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## ABSTRACT

The ecology of the brown bullhead Ictalurus nebulosus (Le Sueur) was studied in three sections of the Ottawa River near Ottawa and Hawkesbury from 1971 to 1974. Brown bullhead comprized about 41.6% of the total number of individuals of all species above Ottawa and 85.9% below Ottawa. Densities from 2,500-7,800 bullhead per ha were estimated in Kettle Island Bay below Ottawa. Extensive tagging revealed that the majority of bullhead remained in the vicinity of a home bay. Different populations inhabited separate bays.

Aggressive behaviour was observed among sexually mature bullhead in an aquarium. A dominant male bullhead inflicted wounds on its tankmates similar to the wounds noted on 5-17% of bullhead captured in the field during the spawning season. Dominance in a social hierarchy may assure that only the more aggressive individuals succeed in reproducing.

Mercury concentrations in the muscle of bullhead in the upper and lower rivers above and below Ottawa and near Hawkesbury were similar and were generally below 0.5 ppm. The levels did not increase with the size of bullhead at any of the four stations examined.

Bullhead in the lotic environments above Ottawa and near Hawkesbury exhibited high growth rates and condition factors which were significantly higher than those exhibited by bullhead in the lower river where more lentic conditions prevail. An analysis of the growth of bullhead at the different stations within each section of river revealed that the bullhead had similar rates of growth.

Bullhead examined from various stations in the lower river had ingested large quantities of detritus, filamentous algae, plant material, chironomids, isopods and amphipods. Their importance in the diet, particularly the plant and algal material has been discussed.

## RESUME

L'écologie de la barbotte brune Ictalurus nebulosus (Le Sueur) a été étudiée, de 1971 à 1974, dans trois secteurs de la rivière Ottawa, près d'Ottawa et d'Hawkesbury. La barbotte brune constitue 41.6% des poissons trouvés en amont d'Ottawa et 85.9% de ceux capturés en aval. On estime à environ 2,500 à 7,800 le nombre de barbottes dans la baie de l'île Kettle, en aval d'Ottawa. Une étude poussée au moyen d'étiquetage a révélé que la majorité des barbottes demeuraient dans le voisinage d'un même domaine, une baie en l'occurrence, et que les différentes populations habitaient leurs baies respectives.

Le comportement agressif chez les mâles ayant atteint leur maturité sexuelle, a été observé dans un aquarium. Les blessures infligées par le mâle dominateur aux autres individus de l'aquarium sont similaires aux blessures observées sur 5 à 17% des barbottes capturées dans la rivière durant la saison de reproduction. Dans la hiérarchie sociale, la dominance pourrait assurer que seuls les individus les plus agressifs peuvent se reproduire avec succès.

La concentration de mercure dans les muscles des barbottes, en amont et en aval d'Ottawa et près d'Hawkesbury, était uniforme, généralement inférieure à 0.5 ppm. Le niveau de concentration de mercure n'augmente pas avec l'accroissement de la taille des barbottes, dans aucun des quatre secteurs étudiés.

Les barbottes des eaux lotiques, en amont d'Ottawa, ont un taux de croissance plus élevé que celui des barbottes vivant en aval d'Ottawa dans des conditions lenitiques. Une analyse de la croissance des barbottes dans chacun des secteurs de la rivière, révèle qu'elles ont un taux de croissance identique.

Les barbottes provenant des secteurs situés en aval d'Ottawa ingèrent des débris, des algues filamenteuses, de la matière végétale, des chirono-

mides, des isopodes et des amphipodes. L'importance nutritive des plantes et algues dans leur diète alimentaire, a été discutée.

## INTRODUCTION

The purpose of this study was to obtain information on the life history and ecology of the brown bullhead (Ictalurus nebulosus) in the Ottawa River in the vicinity of Ottawa and Hawkesbury, Canada. This is an important commercial species which has received little ecological attention in Canada (Scott and Crossman, 1973). Brown bullhead taken in various parts of the Ottawa River have been compared in order to elucidate their age, growth, movements, reproduction and feeding habits. Mercury concentrations in the muscle of brown bullhead were compared, to assess pollutant concentration in relation to body size in various areas of river. A three mile stretch of river below Ottawa was studied in more detail to assess the magnitude of the brown bullhead population, its distribution and movements in regard to the distribution and transport of pollutants such as mercury through an aquatic ecosystem.

The Ottawa River has been the subject of numerous chemical and physical investigations. An excellent review was given in the joint report of the Ontario Water Resources Commission and Quebec Water Board (OWRC-QWB, 1971). Serious biological investigations under the auspices of the University of Ottawa commenced in 1966 and are still being carried out by various investigators (Stobo, 1971; Mackie, 1971; Ericksson, 1974; Croskery, 1974; Rosemarin, 1974; Smith, 1974). In September of 1972 the University of Ottawa obtained a five year grant to study the transport of persistent chemicals in conjunction with the National Research Council (NRC) in a three mile (4.8 km) section of river below Ottawa. The study has become known as the Ottawa River Project. The duration of this thesis research was from May 1971 to May 1974.

## DESCRIPTION OF STUDY AREA

The Ottawa River extends 1,113 km (696 miles) from Lake Temiscamingue to the St. Lawrence River and has a drainage of approximately 145,000 sq km (56,000 sq miles) (OWRC-QWB, 1971). Three sections of the Ottawa River, situated within zone two (Fig. 1) as defined by the OWRC-QWB report, were examined. The upper river is a section of Lac Deschênes situated above Ottawa, extending from the YMCA camp to the Deschênes rapides (Smith, 1974). The lower river is a section of the Ottawa River below Ottawa, extending from the Chaudière Falls to the downstream end of Lower Duck Is. The Hawkesbury section extends from 4.8 km (3 miles) above to 4.8 km below the town of Hawkesbury.

Situated in Lac Deschênes in the upper river, the two areas under study were Shirleys Bay and Britannia Bay. Lac Deschênes is a lake-like expanse of the river characterized by gently sloping shorelines, slow currents and fairly good water quality (Stobo, 1971; Mackie, 1971; Smith, 1974). Shirleys Bay receives the secondary effluent from the Watts Creek sewage treatment plant. Concern over the eutrophying effect of this effluent prompted construction of a causeway across most of the mouth of the bay in 1971. Shirleys Bay has a rock, mud substrate while Britannia Bay has a sandy bottom.

The lower river represents a less homogeneous habitat, characterized by steep shorelines, moderate to fast currents and generally more polluted conditions. The chemical characteristics of the water are generally not directly hazardous to fish life (Ellis, 1944) except in the immediate vicinity of municipal and industrial effluents at Brewery Creek and directly


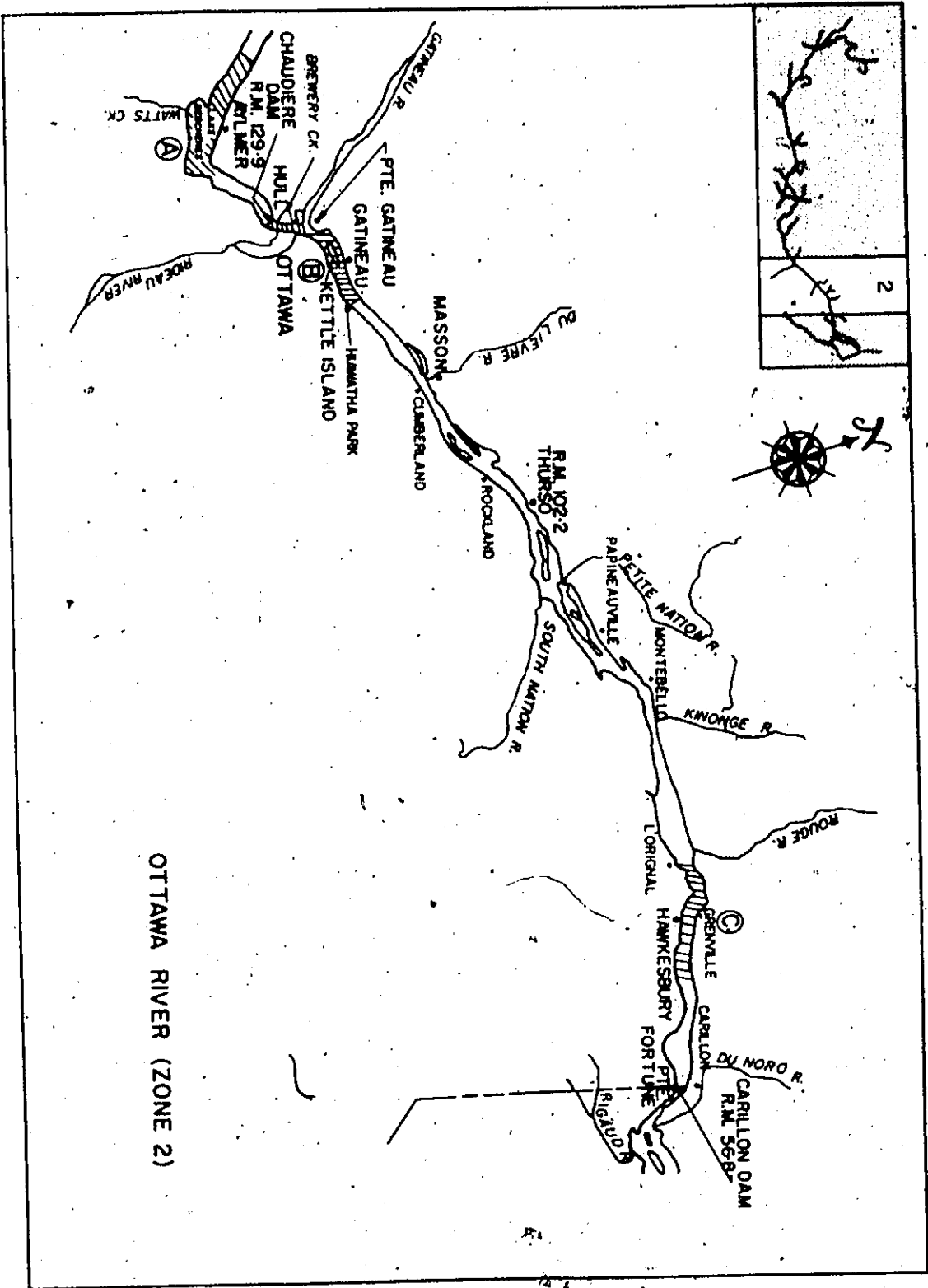


Figure 1. Zone 2 of the Ottawa River Basin as defined by the Ontario Water Resources Commission - Quebec Water Board Report (1971). The three sections of river where brown bullhead were studied are (A) the upper river (B) the lower river (C) near Hawkesbury.



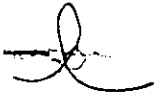
OTTAWA RIVER (ZONE 2)

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below the Canadian International Paper Company (CIP) at Gatineau, Quebec (Stobo, 1971; Mackie, 1971). Hull and Point Gatineau presently have no sewage treatment facilities while Ottawa has a primary treatment plant situated at Green's Creek. About 90% of the organic load entering this section of river comes from the local paper mills, E.B. Eddy Company at the Chaudière Falls and the CIP mill at Gatineau (OWRC-QWB, 1971).

Depths vary in the lower river from 6-26 m in the main channels of the river to less than 3 m in local bays and backwaters such as Brewery Creek, Hay Bay, Governor's Bay, Kettle Is. Bay and the bay at the top of Lower Duck Is. The substrate is mainly clay, sand and wood chips in the main channel with soft mud bottoms in most bays.

The vicinity of Hawkesbury represents an area of slow to moderate currents, moderately steep shorelines and impaired water quality (OWRC-QWB, 1971). A heavy oxygen demand is exerted on the river by the CIP mill at Hawkesbury. The Carillon Dam, constructed in 1962, has created a lotic environment below Hawkesbury which is not able to assimilate the wastes from the mill. Values of about three ppm dissolved oxygen are common in the section of river below Hawkesbury (LeSauteur, 1965). Depths vary from 10 to 15 m. The substrate varies from wood chips, to mud and sand, depending on the proximity of the mill and the current. Most of the current is along the Quebec shore of the river.



## ABUNDANCE, DISTRIBUTION AND MOVEMENTS

## Introduction

Numerous studies are available which give the densities of brown bullhead in lakes and ponds (Emig, 1966) but little data exist for rivers. Sanderson (1958) estimated a density of brown bullhead in the Potomac River of 2.2 kg per ha. Hensel (1966) quoted studies which show that 2,089 adult brown bullhead per ha were found in the backwater Poltruba and three times that number were found in the backwater Prockazhova tun. These are backwaters in the river Elbe in Czechoslovakia.

No published information exists concerning the magnitude and importance of the fish populations in the Ottawa River. Data are available in manuscript form concerning commercial catches and a creel census for the section of river between Rockland and Hawkesbury (Levere, 1969). A gill net survey of the section between Greece's Point and Carillon below Hawkesbury has been conducted by Mr. Albert Courtemance of the Quebec Department of Fish and Wildlife, Montreal District (LeSauteur, 1965). Extensive fish sampling has been conducted in the upper and lower rivers by students of Dr. S.U. Qadri at the University of Ottawa. Some of this data is available in thesis form (Stobo, 1971; Smith, 1974).

