478	1.605	1.790
	14	15	13	16	14
Physical Parameters					
Turbidity (Jackson turbidity units)	8.5-45.0 [1,2]	10.0-40.0 [1,2]	9.5-20.5 [1,2]	8.0-33.0 [1,2]	16.5-41.0 [1]
	21.9	23.6	16.0	16.7	29.0
	3.255	3.196	1.187	1.605	2.282
	14	15	14	16	15

1, 2, 3- Unlike superscripts in a horizontal row indicate that the parameter is significantly different.

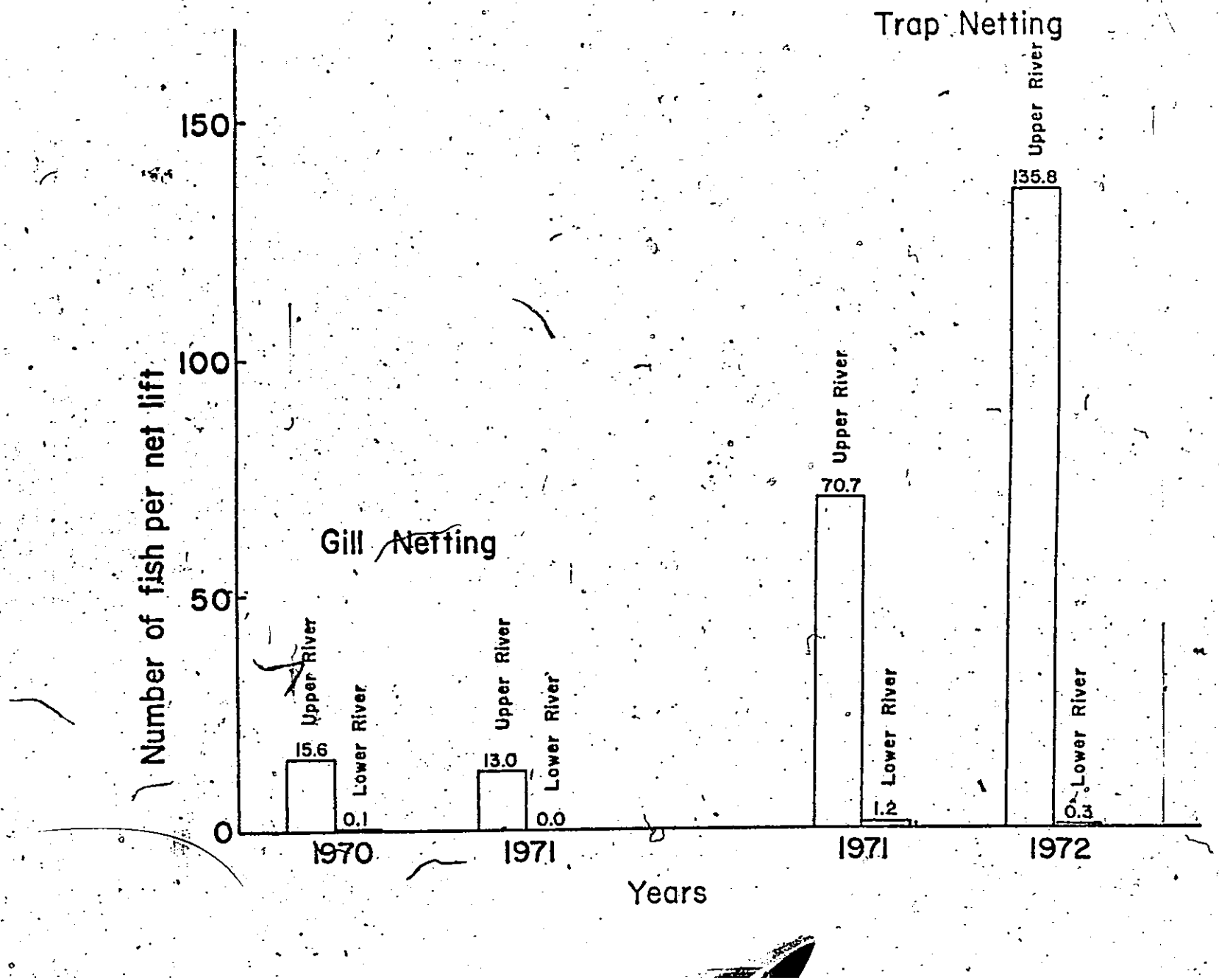
treated separately. For each type of net, the number of fish caught, percent of total catch and number of fish caught per net lift for each species and year are given separately for the upper and lower river (Appendices 3 & 4). From this, the number of channel catfish caught per net lift for each net, year and sector is given (Fig. 4). By observation, it is very clear that channel catfish are found in greater numbers in the upper river. This is further supported by the number of channel catfish caught in the respective areas, namely 2,009 in the upper river to 22 in the lower river. The shorter netting period in 1972 may have resulted in the apparent increase in abundance for this year when compared to 1971.

After tagging 530 channel catfish, tag returns numbered only three. One was recaptured in the same location the day after being tagged. The other two fish were caught by anglers. The first was caught one week after, the second four months after being tagged having travelled approximately five and 16 kilometres upriver respectively. The few tag returns make any quantitative estimates of movement or population size impossible to make.

Relationships Between Fork and Total Lengths

Fork length (F.L.) is used consistently throughout this study as a means of grouping fish. Since total lengths (T.L.) are frequently used by other researchers, it is necessary to determine conversion factors which can be used to convert one length measurement to another. This was determined by regressing one type of measurement on another type. The resulting relationships and the number of individuals used to determine these are as follows:

Fig. 4. Number of channel catfish per gill and trap net lift in the upper and lower sectors of the Ottawa River. Netting from May to October, 1970 and 1971, and from May and June, 1972.


Trap Netting
Gill Netting
Number of fish per net lift
150
100
50
0
Upper River
Lower River
15.6
0.1
13.0
0.0
70.7
1.2
135.8
0.3
1970
1971
1971
1972
Years

Relationship	N
F.L. = -2.49 + 0.95 T.L.	125
T.L. = 2.97 + 1.04 F.L.	125

These relationships are given in terms of cm.

Age and Growth

Age and growth studies of channel catfish from the Ottawa River were undertaken to provide information on their growth in these waters. Another objective was to compare the growth of channel catfish found at these northern latitudes to that of this species found at more southern latitudes.

Length frequency relationships were based on actual measurements as opposed to calculated ones. Relationships were determined for each age class of fish obtained from the upper (Table 4) and lower (Table 5) rivers.

In the upper river, at least 50 percent of the total catch of channel catfish had fork lengths ranging from 36.1 cm - 42.0 cm or were from 8 - 11 years of age. Fish having fork lengths less than 22.0 cm or ages less than three years were not caught. Fish with fork lengths and ages greater than 46.0 cm and 13 years were not very abundant in the sample of the population examined.

Few channel catfish were caught in the lower river. Of those present 81 percent had fork lengths and ages between 42.1 cm - 56.0 cm and 10 - 13 years respectively.

For each age class given in the above mentioned tables the range of lengths was quite broad resulting in a great deal of overlap. Consequently, the Peterson method of age determination from the length-frequency distribution (Tesch 1968) could not be used to aid in validating the aging technique.

Table 4 Age - fork length frequency distribution of 827 channel catfish, sexes combined, caught from May, 1970 to June, 1972 in the upper sector of the Ottawa River.

Fork Length Range (cm)	Age Group																N
	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	
22.1-24.0	6	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7
24.1-26.0	1	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11
26.1-28.0	1	8	4	3	–	–	–	–	–	–	–	–	–	–	–	–	16
28.1-30.0	1	4	8	1	2	–	–	–	–	–	–	–	–	–	–	–	16
30.1-32.0	–	–	3	6	9	2	2	1	–	–	–	–	–	–	–	–	23
32.1-34.0	–	–	1	9	11	16	4	2	1	–	–	–	–	–	–	–	44
34.1-36.0	–	–	–	2	20	27	16	11	3	–	–	–	–	–	–	–	79
36.1-38.0	–	–	–	1	6	53	48	20	8	1	1	–	–	–	–	–	138
38.1-40.0	–	–	–	–	1	15	55	56	39	9	3	–	–	–	–	–	178
40.1-42.0	–	–	–	–	1	5	19	37	59	37	10	2	–	–	–	–	170
42.1-44.0	–	–	–	–	–	1	4	10	22	26	14	1	–	–	–	–	78
44.1-46.0	–	–	–	–	–	–	2	6	6	5	10	4	–	–	–	–	33
46.1-48.0	–	–	–	–	–	–	–	2	3	2	4	2	1	–	–	–	14
48.1-50.0	–	–	–	–	–	–	–	1	1	2	3	–	1	–	–	–	8
50.1-52.0	–	–	–	–	–	–	–	–	–	–	2	3	1	1	–	–	7
52.1-54.0	–	–	–	–	–	–	–	–	–	2	–	–	–	1	–	–	3
54.1-56.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
56.1-58.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
58.1-60.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
60.1-62.0	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1
N	9	23	16	22	50	119	150	146	142	84	48	12	3	2	–	1	827
Mean Fork Length	24.1	26.5	29.3	31.8	34.2	36.2	38.1	39.5	40.7	42.4	44.2	46.0	49.6	52.0	–	59.2	

Table 5 Age - fork length frequency distribution of 21 channel catfish, sexes combined, caught from May, 1970 to June, 1972 in the lower sector of the Ottawa River.

Fork length Range (cm)	Age group											N
	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	
22.1-24.0	-	-	-	-	-	-	-	-	-	-	-	0
24.1-26.0	-	-	-	-	-	-	-	-	-	-	-	0
26.1-28.0	-	-	-	-	-	-	-	-	-	-	-	0
28.1-30.0	-	-	-	-	-	1	-	-	-	-	-	1
30.1-32.0	-	-	-	-	-	-	-	-	-	-	-	0
32.1-34.0	-	-	-	-	-	-	-	-	-	-	-	0
34.1-36.0	-	-	-	-	-	-	1	-	-	-	-	1
36.1-38.0	-	-	-	-	-	-	-	-	-	-	-	0
38.1-40.0	-	-	-	-	1	-	-	-	-	-	-	1
40.1-42.0	-	-	-	-	-	-	-	-	-	-	-	0
42.1-44.0	-	-	-	-	-	-	-	3	-	1	1	5
44.1-46.0	-	-	-	-	-	-	1	-	1	-	-	2
46.1-48.0	-	-	-	-	-	-	-	1	-	-	-	1
48.1-50.0	-	-	-	-	-	-	-	2	1	-	-	3
50.1-52.0	-	-	-	-	-	-	-	-	1	-	1	2
52.1-54.0	-	-	-	-	-	-	-	1	1	1	-	3
54.1-56.0	-	-	-	-	-	-	-	-	-	1	-	1
56.1-58.0	-	-	-	-	-	-	-	-	-	-	-	0
58.1-60.0	-	-	-	-	-	-	-	-	-	-	-	0
60.1-62.0	-	-	-	-	-	-	-	-	-	-	-	0
62.1-64.0	-	-	-	-	-	-	-	-	-	-	-	0
64.1-66.0	-	-	-	-	-	-	-	-	-	-	-	0
66.1-68.0	-	-	-	-	-	-	-	-	-	-	1	1
N	0	0	0	0	1	1	2	7	4	3	3	21

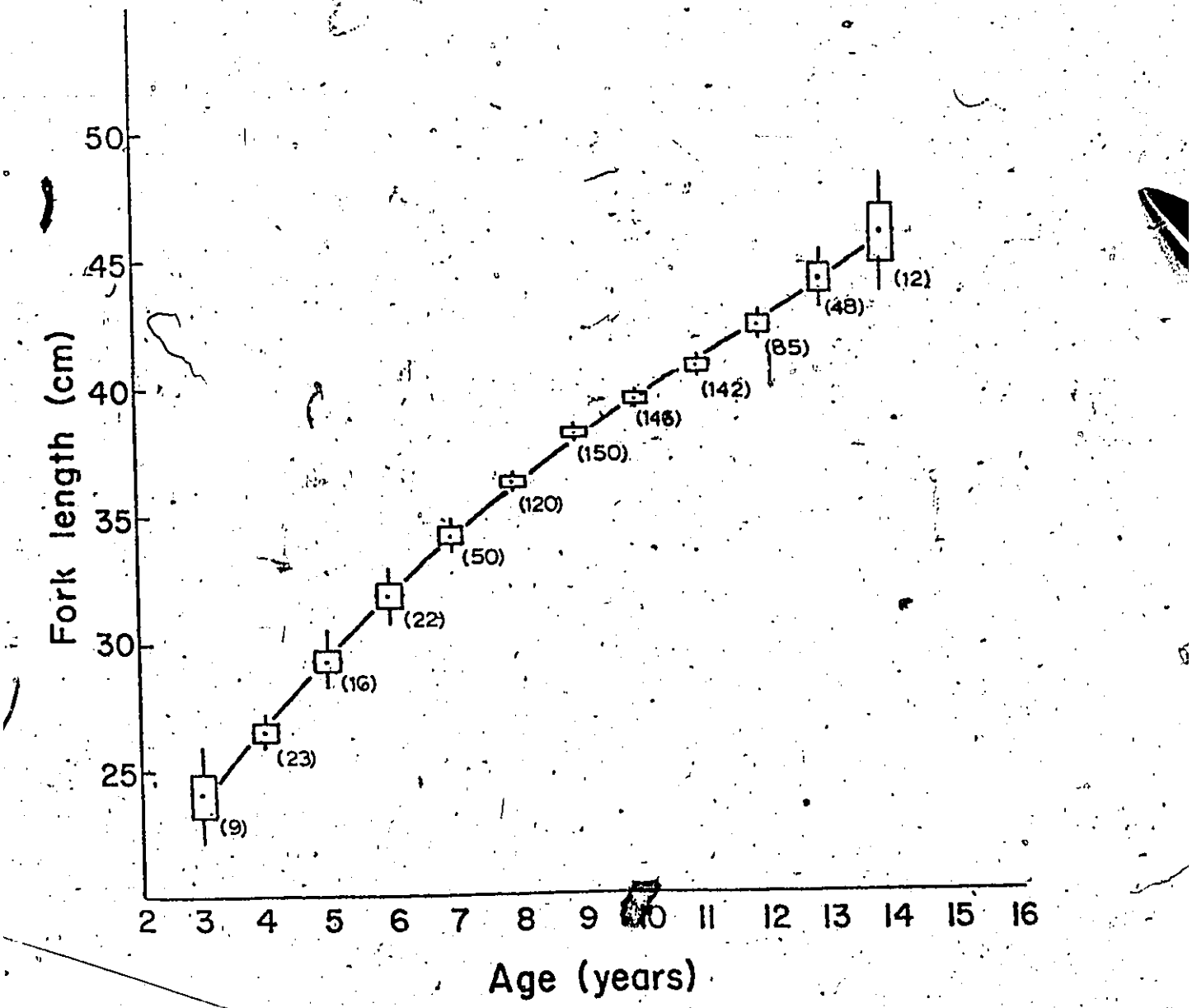
Age-length relationships were determined from the average lengths for each age group of channel catfish in the upper river. Average lengths were used instead of calculated lengths since the sample size for the former measurement was approximately four times greater than that for the latter. As previously mentioned, average lengths were not that different from calculated lengths. Consequently, differences between the average length found for successive age groups can be assumed as being indicative of growth.

Annual growth increments in length of Ottawa River channel catfish are greatest in youngest fish. Annual growth then declines with increasing age until age nine. After this age, growth increments are constant.

Growth increments for ages three and possibly four could in fact be greater than those given in Table 2. Variation in size was noted for each age group (Table 4). The possibility does exist that small individuals of the above mentioned age groups might not have been collected. Assuming this to be the case, then the actual calculated and average lengths for these fish would be somewhat smaller. This would then cause an actual increase in the growth increment over that indicated in Table 2. Growth of fish older than four years probably would not be affected since all individuals of those age groups would be large enough to be netted.

With one exception, the mean fork length for each age was not significantly different between males and females. The one exception was in year class 11 when males were significantly larger than females. Average lengths at each age indicated that males were slightly larger than females. Measurements for both sexes were combined and the age-length relationship determined (Fig. 5). The

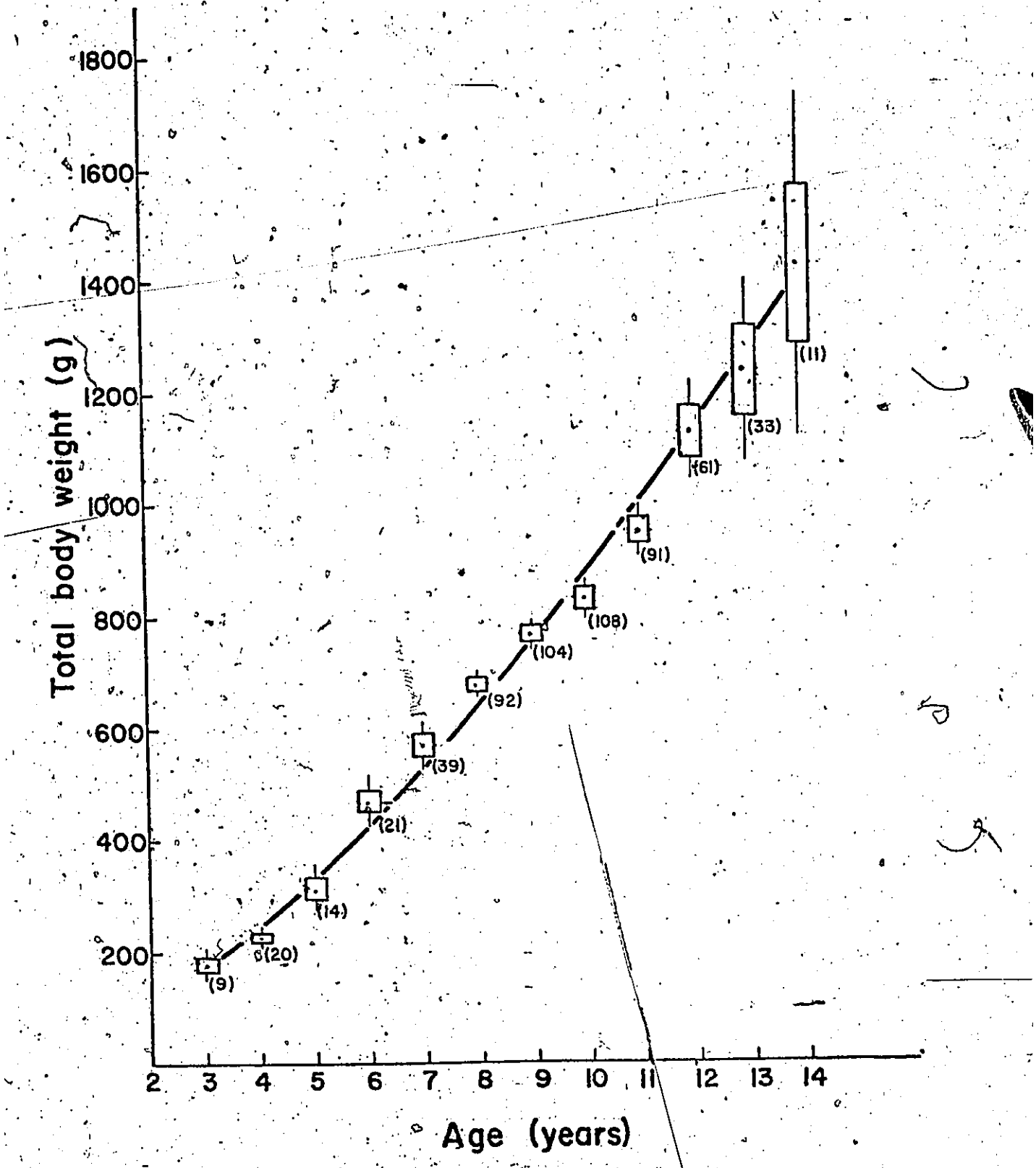
Fig. 5. Age-fork length relationship of 823 channel catfish, sexes combined, caught from May, 1970 to June, 1972 in the Ottawa River. The mean, standard error and 95% confidence limits for each age class are represented by a point, a rectangle and vertical lines respectively. Sample sizes are parenthesized.


Fork length (cm)
50
45
40
35
30
25
(9)
(23)
(16)
(22)
(50)
(120)
(150)
(146)
(142)
(85)
(48)
(12)
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Age (years)

equation of the line is best represented by log F.L. = 1.1668 + 0.43037 log age with fork length given in cm. The line that is drawn in Fig. 5 was determined from the above equation and then converted from logarithms to natural numbers. The broader confidence limits at both the younger and older age classes reflect the smaller sample size of fish in these age groups. Since fewer than five fish were found in each age group older than 14 years, these sample sizes were not large enough to facilitate statistical analyses. Consequently, these values were not included in the above mentioned figure. The mean, range, standard deviation, standard error and number of fish for sexes separate and combined are given (Appendix 5).

Age-weight relationships of fish in the upper river were determined from the average weights. No attempt was made to determine the calculated weight for each age because of the great variability of this measurement which occurs in fish throughout the year. Sexes were combined and the age-weight relationship was determined (Fig. 6). The equation of the line which best describes this relationship is: log wt. = 1.540 + 1.405 log age. Weight is given in grams. The line that is drawn in Fig. 6 was determined from the above equation and then converted from logarithms to natural numbers. Older fish exhibited greater variation about the mean when compared with younger fish. With two exceptions, weights at each age for each sex were not significantly different. The two exceptions were in age classes 3 and 11. In both cases, males weighed more than females. The mean, range, standard deviation, standard error and the number of fish for sexes separate and combined are given (Appendix 6).

Fig. 6. Age-body weight relationship of 608 channel catfish, sexes combined, caught from May, 1970 to June, 1972 in the Ottawa River. The mean, standard error and 95% confidence limits for each age class are represented by a point, a rectangle and vertical lines respectively. Sample sizes are parenthesized.


Total body weight (g)
1800
1600
1400
1200
1000
800
600
400
200
2
3
4
5
6
7
8
9
10
11
12
13
14
Age (years)
(9)
(20)
(14)
(21)
(39)
(92)
(104)
(108)
(91)
(61)
(33)
(11)

The small sample size of channel catfish obtained from the lower river, makes comparisons of growth rate in terms of age-length, age-weight relationships statistically not valid. Raw data on lengths and weights at different ages for these fish is presented (Appendix 7).

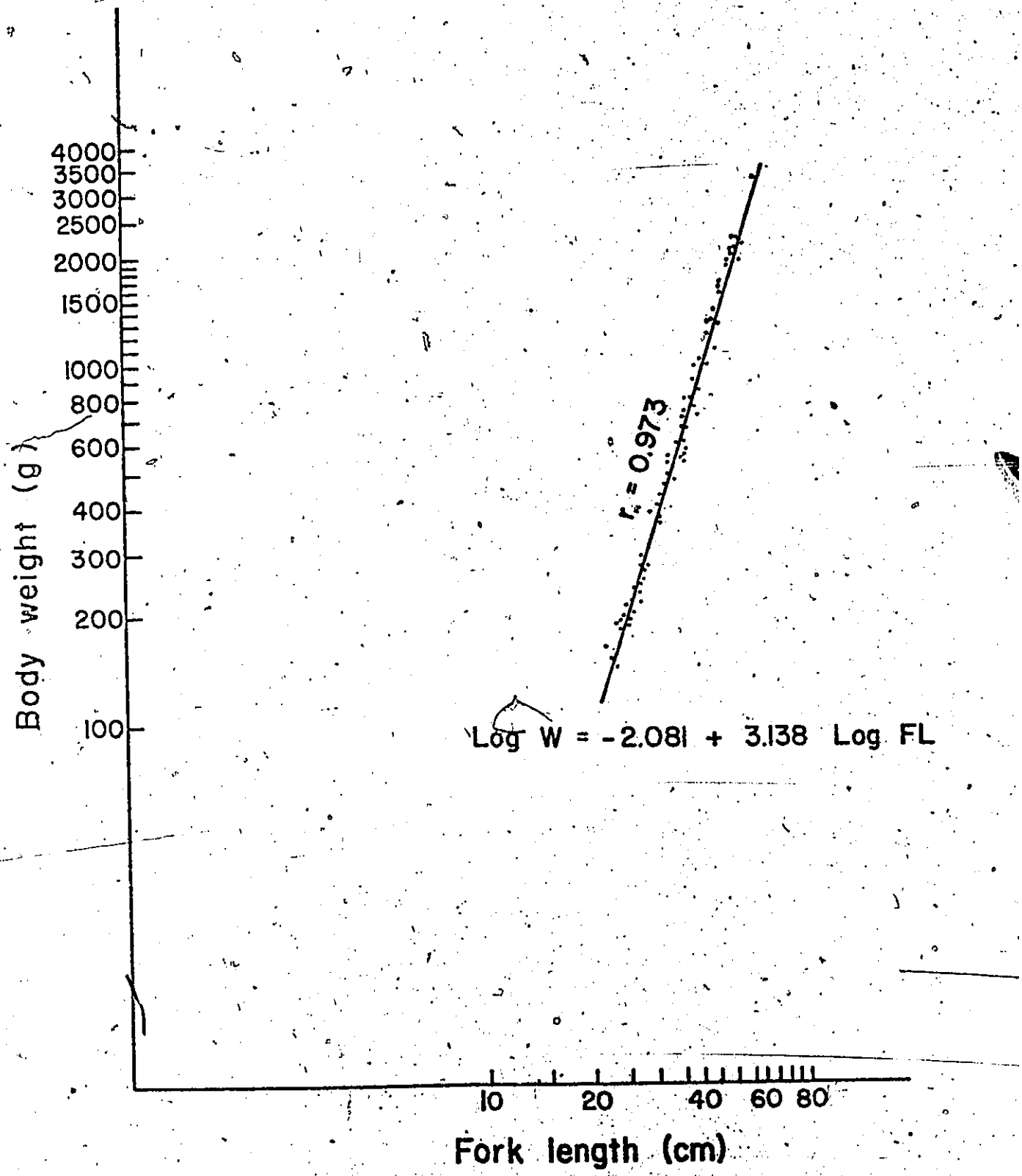
The length-weight relationship in fish can usually be adequately represented by $w = al^b$ (Tesch 1968). If transformed to logarithms the equation is log w = log a + b (log l). The symbols w and l represent the weight and length respectively, log a is the intercept of the line with the Y-axis and b is the regression coefficient.

All lengths and weights of channel catfish were first transformed to logarithms. Log weight was then regressed against log length by the method of least squares. Separate regression lines for length-weight relationships for males and females were determined. Comparison of the upper and lower class limits of these regression lines indicated that these overlapped and consequently length-weight relationships between males and females were not significantly different. The length-weight relationship for both sexes considered together was determined and the following equation was obtained; log w = -2.081 + 3.138 log l where w = weight in grams and l = fork length in centimetres. Upper and lower class limits about b were 3.185 and 3.092 respectively (p = 0.05). A significant correlation coefficient of r = 0.973 was found. Random length and weight values were plotted on double logarithmic paper and the regression line, as determined from the above equation, was drawn (Fig. 7).

Reproductive Biology

The reproductive biology was studied to see if channel catfish from the Ottawa River differed, in this respect, from catfish found

Fig. 7. Fork length - body weight relationship of 925 channel catfish, sexes combined, caught from May, 1970, to June, 1972 in the Ottawa River.


Body weight (g)
4000
3500
3000
2500
2000
1500
1000
800
600
400
300
200
100
r = 0.973
Log W = -2.081 + 3.138 Log FL
10
20
40
60
80
Fork length (cm)

at more southern latitudes.

In the upper river channel catfish population, the proportion of mature females to males was approximately 1.2:1.0 while the proportion of immature females to males was 0.34:1.0. If mature and immature fish are considered together, a proportion of 1.0:1.0 is obtained for the sexes. With or without regard to state of maturity, the proportion of one sex over the other was found to change from month to month. Fluctuations such as these indicate that no one sex is predominant for any one time of the year. Numbers and percentages of each sex on a monthly basis are given (Table 6).

Females matured earlier than males when age and size are both considered. Results obtained are summarized (Table 7). The percentages of immature to mature fish, sexes separate, are indicated. Females were all mature by age six; whereas, all males matured by age eleven. For at least 50 percent of one sex to be mature, females were five years of age to the males six. Females were all mature before attaining a fork length of 33.0 cm whereas males required a fork length of 45.0 cm to acquire the same status. For 50 percent of females and males to be mature, fork lengths of 29.0 cm and 33.0 cm respectively had to be attained.

Seasonal changes in gonad maturity are directly related to changes in gonad weight. The gonadosomatic index (G.S.I.) or coefficient of maturity (Nikolskii 1963) was determined on a monthly basis in 1971 for each sex (Fig. 8). Actual values including sample sizes are given (Appendix 8).

Although no channel catfish were caught which had roe or milt "running", spawning can be assumed as having taken place in late June and early July as determined from the gonadosomatic indices (Fig. 8).

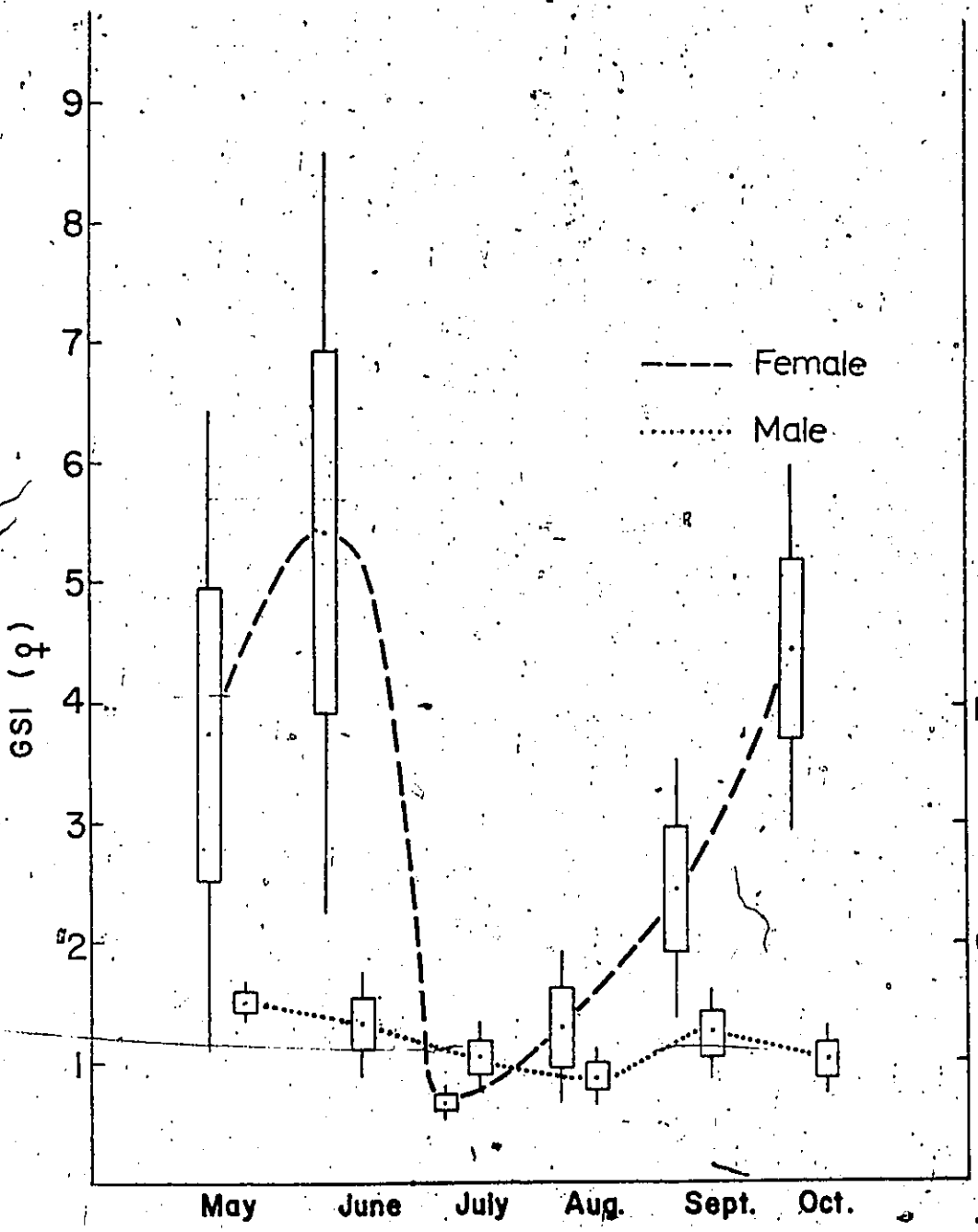
Table 6. Monthly variations in the state of maturity of channel catfish from the Ottawa River.