Studies of brown bullhead in lakes have shown that brown bullhead tended to remain near the location where they were tagged (McCammon and Seely, 1961; Rawstron, 1967). Cooper (1951) and Shoemaker (1952) have shown that yellow and brown bullhead homed to the area of the lake from which they had been displaced. Little published information is

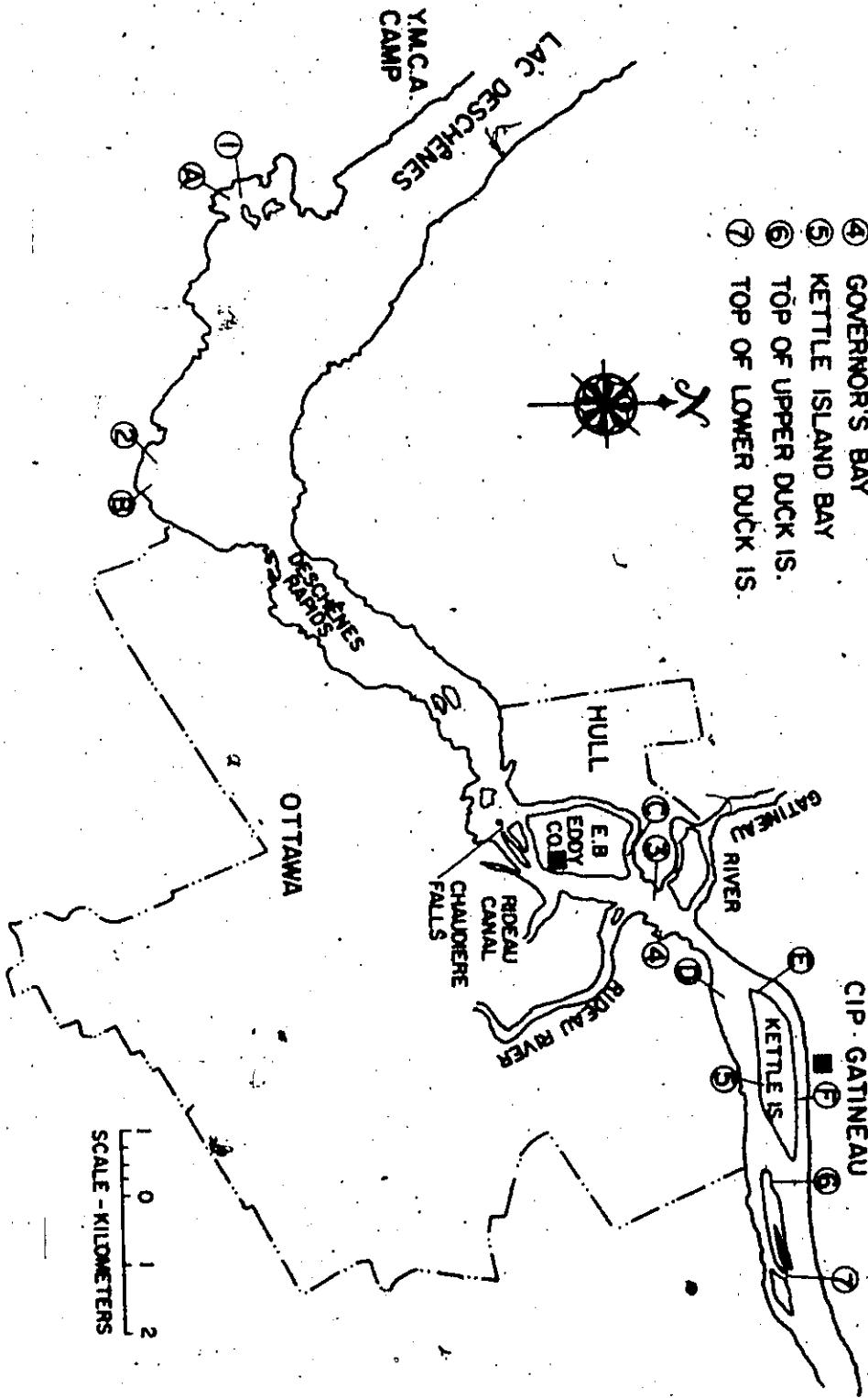
available concerning the distribution and movements of brown bullhead in rivers. Marcy (1969) has conducted studies of the brown bullhead under the influence of thermal pollution near Haddam Neck in the Connecticut River. The mean distance travelled by brown bullhead recovered by anglers was 1.1 km (0.7 miles). The mean distance travelled upstream was 9.7 km (6.1 miles). The mean distance travelled downstream was 4.5 km (2.8 miles). One hundred and twenty-seven (85.1%) of the 149 tagged bullhead recovered by anglers were within 2.4 km (1.5 miles) of the marking site in the thermal discharge canal at Haddam Neck. The maximum distance travelled was a bullhead which moved 45 km (28 miles) upstream. Another bullhead moved 9.7 km (6 miles) downstream. One bullhead moved 17.7 km (11 miles) in 51 days.

#### Materials and Methods

A variety of collecting gear has been used to obtain catch per unit effort data in order to assess the relative abundance of bullhead in various parts of the Ottawa River (Fig. 2). Gill net gangs comprised of four 50 ft sections of  $1\frac{1}{2}$ , 2, 3 and 4 inch stretched mesh; a 6 ft trap net with 2 inch mesh and 150 ft lead;  $2\frac{1}{2}$  ft diameter hoop nets with  $\frac{1}{2}$  or 2 inch mesh; a 100 ft seine with  $\frac{1}{2}$  inch mesh were utilized.

Trap nets set in shallow bays were used to assess the relative abundance of bullhead and other species at various stations. Trap netting was also used as a means of capturing unharmed bullhead for tagging purposes. Hoop nets and gill nets were set in deep and shallow water to assess the abundance and distribution of bullhead and other species in the three mile NRC section of the lower river. Seining was used to catch young-of-the

Figure 2. Gill netting and trap netting stations situated in the upper and lower Ottawa River where brown bullhead were sampled between 1968 and 1973.



TRAP NETTING STATIONS

- ① SHIRLEY'S BAY
- ② BRITANNIA BAY
- ③ HAY BAY
- ④ GOVERNOR'S BAY
- ⑤ KETTLE ISLAND BAY
- ⑥ TOP OF UPPER DUCK IS.
- ⑦ TOP OF LOWER DUCK IS.

GILL NETTING STATIONS

- Ⓐ SHIRLEY'S BAY
- Ⓑ BRITANNIA BAY
- Ⓒ BREWERY CREEK
- Ⓓ NEW EDINBURGH CANOE CLUB
- Ⓔ ABOVE CIP
- Ⓕ BELOW CIP

SCALE - KILOMETERS

0 1 2

year bullhead in Britannia Bay but was generally ineffective in the lower river due to the scarcity of suitable seining locations.

To assess the movements and distribution of bullhead in the lower river, Floy numbered dart tags and coloured Floy Flag tags were applied with a tagging gun (Dell, 1968). Tags were applied between the interneurons of the dorsal fin in the manner described by Keller (1971). An anaesthetic MS-222 (tricaine methane sulfonate) was used during tagging of bullhead in Governor's Bay during May 1971 but was not used in subsequent tagging operations. It was feared that the anaesthetic could have an adverse effect since it was impossible to regulate the dose under the field conditions where the tagging was conducted. This suspicion was confirmed by Huish (1972). Observation of ten bullhead tagged and held in aquaria for a period of over six months indicated no adverse effect or tag loss when not using anaesthetic.

To assess tag loss in the field, 250 bullhead were tagged with numbered dart tags in Kettle Is. Bay and 125 pink Flag tags were applied to bullhead at the top of Upper Duck Is. The adipose fins of these fish were removed with a pair of scissors. It was then possible to recognize bullhead which had lost their tag during subsequent recaptures by the absence of the fin.

To assess general movements of brown bullhead in the lower river, 500 FT-67 numbered 65 mm dart tags were applied at Governor's Bay during May 1971. In order to assess whether these tagged bullhead could move across the river from Governor's Bay, trap nets were set in Hay Bay 1 km

(0.6 miles) away. Large catches of bullhead at this site prompted me to apply 900 red Flag tags in order to obtain a Peterson population estimate for Hay Bay.

The results of tagging in 1971, prompted further tagging to assess the amount of exchange between stations in the lower river. Two thousand brown bullhead were tagged both at Kettle Is. Bay and at Hay Bay, 5.7 km (3.5 miles) upstream; 1500 were tagged at the top of Lower Duck Is. 4 km (2.5 miles) downstream of the Kettle Island station. Trap nets were set every two weeks from May to October 1972 at the three stations to recover the tagged fish.

When bullhead with Flag tags were recovered, the corners of the rectangular end of the tag were clipped such that a record of multiple recaptures was kept. By clipping the corners of the tag closest to the tag insertion, it was possible to record if the bullhead had been taken at a station other than the original tagging site.

To better understand the movements and population size of brown bullhead in a restricted portion of river, the NRC section in the lower river was given more detailed study (Fig. 3). During the summer of 1973, 3,041 bullhead taken in trap nets within Kettle Is. Bay were tagged with FD-67 numbered 57 mm dart tags. An additional 341 brown bullhead taken by hoop netting along three transects in the main channels of the river were also tagged using different lettered number series. To recover bullhead tagged within the bays, gill nets were set every two weeks from May to September along three transects situated in the north and south channels

Figure 3. The NRC study section situated in the lower Ottawa River showing the three transects along which hoop netting and gill netting was conducted during 1972 and 1973.

QUEBEC



CIP

KETTLE ISLAND

KETTLE IS. BAY

OTTAWA RIVER



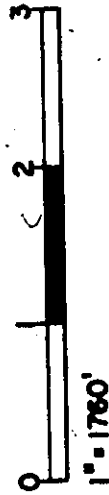
UPPER  
DUCK IS.

TRANSECT 3

TRANSECT 2

TRANSECT 1

ONTARIO



of the river along both sides of Kettle Island, during 1972 and 1973. Hoop nets were set in a similar fashion during 1973.

To obtain accurate estimates of the number of brown bullhead in Kettle Is. Bay, bullhead were tagged on a monthly basis between May and September 1973. A different letter series was used each month. The number and length-weight data was recorded for each tagged fish. During tagging operations, the mouth of the bay was closed with a 300 by 6 ft seine. Following tagging the bullhead were released from the trap net and allowed to redistribute themselves within the bay. The trap net was then opened to recover tagged fish to obtain a Peterson population estimate of bullhead within the bay. The seine was then removed from the mouth of the bay to allow the bullhead to distribute themselves between the bay and the river for two days. A second population estimate was then obtained with the bay open to the river. Four estimates with the bay open and three with the bay closed were obtained in 1973 (Table 8).

## Results

### Abundance

During the course of this study, 45 species of fish have been collected from the Ottawa River (Table 1). By trap netting at various stations it was found that brown bullhead predominated in the upper and lower rivers except at Britannia Bay (Tables 2 and 3). Averaging these catches, it was estimated that in the upper river, brown bullhead comprised 41.6% by numbers and 13.4% of the biomass of all species retained in the trap net. Channel catfish were also abundant in the upper river comprising 30.5% by numbers and 62.7% of the biomass. The distribution of channel

Table 1. Relative abundance of fish species by various fishing gear in the Ottawa River.

Scientific name	Common name	Upper river	Lower river	Gill net	Trap net	Hoop net	Seine net
<u>Ichthyomyzon unicuspis</u>	silver lamprey	-	x	1	1	0	0
<u>Acipenser fulvescens</u>	lake sturgeon	x	x	4	0	0	0
<u>Lepisosteus osseus</u>	longnose gar	x	x	3	3	0	1
<u>Hiodon tergisus</u>	mooneye	x	x	3	2	0	0
<u>Coregonus artedii</u>	lake cisco	x	-	1	0	0	0
<u>Osmerus mordax</u>	rainbow smelt	x	x	0	0	0	1
<u>Esox lucius</u>	northern pike	x	x	2	3	2	2
<u>Esox masquinongy</u>	muskellunge	x	x	1	1	0	1
<u>Cyprinus carpio</u>	carp	x	x	1	2	0	1
<u>Hybognathus nuchalis</u>	silvery minnow	x	x	0	0	0	4
<u>Notemigonus crysoleucas</u>	golden shiner	x	x	1	1	0	2
<u>Notropis atherinoides</u>	emerald shiner	x	x	0	0	0	4
<u>Notropis heterodon</u>	blackchin shiner	x	x	0	0	0	1
<u>Notropis hudsonius</u>	spottail shiner	x	x	0	0	1	3
<u>Pimephales notatus</u>	bluntnose minnow	x	x	0	0	0	2
<u>Rhinichthys cataractae</u>	longnose dace	x	-	0	0	0	1
<u>Semotilus corporalis</u>	fallfish	x	x	1	0	0	2
<u>Carpiodes cyprinus</u>	quillback	-	x	1	2	0	0
<u>Catostomus commersonii</u>	white sucker	x	x	4	2	1	2
<u>Moxostoma anisurum</u>	silver redhorse	x	x	3	2	0	1
<u>Moxostoma carinatum</u>	river redhorse	-	x	0	1	0	0
<u>Moxostoma macrolepidotum</u>	shorthead redhorse	x	x	4	3	1	2
<u>Moxostoma valenciennesi</u>	greater redhorse	-	x	0	1	0	0
<u>Ictalurus natalis</u>	yellow bullhead	-	x	0	1	1	0
<u>Ictalurus nebulosus</u>	brown bullhead	x	x	4	5	5	2
<u>Ictalurus punctatus</u>	channel catfish	x	x	4	3	1	1
<u>Anguilla rostrata</u>	American eel	x	x	0	2	0	1
<u>Lota lota</u>	burbot	x	x	1	1	2	0
<u>Fundulus diaphanus</u>	banded killifish	x	x	0	0	0	2
<u>Ambloplites rupestris</u>	rockbass	x	x	2	2	1	2
<u>Lepomis gibbosus</u>	pumpkinseed	x	x	3	3	3	3
<u>Lepomis macrochirus</u>	bluegill	-	x	0	1	0	0
<u>Micropterus dolomieu</u>	smallmouth bass	x	x	2	2	0	1
<u>Micropterus salmoides</u>	largemouth bass	x	x	1	1	0	1
<u>Pomoxis nigromaculatus</u>	black crappie	-	x	2	3	0	1
<u>Etheostoma exile</u>	Iowa darter	x	-	0	0	0	1
<u>Etheostoma nigrum</u>	Johnny darter	x	x	0	0	0	2
<u>Etheostoma olmstedii</u>	tessellated darter	x	x	0	0	0	2
<u>Perca flavescens</u>	yellow perch	x	x	4	3	4	5
<u>Percina caprodes</u>	logperch	x	x	0	0	0	3
<u>Stizostedion canadense</u>	sauger	x	x	4	2	0	0
<u>Stizostedion vitreum</u>	walleye	x	x	4	3	1	1
<u>Aplodinotus grunniens</u>	freswater drum	-	x	0	1	0	0
<u>Cottus bairdii</u>	mottled sculpin	x	x	0	0	0	1

## Abundance rating

- absent	0	absent	3	1.01-5.00%
x present	1	0.0001-0.10%	4	5.01-50.0%
	2	0.11-1.00%	5	50.01-100%

Table 2 Standing crop as numbers and biomass in kg (parentheses) of brown bullhead from trap net catches in the upper and lower river during 1972.