Month	Immature				Mature				Immature and mature combined			
	Female		Male		Female		Male		Female		Male	
	%	N	%	N	%	N	%	N	%	N	%	N
May	20.0	1	80.0	4	60.6	20	39.4	13	55.2	21	44.7	17
June	50.0	4	50.0	4	45.2	28	54.8	34	45.7	32	54.3	38
July	28.6	2	71.4	5	60.2	53	39.8	35	61.7	55	44.4	40
August	25.0	4	75.0	12	46.6	41	53.4	47	43.3	45	56.7	59
September	8.3	1	91.7	11	57.7	30	42.3	22	48.4	31	51.6	33
October	0.0	0	100.0	1	55.7	39	44.3	31	55.0	39	45.0	32

Table 7. Age and fork length variations in the state of maturity of channel catfish from the Ottawa River.

	Female				Male			
	Immature		Mature		Immature		Mature	
Age	%	N	%	N	%	N	%	N
3	100.0	3	–	–	100.0	5	–	–
4	60.0	6	40.0	4	100.0	8	–	–
5	33.3	2	66.7	4	100.0	5	–	–
6	11.2	1	88.8	8	33.3	2	66.7	4
7	–	–	100.0	16	38.5	5	61.5	8
8	–	–	100.0	37	13.3	4	86.7	26
9	–	–	100.0	34	18.2	6	81.8	27
10	–	–	100.0	27	6.7	2	93.3	28
11	–	–	100.0	24	–	–	100.0	36
12	–	–	100.0	27	–	–	100.0	14
13	–	–	100.0	9	–	–	100.0	11
14	–	–	100.0	8	–	–	100.0	6
15	–	–	100.0	1	–	–	100.0	1
16	–	–	–	–	–	–	100.0	2
17	–	–	–	–	–	–	–	–
18	–	–	100.0	1	–	–	–	–
Fork length								
21.0-24.9	83.3	5	16.7	1	100.0	3	–	–
25.0-28.9	66.7	6	33.3	3	100.0	11	–	–
29.0-32.9	5.9	1	94.1	16	80.0	8	20.0	2
33.0-36.9	–	–	100.0	47	28.2	11	71.8	28
37.0-40.9	–	–	100.0	95	4.8	3	95.2	63
41.0-44.9	–	–	100.0	30	1.8	1	98.2	55
45.0-48.9	–	–	100.0	8	–	–	100.0	15
49.0-52.9	–	–	100.0	10	–	–	100.0	6
53.0-56.9	–	–	–	–	–	–	100.0	1
57.0-60.9	–	–	100.0	1	–	–	100.0	1

Fig. 8. Monthly gonadosomatic indices of female and male channel catfish netted in the Ottawa River in 1971. The mean, standard error and 95% confidence limits for both sexes on a monthly basis are represented by a point, a rectangle and vertical lines respectively.


9
8
7
6
5
4
3
2
1
GSI (♀)
Female
Male
1.0
0.5
GSI (♂)
May
June
July
Aug.
Sept.
Oct.

Fecundity can best be described as the number of ripening eggs found in the female just prior to spawning. For all size classes and ages considered together, the average fecundity for the 16 channel catfish examined was 6,480 eggs. Numbers ranged from 3,730 to 11,500 eggs. Fork lengths and ages of these fish ranged from 36.3 cm to 51.8 cm and 9 to 14 years respectively. A significant and positive correlation ($0.01>r>0.001$) existed for fecundity and fish size. Fecundity and age were not significantly correlated ($r>0.1$). Average fecundities for different sized fish are given (Table 8).

Average egg diameters ranged from 2.55 mm to 4.18 mm. Mean egg diameters increased slightly with larger fish (Table 8). The average egg diameter from the seven fish caught in May was 2.87 mm as opposed to a value of 3.61 mm from the nine fish obtained in June. Since channel catfish were assumed to spawn in June, this last value can be taken as the average size of the oocytes at time of spawning.

Stomach Content Analysis

Examination of the food of channel catfish was undertaken in order that new knowledge of their feeding habits in eastern Canada might be provided. Another objective was to see if food could possibly be responsible for the local distribution of this fish.

From the 267 fish with food in their stomachs, 255 of these were from the upper river while 12 were from the lower river. Unless otherwise stated, the results indicated below are based on the stomach content analyses from upper river fish.

Stomach content analyses reveal that channel catfish feed upon a wide variety of organisms (Appendix 9). The more important food items of each of the following groups: insects, crustaceans, molluscs, fish

Table 8 Fork length variations in the average fecundities and egg diameters of channel catfish from the Ottawa River.

Fork length (cm)	Average fecundity	Average egg diameter (mm)	N
36.0-39.9	4,835.7	3.18	3
40.0-43.9	5,512.6	3.25	8
44.0-47.9	8,292.0	3.26	2
48.0-51.9	9,518.3	3.41	3

and miscellaneous vertebrates and invertebrates are given in Tables 9 to 13 respectively. Those organisms listed in Appendix 9 but not in the above mentioned tables are present only in trace quantities.

The proportions of the insect orders forming the major part of the diet (Table 9) were all relatively constant, with one exception, throughout the entire study period. The hymenopteran species, Lasius umbratus, occurred only in stomachs of fish caught in the last week of August, 1971.

The proportions of crustaceans, molluscs, and fish in the diet did not alter during the study period.

All large pelecypods ingested had no shells so actual identification was impossible. These were most probably, Elliptio complanatus and Lampsilis radiata, the only two large pelecypods found in the study area (Mackie 1971). Shells were present on the remainder of the pelecypods and all of the gastropods so these organisms were identifiable.

Vegetation, found in 62 stomachs or 24.5 percent of those fish having food items present, provided 15.3 percent of the total volume of food organisms ingested. Algae, occurring in 80.6 percent of the stomachs which contained vegetation was the most predominant form of vegetation found in stomachs. The waterweed, Elodea canadensis and the horsetail, Equisetum, found in 16.1 percent and 3.0 percent respectively of the stomachs containing vegetation formed the rest of the vegetation. The internal structure of the algae found in stomachs was somewhat altered, possibly from digestive acids and enzymes and/or preservative making identification difficult. In light of this last finding, further breakdown in the classification of vegetation was not attempted. Also included in the vegetation were diatoms. Quantitative and qualitative estimates of diatoms were not attempted since those

Table 9. Average number, percent frequency of occurence, percent total volume and percent insect volume of the major groups of insects found in the stomachs of channel catfish from the Ottawa River.

Insects	No. of stomachs containing insects	Average no. of organisms	Frequency of occurrence, %	Total volume %	Insect volume %
Total insects	177	164.9	69.4	8.4	100.0
Ephemeroptera	96	14.9	37.6	2.5	29.8
Hexagenia sp	81	16.5	31.8	2.1	25.4
Hymenoptera	31	871.9	12.2	5.0	59.6
Lasius umbratus	30	900.9	11.8	5.0	59.5
Trichoptera	76	5.6	29.8	0.7	8.0
Oecetis sp	14	12.8	5.5	0.08	0.9
Odonata (Zygoptera)	19	2.6	7.5	<0.05	0.5
Enallagma sp	11	3.0	4.3	<0.05	0.4
Neuroptera	2	1.0	0.8	0.00	0.0
Coleoptera	23	2.3	9.0	0.1	1.4
Hemiptera	18	3.1	7.1	0.08	0.9
Corixidae	14	3.1	5.5	<0.05	0.06
Lepidoptera	3	1.0	1.2	<0.05	0.2
Homoptera	4	1.0	1.6	0.00	0.0
Diptera	43	6.7	16.9	0.00	0.0
Tendipedidae	39	4.9	15.3	0.00	0.0

Table 10. Average number, percent frequency of occurrence, percent total volume and percent crustacean volume of the major groups of crustaceans found in the stomachs of channel catfish from the Ottawa River.

Crustaceans	No. of stomachs containing crustaceans	Average no. of organisms	Frequency of occurrence %	Total volume %	Crustacean volume %
Total crustaceans	91	49.1	35.6	2.4	100.0
Amphipoda	78	54.5	30.6	1.8	74.1
Gammaridae (Gammarus fasciatus)	74	50.8	29.0	1.8	72.9
Talitridae (Hyalella azteca)	40	11.6	15.7	<0.05	1.2
Isopoda	11	18.2	4.3	0.1	5.1
Decapoda	11	1.1	4.3	0.5	20.9

Table 11. Average number, percent frequency of occurrence, percent total volume and percent mollusc volume of the major groups of molluscs found in the stomachs of channel catfish from the Ottawa River.

Molluscs	No. of stomachs containing molluscs	Average no. of organisms	Frequency of occurrence %	Total volume %	Molluscan volume %
Total molluscs	99	8.6	38.7	6.6	100.0
Gastropoda	80	9.6	31.4	1.8	27.7
Physidae (Physa)	45	14.3	16.9	1.8	27.0
Valvatidae (Valvata)	18	1.9	7.1	<0.05	0.07
Planorbidae (Lymnaea)	22	1.6	8.6	<0.05	0.1
Amnicolidae (Amnicola)	34	2.3	13.3	0.00	0.00
Pelecypoda	38	2.1	14.9	4.8	72.3
Sphaeridae	15	3.4	5.9	<0.05	0.4
Unionidae	3	1.0	1.2	0.00	0.00
Unidentified (shell-less)	25	1.2	9.8	4.7	71.8

Table 12. Average number, percent frequency of occurrence, percent total volume and percent fish volume of the major groups of fish found in the stomachs of channel catfish from the Ottawa River.

Fish	No. of stomachs containing fish	Average no. of organisms	Frequency of occurrence %	Total volume %	Fish volume %
Total fish	46	1.2	18.0	47.7	100.0
Percidae	12	1.1	4.7	31.8	66.5
Perca flavescens	10	1.1	3.9	31.4	65.8
Etheostoma sp.	1	1.0	0.4	<0.05	0.06
Lepomis gibbosus	1	1.0	0.4	7.3	15.5
Hiodon tergisus	1	1.0	0.4	2.7	5.7
Coregonus artedii	1	1.0	0.4	1.2	2.4
Moxostoma sp.	1	1.0	0.4	0.3	0.6
Unidentified fish remains	30	1.2	11.8	5.7	9.3

Table 13 Average number, percent frequency of occurrence and percent total volume of miscellaneous vertebrates and invertebrates found in the stomachs of channel catfish from the Ottawa River.

	No. or stomachs containing food item	Average no. of organisms	Frequency of occurrence %	Total volume %
Miscellaneous vertebrates	6	1.0	1.6	0.9
Frogs	3	1.0	1.2	0.7
Feathers	1	1.0	0.4	<0.05
Unidentified vertebral columns	2	1.0	0.8	0.08
Miscellaneous invertebrates	36	5.3	1.4	0.2
Oligochaeta	6	5.0	2.4	0.2
Tubificidae (Peloscolex sp.)	2	1.0	0.8	0.0
Lumbricidae	3	7.7	1.2	0.2
Hirudinea	2	1.0	0.8	0.0
Glossiphonidae	1	1.0	0.4	0.0
Nematoda	17	3.7	6.7	0.0
Arachnida (Hydrachnidae)	2	1.0	0.8	0.0
Diplopoda	1	2.0	0.4	0.0
Chilopoda	2	1.0	0.8	0.0
Bryozoa	4	2.2	1.6	0.0

were considered to have been ingested incidentally.

Frogs, found in 1.2 percent of the stomachs containing food and giving 0.7 percent of the total volume of food organisms, were the most important miscellaneous vertebrate ingested. Other miscellaneous vertebrates included two unidentified vertebral columns and one feather. The feather was probably ingested incidentally.

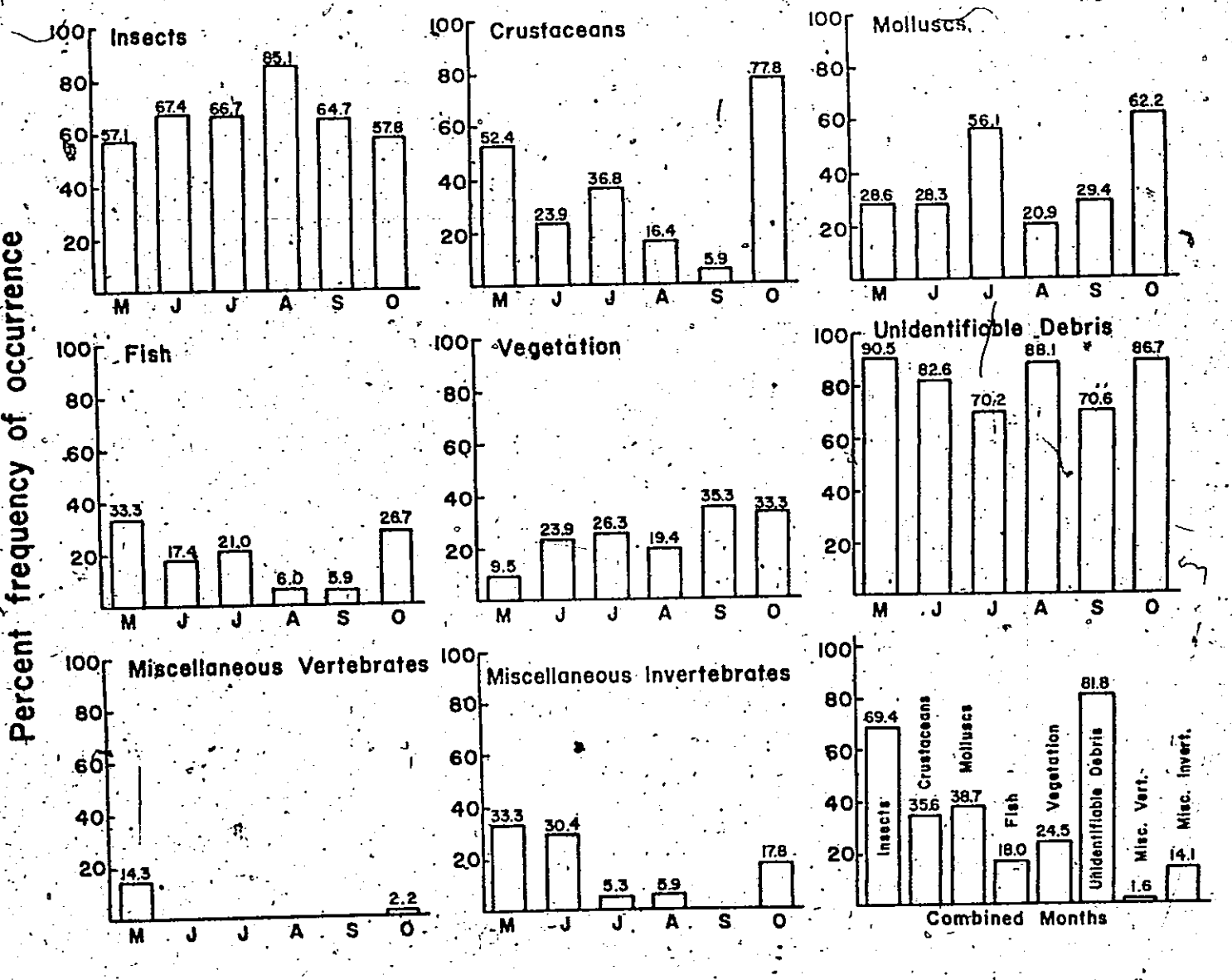
Earthworms of the family Lumbricidae were the most important miscellaneous invertebrate found in that they occurred in 1.2 percent of the stomachs with food present and gave 0.2 percent of the total volume of food organisms ingested. Since earthworms possess few hard parts, digestion of these organisms could be quite rapid leaving behind little trace of their presence. Since earthworms were present, this indicates that these could form a fairly large part of the diet. Nematodes occurred in 6.7 percent of the stomachs possessing food but did not represent any percentage of the total volume of food organisms consumed. Other miscellaneous invertebrates occurring in trace amounts are given (Table 13).

Unidentified fish eggs numbering 3,057 and giving a volume of 2.0 ml (0.1 percent of total volume of food organisms) were found in only one stomach (0.4 percent of the stomachs containing food).

Unidentified debris consisted primarily of partially digested, unrecognizable organisms, wood, mud, sand and a mucous-like substance usually coating partially digested organisms. Unidentified debris occurred in 81.8 percent of the stomachs containing food and gave 18.1 percent of the total volume of stomach contents.

Monthly variations in diet of upper river channel catfish are expressed as percent frequency of occurrence (Fig. 9) and percent

Fig. 9. Seasonal changes from May to October in the percentage occurrence of the major groups of food organisms found in the stoma of channel catfish.


Percent frequency of occurrence
Insects
57.1
67.4
66.7
85.1
64.7
57.8
Crustaceans
52.4
23.9
36.8
16.4
5.9
77.8
Molluscs
28.6
28.3
56.1
20.9
29.4
62.2
Fish
33.3
17.4
21.0
6.0
5.9
26.7
Vegetation
9.5
23.9
26.3
19.4
35.3
33.3
Unidentifiable Debris
90.5
82.6
70.2
88.1
70.6
86.7
Miscellaneous Vertebrates
14.3
2.2
Miscellaneous Invertebrates
33.3
30.4
5.3
5.9
17.8
M J J A S O
69.4
35.6
38.7
18.0
24.5
81.8
1.6
14.1
Insects
Crustaceans
Molluscs
Fish
Vegetation
Unidentifiable Debris
Misc. Vert.
Misc. Invert.
Combined Months

frequency of the total volume (Fig. 10). The above mentioned percentages for all major groups of food organisms over the entire study period are also illustrated in these two figures. These same percentages are also used to indicate the effect of catfish size on the type of food consumed. (Figs. 11 & 12).

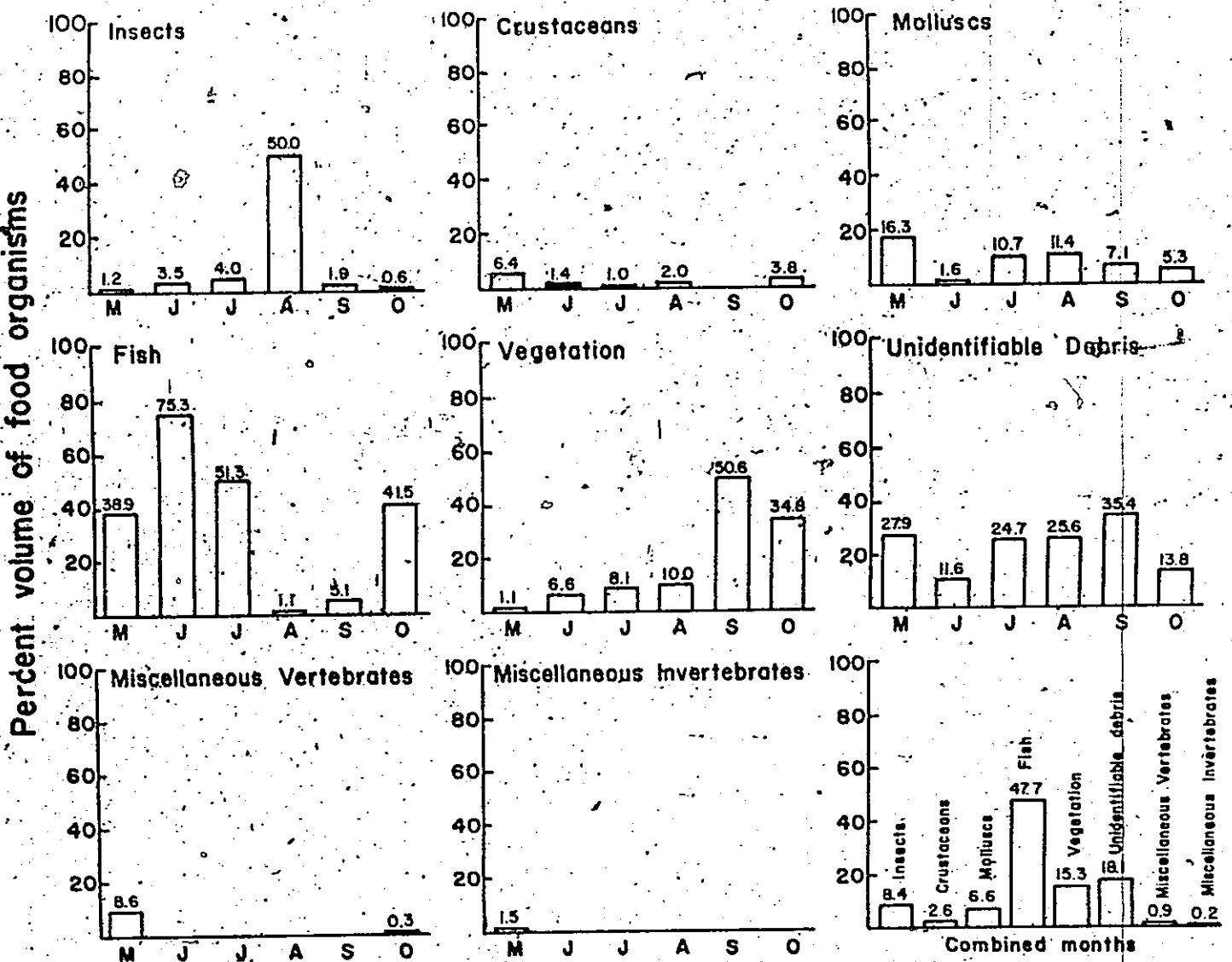
Only 12 fish caught in the lower river had any material in their stomachs. This comprised too small a sample size to permit a statistical comparison of food consumed by fish in the lower river with that ingested by fish in the upper river. Number, percent frequency and percent volume of the various items found in these channel catfish stomachs are given (Table 14). Insects, occurring in 36.4 percent of the stomachs gave less than 0.2 percent of the total volume, whereas forage fish were found in 27.3 percent of the stomachs and gave 71.0 percent of the total volume. The monocotyledonous and dicotyledonous seeds occurring in 45.5 percent of the stomachs and giving 15.3 percent of the total volume appeared to be peas, beans and corn. The origin of these seeds can probably be attributed to domestic sewage coming from local municipalities. Even though the sample size was small, these fish were caught at different times throughout the study period and, consequently, are not isolated cases.

Water Preference Experiments

The main purpose of these experiments was to determine if water quality was responsible for the relative absence of channel catfish in the lower river. Consequently, the preference of channel catfish for water obtained from either different parts of the lower river or from the upper river, namely Britannia Bay, was determined.

Control experiments in which similar water was used on both

Fig. 10. Seasonal changes from May to October in the percentage of the total volume of the major groups of food organisms found in the stomachs of channel catfish.


Percent volume of food organisms
Insects
1.2
3.5
4.0
50.0
1.9
0.6
Crustaceans
6.4
1.4
1.0
2.0
3.8
Molluscs
16.3
1.6
10.7
11.4
7.1
5.3
Fish
38.9
75.3
51.3
1.1
5.1
41.5
Vegetation
1.1
6.6
8.1
10.0
50.6
34.8
Unidentifiable Debris
27.9
11.6
24.7
25.6
35.4
13.8
Miscellaneous Vertebrates
8.6
0.3
Miscellaneous Invertebrates
1.5
Insects
Crustaceans
Molluscs
Fish
Vegetation
Unidentifiable debris
Miscellaneous Vertebrates
Miscellaneous Invertebrates
8.4
2.6
6.6
47.7
15.3
18
0.9
0.2
Combined months
M J J A S O
100
80
60
40
20

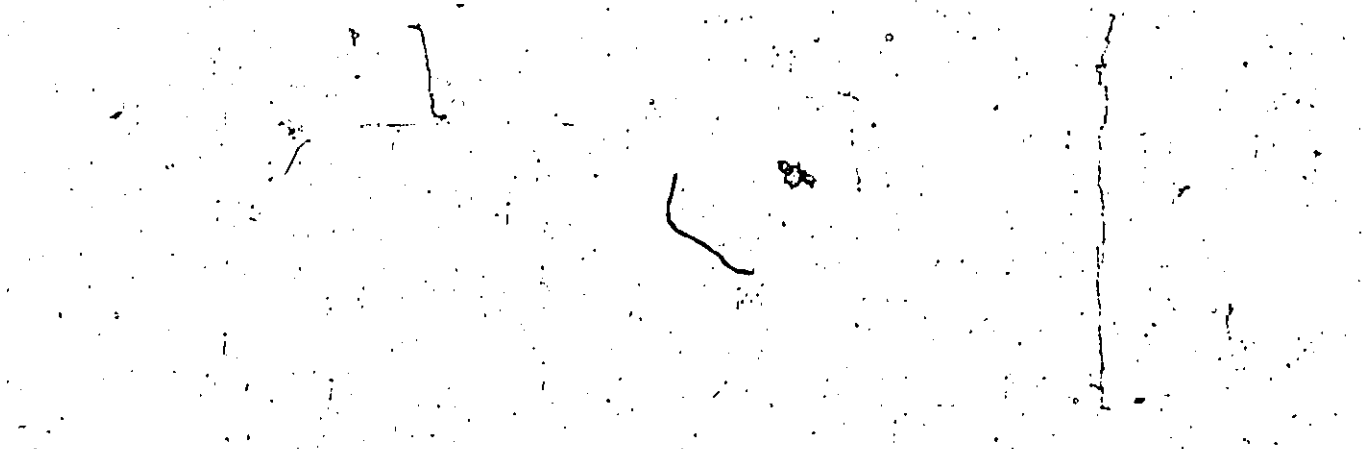
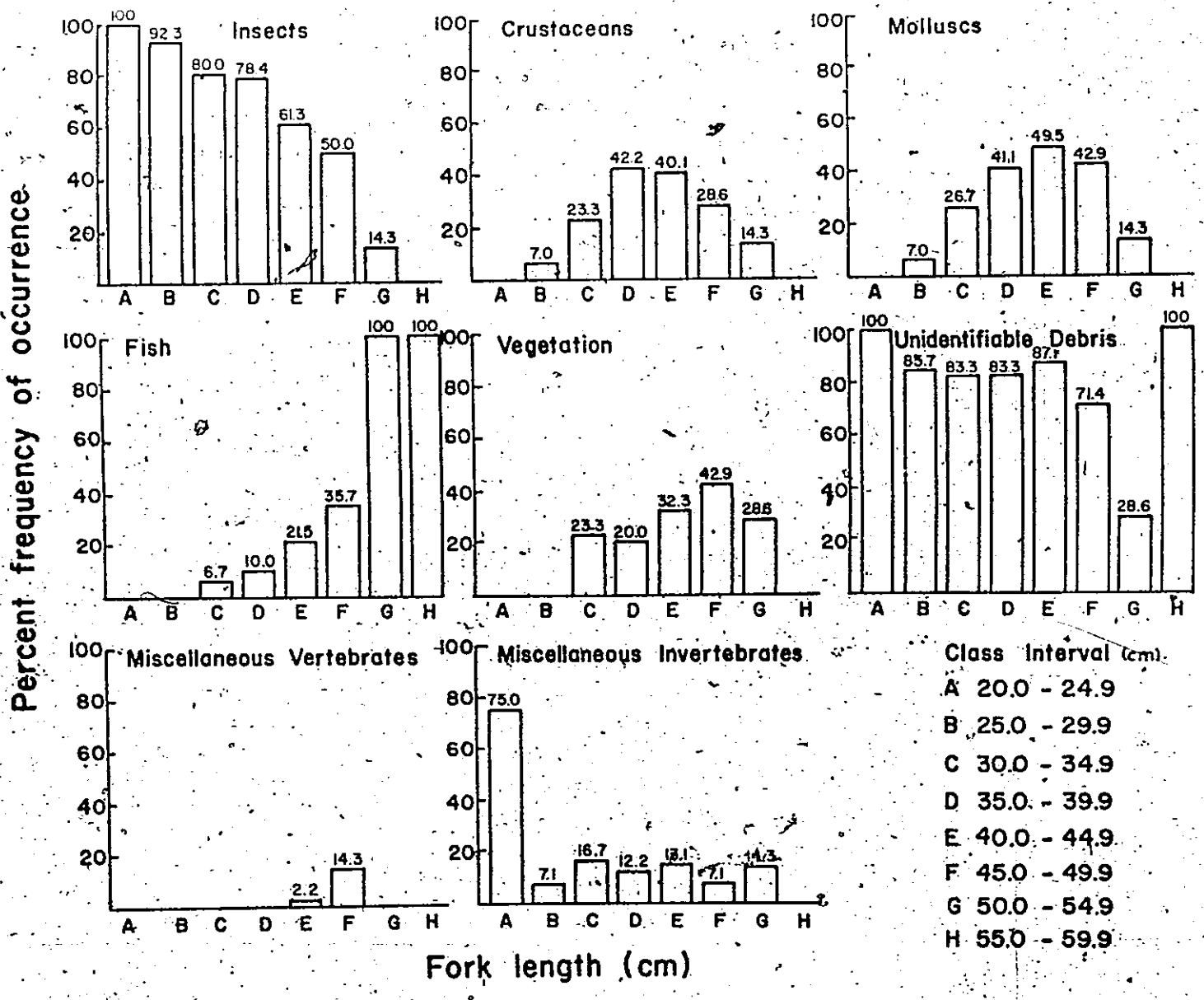


Fig. 11. Variations in channel catfish length and their effect on the percentage occurrence of the major groups of food organisms found in stomachs.



Class Interval (cm)

A 20.0 - 24.9
B 25.0 - 29.9
C 30.0 - 34.9
D 35.0 - 39.9
E 40.0 - 44.9
F 45.0 - 49.9
G 50.0 - 54.9
H 55.0 - 59.9

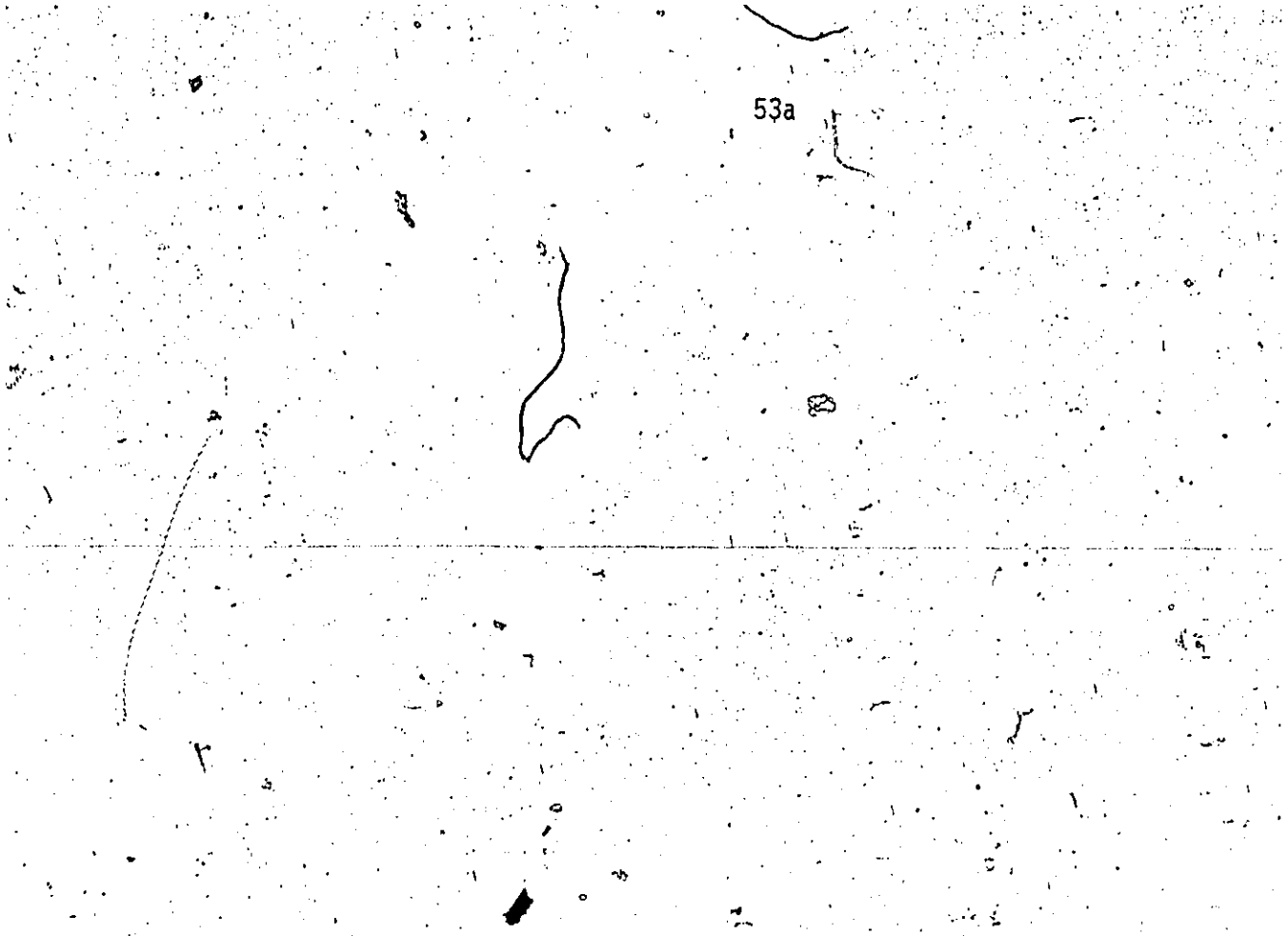


Fig. 12. Variations in channel catfish length and their effect on the percentage of the total volume of the major groups of food organisms found in stomachs.