	UPPER RIVER			LOWER RIVER			
	Shirleys Bay	Britannia Bay	Hay Bay	Governor's Bay	Middle of Kettle Is.	Top of Upper Duck Is.	Top of Lower Duck Is.
No. of net sets	5	3	9	3	8	2	10
Total no. of bullheads in all catches	4,263 (1,065.8)	25 (6.3)	9,759 (2,103.9)	281 (61.0)	11,618 (1,915.4)	610 (100.5)	5,905 (1,095.3)
Mean no. in a catch (C/F)	852.6 (213.2)	8.3 (2.1)	1,084.3 (235.3)	93.7 (20.3)	1,452.3 (212.7)	305 (50.3)	590.5 (114.4)
Range in no. per catch	6-3,000 (1.5-750)	0-14 (0-3.5)	442-2,010 (95.9-436.2)	87-104 (18.9-22.6)	259-3,206 (42.7-528.4)	55-555 (9.1-91.5)	228-1,469 (44.2-284.6)
Per cent by no. of bullheads in total catch of all species	67.5 (36.0)	5.7 (1.5)	89.6 (70.3)	63.6 (29.2)	96.0 (91.0)	88.9 (69.6)	92.3 (78.3)

Table 3 Estimates of relative abundance of fish by numbers and biomass in the upper and lower river derived from trap netting in 1972.

Species	UPPER RIVER		LOWER RIVER	
	General abundance as a % of the total no. of individuals of all species	General abundance as a % of the total biomass of all species	General abundance as a % of the total no. of individuals of all species	General abundance as a % of the total biomass of all species
Brown bullhead	41.60	13.36	85.90	67.66
Silver lamprey	---	---	0.06	0.014
Longnose gar	2.90	3.72	1.32	2.80
Mooneye	0.00	0.00	0.22	0.11
Northern pike	1.00	1.32	0.23	0.94
Muskellunge	0.10	0.06	0.002	0.004
Carp	0.30	1.41	0.20	3.16
Golden shiner	0.00	0.00	0.02	0.003
White sucker	0.30	0.36	0.16	0.65
Shorthead redhorse	1.10	1.43	1.81	5.51
Silver redhorse	1.30	5.34	0.83	6.34
Greater redhorse	---	---	0.05	0.05
Quillback	---	---	0.24	1.62
Channel catfish	30.50	62.68	0.29	1.22
Eel	0.90	1.16	0.49	2.16
Burbot	0.001	0.001	0.004	0.008
Rockbass	3.00	0.96	0.24	0.28
Pumpkinseed	11.20	3.31	1.65	0.83
Bluegill	---	---	0.002	0.001
Black crappie	---	---	2.76	2.02
Smallmouth bass	1.10	0.51	0.28	0.31
Largemouth bass	1.00	1.09	0.03	0.15
Sauger	0.60	0.21	0.09	0.07
Walleye	2.80	2.37	1.09	2.59
Yellow perch	0.50	0.71	1.98	0.69
Freshwater drum	---	---	0.06	0.47

catfish has been discussed by Smith (1974). In the lower river brown bullhead comprised 85.9% by numbers and 67.7% of the biomass.

By averaging gill net catches from 1968-1971 it was found that the catch per unit of effort (C/f) of brown bullhead was highest below Hawkesbury (Table 4) tending to indicate that bullhead are more abundant in this area. While the C/f varied between stations depending on the type of habitat sampled, it generally tends to increase as one goes downstream. Thus stations with higher water velocities or directly below mill effluents, such as the mouth of the Gatineau River and below the CIP mill at Gatineau respectively, had low standing crops of bullhead. Organically enriched stations with low water velocities such as Brewery Creek, the New Edinburgh Canoe Club and below Hawkesbury had high standing crops.

A comparison of my gill net catches below Hawkesbury in 1970 and 1971 (Table 5) shows that a marked decline in abundance of brown bullhead took place. The C/f below Hawkesbury was 86 in 1970 and only 9 bullhead per net set in 1971. Comparing the catches below Hawkesbury for 1970 and 1971 the C/f were found to be significantly different, student's  $t = 4.6480$  for 3 degrees of freedom,  $P \leq 0.02$ . This probably explains the wide confidence limits below Hawkesbury shown in Table 4.

The catch above the mill (C/f = 11) was not significantly different from below the mill (C/f = 9) during 1971. A plant shutdown during July 1971 coupled with efforts by Canadian International Paper Company to improve their effluent resulted in improved water quality below Hawkesbury. The dissolved oxygen was 3 ppm during July and August 1970. In 1971, the

Table 4. Catch per unit effort (C/f) of brown bullhead by numbers taken in gill nets from 1968-1971.

Station	C/f	Standard error	No. of gill net sets	95% confidence limits
UPPER RIVER				
Shirleys Bay	4.00	---	1	---
Britannia Bay	0.35	0.0248	65	0.30 - 0.40
LOWER RIVER				
Brewery Creek	13.55	1.9930	18	9.34 - 17.76
Governor's Bay	2.40	0.6000	5	0.73 - 4.07
New Edinburg Canoe Club	15.71	3.2454	21	8.94 - 22.48
Mouth of Gatineau River	0.41	0.939	17	0.21 - 0.61
Above CIP Gatineau	2.83	1.0744	12	0.47 - 5.09
Below CIP Gatineau	1.08	0.1486	12	0.75 - 1.41
HAWKESBURY				
Above CIP Hawkesbury	7.33	3.6667	3	-8.44 - 23.11
Below CIP Hawkesbury	39.8	18.86	5	-12.56 - 92.16

Table 5 Catch per unit of effort (C/f) of brown bullhead by numbers in gill nets set above and below Hawkesbury during 1970 and 1971.

Station	Year	C/f	Range of catch	Number of net sets	Dissolved oxygen ppm
Above Hawkesbury	1970	0.0	---	1	6
	1971	11.0	5-17.	2	5-6
Below Hawkesbury	1970	86.0	67-105	2	3-4
	1971	9.0	0-22	3	5-9

Table 6 Catch per unit of effort (C/f) by numbers of brown bullhead taken in hoop nets and gill nets during 1972-1973, within the NRC section of the lower river.

Netting method	Channel	Transect 1			Transect 2			Transect 3		
		C	f	C/f	C	f	C/f	C	f	C/f
Hoop net 1973	South	197	(11)	17.9	869	(7)	124.1	60	(6)	10.0
	North	20	(5)	4.0	295	(5)	59.0	57	(7)	8.1
Gill net 1972	South	9	(6)	1.5	4	(3)	1.3	2	(4)	0.5
	North	3	(5)	0.6	3	(4)	0.75	1	(2)	0.5
Gill net 1973	South	0	(5)	0.0	3	(6)	0.5	1	(5)	0.2
	North	1	(4)	0.25	23	(7)	3.3	3	(4)	0.75

levels were 9 ppm in June and 5 ppm in July and August, based on water samples taken near the surface.

#### Standing Crop of Bullhead in NRC Section

Hoop net and gill net catches, set during 1972 and 1973, along the three transects gave estimates of the relative abundance of bullhead in various segments of the NRC section (Table 6). The abundance of bullhead, expressed in terms of C/f, was lower along transects one and three in both the north and south channels of the river. This is similar to the results from trap netting in 1972 which indicated that the abundance of bullhead declines with increasing distance from Kettle Is. Bay.

Hoop netting in 1973 indicated that bullhead were more abundant in the south channel than in the north channel. Gill netting in the same areas in 1973 indicated that the opposite was true. This reversal may be attributed to the fact that the SIP mill at Gatineau was on strike during most of the summer of 1973. The C/f of 3.3 bullhead per net set found during 1973 below the mill was atypical since it exceeded values found between 1968 and 1971 (Table 4). Gill netting along the same transects when the mill was in production in 1972 indicated that bullhead were more abundant in the south channel and this appears to be the usual situation.

#### Tag Retention

Tag retention of Floy dart tags and Flag tags applied at various stations appears to have been very high as evidenced by the high rates of tag recovery (Table 9). Based on double marking procedures it was calculated that 9 out of 44 (20%) of the marked bullhead recaptured at

Lower Duck Is. had lost their pink Flag tags, during 1972. Only one out of 131 (.76%) of the bullhead tagged with numbered dart tags at Kettle Is. were noted without tags in 1972 and 1973.

Open sores around the base of the dart tag, as noted by Stobo (1972) in yellow perch, were not evident in brown bullhead. Tag losses due to tags working themselves loose or due to the loss of the vinyl tube from its base (Keller, 1971; Rawstron, 1973) were very infrequent in the catch. Such losses can be attributed to the tagging technique and the procedures recommended by the above authors were utilized to minimise tag loss.

One bullhead was recaptured in the vicinity of Hay Bay three years after it was tagged. Tagged bullhead were still very common in Hay Bay and Kettle Is. Bay a year after tagging took place. The frequency of recovery of numbered dart tags in Kettle Is. Bay averaged over the summer of 1972 was 0.0111 and 0.0055 during 1973. Similarly the frequency of red Flag tags in the catch at Hay Bay was 0.0185 during 1971 and 0.0096 during 1972. This is about a 50% decline in frequency of recovered tags from one year to the next at both locations. It is not known what proportions were due to tag loss and to total annual mortality.

#### Population Size and Density

In order to obtain some idea of population size of bullhead, Peterson population estimates using Flag tags were attempted at three stations in the lower river.

Table 7 Peterson population estimates of brown bullhead conducted in lower river in 1971 and 1972.

Station	Date	Peterson estimate	95% Confidence limits
Hay Bay	August 17, 1971	28,369	+ 39,301 - 22,222
Kettle Is. Bay	May 26, 1972	35,579	+ 44,592 - 25,617
Top of Lower Duck Is.	June 9, 1972	10,152	+ 14,226 - 7,892

These estimates show that very large numbers of bullhead were in the vicinity of these bays. The population estimates were in general agreement with the C/f data derived from trap netting (Table 2). Lower Duck Is. station had the lowest C/f and lowest population estimate of the three stations. It is probable that bullhead were less abundant at this site because it was downstream of the CIP mill at Gatineau and was influenced by the mill (Stobo, 1971).

These estimates were conducted with the bays open to the river. Since the river is an open system, it is impossible to state to what areas these estimates apply. To overcome this and to get an in depth understanding of the dynamics of one area, Kettle Is. Bay within the NRC section was chosen for more detailed study. Estimates of the size of the population of bullhead in Kettle Is. Bay were obtained by closing the bay during 1973. Table 8 lists the population estimates conducted in 1973. In general it can be seen that the estimates fluctuated 50% or more. The May and July estimates with Kettle Is. Bay open were within the range of confidence limits

Table 8 Population estimates of brown bullhead in Kettle Island Bay during 1973.

Date estimated	Bay open	95% Confidence limits	Bay closed	95% Confidence limits	No. per ha
May 28	25,492	+43,952 -17,957	---	---	---
June 30	---	---	13,464	+97,777 -7,248	2,692
July 10	21,717	+45,360 -14,332	---	---	21
Aug 4	---	---	12,448	+14,879 -10,707	2,489
Aug 10	12,903	+16,434 -10,634	---	---	---
Sept 27	---	---	38,929	+57,481 -29,483	7,785
Oct 2	65,487	+106,533 -47,276	---	---	---

of the estimates made during 1972 (Table 7). With the bay closed the June estimate of 13,464 showed close agreement with the August estimate of 12,448, although only the latter had reasonable confidence limits. The estimates of late September and October do not show close agreement with those earlier in the season, having sharply increased. However, since these estimates have reasonable confidence limits they are believed to be valid. In October, numerous recaptures were made of bullheads tagged earlier in the season along the three transects (See the next section). It is believed that the increased estimates represent a migration of bullhead from deep to shallow water, and into Kettle Is. Bay.

Knowing the area of Kettle Is. Bay from planimetry, the number of brown bullhead in the bay in August divided by the area was:

$$\frac{12,448 \text{ bullhead}}{5 \text{ ha}} = 2,489.6 \text{ bullhead per ha in the shallow zone}$$

During 1973 extensive netting operations were conducted in the NRC section of river and in Kettle Is. Bay. By comparing the gill net and hoop net C/f in shallow (< 3 m) and deep zones (> 3 m) it was ascertained that brown bullhead were much more abundant in the littoral zone. By calculating the mean C/f along the transects in shallow and deep zones respectively, the per cent occurrence by which brown bullhead occupy each zone was calculated according to the following formula:

$$C/f \text{ shallow} + C/f \text{ deep} = 100\%$$

$$\frac{C/f \text{ shallow} \times 100\%}{C/f \text{ shallow} + C/f \text{ deep}} = \text{per cent occurrence in shallow zone}$$

$$\frac{C/f \text{ deep} \times 100\%}{C/f \text{ shallow} + C/f \text{ deep}} = \text{per cent occurrence in deep zone}$$

This was done separately for hoop nets and gill nets. Using hoop nets it was calculated that 78.11% of the bullhead were in the shallow zone and 21.33% were in the deep zone. Using gill nets it was estimated that 91.19% were in the shallow zone and 8.81% were in the deep zone. Averaging the results of the two methods it was estimated that 84.65% was the relative abundance of bullhead in the shallow zone and 15.07% was their relative abundance in the deep zone.

Using these percentages it was then possible to estimate the relative density of bullhead in the deep and shallow zones. Knowing the per cent occurrence of bullhead in the shallow and deep zones and knowing their density in Kettle Is. Bay one can calculate the density of bullhead in the deep zone near the bay.

$$\begin{aligned} \text{No. bullheads per ha in deep zone} &= \frac{2,489.6/\text{ha in littoral zone} \times 15.1\%}{84.6\%} \\ &= 443.22/\text{ha} \end{aligned}$$

#### Distribution and Movements

In order to understand the relationship between the bays and the rest of the river, extensive tagging was undertaken to ascertain the distribution and movements of brown bullhead. During the three years of study 10,789 brown bullheads were tagged and 2,046 (19.0%) tags were recovered by various means. A summary of the tagging is given in Table 9.

From June 1 - 4, 1971, 500 brown bullhead were tagged in Governor's Bay. During 1971 and 1972 anglers returned 13 tags. Another 16 tags were recovered at Governor's Bay during the tagging period by trap netting and

Table 9 Summary of tag recoveries of brown bullhead from the lower Ottawa River from 1971 to 1973.

Tagging site	Date tagged	Tag type	Number tagged	No. recovered at home site trap net	No. recovered		Per cent recovery followed by total
					recovered by gill nets, at other anglers, stations and trap net	recovered by gill nets, at other anglers, stations and trap net	
Governor's Bay	June 1-4/71	P series	500	17	4	5.8	29
Hay Bay	August 17/71	Red Flag	900	136	5	16.0	146
Hay Bay	May 19-24/72	Yellow Flag	2000	143	7	8.3	165
Kettle Is. Bay	May 25-26/72	Blue Flag	2000	403	15	22.8	455
Top Lower Duck Is.	June 6-9/72	Orange Flag	1500	153	6	11.7	176
Top Lower Duck Is.	July 27/72	Pink Flag	125	34	0	28.0	35
Kettle Is. Bay	July 26/72	B series	250	130	0	52.0	130
Kettle Is. Bay	May 22-24/73	B series	735	240	4	32.2	244
Kettle Is. Bay	June 27-29/73	E series	962	305	5	32.2	310
Kettle Is. Bay	Aug 1-3/73	F series	963	310	0	32.2	310
Kettle Is. Bay	Sept 25-26/73	L series	503	37	0	7.4	37
Transect one	Summer 1973	C series	115	0	0	2.6	3
Transect two	Summer 1973	A series	132	0	0	2.3	3
Transect three	Summer 1973	C series	104	0	0	2.9	3
Totals			10,789			19.0	2,046

one was recovered on June 9 by an angler. Tag recoveries during the rest of the summer and the following year seemed to indicate that the bullhead had dispersed away from Governor's Bay. By the end of June 1971 a tagged bullhead had been recaptured 16.1 km (10 miles) downstream near Petrie Is. by a commercial fisherman Mr. L. Provost. Other tagged bullhead were taken in the mouth of the Gatineau River (1), Hay Bay (7) and the Rockliffe Boat House (1) on the Ontario shore. These three sites are situated at distances less than 1.6 km (1 mile) from the marking site.

Brown bullhead were able to move across river as well as upstream and downstream. While the river in this section is up to 26 m (80 ft) deep with stream flows of about 2-4 m per sec, the movements of bullhead did not appear to be restricted by such factors as depth or stream flow.

To assess the amount of movement between areas in the lower river in 1972, trap nets were set in Hay Bay, Kettle Is. Bay and a bay at the top of Lower Duck Is. Some trap nets were also set at Governor's Bay and at the top of Upper Duck Is. at points intermediate between the three main stations.

Of the 5,500 bullhead tagged at the three main stations, 588 (10.69%) were recovered during the summer of 1972 (Table 10). The great majority, 85-96% were retaken at the original tagging site. In addition to the coloured Flag tags applied in 1972, many of the red Flag tags applied at Hay Bay in 1971 were also recovered. At all three stations, many bullhead were recaptured repeatedly, some as many as six times. The multiple recapture of blue Flag tags at Kettle Is. Bay during 1972 and 1973 amply illustrates that many of the tagged bullhead stayed close to the marking site

Table 10 Tag recoveries by using trap nets, 1972.

Tag colour and tagging location	No. and date tagged	Hay Bay		Middle of Kettle Is.		Top of Lower Duck Is.		Governor's Bay		Top of Upper Duck Is.		Total tag recoveries
		No. of tag returns	% recovery	No. of tag returns	% recovery	No. of tag returns	% recovery	No. of tag returns	% recovery	No. of tag returns	% recovery	
Hay Bay (red tags)	900 Aug. 1971	136	96.45	4	2.84	1	.71	0.0	0.0	0.0	0.0	141
Brewery Creek (yellow tags)	2,000 May 1972	143	94.70	6	3.97	1	.66	1	.66	0.0	0.0	151
Middle of Kettle Is. (blue tags)	2,000 May 1972	22	8.18	232	86.25	11	4.09	1	.37	3	1.12	269
Top of Lower Duck Is. (orange tags)	1,500 May 1972	3	1.83	7	4.27	153	93.29	0.0	0.0	1	.61	164

over an extended period (Table 11). While the great majority of bullhead were taken at the home site there was evidence that some individuals had moved to other stations (less than 5% of the tag recoveries). A fair number of the multiple recaptures at the home site had been clipped at the other stations indicating that these fish had made movements to other stations and then returned to the home site (Table 11, Other stations).

Movements appeared to be greater in spring and fall than during the summer; since more tag recoveries occurred during these times at sites other than the home site. There may be a tendency for bullhead to be carried downstream in the spring. On May 17, 1972 another tagged bullhead from Governor's Bay plus a red Flag tag from Hay Bay were recaptured at Petrie Is. by Mr. Provost. Another bullhead from Governor's Bay was taken at the top of Lower Duck Is. 8.1 km (5 miles) downstream on June 8, 1972.

In Table 10 it was noted that the per cent recoveries of tags at the three stations declined with increasing distance from the marking site. Assuming that the chance of recapturing a tagged fish at a particular site is in proportion to the number of fish examined and the number of tagged fish at large, the per cent frequency of tag recoveries has been calculated for the various stations.

$$\text{per cent frequency of recapture} = \frac{\text{no. of tag recoveries} \times 100}{\text{total no. of bullhead examined at any station}}$$

Knowing the distance between stations the % frequency values of recaptured tagged fish can be graphed (Fig. 4) to give a rough probability density distribution. The graph acts as a model by which one can predict

Table 11 Multiple recoveries of blue Flag tags in Kettle Is. Bay during 1971 and 1972 by trap netting.

Date	No. of times recovered						Other † stations	Total catch of bullhead
	1	2	3	4	5	6		
1971								
May 26								1207
May 27	51							1380
June 22	75	1						3206
July 7	16	1						701
July 26	2							259
July 28	1							55
August 11	14	3						839
September 1	26	5					1	938
September 20	18	14	2				2	3088
September 22	1	1						555
1972								
February 21 *	2							140
March 8 *	2							280
April 7 *	1							450
May 22	20	6						539
May 23	1	1						97
May 24	7	1						405
May 25	12	5						1395
May 28	7	4	1					580
June 27	4	4	1					328
June 28	1		1					125
June 29								85
June 30	4	1						153
July 10	6	5	2				1	687
July 11	5	2						873
August 1	1							268
August 2	1		1					110
August 3	1	3	2	2			5	1296
August 4	4	3	1	1			2	2111
August 10		3	2	1	1			1271
September 26	12	2			1	1		2943
September 27	8	3	1	1	1			1646
October 2	8	3						2033
Total	311	71	15	5	3	1	11	30,043

\* hoop net

† retaken at Kettle Is. Bay after having been taken at another station

the chance of recapturing a tagged fish at any distance from the tagging site. Assuming that the population of bullheads is represented by the area under the density probability curve, the probability of recapture within any given distance is represented by the percentage of the total area under the curve.

Since the probability of capturing a tagged fish declined very rapidly (Fig. 4) within 1.6 km (1 mile) of the tagging site, it is apparent that the majority of the bullhead stayed close to the marking site. The frequency of bullhead continued to decline with increasing distance from the marking site. This conclusion agrees with C/f data derived from gill netting and trap netting (Tables 2 and 6). The C/f was low at intermediate stations such as Governor's Bay and the top of Upper Duck Is. indicating that bullhead there were much less abundant. Tagged fish were recovered at these intermediate stations which had come from the stations on either side, upstream and downstream.

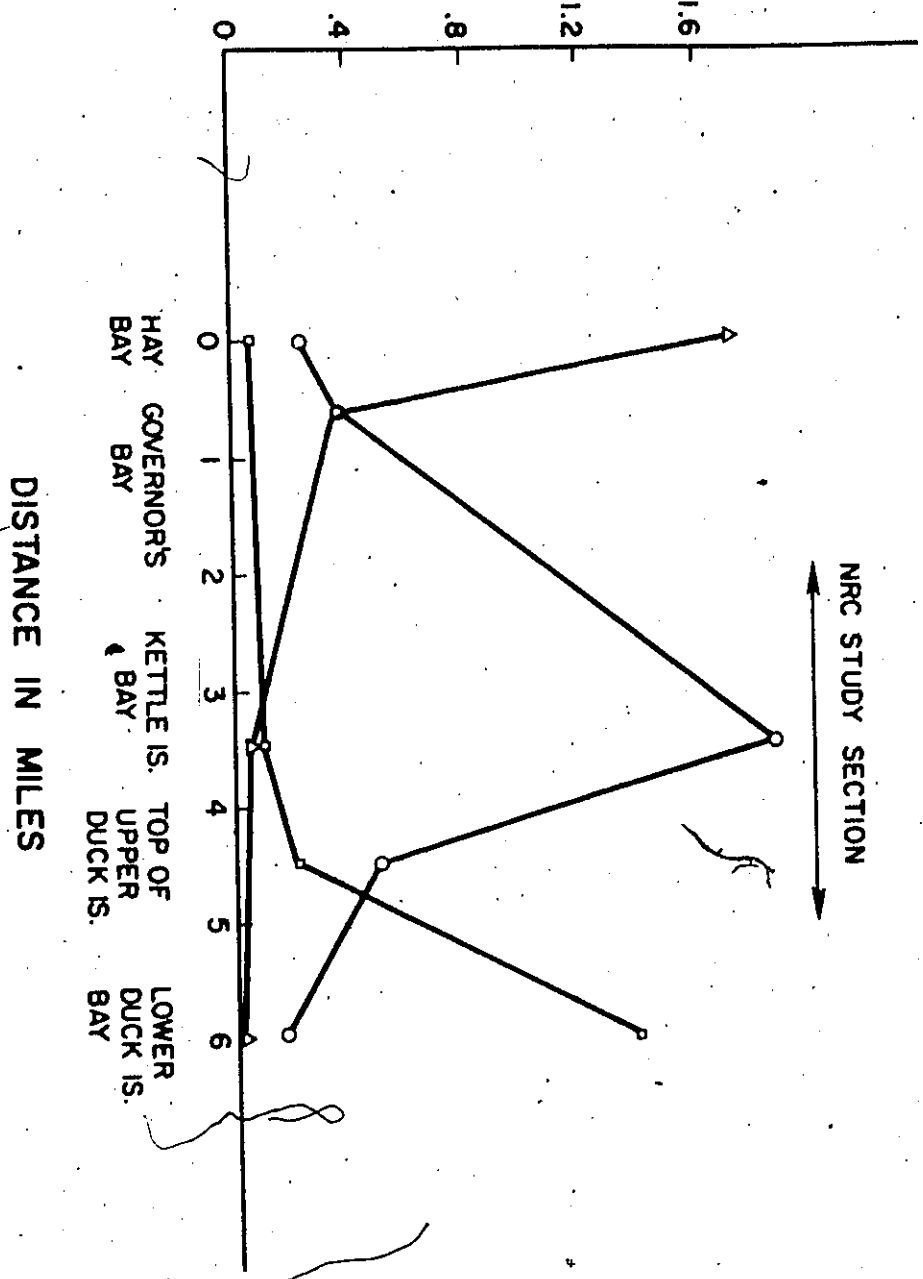
In addition to those tags recovered by trap netting at stations other than the home site, a fair number of tags were recovered by gill netting, hoop netting and by anglers. Gill nets were used to sample three transects in the NRC section during 1972 and 1973 and hoop nets were also used during 1973.

Sampling along the transects coupled with tagging bullhead in Kettle Is. Bay demonstrated that there was an exchange of bullhead between the bay and the river. During 1972, blue flag tags applied in Kettle Is. Bay were recovered by gill netting along the transects. Three blue tags were recovered in the south channel and one in the north channel of

Figure 4. Probability density distributions showing the chance of recapture of tagged fish in the total catch of bullhead with distance from the marking site.

The percentage of the total area under the Kettle Island curve, between the limits of the NRC section, represents the fraction of the Kettle Island population remaining in the NRC section. The percentage of the total area, between the NRC limits, under the Hay Bay and Lower Duck Island curves represents emigration from these stations into the NRC section.

% FREQUENCY OF RECAPTURED TAGS



- TAGGING SITES
- △ HAY BAY
  - KETTLE IS. BAY
  - LOWER DUCK IS. BAY

DISTANCE IN MILES

NRC STUDY SECTION

transect 1, two tags were recovered in the south channel of transect 2 and one tag was taken in the north channel of transect 3. In addition four blue tags were taken by Mr. D. Osterberg, another researcher, in Governor's Bay.

Similar movements were indicated by the recovery of orange Flag tags from the top of Lower Duck Is. and yellow and red Flag tags from Hay Bay. During 1972, one orange tag was taken in the north channel and one in the south channel of transect 2. In addition two orange tags were recovered in gill nets set in Governor's Bay 8.3 km (5.1 miles) upstream from the top of Lower Duck Is. Aside from the red tags recovered near Petrie Is., three tags from Hay Bay were recovered in Governor's Bay by gill netting and one in the mouth of Leamy Creek by an angler. Three different coloured Flag tags, one from each of the three tagging stations, were recovered by an angler. Mr. L. Mercier. These bullhead were taken behind the Canadian Mint in Ottawa above the MacDonald Cartier Bridge between August 5 and 13, 1972.

Recoveries from trap netting and these other sources were more numerous along the south channel and upstream of the original tagging sites. Most bullhead were taken in nets set close to the Ontario and Kettle Is. shores. This probably indicates a tendency for brown bullhead to disperse in an upstream direction along the Ontario and Kettle Is. shores in the south channel of the river during the summer of 1972.

A similar pattern of tag recoveries was noted for brown bullhead taken in hoop nets during 1973. Four blue Flag tags were taken in the south channel of transect 1, four in the south channel and three in the north

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channel of transect 2, and one in the north channel of transect 3. The only difference would appear to be a greater recovery of tagged fish in the north channel below CIP, along transect 2. The average frequency of tagged fish in the catch was 0.0131 on transect 1, 0.0039 in the south channel and 0.0222 in the north channel of transect 2, and 0.0625 in the north channel of transect 3. Thus it would appear that there was a greater tendency for tagged bullhead to disperse along the shore of Kettle Is. downstream into the north channel while the CIP mill was on strike in 1973 than was evident in 1972. But hoop netting and the number of tag recoveries would still tend to indicate that more bullhead were present in the south channel.

None of the 341 bullhead tagged along the transects during 1973, were recaptured where they were tagged. Instead, it was found that many had moved into Kettle Is. Bay. One bullhead was taken by trap netting in the bay on July 10, 1973 which had been tagged on transect 1. Eight more bullhead were recovered in Kettle Is. Bay between September 26 and October 2. Two bullhead were from transect 1, three from transect 2 and three from transect 3. It is believed that these tag recoveries coupled with the increase in the population size in Kettle Is. Bay during October (Table 8), represent a movement of brown bullhead from the main river into Kettle Is. Bay.

Brown bullhead which doesn't appear to be a fast swimming species can still move surprising distances. As mentioned previously a bullhead from Governor's Bay moved 16.1 km (10 miles) in less than 30 days. During 1972, a bullhead which had been tagged in Hay Bay May 19 or 24 was retaken by trap netting in Kettle Is. Bay 5.7 km (3.5 miles) downstream on May 25.