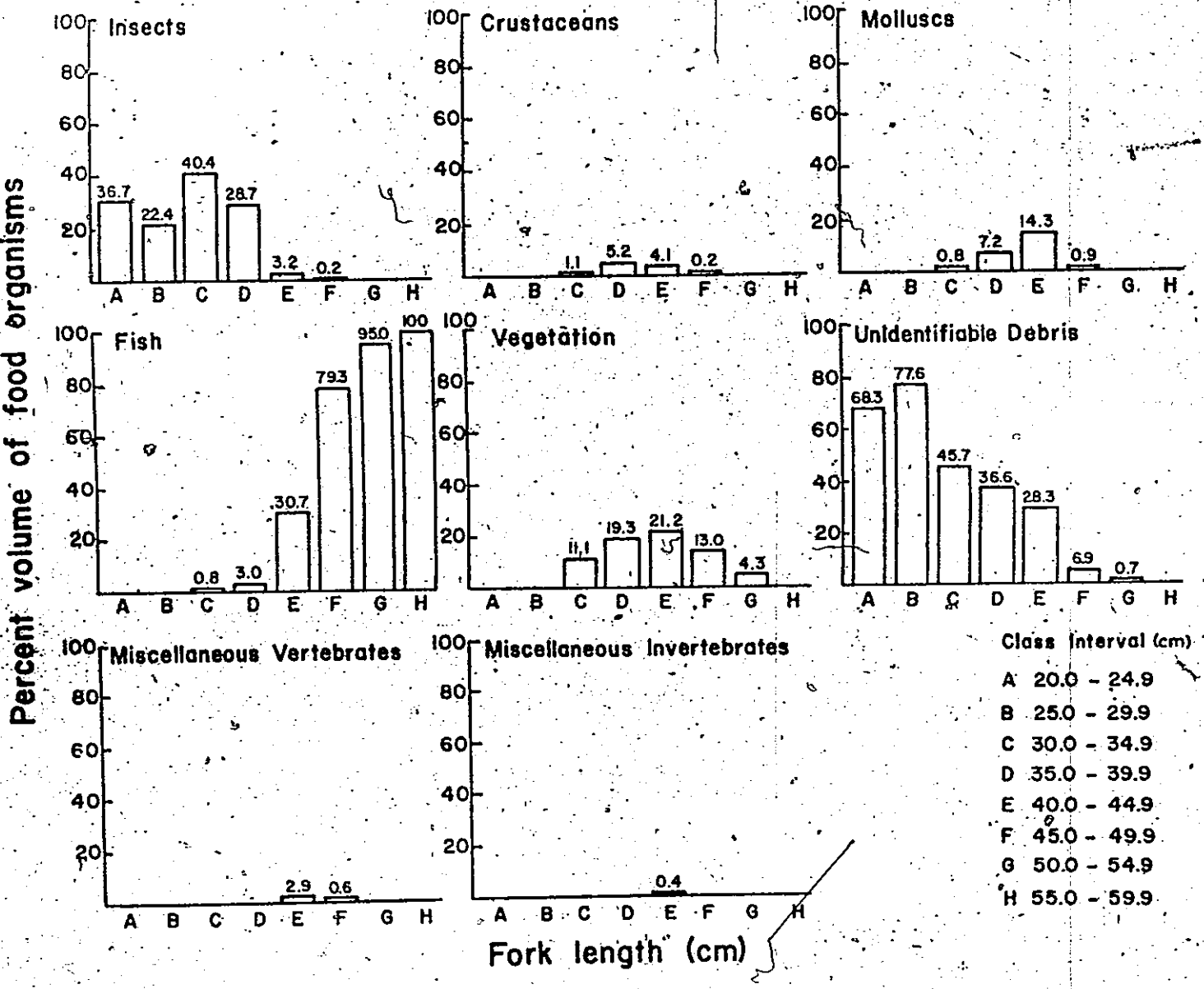

Insects
36.7
22.4
40.4
28.7
3.2
0.2
Crustaceans
1.1
5.2
4.1
0.2
Molluscs
0.8
7.2
14.3
0.9
Fish
0.8
3.0
30.7
79.3
95.0
100
Vegetation
11.1
19.3
21.2
13.0
4.3
Unidentifiable Debris
68.3
77.6
45.7
36.6
28.3
6.9
0.7
Miscellaneous Vertebrates
2.9
0.6
Miscellaneous Invertebrates
0.4
A B C D E F G H
100
80
60
40
20
Percent volume of food organisms
Fork length (cm)
Class Interval (cm)
A 20.0 - 24.9
B 25.0 - 29.9
C 30.0 - 34.9
D 35.0 - 39.9
E 40.0 - 44.9
F 45.0 - 49.9
G 50.0 - 54.9
H 55.0 - 59.9

Table 14. Number, percent frequency and percent volume of each item found in stomachs of channel catfish caught in the lower river.

Food item	N	%F	%Vol.
Insects	7	36.4	*
Coleoptera	1	9.1	*
Trichoptera	6	27.3	*
Hydropsyche sp.	1	9.1	*
Phryganea cinerea	1	9.1	*
Centipede	1	9.1	*
Fish	5	27.3	71.0
Perca flavescens (Perch)	3	18.2	49.2
Lepomis gibbosus (Pumpkinseed)	1	9.1	21.4
Moxostoma sp. (Sucker - scales)	-	9.1	*
Unidentified vegetation	-	18.2	1.4
Monocot-, Dicot- seeds	-	45.5	15.3
Bark	-	9.1	0.9
Unidentified debris	-	81.8	11.3

* - less than 0.2%

sides of the tank indicated that there were no significant differences in the amount of time spent in one chamber or the other when the paired Student's t-test was applied to the data ($p>0.10$).

Water from the lower C.I.P. channel was first compared with that obtained from the upper river. From the paired Student's t-test used in analyzing the data, no significant preference for either water type was found. Since no differences were noted, the assumption was made that channel catfish did not prefer water from one area over the other. Values obtained from the paired Student's t-test for the control and actual experiments are given (Appendix 10).

Chemical analyses of Britannia Bay and lower C.I.P. waters were similar to values presented in Table 2 for the same locations.

Since water from below the C.I.P. mill was considered to be of the poorest quality when compared to the other sites in the study area (Table 2), and since no preferences was noted for waters from the upper river or from this polluted area, no further experiments were carried out using waters from other parts of the lower river.

DISCUSSION

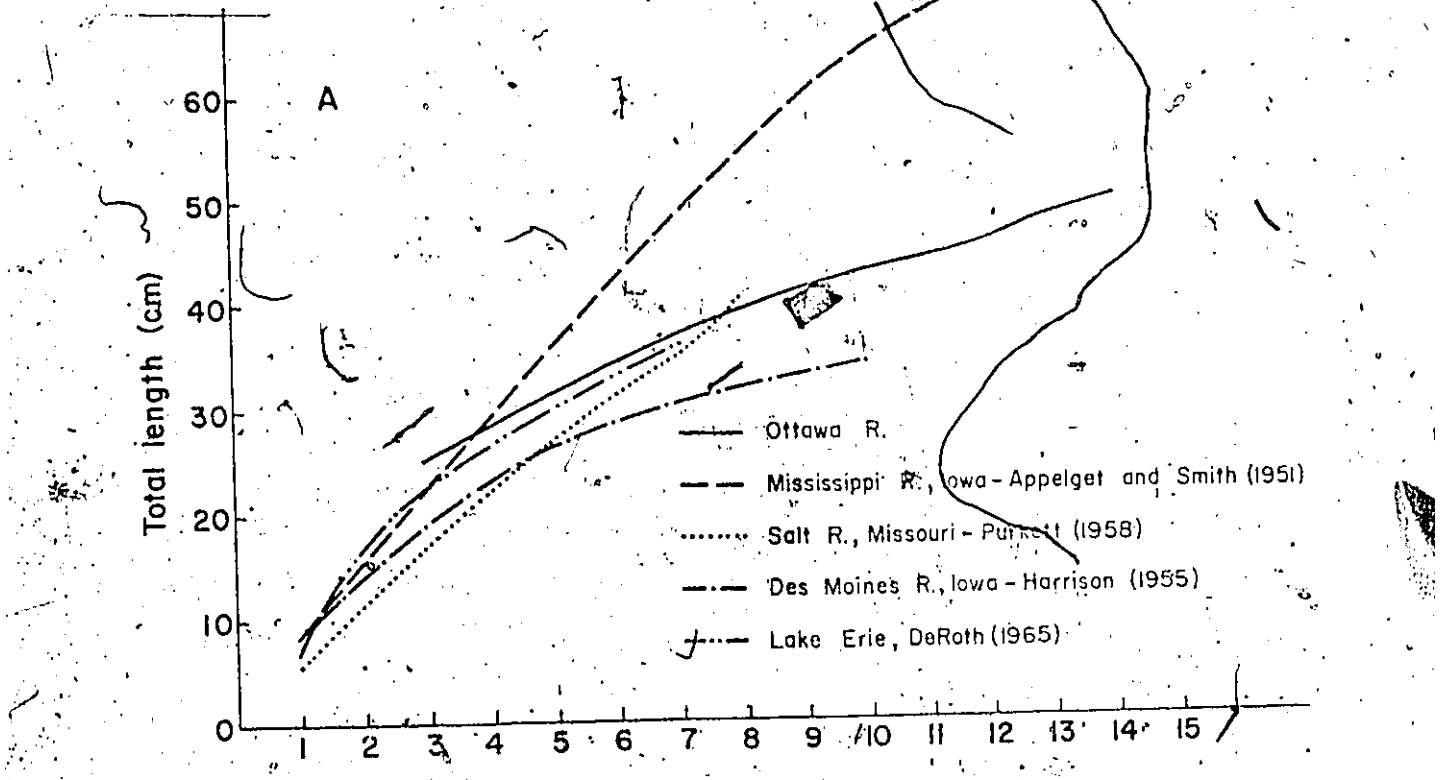
Growth of Channel Catfish

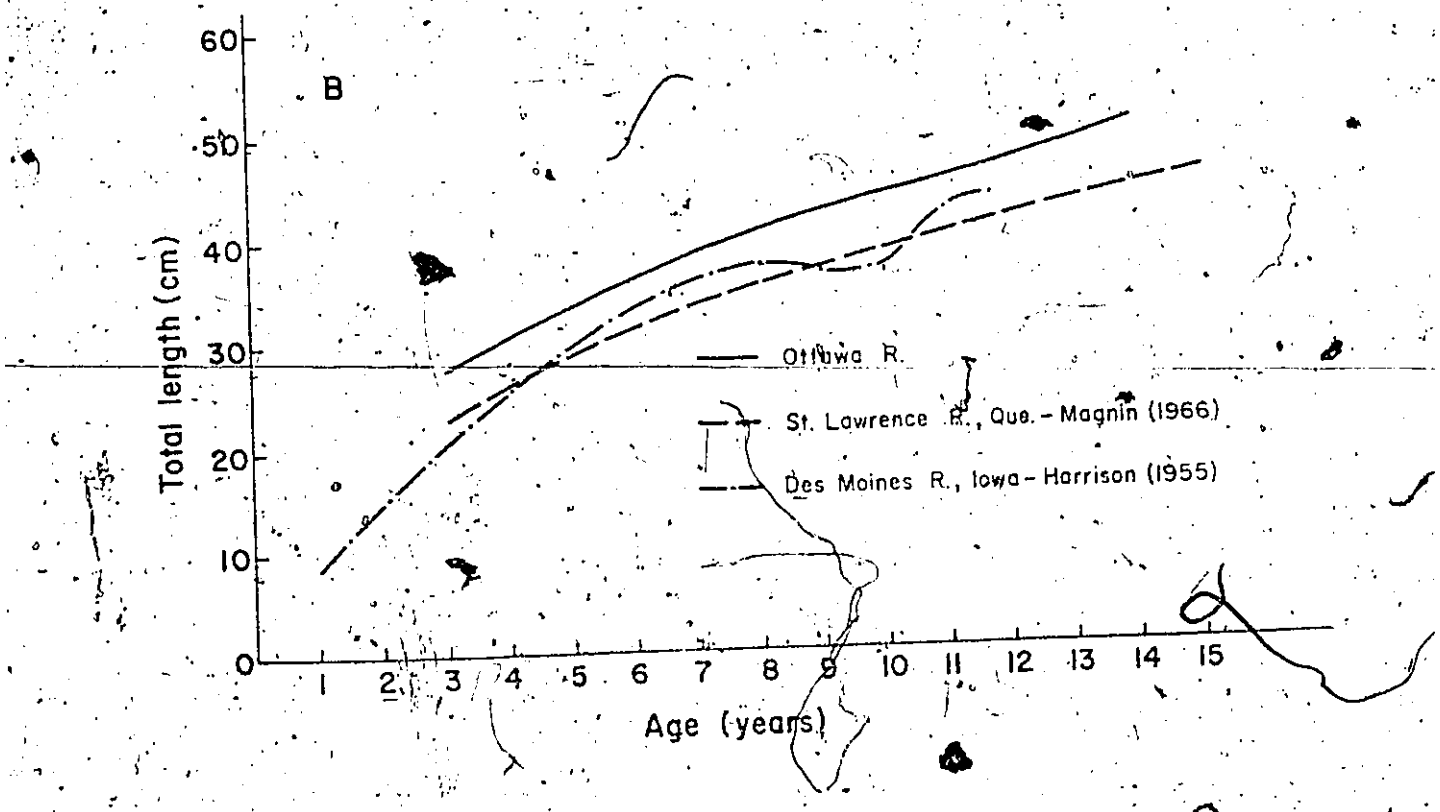
Increase in length based on both calculated and average measurements for Ottawa River channel catfish was compared to growth of this species obtained from different locations in North America (Figs. 13A and 13B). Since most of the other growth studies on channel catfish used total lengths, fork lengths of Ottawa River channel catfish were converted to total lengths by using the following formula: T.L. = 2.97 + 1.04 F.L. to facilitate comparisons.

Rate of increase in length of Ottawa River channel catfish was essentially very similar to that found for this species in rivers at other locations and more southerly latitudes. Carlander (1969) had a similar conclusion based on fish data collected but he also noted that more of the faster growing catfish had been reported as coming from the southern states. These faster growing fish were essentially found in fertile lakes and reservoirs. Growth has been shown to be affected by many factors (Carlander ibid). It is difficult to say why Ottawa River channel catfish grew at a slightly faster rate than catfish from other locations, particularly from nearby Lake Erie (DeRoth 1965) and the St. Lawrence River (Magnin and Beaulieu 1966) as indicated in Figs. 13A and 13B respectively. Dissimilarities between lakes and rivers cannot be used to explain this growth variation since channel catfish have been shown to have similar growth rates in each (Hall and Jenkins 1954). Lake Erie and the St. Lawrence River could possibly be more turbid than the Ottawa River. This might be a factor since channel catfish have been thought to grow faster in cleaner waters (Hall and Jenkins ibid., Finnell and Jenkins 1954), although evidence exists indicating

Fig. 13a. Growth comprisons of channel catfish from different areas based on calculated total lengths.