Two blue tags applied at Kettle Is. Bay on May 25 were recaptured at the top of Lower Duck Is. on June 6, 4 km (2.5 miles) downstream. One of these had been retaken previously at Kettle Is. Bay on May 26, indicating that it had moved 2.5 miles in 11 days. Blue tags continued to be recovered at Lower Duck Is. on June 7 (3), 8 (1) and 9 (1), a further indication that movement was greatest during the spring. This does not imply that the movements were just in a downstream direction. On June 21 three tags from Kettle Is. Bay were recovered at Hay Bay and on June 22, four tags from the top of Upper Duck Is. were recaptured in Kettle Is. Bay. It is possible that they moved upstream in much less time since the netting was only done on a bi-weekly basis. During 1973, a numbered tag applied in Kettle Is. Bay on May 22 was recaptured by an angler on May 26 at Hiawatha Park, having moved downstream 5 km (3.1 miles) in four days.

#### Discussion

It is apparent that brown bullhead are one of the most abundant species in the Ottawa River. A density of 2,490 bullhead per ha in Kettle Is. Bay exemplifies this abundance. Numerous studies of lakes and ponds have shown that brown bullhead can attain densities of 2-286.6 fish per ha and standing crops of 0.90-149 kg per ha (Emig, 1966). My estimate and those referred to by Hensel (1966) greatly exceed those of lakes and ponds. Since my trap net only retained adult bullhead greater than 16 cm, which were unable to escape through the 2 inch mesh, the number of bullhead in Kettle Is. Bay must greatly exceed the population estimates. Massengill (1972) reported 4,836 and 3,167 brown bullhead per ha during

the winters of 1970 - 1971 and 1971 - 1972, in the thermal discharge at Haddam Neck in the Connecticut River. It is apparent that brown bullhead can attain densities in the backwaters of rivers which greatly exceed the densities quoted for natural populations of bullhead in lakes and ponds.

Evidence is presented concerning the abundance of bullhead in terms of standing crop in different areas. It is apparent that brown bullhead become more abundant as one proceeds downriver. The abundance is shown by a sizeable commercial fishery between Rockland and Hawkesbury (Levere, 1969). The fishery is mainly conducted with hoop nets and Levere found that 95.6% of the catch in lbs of all commercial species were brown bullhead. The commercial catch on the Ontario side of the river between Rockland and Hawkesbury from 1964-1968 varied between 57,987 and 113,941 lbs annually. The total catch of all commercial species above and below Ottawa from both sides of the Ottawa River during 1968 was 395,641 lbs valued at \$118,443. (OWRC-QWB, 1971). Assuming that 95.6% were brown bullhead, the catch of this species during 1968 was about 376,600 lbs. This is close to the entire commercial bullhead catch for the province of Ontario taken from the lower Great Lakes and southern inland waters (Adams and Kolenosky, 1974).

It seems likely that the commercial catch reflects what the market will bear more than the yield which the Ottawa River is capable of producing. At present Brown bullhead are not exploited in many areas of the Ottawa River. The total catch could be increased if there was a greater demand for the resource.

The abundance of bullhead between Rockland and Hawkesbury is also indicated by a creel census conducted by Levere (1969). Brown bullhead were the fish species most sought after by anglers. Various lakes and reservoirs in the United States have catch rates which vary between 0.002 and 0.89 brown bullhead per angler hour (Emig, 1966). Recalculating Levere's data on this basis, one derives a success rate of 0.77 brown bullhead per angler hour for the Ottawa River. This is a high success rate in comparison to other waters indicating that bullhead are very abundant.

Similarly below Hawkesbury Mr. Albert Courtemance found that of 5,639 fish caught in 45 gill net sets of 1½, 2, and 4 inch mesh, 5,385 (95.3%) were brown bullhead (LeSauteur, 1965). This is a C/f of 119.7 bullhead per net set. Low oxygen levels in the order of 3 ppm were believed to be detrimental to less tolerant species; thus favouring the more tolerant bullhead since competition with other species was eliminated.

This assertion may have some validity. Conditions observed below Hawkesbury in 1970 were similar to those noted by Courtemance. Improved water quality during 1971 led to a significant decline in the abundance of brown bullhead. While the reason for this change is not definite, it is apparent that the abundance of bullhead can change in response to changing environmental conditions.

For the purposes of this study, tag retention was more than adequate. There was no indication that any appreciable tag loss or mortality occurred in the short period between tagging and recapture of bullhead for population estimates. It would appear that a greater tag loss occurs with Flag tags

than with numbered FD-67 dart tags (Rawstron, 1973). This was not important for the movement studies where only the location and number of tags recovered was of interest. It is assumed that the rate of tag loss which occurred would have been the same at all three stations where Flag tags were used in 1972.

Studies of streams and rivers (Funk, 1957; Gerking, 1959) have shown that many species of fish exhibit restricted movement. Funk termed a species of fish as being sedentary if they remained within 1.6 km (1 mile) of the point of release. Those fish which ranged more or less freely were termed as being mobile. While Gerking (1959) believed mobile fish should be called strays, the term sedentary appears to have gained acceptance to describe the majority of a population which exhibit restricted movement (Hynes, 1970; Malinin, 1969).

It is evident from this thesis that the majority of brown bullhead in the Ottawa River exhibit restricted movement and are sedentary according to the criterion of Funk. It would appear that a strong affinity exists between brown bullhead and the bays where they were tagged. On the basis of tagging during 1972, it would appear that different populations of brown bullhead reside in Hay Bay, Kettle Is. Bay and the bay at the top of Lower Duck Is. Evidence has been presented to show that most of the bullhead are sedentary, remaining in the vicinity of their home bay. Bullhead were noted to disperse over the section of the river near the bay, but there was also a strong tendency for bullhead to return to their home bay. The frequency of tagged bullhead in the catch declined rapidly less

than a mile from the home bay, indicating that the majority of the fish remained in the vicinity of their home bay from one year to the next.

Many bullhead were recaptured repeatedly at Hay Bay, Kettle Is. Bay and the top of Lower Duck Is. There was no tendency for bullhead tagged in Governor's Bay and along the three transects in the NRC section to be recaptured at the tagging site. Instead there appeared to be a tendency for these tagged fish to disperse towards one of the three main bays. Many of the bullhead tagged at Governor's Bay were recaptured at Hay Bay and all of the tag recoveries of bullhead tagged along the three transects were made in Kettle Is. Bay. This is similar to the finding of McCammon and Seeley (1961) where it was found that bullhead caught and tagged at the center of Clear Lake tended to move into the arms or bays of the lake. Bullhead tagged in the arms generally remained there.

The habitat preference of brown bullhead during the day is in areas of soft oozy mud and sunken logs where the water is 2-5 m deep (Keast, 1970). During June 1972, I observed brown bullhead in such areas of a bay at Heney Lake, Quebec. The presence of such conditions explains the abundance of bullhead in bays in the lower river. The absence of mud bottoms may explain the scarcity of bullhead at Britannia Bay and Governor's Bay. As flow rates decrease downstream the preferred habitat of bullhead becomes much more common, which may serve to explain the greater abundance of the species towards Hawkesbury.

Kettle Is. Bay would appear to be the center of concentration of bullhead in the NRC section. Weedy backwater areas such as Kettle Is. Bay are essential for reproduction, as discussed in the next section.

Croskery (1974) has demonstrated that significantly higher quantities of entomostracans are present in Kettle Is. Bay than in the main channels of the river. Various authors (Cable, 1929; Raney and Webster, 1940; Frank, 1955) have shown that young bullhead feed primarily on zooplankton. By the end of the first season, the young bullhead in the Ottawa River have achieved a size whereby larger benthic invertebrates such as chironomids, isopods and amphipods comprise the majority of the diet.

Kettle Is. Bay has a poor benthic invertebrate fauna (Qadri, et al., 1973). The densities (>2500 per ha) of brown bullhead in Kettle Is. Bay exceed those densities (<250 per ha) found in lakes and ponds by at least an order of magnitude. It does not seem likely that Kettle Is. Bay produces an adequate food supply to sustain the adult bullhead population in the bay.

Qadri, et al. (1973) have shown that the highest concentrations of benthic invertebrates are in the littoral zone, especially along the shores of the islands and along the Ontario shore of the south channel of the NRC section. These areas correspond to those areas of aquatic vegetation outlined by Ericksson (1973). These are the littoral areas where most brown bullhead were taken by hoop netting and gill netting. It appears likely that brown bullhead spend the day in the bays of the Ottawa River and disperse more widely to feed at night (Darnell and Meierotto, 1965; Keast, 1970). Netting along the transects of the NRC section indicates that they disperse along those shorelines with the highest benthic invertebrate food supply. Hoop nets set facing the mouth

of Kettle Is. Bay received high catches of bullhead between 3:30 and 5:30 a.m. indicating that the bullhead return to the bay about dawn.

During the fall the majority of the population probably returns to the vicinity of the bay to spend the winter buried in the mud (Loeb, 1964, Massengill, 1972). Thus the population estimate of 65,487 with the bay open, conducted in October, may give an accurate estimate of the adult population of bullhead in the NRC section.

## FECUNDITY AND REPRODUCTIVE BEHAVIOUR

## Introduction

The reproductive biology of the brown bullhead has been the subject of numerous studies. The age at which brown bullhead become sexually mature has received little study. Various authors (Emig, 1966; Carlander, 1969; Frank, 1956) have reported counts of mature ova which are between 1,250 and 13,800, but the number of individuals examined by any one investigator never exceeded six. Consequently, the relationship between fecundity and body size is not clear. Harlan and Speaker (1956) state that brown bullhead are sexually mature at age three. Breder (1939) was under the impression that three pair of brown bullhead which spawned in an artificial pond were age one. Swingle (1957) noted that brown bullhead stocked in ponds in Alabama reproduced at one year of age.

The present study has utilized both aquarium and field observations to elucidate various aspects of the reproductive behaviour of brown bullhead. These observations have been compared with the findings of other authors. An attempt has been made to explain the significance of behaviour in aquaria in relation to the actual situation in nature.

Many authors, including Ecleysmere (1901), Kendall (1910), Fowler (1917) and Breder (1939), have reported various aspects of the reproductive behaviour of brown bullhead under natural conditions. The behaviour prior to and during spawning has mostly been observed in aquaria (Smith and Harron, 1904; Breder 1932, 1935). This material has been reviewed by Breder and Rosen (1966).

The spawning behaviour of brown bullhead was noted to be similar to other ictalurids such as the channel catfish Ictalurus punctatus (Clemens and Sneed, 1957), flathead catfish Pylodictus olivaris (Fontaine, 1944), yellow bullhead I. natalis and black bullhead I. melas (Wallace, 1969a). Recent behavioural and physiological studies (Todd, 1968; Wallace, 1969b; Atema, 1970; Kendle, 1970) have shown that bullhead species exhibit complex social behaviour based primarily on olfactory communication mediated by pheromones.

Little has been said about the behaviour of bullhead prior to spawning. Pearson and Miller (1935) described aggregations of wild yellow bullhead with injuries on the fins and body suggestive of fighting. Kendall (1910) and Breder (1939) described similar marks on brown bullhead. Breder believed that at least some of the marks were due to the catfish mauling each other.

Todd (1968) noted that aggregations of 6-8 yellow bullhead in 200 liter aquaria were generally not territorial and did not behave aggressively towards each other for most of the year. During the reproductive season, from March to May, the aggregations broke down and within several weeks the bullhead had scars on their dorsal surface and tails from fighting. By the end of the month, only one fish remained in each tank, the others having been killed or severely injured.

Similar aggressive behaviour to that exhibited by yellow bullhead in Todd's study has been noted by Wallace (1969a) in yellow, brown and black bullhead and by Clemens and Sneed (1957) in channel catfish. The role of

these aggressive encounters with regard to reproduction in nature needs further study.

#### Materials and Methods

Brown bullhead from Shirleys Bay, Governor's Bay and above Hawkesbury, collected in May and June of 1971, were used to determine fecundity. Bullhead collected from Kettle Is. Bay during 1973 were used to determine seasonal changes in the Gonadal-somatic Index (GSI). The GSI was derived from the weight of the gonads expressed as a percentage of the total body weight of the fish. Gilson's fluid (Simpson, 1951) was used to dissolve ovarian tissue from the eggs. Estimates of the number of mature ova in the pair of gonads were determined gravimetrically on the basis of the mean weight of three subsamples taken from the eggs and oven dried at .80 C (Dennison and Bulkley, 1972).

During my observations of spawning pairs, the sexes of the brown bullhead could be recognized externally. In males, the snout and interorbital region were broader and flatter than in the female and the male was generally the larger of the two fish (Smith and Harron, 1904).. Mature males also developed a pair of swellings behind the eyes. This character was noted in the brown bullhead as well as the channel catfish. These characters were verified by an examination of the gonads of 20 suspected male bullhead collected during the spawning season from late June to early July.

To study various aspects of pairing behaviour, observations were conducted both in the laboratory and in the field. Sixteen brown bullhead varying in size from 28-33 cm were collected on June 3, 1971 using a trap net in the Ottawa River. At the university, the fish were placed in a 235

gal (889 liter) aquarium measuring 5 by 2.5 by 2.5 ft. The water temperature throughout the observation period was 20-21 C and a 12 hr photoperiod of 1,350 lux was maintained. The fish were fed chopped beef heart and earthworms daily. These bullhead were observed over the following two months for about one hour per day at various times.

Field observations were conducted by capturing bullhead in trap nets and examining them for scars and by observing bullhead in shallow water, during the latter part of June and the beginning of July 1971 and 1972. Observations of spawning pairs and nesting sites were conducted in the upper and lower Ottawa River and at Heney Lake, Quebec.

## Results

### Fecundity

The fecundity of brown bullhead at the three stations varied between 2,200 and 8,800 mature ova per female. The relationship between fecundity and total length (TL) was curvilinear and a straight line was derived by a log-log transformation of the data (Bagenal, 1971). A linear relationship was found between fecundity and total body weight.

The regression of fecundity versus total length was significant ( $P < .05$ ) at Governor's Bay and Hawkesbury and was almost significant ( $P < 0.10$ ) at Shirleys Bay. The regression of fecundity versus body weight was significantly correlated at Governor's Bay and Hawkesbury, but exhibited a non significant correlation at Shirleys Bay. The non significant correlations at Shirleys Bay were probably due to the narrow size range of bullhead in the sample. Dennison and Bulkley (1972)

found a similar situation with the fecundity of black bullhead.

The range in fecundity at the three stations was as follows:

Station	Range in no. of ova	$\bar{X}$	SE	Range in TL of bullhead (cm)	Mean size (cm)	No. of fish
Shirleys Bay	3,949-8,823	6,040	469	27.5-30.6	29.1	10
Governor's Bay	2,196-7,051	3,719	363	21.5-29.9	26.3	15
Above Hawkesbury	2,482-7,633	4,921	220	23.9-34.0	29.7	37

The relationship between fecundity (Y) and total length (X) in mm was as follows:

Station	Fecundity vs TL	Correlation coefficient	No. of fish
Shirleys Bay	$\log Y = -.59544 - 3.9463 \log X$	.5631 n.s.	10
Governor's Bay	$\log Y = -.27232 - 2.59.8/\log X$	.6450**	15
Above Hawkesbury	$\log Y = -.21753 - 2.3675 \log X$	.7042***	37

\* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ , n.s. not significant

The relationship between fecundity (Y) and body weight (X) in grams was as follows:

Station	Fecundity vs Body Weight	Correlation coefficient	No. of fish
Shirleys Bay	$Y = 3,131 - 7.3136 X$	.2498 n.s.	10
Governor's Bay	$Y = 376 - 12.8441 X$	.6953**	15
Above Hawkesbury	$Y = 1,855 - 7.2556 X$	.7077***	37

A one-way analysis of covariance (LeCren, 1951) was used to compare the fecundity versus total length regressions at the three stations (NRC computer programme, Biomathematics section). The analysis indicated that the slopes of the three regressions were not significantly different. The y intercept at Shirleys Bay was significantly different ( $P < .01$ ) from Governor's Bay and above Hawkesbury. No significant difference was found between the y intercepts for the latter two stations. Thus the fecundity relationship for Governor's Bay was not significantly different from above Hawkesbury; but both of these were significantly different from Shirleys Bay. It is apparent that Shirleys Bay had a higher fecundity to total length ratio than did the other two stations.

#### Sexual Maturity

Sexual maturity was attained by age three in the majority of bullhead from the three stations (Table 12). It is possible that some fish younger than three years become sexually mature, but my samples for these first two year classes were inadequate. Those age one and two bullhead examined were immature.

Fish collected during early June could be easily classified as mature on the basis of the size, colour and weight of the gonads (Davis and Posey, 1958; Turner and Summerfelt, 1971). Mature females had GSI's from 3.3-14.2% while immature females had GSI's less than .2% of the body weight (0.67-1.8%). Mature males had GSI's greater than 0.1% (0.13-0.37%) while immature males had GSI's less than 0.1% (0.06-0.9%).

The GSI of both sexes peaked about mid June which agrees well with the observations of spawning pairs in the field (Fig. 5). Allowing 7-10 days for the young to hatch and 5-6 days for the

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Figure 5. Seasonal changes in the Gonadal-somatic Index of female brown bullhead collected from the lower Ottawa River during 1973. The mean, standard error and 95% confidence limits of the Gonadal-somatic Index on a monthly basis are represented by a horizontal line, a rectangle and vertical lines respectively.

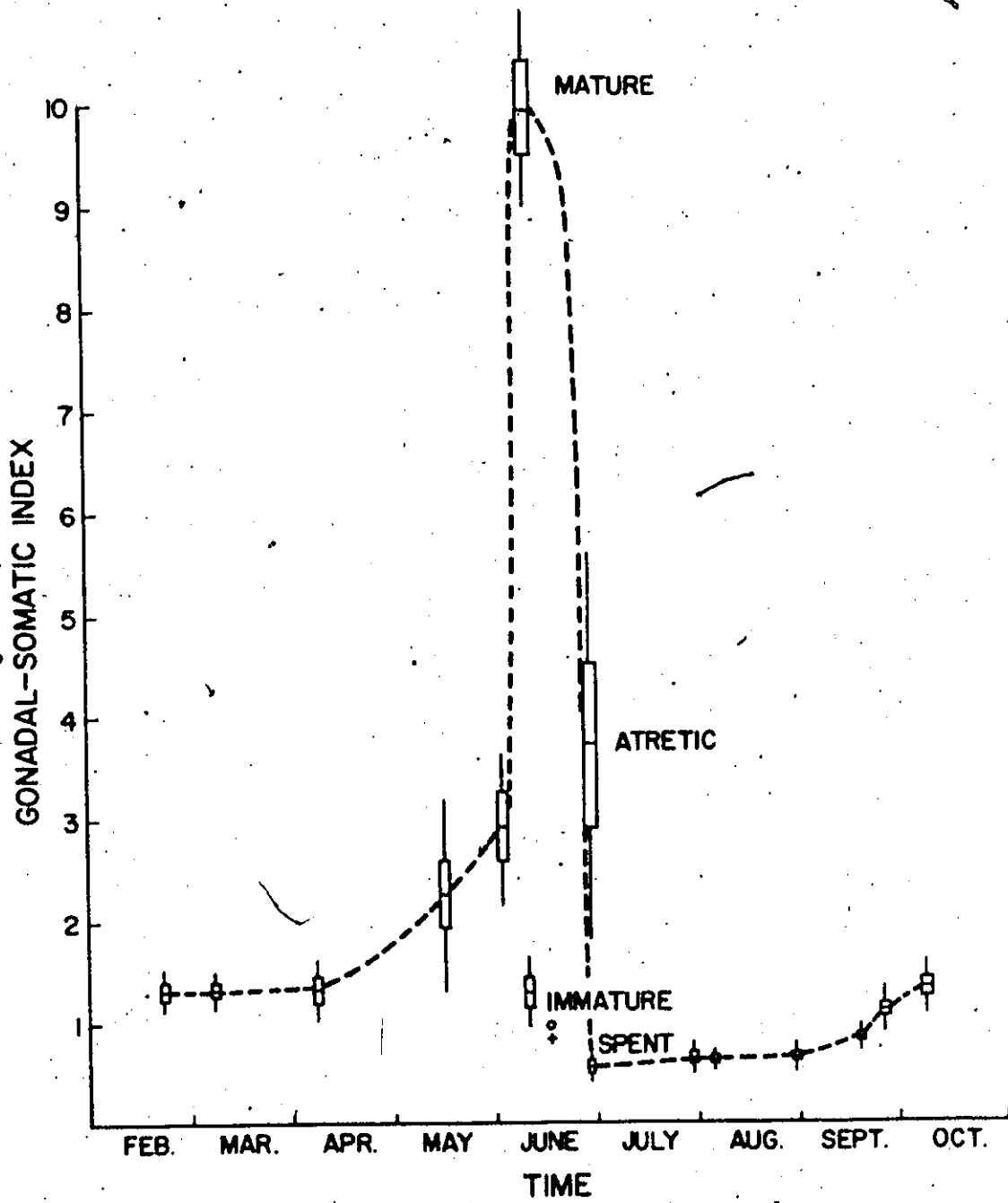


Table 12. Sexual maturity according to age of brown bullhead collected from the Ottawa River June 4-10, 1971. The number and per cent below it, of mature and immature fish are given for each age group.

Age	Females											
	Males						Females					
	Shirleys Bay		Governor's Bay		Above Hawkesbury		Shirleys Bay		Governor's Bay		Above Hawkesbury	
	I	M	I	M	I	M	I	M	I	M	I	M
2	1	0	1	0	1	0	-	-	1	0	-	-
	100	0	100	0	100	0			100	0		
3	1	6	1	6	-	-	2	16	0	8	2	1
	14.3	65.7	14.3	65.7			11.1	88.9	0	100	66.6	33.3
4	0	1	1	9	0	5	0	1	0	7	1	5
	0	100	10	90	0	100	0	100	0	100	16.7	83.3
5	0	1	0	6	1	16	0	2	1	8	3	15
	0	100	0	100	5.9	94.1	0	100	11.2	88.8	16.7	83.3
6	0	1	0	1	0	8	-	-	0	3	1	11
	0	100	0	100	0	100			0	100	8.3	91.7
7	-	-	0	1	0	4	-	-	-	-	1	6
			0	100	0	100					14.3	85.7
8	-	-	-	-	0	2	-	-	-	-	0	2
					0	100					0	100

young to become freeswimming (Breder, 1939), it is probable that the eggs of brown bullhead were laid about the third or fourth week of June as the water temperature approached 21 C. The GSI's for males are summarized in Appendix 1. In the fall, there was a slight increase of the GSI but most of the increase in weight of the gonads occurred in the spring.

Female bullhead, three years or more in age, collected on June 29, 1973 were separable into those which had shed their eggs (70.6%) and those whose gonads were undergoing atresia (29.4%). This would seem to indicate that a considerable portion of the sexually mature bullhead had not spawned. This is similar to results found by Turner and Summerfelt (1971) who estimated that 45% of mature female flathead catfish did not spawn.

#### Sex ratios

In the vicinity of Shirleys Bay and above Hawkesbury females were more prevalent than males (Table 13). The differences were not great, suggesting that about equal sex ratios exist. At Hay Bay, Governor's Bay, the top of Upper Duck Is. and below Hawkesbury, males were more prevalent than females. It is possible that some behaviour associated with spawning could have biased the ratios at Hay Bay and Governor's Bay where most of the bullhead were collected in June and early July. But males still predominated at the top of Upper Duck Is. in samples of bullhead collected in August, suggesting that the differences in the lower river were not entirely due to reproductive behaviour. The size distributions of both sexes were similar at all stations, suggesting that the differences in sex ratio were not due to sampling bias.

In four out of the six stations examined there was a tendency for

Table 13. Sex ratios of brown bullhead according to age at various stations in the Ottawa River during 1971. Ratios expressed in terms of numbers and as a percentage beneath of each age.

Age	Shirleys Bay		Hay Bay		Governor's Bay		Upper Duck Is.		Above Hawkesbury		Below Hawkesbury	
	M	F	M	F	M	F	M	F	M	F	M	F
1	2	2	0	0	0	0	0	0	0	0	0	0
	50:50											
2	5	0	7	4	1	1	0	0	1	0	0	0
	100:0		64:36		50:50				100:0			
3	23	27	19	11	16	19	11	7	1	4	12	9
	46:54		63:27		46:54		61:39		20:80		57:43	
4	34	41	29	12	36	21	10	15	6	6	10	9
	45:55		71:29		63:37		40:60		50:50		53:47	
5	8	15	28	21	46	17	21	9	24	26	15	14
	35:65		57:43		73:27		70:30		48:52		52:48	
6	2	2	16	12	13	10	3	7	12	13	12	11
	50:50		57:43		57:43		30:70		48:52		52:48	
7	1	0	1	5	2	4	1	0	4	11	0	3
	100:0		17:83		33:67		100:0		27:73		0:100	
8	0	1	1	2	0	3	0	0	2	2	1	1
	0:100		33:67		0:100				50:50		50:50	
Total	75	88	101	67	114	65	46	38	50	62	50	47
	46:54		60:40		64:36		55:45		45:65		52:48	

females to be more prevalent than males after age six. In the upper river females were slightly more prevalent than males for most age groups (Table 14). In the lower river males outnumber females until age six after which females predominate. Near Hawkesbury about equal sex ratios exist until age seven.

#### Aquarium Observations of Prespawning Aggression

The day after the sixteen bullhead were placed in the aquarium, two females filled with mature ova were found dead in the tank. These fish had whitish bite marks on the back anterior to the dorsal fin. Over the next three weeks two males and one female bullhead were found dead with similar marks on the body and sections torn out of the dorsal and caudal fins.

During the last week of June, it was noted that the largest bullhead in the tank, a 33 cm male, had established a territory at the left end of the tank. The other bullheads, all of which were believed to be sexually mature, crowded at the right end of the tank near the bottom or hovered near the surface. A ripe female was noted to occupy the male's territory hovering near the surface much of the time and taking no part in defending the territory.

Signs of aggression increased and the dominant male vigorously displayed himself exhibiting mouth displays (mouth held widely open toward antagonist) and chasing individual bullhead which ventured from their end of the tank. On June 29, two dead subordinate males were removed with severe wounds on the body near the head and on the dorsal and caudal fins.

Table 14. Sex ratios of brown bullhead according to age in various sections of the Ottawa River during 1971. Ratios expressed in terms of numbers and as a percentage beneath for each age.

Age	Upper River		Lower River		Hawkesbury	
	M	F	M	F	M	F
1	2	2	0	0	0	0
	50:50					
2	5	0	8	5	1	0
	100:0		62:38		100:0	
3	23	27	46	27	13	13
	46:54		63:37		50:50	
4	36	41	75	48	16	15
	45:55		61:39		52:48	
5	8	15	95	47	39	40
	35:65		67:33		49:51	
6	2	2	32	29	24	24
	50:50		52:48		50:50	
7	1	0	4	9	4	14
	100:0		31:69		22:78	
8	0	1	1	5	3	3
	0:100		17:83		50:50	
Total	75	88	261	170	100	109
	46:54		61:39		48:52	

While previously the bites on the body and fins had been superficial, these fish had sections of the skin and flesh missing. The sequence of attack by the territorial male was similar on the aggressive encounters observed in yellow bullhead by Todd (1968). The behavioural units included approach, circle, mouth display, lateral display, nip and bite, which have been described and depicted by Todd. The subordinates showed little aggression and tried to flee from the dominant male.

Several bullhead badly mauled in these encounters were removed to separate aquaria. Although treated with malachite green, these fish were very lethargic, lost interest in feeding and died about a week later.

The encounters described differ from Todd's (1968) description of a bullhead community in an aquarium where each individual establishes its position in a social hierarchy. The level of aggression exhibited and the size of the territory defended were much greater in the situation I observed. This territorial behaviour was prespawning behaviour, since the pair spawned on July 6, 1971 soon after being removed to another aquarium.

With the removal of the first pair of fish, a second pair of bullhead established a similar territory and the male of this pair exhibited similar aggression. On July 12, 13 and 14 three dead male bullhead with wounds were removed. The remaining bullhead were removed on July 15 leaving the two breeding pairs in their respective aquaria.

Following the spawning of pair one, the male was reintroduced into the original aquarium on August 6 where the second pair had constructed a nest without spawning. Formerly dominant over the other two, he was viciously attacked by the pair. Attacking from the side they bit the

introduced male on the back and caudal fin. The male of the second pair locked jaws with the introduced male in a mouth fight which lasted almost a minute in duration.

#### Field Observations of Prespawning Aggression.

Trap netting of bullhead in the 16-35 cm size range during the summer of 1972 confirms that fighting does occur in nature. In conjunction with tagging studies trap nets were set every two weeks at Hay Bay, Kettle Is. Bay and the top of Lower Duck Is. in the lower river. The incidence of fish with fresh bite marks rose dramatically during June, the spawning season, at all three stations. The majority of bullhead had whitish scratches and teeth marks over various parts of the body. From 5% to 17% of the bullhead in the net ranging in size from 23-25 cm had open wounds on the body and fins exposing the underlying tissue and exuding blood (Table 15). Examples of the wounds are shown in Fig. 6.