Fig. 13b. Growth comparisons of channel catfish from different areas based on average total lengths.


A
Total length (cm)
0
10
20
30
40
50
60
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Ottawa R.
Mississippi R., Iowa - Appelget and Smith (1951)
Salt R., Missouri - Purnell (1958)
Des Moines R., Iowa - Harrison (1955)
Lake Erie, DeRoth (1965)


B
Total length (cm)
0
10
20
30
40
50
60
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Age (years)
Ottawa R.
St. Lawrence R., Que. - Magnin (1966)
Des Moines R., Iowa - Harrison (1955)

equal growth regardless of turbidity (Hastings and Cross 1962). Availability of suitable food and population densities are probably the main factors affecting growth. Food organisms, to be discussed later, did not appear to be limited in the upper river of the study area. Unfortunately, little information is available on the accessibility of food organisms at other locations so the effect of this factor cannot be discussed. Population densities were not determined in this and most of the other studies so no comparisons can be made with regard to this factor.

Magnin and Beaulieu (1966) found very uniform growth for channel catfish in the St. Lawrence River. In their study, fish as old as 22 years were caught. It must be mentioned that a very small sample size was used for their study and this could have biased their results. These researchers also estimated, on the basis of age-length relationships, the age of a previously caught channel catfish having a total length of 80.7 cm as approximately 40 years. Although one cannot rule out the possibility of a fish attaining this age, it is highly improbable. From my Ottawa River channel catfish data, fluctuations in length for any age were not uncommon. One good example of this was the 13 year old fish caught in the lower river which had attained a total length of 73.3 cm. Consequently, the fish estimated at being about 40 years of age (Magnin and Beaulieu ibid) could have been much younger.

Growth of Ottawa River channel catfish can be considered very similar to that found elsewhere, in rivers, for the same species.

Reproductive Biology

The onset of maturity for any fish species is usually related to the attainment of a particular size by the individual (Nikolskii

1963). The ranges of total lengths for which 50 percent of Ottawa River channel catfish were mature were 33.1 cm to 37.3 cm for females and 37.3 cm to 41.4 cm for males. These results compare very favourably with the range of 30.5 cm to 38.1 cm for combined sexes of this species from Iowa and Missouri (Barnickol and Starrett 1951) and 30.5 cm for females found in Louisiana (Davis and Posey 1958). The age for maturity of Ottawa River channel catfish, namely, five years for females and six years for males is slightly older than ages found for this species at more southern latitudes. This is indicated by the mature four to five year old channel catfish, sexes combined, from Iowa and Missouri (Barnickol and Starrett ibid). Cross (1951) found that female channel catfish from Oklahoma started to mature at age two whereas Ottawa River female fish did not start to mature until age four. These two year old maturing channel catfish were found in a reservoir. Since reservoirs are generally considered to be quite fertile, food quantities could have been greater. Consequently, these fish would grow faster than those from the Ottawa River. Considering this to be the case, faster growth of these channel catfish from Oklahoma would explain why these fish were maturing at such an early age.

Ottawa River male channel catfish were found to mature later than the females. Similar results have been found for males of the same species at other locations (Davis 1959, DeRoth 1965). These findings are contradictory to the popular opinion that males mature before females. The state of maturity of male channel catfish, particularly after the spawning period, is very difficult to determine and there is the possibility that fish classified as immature could, in fact, have been capable of reproducing. Evidence supporting this possibility

comes from Sneed and Clemens (1963) who found that young but fully mature males which were capable of reproducing have rather small testes that appear to be poorly developed.

The spawning period of late June to early July in 1971 as determined from the gonadosomatic indices for Ottawa River channel catfish is similar to times reported as being from late May to mid July (Davis 1959, Marzolf 1957) and June and July (Osburn 1901, Stevens 1959). The actual time for spawning in any one year is undoubtedly temperature dependent. During the time that spawning took place in the Ottawa River, water temperatures were 20.6° C to 23.3° C. These temperatures are very similar to the optimum temperatures at which channel catfish spawn of 21.7° C (McClellan 1954); 23.8° C (Appelget and Smith 1951) and 23.9° C (Katz 1954). Consequently, for any one year, channel catfish at more southern latitudes would spawn earlier in the year since these waters would warm up and reach the desirable spawning temperatures sooner.

The fecundity of a fish species is indicative of the spawning behaviour of that fish. Those fish which have floating, pelagic eggs are very fecund whereas those which protect their eggs are least fecund (Nikolskii 1963). Channel catfish protect their eggs (Clemens and Sneed 1957) so this explains the relatively low fecundity found for this species. Ottawa River channel catfish fecundity was somewhat lower than values given for this species having similar lengths at other locations. Menzel (1945) found that channel catfish from Virginia had a fecundity of 7,430 while those from the Ottawa River for similar lengths had a fecundity of 6,213. Ottawa River channel catfish had a lower fecundity of 4,836 when compared to 8,110 found in Ohio for similar sized fish (Lagler 1939). Fecundity adapts to environmental conditions to ensure the survival

of the species (Bagenal 1967). These conditions would not be similar at all locations so this could account for any of the previously mentioned differences. The lower fecundity of Ottawa River channel catfish is not unexpected. The prolificness of a fish is directly related to food supply (Scott 1962). In northern waters, fish food would be less abundant than at more southern latitudes. The lower fecundity of Ottawa River channel catfish as previously discussed can therefore be accounted for.

Examination of fecundity at different lengths indicates that older and larger fish have higher fecundities (Table 8). The rate of increase for fecundities is greatest for channel catfish having fork lengths ranging from 43.9 cm to 47.9 cm. For fish having fork lengths greater than 48.0 cm, this rate decreases. This decrease could have resulted from the small sample size or from the fact that the fish were becoming senile (Nikolskii 1963).

Egg size at time of spawning for channel catfish is quite constant regardless of location. The egg diameter of 3.6 mm found for Ottawa River channel catfish is quite similar to values found in Iowa of 3.5 mm (Shira 1917) and Virginia of 3.5 mm - 4.0 mm (Menzel 1945).

Gonad development in female channel catfish as indicated by gonadosomatic indices starts approximately two months following spawning. It is interesting to note that by October, the average GSI was higher than that of the previous May. This phenomenon could be explained if ovaries had to attain a certain degree of development prior to the onset of winter. With reduced food intake during these months, these catfish could obtain some energy by reabsorption of their ovaries to a limited extent. Then, in the months immediately prior to spawning, the ovaries would be at a fairly advanced stage of development as compared to the previous summer. The energy derived from the somewhat limited food supply

at this time of year would then be sufficient to allow the ovary to reach full development in time for spawning. It would have been very interesting to study the GSI of this fish throughout the winter months to see if the above mentioned actually occurred. Unfortunately these fish could not be sampled during these times.

Food of Channel Catfish

Ottawa River channel catfish with fork lengths ranging from 21.9 cm to 30.0 cm (total lengths of 25.6 cm to 34.2 cm) fed predominantly on insects. Information was not obtained on the food of young channel catfish (less than 21.9 cm), although it would be safe to assume that insects would still form an important part of their diet. Comparison of food habits of Ottawa River channel catfish with those reported from other locations showed some similarities with respect to length of fish and type of food ingested. Darnell (1958) found that channel catfish having total lengths ranging from 7.6 cm to 11.9 cm fed primarily on small, bottom-inhabiting arthropods and to a minor extent on undetermined organic material, detritus, foraminifers, filamentous algae, and vascular plants. Channel catfish from Louisiana with total lengths up to 37.6 cm fed on amphipods, small insects, algae and undetermined matter (Perry 1969). Insects were the predominant food item in the stomachs of channel catfish from Iowa having total lengths less than 10.2 cm (Bailey and Harrison 1948). These researchers also found that channel catfish with total lengths from 10.2 cm to 30.2 cm fed somewhat equally on insects, fish, plants and detritus.

Transition zones can be considered as being the range in length of a fish species when the emphasis on insects as the predominant food item is shifted to that of fish. Ottawa River channel catfish whose fork

lengths fell between 30.0 cm and 45.0 cm (total lengths of 34.2 cm and 49.8 cm) could be considered as lying in this zone. Fish having lengths greater than the upper range mentioned feed almost entirely on fish. Ottawa River channel catfish can be considered as starting to feed predominantly on fish (adoption of piscivorous feeding habits) at a fork length of 40.0 cm (total length of 44.6 cm). The range of lengths for the transition zone and the length of fish when it is considered piscivorous are larger than those found by other researchers. Brown and Dendy (1961) found channel catfish from Alabama having total lengths ranging between 20.3 cm to 33.0 cm in the transition zone. Channel catfish from Oklahoma (Jearld and Brown 1971) and Nebraska (Russell 1965) had a narrow transition zone of 29.0 cm to 32.0 cm total length. Piscivorous feeding habits have been recorded at the following total lengths and locations respectively: 35.6 cm, Louisiana (Lambou 1959); 37.6 cm, Louisiana (Perry 1969); 38.1 cm, Georgia (Busbee 1968); and 39.4 cm, Alabama (Swingle 1954). From the results of these and other researchers, the length(s) at which channel catfish change their emphasis in diet from insects to fish does not appear to be related to the latitude at which the fish were caught. Any of the differences noted could be attributed to local conditions and more specifically to the food supply available. The length at which a fish begins to change its feeding habits often is not precise and consequently, one can expect a certain degree of variation in the interpretation of the results. This could account for the above mentioned differences.

Channel catfish have been considered to have omnivorous feeding habits (Bailey and Harrison 1948, Darnell 1958, Harlan and Speaker 1956). Results obtained from this study indicate that channel catfish are only omnivorous during the transition zone. An accurate way of describing the

feeding habits of channel catfish as obtained from this study would be to classify small fish (fork lengths up to 30.0 cm) as insectivorous, medium size fish (fork lengths from 30.0 cm to 45.0 cm) as omnivorous, and large fish (fork lengths greater than 45.0 cm) as piscivorous. From this study, channel catfish can also be considered as being both bottom and pelagic feeders.

Change in the diet of Ottawa River channel catfish with respect to time of the year showed slight trends as based on Figures 9 and 10. It is evident that the importance of insects in the diet was slightly reduced in May and October. Lower water temperatures at these times could have caused a reduction in the activity and/or numbers of aquatic insects. Consequently, there would have been fewer available as food for channel catfish. The sudden increase in importance of insects in August was due to large swarms, undoubtedly mating flights, of the winged form of the terrestrial ant species, Lasius umbratus, which landed in the water and consequently became food for channel catfish.

The seasonal fluctuations in the abundance of crustaceans and in particular the amphipod, Gammarus fasciatus, is particularly evident for July and October (Fig. 9). My findings correlate well with those of Mackie (1971) who reported that this species had two periods of peak abundance, these being late June and late September. He also found that the second peak was almost twice that of the first.

Few channel catfish fed on fish during August and September. Increased abundance of aquatic vegetation at this time of year probably hindered channel catfish in their attempts to obtain this food item. This explanation is feasible since forage fish populations would not decrease during these months.

Seasonal trends in vegetation, namely, its being least abundant in the spring and most abundant in late summer, supports the above mentioned hypothesis. The fact that more vegetation was found in channel catfish stomachs in September (Fig. 10) suggests that vegetation, primarily algae, was at its peak abundance at this time.

Ottawa River channel catfish fed primarily in amongst aquatic vegetation. Evidence supporting this claim comes from stomach content analyses. Excluding the ant, Lasius umbratus, because of the seasonal periodicity of its availability as a food item, the most important insect in the diet of this fish would be the ephemeropteran, Hexagenia sp. The odonatan, Enallagma sp., and unidentified trichopterans were also quite important insects in the diet. The most important crustacean and mollusc ingested were the amphipod, Gammarus fasciatus, and the gastropod, Physa sp., respectively. Mackie (1971), working in the same study area, found that all of the above mentioned organisms were associated with aquatic vegetation. Yellow perch, Perca flavescens, was the most important fish species fed upon. Trautman (1957) describes the habitat of yellow perch as being areas "where there was an abundance of rooted aquatics." From these findings, it is obvious that channel catfish feed primarily in amongst the aquatic vegetation. Vegetation found in the stomachs of channel catfish could have been incidental, taken in along with the above mentioned food. From Figs. 9 and 10, the interrelationships among insects, crustaceans, molluscs and fish to vegetation are too complex to state whether vegetation accompanied any of these food items. Examination of the feces of a few channel catfish indicated that cell walls of algae were intact although the chlorophyll was often bleached out. Bleaching probably resulted from 70% alcohol in which they were preserved.

It is doubtful if any nourishment is derived from this aquatic vegetation, particularly algae. The large quantity of vegetation found in stomachs suggested that channel catfish fed haphazardly, ingesting all organisms and deriving nourishment from these.

Within the scope of this study, low temperatures did not restrict digestion or feeding of channel catfish. The lowest temperature at which fish were caught was approximately 11° C. Temperatures have not been reported at which subadult and adult channel catfish start and stop feeding. Temperatures of 12.8° C and 15.5° C for starting and stopping feeding for fingerling channel catfish in artificial ponds have been reported (Morris 1967). It is expected that feeding intensities will decrease with water temperatures less than 11° C. Decreased activity of fish at cold temperatures would explain this.

Matter ingested by the lower river channel catfish (Table 14) was quite different from that of the upper river fish. The effect of domestic sewage and wood wastes as evidenced by the stomach content analysis of channel catfish was apparent by the presence of monocotyledonous and dicotyledonous seeds and bark. In the lower river, 86% of the channel catfish caught had fork lengths greater than 40.0 cm. As previously mentioned, this is also the length at which upper river fish could be classified as having piscivorous feeding habits. This explains why fish was the predominant food organism ingested, almost to the exclusion of everything else. The few channel catfish found in this area make any comprehensive study of feeding habits difficult to carry out.

Local Distribution and Its Possible Explanations

Channel catfish younger than three years were absent from my samples. Their behaviour patterns, as documented in the literature, can

be used to explain their absence in the sample. After hatching, young channel catfish are found in shallow waters (Harlan and Speaker 1956). Thus, use of seines and minnow traps would be the only way of capturing them since other netting methods require relatively deeper water. Fingerling channel catfish in artificial pools have shown strong hiding tendencies (Brown et al 1970). Under natural conditions of still water, fish of this size could have been located beneath debris and consequently would not have been collected. Fingerlings and subadults are more tolerant to fast currents than adults (Trautman 1957). These fish could have congregated in fast waters such as the Deschênes Rapids. If this were the case, these fish would not have been collected because no gear has been designed to sample these areas. Consequently, young fish were probably present within the study area but because of the nature of their habitat requirements, were inaccessible to the sampling methods employed.

Negligible numbers of channel catfish were found in the lower river as opposed to the upper river. These results were not unexpected since this distribution pattern has been known to exist from 1966 and probably much earlier (Stobo 1971, Qadri unpublished data). From the water preference experiment, no factors were found which affected the fish. Consequently, one can only infer what is causing the local distribution by noting differences between the upper and lower river.

One of the main differences between the upper and lower river is the morphometry of the river basin. The upper and lower river sections are generally regarded as having lake and river like qualities respectively. On this basis alone, the local distribution pattern cannot be explained since channel catfish are normally found in rivers (Scott 1967). A sizeable channel catfish population is also known to exist in the river

approximately 50 km downstream from Ottawa and Hull, near Rockland, Ontario.

Physical parameters account for the major differences in water quality between the two areas. High levels of suspended materials, namely wood wastes and sewage fungus, have been reported for the lower river as compared to the upper river where negligible amounts were found (O.W.R.C. & Q.W.B. 1971).

Chemical parameters were found to be quite similar between the two areas. Mackie (1971) and Stobo (1971) had similar findings. It is recognized though, that pollutants could have been discharged in concentrations high enough to be capable of temporarily affecting the water chemistry. These "slugs" of pollutants could have been missed by the non-continuous nature of the water sampling program.

Channel catfish, by not preferring either Britannia Bay water or that from below the C.I.P. mill as determined from the water preference experiments, were, in effect, indicating that they were perceiving no appreciable differences in water chemistry between the two areas. These water preference experiments, however, did not indicate the effect suspended materials might have on the behaviour of channel catfish since these solids were effectively removed by the cheese cloth filters. It is doubtful, though, if these suspended materials would have any effects on channel catfish in the river since Cole (1935) found that even a two percent suspension of wood fibres was not harmful to healthy fish. Dill (1944) also found this species in turbid water.

Suspended solids could have some effect on the reproductive biology of channel catfish. Channel catfish build nests for spawning purposes under rocks, logs, in holes or in other protected sites on the

river bottom (Brown 1942, Davis 1959, Harlan and Speaker 1956). These would be somewhat susceptible to being covered with suspended materials as they settle out. Following spawning, male channel catfish guard the eggs and by body movements can prevent them from being covered with silt and the like (Clemens and Sneed 1957). In the lower river, it is possible that males could prevent the eggs from becoming covered with the previously mentioned suspended solids. Since other fish species are capable of reproducing in the lower river, as evidenced by young of the year fish found in seine hauls, there is no reason to suspect that channel catfish could not.

Indirectly, via the food chain, these suspended materials could have devastating effects on channel catfish. Young channel catfish in the upper river can be considered insectivorous with the ephemeropteran, Hexagenia sp., being most important in the diet. In the lower river, very reduced numbers of ephemeropterans were found. Other insect orders were found in numbers comparable with the upper river except in the more polluted waters where decreases in abundance were noted (Mackie 1971). Reduced numbers of ephemeropterans cannot be used to explain entirely the paucity of channel catfish in the lower river since other insect orders were available as food items. It is not known, though, the extent to which these other insects could be utilized. Mackie (ibid.) has attributed these low numbers of ephemeropterans in parts of the lower river to low dissolved oxygen levels. Decomposition of deposits of organic material, wood fibres and raw sewage account for this. This attribution could also be used to explain the decreased abundance of amphipods which Mackie (ibid.) found in the lower river. Amphipods which constituted a fairly important part of the diet of upper river

channel catfish were greatly reduced in abundance in the lower river because of wood waste deposits (Mackie ibid., O.W.R.C. and Q.W.B. 1971). The overall effect of these deposits of organic material, wood wastes, and raw sewage which cover much of the riverbed, is to reduce the abundance of bottom fauna. Consequently, the amount of food available for consumption is reduced. Most affected by these decrease would be young channel catfish since they are primarily bottom feeders. With decreased food supplies, interspecific competition for this limited resource could result in an overall reduction in the fish population.

Brown bullheads, Ictalurus nebulosus (LeSueur), were found to be very abundant in the lower river (Appendix 4). Since this species is closely related to channel catfish, competition for the limited food available in the lower river could have occurred, resulting in the almost total exclusion of channel catfish in this area. If food was not limiting, then both species could possibly live together in the same area which could explain their dual existence in the upper river (Appendix 3). Since brown bullheads are normally found in more adverse conditions than channel catfish (Scott 1967), their adaptations for this type of existence could explain their success in the lower river. Although the information obtained from this project neither confirms nor rejects this theory, competitive exclusion of channel catfish in the lower river must not be discounted.

Movements of channel catfish into and out of the lower river must also be considered since this fish has been known to travel distances as far as 344 km (Hubley 1963). Since only large fish having piscivorous feeding habits have been found to survive in the lower river, then one might expect that only those fish possessing similar food habits would

have a chance of enduring the rigors of this section. Funk (1955) found generally that "medium sized" channel catfish were more mobile than "smaller and larger" fish which were rather sedentary. If this were the case for Ottawa River channel catfish and the "medium sized" fish moving into the lower river were of a size which did not utilize fish in their diet, then survival of this fish would be doubtful because of the above mentioned reasons. A zone of degredation is found downriver outside the study area in which BOD_5 and dissolved oxygen levels are very high and low respectively (O.W.R.C. and Q.W.B. 1971). This zone could act as a barrier and discourage channel catfish from moving upriver. If this zone does act in this manner, then movement would occur only in the spring when increased flow rates would essentially flush out this zone. Some downstream movement from the upper to lower river could occur, although to do so fish would have to be swept with the current down rapids and through turbines or flood gates of the dam located at the Chaudiere Falls. Movements of channel catfish between the Ottawa River and either the Rideau or Gatineau Rivers can be considered negligible. The Rideau Falls prevent fish from entering the Rideau River from the Ottawa River although the reverse could be true. Channel catfish could possibly be present in the Rideau River although sizeable numbers have not been reported (Adlam pers. comm. 1973). Because of the extensive logging operation in the Gatineau River, it was impossible to sample this river at any place except at the mouth. Since no channel catfish were caught at this location, it is felt that movement of channel catfish from the Gatineau to the Ottawa River would be negligible. Channel catfish have been reported in the Gatineau River (Dymond 1939). From the actual number of channel catfish found in the lower river the effect

of immigration into this area can be considered as negligible.

In 1964, construction of the Carillon Dam which is located downriver from Hawkesbury, was completed. Impoundment has resulted in raising the river levels as far upriver as the base of the Chaudiere Falls. The extent that levels were raised in the lower sector of the study area is not known. With increased depths, the possibility does exist that the number of suitable spawning sites for channel catfish could have been reduced. Channel catfish could then have left this area for other parts of the river where more suitable sites might be found. This is one theory which can be used to explain the absence of channel catfish in the lower river.

The local distribution pattern of channel catfish within the study area has been easy to define but difficult to explain because of the complex nature of the problem. The relative absence of channel catfish in the lower river can, most probably, be attributed to the direct or indirect effects of suspended solids and deposits of organic matter, wood fibres and raw sewage. The presence of chemical pollutants not detected at sampling times must not be overlooked as a factor affecting channel catfish distribution. Some of the more plausible theories have been discussed but not until more research into the problem is carried out can a more definite answer be arrived at.

MANAGEMENT RECOMMENDATIONS

The channel catfish population in the Ottawa River upriver from Ottawa-Hull is quite large and is not efficiently utilized. Utilization of this fish by anglers and commercial fishermen alike should be encouraged. From my study of channel catfish, I can make the following management recommendations:

Channel catfish should attain a minimum fork length of 33.0 cm or a total length of 37.4 cm before being harvested by commercial fishermen. This would insure that a sizeable portion of the population would be able to reproduce each year. Trap net use only is recommended since this would enable commercial fishermen to be selective in their catch. No minimum size is required for the sport fishery at the present time.

If natural recruitment of this species declines in the future, construction of artificial spawning beds or catfish rearing ponds should be considered. These are described in the literature.

Fish farming of channel catfish should be attempted to determine its feasibility in Canadian waters. Brood stock could be obtained from the Ottawa River.

SUGGESTED FIELDS OF RESEARCH

In most ecological studies of channel catfish, few fish younger than three years of age are caught. If these fish are in rapids or other areas with strong currents, as I suspect, research should be carried out to develop netting gear to sample these areas.

The effect of suspended materials in the water and the nature of the substrate on channel catfish feeding and spawning should be investigated.

Relationships between channel catfish and brown bullheads, particularly competition for territory, food, and spawning sites should be examined.

Caloric tests of ingested and egested vegetation should be made in order to determine if channel catfish have derived any nourishment from these materials.

SUMMARY AND CONCLUSIONS

1. Biological investigations were carried out on channel catfish from June to late October, 1970, from May to late October, 1971, and May and June, 1972.
2. A total of 2,031 channel catfish caught in a 33 km stretch of the Ottawa River near the cities of Ottawa and Hull were examined.
3. The Ottawa River study area was subdivided as follows: upper river (Lac Deschênes), middle river (between the Deschênes Rapids and Chaudière Falls), lower river (below Chaudière Falls to lower Duck Island). The major emphasis of the program was on the upper and lower river areas.
4. From the statistical tests employed, I was unable to show significant differences between the upper and lower river for water quality as based on chemical parameters.
5. A total of 530 channel catfish were tagged. The few tag returns, namely three, make any quantitative estimate of movement of population size impossible to make.
6. The majority of channel catfish (98.9%) were found in the upper river.
7. Aging of channel catfish was accomplished by decalcifying and cross sectioning pectoral spines. Ages were read along the lateral axis of the cross section.
8. Calculated growth was accomplished by assuming direct proportions between growth of spine radius and growth in length of the fish.
9. Growth of channel catfish in the Ottawa River was similar to growth rates of this species found in other riverine habitats.
10. Increases in length and weight with age for either sex were similar and can be represented by the following equations respectively:

log F.L. = 1.1668 + 0.43037 log age, log wt. = 1.540 + 1.405 log age, F.L. is in centimetres and wt. is in grams.

11. Length weight relationships are similar for both sexes and are represented by log wt. = -2.081 + 3.138 log F.L., wt. is in grams and F.L. is in centimetres.

12. Ottawa River channel catfish attain maturity at lengths similar to those found for this species at other locations. Fifty percent of the females mature between 29.0 and 32.9 cm fork length and males between 33.0 and 36.9 cm.

13. Ottawa River channel catfish mature at an older age than fish from more southern latitudes. Fifty percent of the females were mature at five years and males at six years.

14. State of maturity of male channel catfish at times other than at spawning is difficult to assess.

15. Spawning is temperature dependent. Water temperatures of 20.6° C to 23.3° C are comparable to those given at other locations.

16. The average fecundity of 6,480 eggs was less than fecundities reported for this fish at more southern latitudes.

17. The average egg diameter at time of spawning of 3.6 mm is similar to values given at other locations.

18. Feeding habits can be classified according to fish length as follows: fork lengths up to 30.0 cm - insectivorous, fork lengths from 30.0 cm to 45.0 cm - omnivorous, and fork lengths greater than 45.0 cm - piscivorous.

19. Seasonal variation in diet is directly related to the availability of food organisms.

20. Channel catfish were feeding primarily in amongst aquatic vegetation.

21. Water preference experiments in the laboratory indicated that channel catfish did not prefer water from the upper river over that from the lower.

22. No definite evidence was found to explain the relative absence of channel catfish in the lower river.

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APPENDICES

Appendix 1. Derivation of correction factors for frozen lengths and weights.

Sturges' formula (Sturges 1926): $m = 1 + 3.3 \log N$

where m = number of classes
N = number of samples

In the shrinkage experiment, N = 28. Therefore, from the above formula, m = 6.

Fork length: Range in length of frozen fish: 24.7 cm - 65.9 cm
Amplitude: 65.9 - 24.7 = 41.2 cm
Class interval: $C = \frac{\text{amplitude}}{\text{number of classes}} = \frac{41.2}{6} = 6.9$

Class sizes and the corresponding average shrinkage (Correction factor)

24.7 cm - 31.6 cm	0.5 cm
31.7 cm - 38.6 cm	0.7 cm
38.7 cm - 45.6 cm	0.9 cm
45.7 cm - 52.6 cm	1.6 cm
52.7 cm - 59.6 cm	1.2 cm
59.7 cm - 66.6 cm	1.1 cm

The correction factor was then added to each "frozen length" for the appropriate class size. The paired Student's t-test was applied to compare fresh with calculated fresh fork lengths. No significant differences were found.

Similar operations for total lengths and body weights were carried out. In both instances, no significant differences for calculated fresh total length and calculated fresh weight were found.

Appendix 2. Average monthly water temperatures obtained from the Britannia Purification Plant for 1970 and 1971.

Month	1970 Mean Temp.(C)	1971 Mean Temp.(,C)
January	1.67	1.67
February	1.67	1.67
March	1.67	2.22
April	2.78	4.44
May	11.11	11.67
June	18.89	20.56
July	21.67	23.33
August	23.33	*
September	18.89	21.67
October	11.67	16.67
November	8.33	9.44
December	2.78	3.33

* - average temperature not available.

Appendix 3. Gill and trap net catches in the upper river on a yearly basis from May, 1970 to June, 1972.

Species - Common name	Gill Netting						Trap Netting					
	1970			1971			1971			1972		
	N	% of total catch	#/lift	N	% of total catch	#/lift	N	% of total catch	#/lift	N	% of total catch	#/lift
Ictalurus punctatus (Rafinesque) - Channel catfish	156	62.4	15.6	260	54.3	13.0	778	23.8	70.7	815	30.5	135.8
Ictalurus nebulosus (LeSueur) - Brown bullhead	3	1.2	0.3	13	2.7	0.7	469	14.4	42.6	1,110	41.6	185.0
Perca flavescens (Mitchill) - Yellow perch	10	4.0	1.0	48	10.0	2.4	51	1.6	4.6	13	0.5	2.2
Stizostedion vitreum vitreum (Mitchill) - Yellow pickerel	11	4.4	1.1	16	3.3	0.8	146	4.5	13.3	75	2.8	12.5
Stizostedion vitreum canadense (Smith) - Sauger	3	1.2	0.3	30	6.3	1.5	3	0.1	0.3	15	0.6	2.5
Ambloplites rupestris (Rafinesque) - Rock bass	3	1.2	0.3	13	2.7	0.7	38	1.2	3.5	79	3.0	13.2
Lepomis gibbosus (Linnaeus) - Pumpkinseed	4	1.6	0.4	9	1.9	0.5	1,248	38.2	113.5	298	11.2	50.0
Micropterus dolomieui (Lacepède) - Smallmouth bass	6	2.4	0.6	16	3.3	0.8	92	2.8	8.4	55	2.1	9.2
Micropterus salmoides (Lacépède) - Largemouth bass	0	0.0	0.0	0	0.0	0.0	3	0.1	0.3	0	0.0	0.0
Hiodon tergisus (LeSueur) - Mooreye	37	14.8	3.7	29	6.1	1.5	3	0.1	0.3	0	0.0	0.0
Coregonus artedii (LeSueur) - Cisco	0	0.0	0.0	1	0.2	0.1	0	0.0	0.0	0	0.0	0.0
Esox lucius (Linnaeus) - Northern pike	3	1.2	0.3	15	3.1	0.8	75	2.3	6.8	27	1.0	4.5
Esox masquinongy (Mitchill) - Muskellunge	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	2	0.1	0.3
Cyprinus carpio (Linnaeus) - Carp	0	0.0	0.0	0	0.0	0.0	1	0.0	0.1	7	0.3	1.2
Moxostoma anisurum (Rafinesque) - Silver redhorse sucker	3	1.2	0.3	1	0.2	0.1	81	2.5	7.4	35	1.3	5.8
Moxostoma macrolepidotum (LeSueur) - Northern redhorse sucker	3	1.2	0.3	2	0.4	0.1	26	0.8	2.4	29	1.1	4.8
Catostomus commersoni (Lacépède) - Common white sucker	5	2.0	0.5	14	2.9	0.7	63	1.9	5.7	9	0.3	1.5
Lota lota (Linnaeus) - Burbot	0	0.0	0.0	0	0.0	0.0	2	0.1	0.2	0	0.0	0.0
Lepisosteus osseus (Linnaeus) - Longnose gar	3	1.2	0.3	12	2.5	0.6	149	4.6	13.5	77	2.9	12.8
Anguilla rostrata (LeSueur) - American eel	0	0.0	0.0	0	0.0	0.0	37	1.1	3.4	24	0.9	4.0

	1970	1971	1972
Number of gill net sets -	10	20	10
Number of trap net sets -	0	11	6

Appendix 4. Gill and trap net catches in the lower river on a yearly basis from May, 1970 to June, 1972.