A record was kept of the frequency of the wounds on various parts of the body and fins. The fins bore 64.6% of the scars while 35.4% were on the body of the bullhead. The dorsal and anal fins were the most frequently bitten, then the caudal peduncle. Scars about the mouth, head and dorsal part of the body were also frequent. Averaging the results of the three stations, 91.6% of the scarred fish had one wound, 7.9% had two, and 0.48% had three or more. During late July, wounds were still noted but were healing. Fin rays were being regenerated and new skin was noted forming over the wounds.

It could be argued that the high incidence of scarred fish was due to their being held in the trap net. Scarred fish were also taken in hoop nets. Bullhead taken outside the spawning season by the same gear did not

Figure 6. Wounds on brown bullhead collected in trap nets from the lower Ottawa River during June, 1973.



Table 15. No. of brown bullhead examined in trap nets at various stations during 1972 bearing wounds and scars.

Date	Brewery Creek		Kettle Is. Bay		Lower Duck Is.		Total	%
	June 21	July 5	June 22	July 7	June 23	July 8		
<b>FINS</b>								64.63
Dorsal	16	38	52	11	12	46	175	26.24
Anal	20	22	49	7	8	14	120	17.99
Caudal	10	6	13	3	6	10	48	7.20
Pelvic	6	12	17	2	2	8	47	7.05
Pectoral	5	6	13	0	3	14	41	6.15
<b>BODY</b>								35.39
Caudal Peduncle	14	17	16	3	8	9	67	10.04
Head	11	5	23	5	2	2	48	7.20
Sides & back	15	2	22	4	5	11	59	8.85
Mouth	13	8	33	1	2	5	62	9.3
Total scars observed	110	116	238	36	48	119	667	
No. of fish with scars	101	116	229	36	46	111	639	
Total catch of bullhead	613	832	3206	701	268	901	6521	
% with scars	16.48	13.94	7.14	5.14	17.16	12.32	---	9.80

exhibit scars, suggesting that the nets did not cause the wounds. It was not possible to quantify the frequency of scarred bullhead in hoop and gill nets. It is not known whether scarring was increased by aggression among bullhead while being held in the trap net. Scars caused by the silver lamprey Ichthyomyzon unicuspis were noted in less than 0.1% of the bullhead and were not included in these observations.

#### Prespawning Aggregations

On May 24, 1958, Mr. Harold Sullivan (personal communication) observed bullhead aggregated in groups in English Bay in the Rideau Lakes. Six or seven schools of bullhead were noted in 4-5 ft of water near the weedless center of a bay about 75 ft wide. Each school was arranged in a circle about seven feet across, consisting of about 60-70 bullhead. All the fish in a school appeared to be arranged in five or six rings with their heads pointed towards the center of the circle. Each bullhead was about four or five inches from its nearest neighbour. There were about 12 to 18 fish in the center ring and about 40-50 fish in the outer ring.

The bullhead were suspended in the water about 12-24 inches below the surface with their heads pointing towards the surface. The fish were immobile and did not move when the boat passed over them. It was possible to strike the bullhead with a lure, but they showed no interest in it. Several bullhead were taken with a dip net. One of these had an open wound on its caudal peduncle. Mr. Sullivan did not know whether the fish he observed were yellow bullhead or brown bullhead. Both species are known to occur in the Rideau Lakes.

Mr. Lucien Provost (personal communication) has observed large aggregations of brown bullhead in bays in the Ottawa River near Rockland. One such aggregation noted during early May was 45 ft by 27 ft. The bullhead were hovering in the water but were not arranged in any particular fashion. The bullhead milled about in a manner similar to the very young bullhead. Some bullhead were noted to jump two or three feet out of the water.

#### Nesting Behaviour in Aquaria

The first pair of bullhead which had been placed in a second tank shaded by a dark plastic cover were noted to have spawned without constructing any nesting depression. Shunning the end of the aquarium covered by gravel, the pair spawned at the end of the tank which happened to have a bare slate bottom (Fig. 7).

The second pair in the original aquarium constructed a nesting depression (Fig. 8) which they guarded until mid August without laying any eggs. While the second tank had been shaded from the onset, the original tank was exposed to overhead lights for about a month. Shading the tank thereafter did not induce the second pair to spawn.

#### Nesting Locations in the Field

Four areas were examined in the Ottawa River in an effort to locate nesting sites. These were Britannia Bay, Governor's Bay, Brewery Creek and the top of Kettle Is.

On July 5, 1971 the area west of the pier at Britannia Beach in the upper river was examined. I observed one pair of bullhead guarding

Figure 7. First pair which spawned without constructing a nest. The male is over the eggs and the female is the fish on the right side.

Figure 8. Second pair which constructed a nest, but did not spawn. The male is over the nest and the female is on the left side.



newly freeswimming fry and another pair guarding larvae in a nest depression similar to that depicted by Gill (1905). The nest depression was situated in a dense bed of Vallisneria in about eight to ten inches of water. The nest was about six inches in depth and elliptical in shape, about the same length as the male which was in the nest on top of the wriggling larvae. The male did not move from his post, although I approached within a foot of him with a scuba mask to examine the fry. A female bullhead was noted about ten feet away (3 m) possibly acting as a sentry. These fish, as well as the other pairs I observed, were over 12 inches (30 cm) in length. Returning the next day I found that the parents and young had vacated the nest.

The water temperature was 23 C in the shallow area near the nest. The nest had been excavated in the sand in an area of little or no current.

Nests were difficult to locate in the lower river due to their concealed position and the high turbidity. It was possible to estimate the number of breeding pairs and the approximate location of the nests by mapping the position of newly freeswimming young bullhead. The jet black young were seen aggregated in dense schools during the period July 5-16, 1971. When approached, one or both parents were usually seen to flee from the vicinity of the school.

In Britannia Bay, Governor's Bay and at the top of Kettle Is. where aquatic vegetation was sparsely distributed and trees were situated back from the shoreline, few families of bullhead were located. In Britannia Bay, on July 16, only eight groups of young were located along about a mile and a half (2.4 km) of shoreline (Fig. 9). Some schools were noted to be

Figure 9. Location of nesting sites of brown bullhead in Britannia Bay during 1971. Depths (ft) are shown in parenthesis; aquatic vegetation, the shaded area; current, solid arrows; nesting sites, open circles with letter designations A to H.



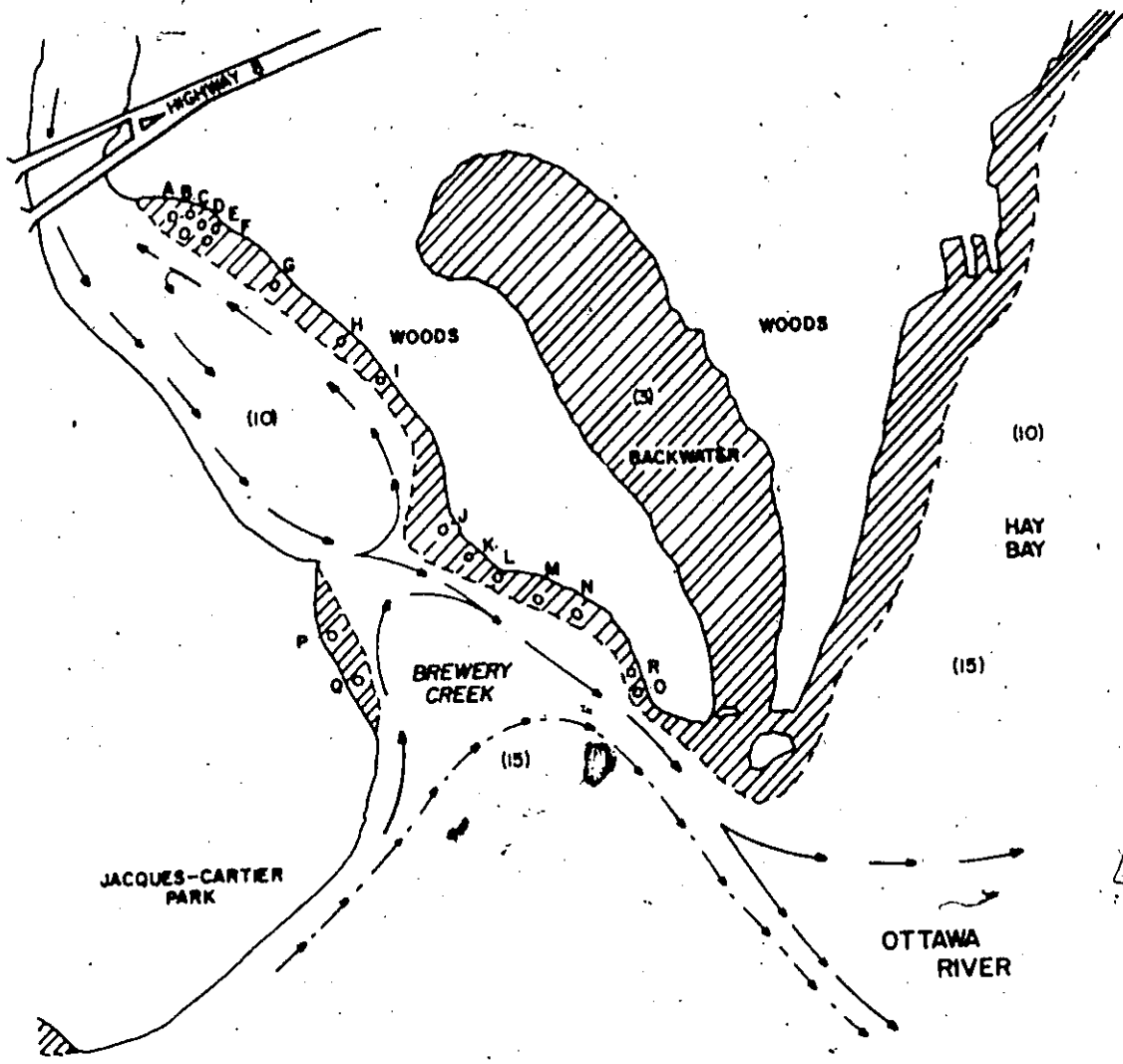
near suspected nesting depressions which had revealed themselves due to a decline in water level. These depressions were situated in dense weeds of Elodea, Vallisneria and Scirpus respectively (Sites B, C and D), under logs (F) and rocks (H) where there was adequate shading. No schools were located along the flat rock shoreline of Governor's Bay and three schools were located along the sandy, current swept, shoreline of the top of Kettle Is. in the CIP north channel. These schools were hidden under emergent clumps of Sagittaria which was rather sparse along the Kettle Is. shoreline. The lack of shading by trees on the shoreline and other suitable cover may restrict spawning in these three areas.

It is believed that light is an important factor when bullhead choose a nesting site. Breder (1935) noted that the eggs are sensitive to light and the larval stages exhibit negative phototaxis (Armstrong, 1964). Other factors such as dissolved oxygen must also be important.

In Brewery Creek during 1971, 17 schools of young bullhead (Fig. 10) were noted in an uneven distribution. Six of the aggregations, each about 15-20 ft apart, were found in a small area of about 50 ft of shoreline in the northwest corner of the creek where overhanging trees provided dense shade over the water. Other groups were noted in dense aquatic vegetation such as arrowhead Sagittaria and bullrush Typha towards the mouth of the creek.

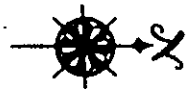
A shallow weed-choked backwater examined in 1971 between Brewery Creek and Hay Bay did not have any bullhead breeding in it, although it was well shaded by surrounding trees. There was no current to allow an exchange of water between this area and the Ottawa River.

Figure 10. Nesting sites of brown bullhead in 1971 and 1972 in the vicinity of Brewery Creek and the backwater below it. The approximate depths (ft) are given in parenthesis. Aquatic vegetation is the shaded area. Current in 1971, solid arrows; in 1972, dashed arrows. Nesting sites in 1971 are shown by open circles designated A to Q, in 1972 by a square designated R.



0 1 2 3  
 1 inch = 380 ft

(80)



A strong eddy current existed in the mouth of Brewery Creek prior to 1972 (Stobo, 1971), which ensured oxygen concentrations of above 7 ppm in the area where bullhead were noted breeding in 1971. In the spring of 1972, the flow of water through Brewery Creek was drastically curtailed to allow the construction of sewer and water mains in Hull. Raw sewage was still being emptied into the creek. Severe oxygen depletion developed in Brewery Creek during the summer and values of less than 1 ppm were still evident in October 1972 (Smith, 1974). An examination on July 10, 1972, of the same area of Brewery Creek examined for young fish in 1971, showed that only one pair of bullhead had spawned. A school of young bullhead was located near the outer edge of the mouth of the creek which was within the influence of oxygenated water from the Ottawa River. No young bullhead were noted within Brewery Creek in the area of oxygen depletion.

#### Prespawning Behaviour in the Aquarium

Close body contact was maintained by both pairs of bullhead prior to spawning. The second pair lay with their tails to the opening of the nest (Fig. 11). At frequent intervals the female fanned the bottom with her pelvic and anal fins and pressed her abdomen against the bottom with a quivering convulsive movement. The male often accompanied the female in this action. Smith and Harron (1904) believed that this was for the purpose of loosening the eggs in the female. It is also possible that some chemical marker was released at the spot since Breder (1935) noted that when the eggs were removed from the parents, they continued to incubate the site from which the eggs had been taken.

Figure 11. Male and female of the second pair over nest with tails towards the same end of the nest while in close body contact.

Figure 12. Male and female of the second pair over nest facing in opposite directions while maintaining close body contact.



At intervals the pair left the nest to swim around the tank.

Finally they took up a position close together with each fish facing in the opposite direction (Fig. 12). The release of eggs was not observed having taken place some time before 9 a.m. July 11, 1971. The first pair was still lying side by side in opposite directions with their tails curved over one another. Periodically the male embraced the female by wrapping his body over her head (Figs. 13 and 14).. Breder (1935) noted a pair that deposited spawn six times over a period of three hours. He did not observe the pair twisting their caudal fins over each other's heads, stating only that they lay in opposite directions side by side. The position depicted is identical to that mentioned by Fontaine (1944) and depicted for black and yellow bullhead by Wallace (1969a).

#### Incubation

During my observations of bullhead in aquaria, the male did all of the incubating, while the female remained passively nearby. These fish subsequently died and their sex was verified by examining their gonads. Breder (1935, 1939) believed that the opposite was true, but conceded that he had not sexed the fish he observed.