Species - Common name	Gill Netting						Trap Netting					
	1970			1971			1971			1972		
	N	% of total catch	#/lift	N	% of total catch	#/lift	N	% of total catch	#/lift	N	% of total catch	#/lift
Ictalurus punctatus (Rafinesque) - Channel catfish	2	0.3	0.1	0	0.0	0.0	12	0.1	1.2	3	0.0	0.3
Ictalurus nebulosus (LeSueur) - Brown bullhead	51	8.3	1.4	27	13.9	4.5	13,765	93.9	1,376.5	10,501	92.5	1,050.1
Perca flavescens (Mitchill) - Yellow perch	319	52.1	8.9	108	55.7	18.0	209	1.4	20.9	93	0.8	9.3
Stizostedion vitreum vitreum (Mitchill) - Yellow pickerel	14	2.3	0.4	9	4.6	1.5	75	0.5	7.5	95	0.8	9.5
Stizostedion vitreum canadense (Smith) - Sauger	25	4.1	0.7	2	1.0	0.3	6	0.0	0.6	0	0.0	0.0
Ambloplites rupestris (Rafinesque) - Rock bass	11	1.8	0.3	2	1.0	0.3	45	0.3	4.5	27	0.2	2.7
Lepomis gibbosus (Linnaeus) - Pumpkinseed	7	1.1	0.2	0	0.0	0.0	176	1.2	17.6	45	0.4	4.5
Micropterus dolomieui (Lacépède) - Smallmouth bass	1	0.2	0.0	0	0.0	0.0	2	0.0	0.2	0	0.0	0.0
Micropterus salmoides (Lacépède) - Largemouth bass	1	0.2	0.0	0	0.0	0.0	1	0.0	0.1	10	0.1	1.0
Pomoxis nigromaculatus (LeSueur) - Black crappie	6	1.0	0.2	0	0.0	0.0	116	0.8	11.6	89	0.8	8.9
Hiodon tergisus (LeSueur) - Mooneye	56	9.2	1.6	6	3.1	1.0	2	0.0	0.2	14	0.1	1.4
Esox lucius (Linnaeus) - Northern pike	36	5.9	1.0	24	12.4	4.0	45	0.3	4.5	28	0.3	2.9
Esox masquinongy (Mitchill) - Muskellunge	2	0.3	0.1	0	0.0	0.0	6	0.0	0.6	0	0.0	0.0
Notemigonus crysoleucas (Mitchill) - Golden shiner	1	0.2	0.0	0	0.0	0.0	0	0.0	0.0	2	0.0	0.2
Cyprinus carpio (Linnaeus) - Carp	0	0.0	0.0	0	0.0	0.0	22	0.2	2.2	44	0.4	4.4
Carpiodes cyprinus (LeSueur) - Quillback sucker	1	0.2	0.0	0	0.0	0.0	29	0.2	2.9	3	0.0	0.3
Moxostoma anisurum (Rafinesque) - Silver redhorse sucker	6	1.0	0.2	1	0.5	0.2	17	0.1	1.7	67	0.6	6.7
Moxostoma macrolepidotum (LeSueur) - Northern redhorse sucker	39	6.4	1.1	3	1.5	0.5	39	0.3	3.9	237	2.1	23.7
Moxostoma valenciennesi (Jordan) - Greater redhorse sucker	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	1	0.0	0.1
Catostomus commersoni (Lacépède) - Common white sucker	11	1.8	0.3	3	1.5	0.5	6	0.0	0.6	41	0.4	4.1
Acipenser fulvescens (Rafinesque) - Lake sturgeon	19	3.1	0.5	8	4.1	1.3	0	0.0	0.0	0	0.0	0.0
Lepisosteus osseus (Linnaeus) - Longnose gar	3	0.5	0.1	1	0.5	0.2	62	0.4	6.2	0	0.0	0.0
Anguilla rostrata (LeSueur) - American eel	0	0.0	0.0	0	0.0	0.0	28	0.2	2.8	55	0.5	5.5
Ichthyomyzon unicuspis (Hubbs and Trautman) - Silver lamprey	1	0.2	0.0	0	0.0	0.0	3	0.0	0.3	2	0.0	0.2

	1970	1971	1972
1 - Number of gill net sets -	36	6	0
Number of trap net sets -	0	10	10

Appendix 5. Mean fork length at each age for channel catfish, sexes separate and combined, caught in the upper river from May, 1970 to June, 1972. Ranges, standard deviations, standard errors and sample sizes are indicated.

Age	Sex	Mean F.L. (cm)	Range (cm)	Standard deviation	Standard error	N[1]
3	F	22.8	22.3-22.8	0.5099	0.2550	4
	M	25.2	21.9-28.1	2.6584	1.1889	5
	F&M	24.1	21.9-28.1	2.2930	0.7643	9
4	F	26.9	24.9-29.0	1.4942	0.5283	8
	M	26.1	24.0-29.3	1.5598	0.4703	11
	F&M	26.5	24.0-30.0	1.6217	0.3381	23
5	F	29.5	26.7-32.0	1.8845	0.6663	8
	M	29.5	28.3-32.5	1.5211	0.6210	6
	F&M	29.3	26.7-32.5	1.7181	0.4295	16
6	F	31.6	26.3-36.1	2.9568	0.8915	11
	M	32.6	31.0-34.6	1.3156	0.4651	8
	F&M	31.8	26.3-36.1	2.4819	0.5291	22
7	F	34.9	32.1-40.4	2.0720	0.4880	18
	M	35.2	31.3-37.2	1.5188	0.3924	15
	F&M	34.2	29.6-40.4	2.2460	0.3180	50
8	F	36.5	32.0-42.1	2.1202	0.3439	38
	M	37.1	32.6-41.4	2.0256	0.3376	36
	F&M	36.2	31.9-42.1	2.2094	0.2017	120
9	F	38.4	32.0-45.0	1.9485	0.3248	36
	M	38.7	32.8-42.9	2.2478	0.3799	35
	F&M	38.1	32.0-45.0	2.2585	0.1844	150
10	F	38.7	30.3-45.9	2.8030	0.5205	29
	M	40.4	35.1-47.0	3.1761	0.5447	34
	F&M	39.5	30.3-47.0	2.7103	0.2243	146
11	F	40.1	36.0-44.2	1.7892	0.3578	25
	M	42.1	35.3-49.7	2.6609	0.4207	40
	F&M	40.7	33.5-49.7	2.3669	0.1986	142
12	F	42.8	37.9-52.2	3.1115	0.5988	27
	M	43.2	39.9-52.6	3.9965	0.9420	18
	F&M	42.4	37.9-52.6	2.7368	0.2968	85
13	F	44.9	41.5-51.0	4.1813	1.3938	9
	M	45.6	42.2-60.7	4.8747	1.3520	13
	F&M	44.2	38.0-60.7	3.8619	0.5574	48

Appendix 5.. (cont.)

Age	Sex	Mean F.L. (cm)	Range(cm)	Standard deviation	Standard error	N[1]
14	F	46.1	40.2-51.8	4.8524	1.9810	6
	M	46.0	44.1-50.6	3.4335	1.7168	4
	F&M	46.0	40.2-50.6	3.7421	1.0803	12
15	F	50.9	-	-	-	1
	M	50.0	-	-	-	1
	F&M	49.6	48.0-50.9	1.4844	0.8570	3
16	F	-	-	-	-	0
	M	52.0	50.6-53.3	1.9092	1.3500	2
	F&M	52.0	50.6-53.3	1.9092	1.3500	2
17	F	-	-	-	-	0
	M	-	-	-	-	0
	F&M	-	-	-	-	0
18	F	59.2	-	-	-	1
	M	-	-	-	-	0
	F&M	59.2	-	-	-	1

1 - the sample size of F&M can be greater than F and M since all fish were not sexed.

Appendix 6. Mean weights at each age for channel catfish, sexes separate and combined, caught in the upper river from May, 1970 to June, 1972. Ranges, standard deviations, standard errors and sample sizes are indicated.

Age	Sex	Mean Wt. (g)	Range (g)	Standard deviation	Standard error	N[1]
3	F	147	131-156	11.151	5.575	4
	M	205	168-240	32.280	14.436	5
	F&M	179	131-240	38.965	12.988	9
4	F	248	204-300	35.813	12.662	8
	M	212	183-263	27.719	8.358	11
	F&M	229	183-300	35.456	7.928	20
5	F	324	231-407	64.343	22.749	8
	M	311	209-463	82.663	33.747	6
	F&M	318	209-463	69.996	18.707	14
6	F	449	241-615	117.427	35.406	11
	M	491	361-599	100.661	35.589	8
	F&M	468	241-615	104.215	22.742	21
7	F	603	453-1023	135.594	31.960	18
	M	502	382-700	90.873	23.463	15
	F&M	572	343-1023	127.672	20.444	39
8	F	690	417-1068	140.552	22.801	38
	M	701	446-980	114.145	19.024	36
	F&M	680	417-1068	128.192	13.365	92
9	F	788	476-1413	157.929	26.322	36
	M	750	474-1092	132.205	22.347	35
	F&M	769	383-1123	151.052	14.812	104
10	F	803	417-1342	179.883	32.842	30
	M	889	596-1675	224.037	38.422	34
	F&M	834	417-1723	201.725	19.411	108
11	F	886	680-1386	141.553	28.311	25
	M	1072	656-1775	240.789	38.072	40
	F&M	956	563-1775	222.840	23.360	91
12	F	1149	757-2310	352.298	67.800	27
	M	1175	759-2038	461.009	108.661	18
	F&M	1135	757-2038	353.901	45.312	61
13	F	1282	782-2205	544.002	181.334	9
	M	1314	1008-2989	526.711	146.083	13
	F&M	1245	733-2989	469.424	81.716	33

Appendix 6. (cont.)

Age	Sex	Mean Wt. (g)	Range (g)	Standard deviation	Standard error	N[1]
14	F	1445	928-2326	572.738	233.819	6
	M	1446	1086-1977	434.529	217.264	4
	F&M	1439	928-2326	470.208	141.773	11
15	F	2177	-	-	-	1
	M	1909	-	-	-	1
	F&M	2043	1909-2177	189.505	134.000	2
16	F	-	-	-	-	0
	M	2133	2093-2172	55.861	39.500	2
	F&M	2133	2093-2172	55.861	39.500	2
17	F	-	-	-	-	0
	M	-	-	-	-	0
	F&M	-	-	-	-	0
18	F	3429	-	-	-	1
	M	-	-	-	-	0
	F&M	3429	-	-	-	1

1 - the sample size of F&M can be greater than F and M since all fish were not sexed.

Appendix 7. Raw data on fish caught in the lower river.

Age	Fork length (cm)	Total length (cm)	Weight (g)	Sex	G.S.I.[1]	Maturity[2]	Month caught
7	39.6	44.3	972	F	1.07	M	August
8	28.7	32.6	278	M	0.19	I	July
9	36.0	40.4	473	F	0.71	M	October
9	44.4	49.6	1295	M	1.16	M	August
10	43.8	48.7	1332	M	0.55	M	July
10	48.7	53.6	1605	F	1.63	M	August
10	42.1	46.6	886	M	0.78	M	June
10	48.6	48.5	870	F	0.97	M	August
10	47.5	53.6	1587	M	0.38	M	September
10	48.7	53.6	1954	F	7.79	M	September
10	53.3	58.3	2292	F	0.56	M	September
11	50.3	55.7	2122	M	0.55	M	May
11	49.4	54.1	1929	F	1.99	M	July
11	53.8	58.7	2186	M	0.44	M	May
11	45.0	50.1	1234	M	0.58	M	June
12	44.0	49.4	1161	F	1.16	M	August
12	54.4	59.2	2362	F	0.82	M	August
12	53.2	57.6	2545	M	0.34	M	August
13	42.2	47.2	964	F	0.21	M	May
13	50.7	56.4	1735	F	1.28	M	July
13	67.0	73.3	3682	M	0.77	M	June

1 - G.S.I. = $\frac{\text{gonad weight} \times 100}{\text{total body weight}}$

2 - Maturity - M = mature
I = immature

Appendix 8. Monthly gonadosomatic indices of male and female channel catfish, caught from May to October, 1971. Means, ranges, standard errors, 95% confidence limits and sample sizes are indicated.

	Month	Mean G.S.I.	Range G.S.I.	Standard error	95% Confidence limits	N
Males	May	0.377	0.357-0.397	0.020	0.332-0.422	11
	June	0.330	0.277-0.383	0.053	0.220-0.440	22
	July	0.259	0.225-0.293	0.034	0.189-0.329	24
	August	0.222	0.194-0.250	0.028	0.165-0.279	41
	Sept.	0.312	0.265-0.359	0.047	0.214-0.410	21
	Oct.	0.256	0.220-0.292	0.036	0.180-0.332	18
Females	May	3.746	2.516-4.976	1.230	1.089-6.403	14
	June	5.415	3.903-6.927	1.512	2.238-8.592	19
	July	0.671	0.611-0.731	0.060	0.548-0.794	36
	August	1.295	0.967-1.623	0.328	0.625-1.965	33
	Sept.	2.461	1.932-2.990	0.529	1.375-3.547	28
	Oct.	4.467	3.715-5.219	0.752	2.931-6.003	31

Appendix 9. List of organisms found in stomachs of channel catfish obtained from the Ottawa River from May, 1970 to June, 1972.

INSECTS

Trichoptera
- Leptoceridae
  - Oecetis
  - Leptocella
  - Athripsodes
  - Leptocerus
  - Mystacides
- Phryganeidae
  - Phryganea
- Limnephilidae
  - Limnephilus
- Psychomyiidae
  - Polycentropus
  - Phylocentropus
- Hydroptilidae
  - Agraylea
- Hydropsychidae
  - Hydropsyche
  - Macronema

Ephemeroptera
- Baetidae
  - Cloen
  - Caenis
  - Ephemerella
- Ephemeridae
  - Hexagenia

Odonata (Zygoptera)
- Coenagrionidae
  - Enallagma
  - Ischnura

Neuroptera
- Sialidae
  - Sialis

Lepidoptera
- Notodontidae
  - Heterocampa
- Tineidae

Hymenoptera
- Formicidae
  - Lasius umbratus
- Apidae
  - Apis mellifera

Diptera
- Heleidae (Ceratopogonidae)
  - Bezzia gp.
- Dolichopodidae
- Tipulidae
  - Tipula
- Tendepedidae (Chironomidae)
  - Chironomus
  - Coelotanypus
  - Cricotopus
  - Cryptochironomus
  - Demicryptochironomus
  - Dicrotendipes
  - Glyptotendipes
  - Nilothauma
  - Orthocladius
  - Parachironomus
  - Paratanytarus
  - Pentaneura (Ablabesmyia)
  - Prodiamesa
  - Psectrocladius
  - Pseudochironomus
  - Stictochironomus
  - Xenochironomus
- Bibionidae
  - Bibio

Homoptera
- Cicadellidae
  - Aphrodes
  - Draeculacephala
- Eurymelidae
  - Idiocercus

Hemiptera
- Corixidae
  - Sigara
  - Trichocorixa
- Belostomatidae
  - Belostoma
- Nepidae
  - Ranatra
- Miridae

Appendix 9. (cont.)

INSECTS (cont.)

Coleoptera
- Elmidae
  - Microcylloepus
- Elateridae
  - Melanotus
  - Aeolus
- Hydrophilidae
  - Berosus
  - Hydrochara
- Nitulidae
  - Glischrochilus
- Haliplidae
  - Haliplus
- Cantharidae
  - Cantharis
  - Chauliognathus
- Scarabaeidae
  - Serica
  - Diplotaxis
- Melandryidae
  - Synchroa
- Meloidae
  - Epicauta
- Carabidae
  - Pterostichus

CRUSTACEANS

Amphipoda
- Gammaridae
  - Gammarus fasciatus
- Talitridae
  - Hyalella azteca

Isopoda
- Asellidae
  - Asellus

Decapoda
- Astacidae
  - Orconectes virilis

MOLLUSCS

Gastropoda
- Amnicolidae
  - Amnicola
- Lymnaeidae
  - Limnaea
- Physidae
  - Physa
- Planorbidae
  - Gyraulus
- Valvatidae
  - Valvata

Pelecypoda
- Sphaeriidae
  - Musculium
  - Pisidium
  - Sphaerium
- Unionidae
  - Elliptio

FISH

Perciformes
- Percidae
  - Etheostoma sp.
  - Perca flavescens
- Centrarchidae
  - Lepomis gibbosus

Osteoglossiformes
- Hiodontidae
  - Hiodon tergisus

Cypriniformes
- Catostomidae
  - Moxostoma sp.

Salmoniformes
- Salmonidae
  - Coregonus artedii

Appendix 10. Results of the paired Student's t-test used in the water preference experiment.

Control experiment - similar water in both chambers

	Mean time (sec.)	Standard deviation	Standard deviation of D	Standard error of D	Mean D	df	Paired t
Chamber A	893.3	449.1	898.1	366.6	13.7	5	0.037
Chamber B	907.0	449.0					

Britannia Bay and lower C.I.P. channel water compared

	Mean time (sec.)	Standard deviation	Standard deviation of D	Standard error of D	Mean D	df	Paired t
Britannia Bay water	836.1	409.5	747.5	163.1	17.6	20	0.108
Lower C.I.P. channel water	818.5	405.0					