Under aquarium conditions, Smith and Harron (1904) and Breder (1935) have stated that both parents may incubate the young. Neither of them gives a good description. Breder (1935) noted that very rarely both parents incubated at the same time. Under the conditions of an outdoor pond Breder (1939) noted that only one bullhead parent from each of the three pairs incubated the eggs, not leaving the nest during this period. Its mate remained quiescent nearby or patrolled around the nest.

Figure 13. First pair commencing spawning embrace. The male is situated parallel to and beside the female with his head away from the viewer. In both fish the caudal fin is wrapped over the head of its mate.

Figure 14. First pair in full spawning embrace. The male can be seen curving his tail over the female. These photos were taken on July 12, 1971 a full day after the eggs had been laid. It is doubtful that any eggs were extruded by this stage, but the fish were still noted to embrace periodically.



13.

14

While adult brown bullhead can withstand dissolved oxygen levels less than 1 ppm (Cooper and Washburn, 1949), the eggs require constant fanning and agitation (Breder, 1935; Armstrong, 1962). The male agitates the eggs using his anal and pelvic fins causing them to become dislodged from the substrate (Fig. 15). The paired fins are generally used in fanning. It can be assumed that the fanning of the male not only helps to agitate the eggs but also serves to create a flow of aerated water over the eggs. The male may also create a current by periodically slowly yawning over the eggs in a syringe like action (Fig. 16) as previously described by Breder (1935).

Breder (1939) described a pair of brown bullhead which had spawned in an upright flower pot where one of the parents fanned the eggs using its caudal fin. It was not possible for this fish to agitate the eggs using its anal fin but it managed to hatch the eggs by fanning them with the tip of its tail.

On June 24, 1972, I observed a male brown bullhead incubating eggs in a similar manner at Heney Lake, Quebec. The eggs were in an almost vertical burrow, about 1 ft long, situated in the sand bottom in four ft of water. The male was fanning the eggs with his caudal fin. Periodically, the male entered the burrow head first to mouth the eggs. The female was about 20 ft away. About every ten minutes the female approached the male, but at no time did she enter the burrow to incubate the eggs. The young were noted freeswimming on July 4. It is apparent that this method of incubation is not so atypical as Breder assumed, and that brown bullhead can hatch eggs without agitation by fanning them to ensure an exchange of water over the eggs.

Figure 15. Male from first pair incubating eggs using his pectoral, pelvic and anal fins. This action creates a strong current of water over the eggs as well as agitating the eggs, which can be seen being lifted from the bottom by the actions of the male.

Figure 16. Male from first pair incubating the eggs using a side to side action of his anal fin to agitate the eggs and yawning to create a syringe-like current of water over the eggs.



15



16

The eggs laid in the aquarium hatched on July 17 and 18, 1971. The male continued to guard the young fry until they became free swimming on July 22, 1971. The egg yolk larvae were noted to wriggle or skate along the bottom of the aquarium. They exhibited a negative phototaxis by skating away from the light as the tank cover was removed. By the time the fry had become free swimming they had become completely black in colour and no longer avoided the light. Attempts were made to feed the young newly hatched brine shrimp; but not enough could be hatched to adequately feed them. The young gradually diminished in number and by August 5, none of them remained alive. This was similar to the observations of Breder (1935) who believed the young were the victims of too much handling by the parents. It seems more likely, as noted by Smith and Harron (1904) that only weakened young were eaten.

#### Discussion

The number of eggs carried per female appeared to be a curvilinear function of the total length of the fish. As one would expect, the fecundity tends to increase with the size of the fish. The mean fecundity was higher at Hawkesbury than at Governor's Bay simply because the mean size of the fish sampled was greater. While the mean size of bullhead was higher at Hawkesbury than Shirleys Bay, the fish from the latter section of river had the highest mean fecundity. This was a further indication that fecundity of bullhead was highest in the upper river. Similarly six brown bullhead ranging from 16.7-20.2 cm contained 1,250-2,105 eggs in Czechoslovakia (Frank, 1956). In Minnesota five brown bullhead from 26.7-33.0 cm contained

6,180-13,800 eggs (Carlander, 1969). A comparison of the range in number of eggs would tend to indicate that the fecundity of bullhead in Minnesota was higher than that found in the Ottawa River.

Sexual maturity was attained by the time the bullhead in the Ottawa River were age three. Most bullhead greater than 20 cm were sexually mature. It was not ascertained whether sexual maturity can occur at an earlier age at this latitude, although this does occur farther south.

Bennett (1971) noted that in most freshwater fish populations, females predominate in the older fish suggesting that males die at an earlier age than females. Redd (1970) believed that the injuries due to aggression between rival males and from guarding the young could account for a higher mortality of males.

Evidence has been presented to indicate that aggression does occur among mature bullhead in the lower Ottawa River during the spawning season. It is strange to note that males predominated over females until age six in the lower river. While a higher mortality of males may occur after age six, it does not appear to apply to younger bullhead.

Turner and Summerfelt (1971) tried to explain the preponderance of female flathead catfish in gill catches on the basis of a migration of males to spawning sites. This does not explain the preponderance of male bullhead in trap net catches during the spawning season in the lower river. However, some aspect of behaviour which at present is not understood may lead to a segregation of the sexes prior to pair formation. In this regard it would be helpful to know more about the significance of bullhead aggregations which have been noted to occur prior to spawning.

Pearson and Miller (1935) noted that aggression had occurred among yellow bullhead noted in aggregations in early May. My aquarium observations indicated that aggression occurs, possibly as a means of gaining dominance in the social hierarchy and obtaining a spawning territory. The peculiar arrangement of yellow bullhead in a circle and the aggregations of brown bullhead where individuals were noted to jump out of the water may be linked to such a process.

Dominance in a social hierarchy may ensure that the largest and most aggressive bullhead males have the receptive females during the spawning season. Competition between rival males for females may be a chief source of aggression. Wallace (1969a) also found that fighting occurred between the sexes when a female yellow bullhead would not accept a male or when the male was not ready to spawn. I observed that once a pair has established a territory they defend it against intruders. Initially, defence appears to be a function of the male, but by the time the nesting site has been chosen both fish defend the nest. While the male incubates the eggs the female remains nearby and may help defend the nest against intruders.

Wallace (1969a) described two submissive postures in black, yellow and brown bullhead, flight and roll. During flight from an aggressor the subordinate bullhead may receive bites on its pectoral and anal fins as it tries to escape but it is more commonly bitten on its caudal fin. The subordinate may take a position near the surface, where it will be exposed to fewer attacks from the aggressive fish. Roll is a submissive posture assumed by a subordinate fish under attack. By rolling the dorsal part of

the body downward, exhibiting its dorsal side, the subordinate inhibits the attack. This usually occurs when an gravid female is placed with an aggressive male for the first time. These behaviour patterns explain the high frequency of scars on the dorsal surface, anal fin, caudal peduncle and caudal fin of brown bullhead examined in the Ottawa River.

The availability of shaded locations in vegetated bays and backwaters, with adequate oxygen levels, may be a factor limiting the number of breeding sites and hence the number of breeding pairs of bullhead. It was noted that only seventeen pairs of bullhead were successful at spawning in Brewery Creek during 1971. Since most bullhead over age three were sexually mature, the population of mature bullhead in the vicinity of Brewery Creek and Hay Bay must exceed 25,000 fish. Although many pairs of bullhead probably spawned in other areas in the vicinity of Brewery Creek, it is not likely that these areas were large enough to accommodate all the potential spawners. Even assuming 100 pairs spawned, then 99.2% of the mature bullhead may not have reproduced. About 30% of mature females at Governor's Bay were resorbing their eggs and sex ratios in the lower river indicated males were more abundant. Therefore it is probable that only a small percentage of the mature bullhead actually spawn each year.

Todd (1968) and Atema (1970) have demonstrated that bullhead established a complex social hierarchy. Pheromones mediate an individual's position in the social hierarchy communicating information concerning an individual's sex, age, size, reproductive state, individual characteristics and perhaps even family identification (Todd, 1971). Kendle (1970) observed that female black bullhead were attracted by a pheromone released

by the male during the spawning season. Timms and Kleerekoper (1972) studied how male channel catfish were attracted by a pheromone released by the sexually ripe female. Swingle (1957) found that at stocking densities of 7,400-14,900 southern brown bullhead per ha reproduction was completely inhibited. Swingle believed the bullhead gave off a repressive excretion which inhibited reproduction. It seems likely that such pheromones may inhibit reproduction of brown bullhead, occurring at high densities, in bays in the Ottawa River.

## MERCURY CONCENTRATIONS IN BROWN BULLHEAD

## Introduction

Mercury pollution became of general public interest in Canada early in 1970 following the revelation of widespread mercury contamination (Fimreite, 1970). Sampling of fish in zone two of the Ottawa River below Ottawa during 1969 showed Hg levels exceeding 0.5 ppm in walleye, sauger, sturgeon, northern pike, yellow perch, rockbass and suckers (OWRC-QWB, 1971). A similar situation was found in sauger collected in 1968 and sent by Dr. S.U. Qadri to the Canadian Wildlife Service (Fimreite et al., 1971). Six brown bullhead from below Ottawa had levels between 0.12-0.50 ppm Hg with a mean of 0.29 ppm (OWRC-QWB, 1971). Concern over the threat to public health from eating contaminated fish prompted the Ontario government to impose a ban on commercial fishing in the Ottawa River downstream of Ottawa and anglers were advised not to eat their catch.

The sources of Hg contamination were believed to be the E.B. Eddy Company in Ottawa-Hull and the Canadian International Paper Company in Gatineau, both of which had been using mercurial slimicides (OWRC-QWB, 1971). Sediment Hg concentrations between 0.03-2.0 ppm were found below these mills in 1968 and 1969. Sediment values of 1.89 ppm below E.B. Eddy and 1.99 ppm below CIP at Gatineau were still present two years later (Oliver and Kinrade, 1971). Sediment values near these mills were about seven times higher than in other areas of the Ottawa River. The levels in fish species were two to six times higher below Ottawa than above the city (OWRC-QWB, 1971).

Joint studies between the University of Ottawa and the National Research Council were undertaken to examine the distribution and transport

of pollutants such as Hg through a flowing water ecosystem. Extensive sampling of fish, plants and other biota, as well as abiotic sediments and water, have been conducted to monitor changes in pollutant levels between 1971 and 1973. My studies of Hg concentration in the muscle of brown bullhead were part of this effort.

#### Materials and Methods

Muscle tissue of ninety brown bullhead from Shirleys Bay and Britannia Bay in the upper river, from Hay Bay and the top of Upper Duck Is. in the lower river, and from below Hawkesbury were analysed to determine their total Hg concentration. The grade of reagents, apparatus and basic procedures used to digest the fish tissue were those outlined by Malaiyandi and Barrette (1972).<sup>1</sup> The quantities of reagents used were adjusted for use with the MAS-50 mercury analyser.

Five g of frozen axial muscle tissue taken from above the lateral line over the anal fin were added to the digestion apparatus. The tissue was dissolved in about 15 minutes at 60 C using 6 ml of 5.6N nitric acid and 4 ml of 18N sulfuric acid in the presence of 0.25 g of vanadium pentoxide catalyst. The apparatus was allowed to cool and three drops of 30% hydrogen peroxide were added. The apparatus was washed down with 3% sulfuric acid to concentrate the digest. The digest solution was filtered through glass wool filter paper into a stoppered vial. The clear green digest solution was brought up to 100 ml using 3% sulfuric acid.

Mercury concentrations were determined on a MAS-50 Coleman mercury analyser by flameless atomic absorption. Fifty ml of 2.8N nitric-sulfuric

<sup>1</sup>personal communication, 1971.

acid diluting medium was added to acidify the glass of a 300 ml bubbling bottle. Twenty ml of digest solution was then added. The sample was then reduced by the addition of 20 ml of hydroxyl ammonium sulfate solution followed by 20 ml of stannous chloride solution. An air bubbler connected to the mercury analyser was immediately inserted into the bubbling bottle. Since the Hg from one gram of digested tissue was vaporized and run through the analyser the peak absorbance recorded by the machine recorded the readings in ppm. By running blank standards through the machine the background level of Hg in the reagents was determined and this was subtracted from the readings.

#### Results

Mercury concentrations in the muscle of 90 brown bullhead tested varied from 0.06-0.56 ppm (Table 16). No significant correlation between Hg concentration and fork length or between Hg concentration and total body weight was found at any of the stations in the upper river, lower river or near Hawkesbury. The results and their corresponding linear regressions are depicted in Figs. 17 and 18. Aside from the non statistically significant regression between Hg level and fork length at Britannia Bay which was positive in slope, the remaining regressions had slopes close to zero with non statistically significant negative correlation coefficients. No trend according to age or difference in levels according to sex was discernable in the data. These results were similar to analyses of Hg in bullhead collected from Kettle Is. Bay and tested at NRC (Norstrom and Peter, 1972).

Table 16 Total mercury concentrations in muscle of brown bullhead at various stations in the Ottawa River during 1971.

Station	No. of bullhead	Mean mercury level (ppm)	SE	Range mercury levels (ppm)	Range in fork length (cm)
Brittania Bay and Shirleys Bay	26	0.195	0.127	0.065-0.560	22.5-34.3
Hay Bay	25	0.148	0.047	0.063-0.350	18.0-29.5
Top of Upper Duck Is.	14	0.225	0.056	0.120-0.290	20.8-28.2
Below Hawkesbury	25	0.186	0.066	0.055-0.340	22.5-33.2
Kettle Is. Bay (tested by NRC, 1972)	18	0.133	0.011	0.050-0.200	18.4-29.9

#### Discussion

While many surveys have shown widely varying levels of Hg in the tissue of individual fish and between species, few studies have been conducted to investigate the relationship between Hg concentration and fish size or tried to explain the underlying mechanisms which determine the concentration of Hg in fish tissue.

It has generally been assumed that the levels of Hg increase with increasing size of a fish species. A linear relationship between age or weight of pike and the Hg content in musculature was shown to exist in northern pike collected from areas with mercury contamination in Sweden (Johnels, Westermark et al. 1967). Similar results were shown with such species as northern pike, sucker, walleye and sauger in Lake Winnipeg, Manitoba (Bligh, 1971).

Johnels, Westermark et al. (1967) showed that the relation between Hg content of axial muscle and total body weight was dependent upon the

Figure 17. Total mercury concentration in bullhead muscle in relation to total body weight of fish taken from Britannia Bay, Hay Bay, the top of Upper Duck Island and near Hawkesbury during 1971.

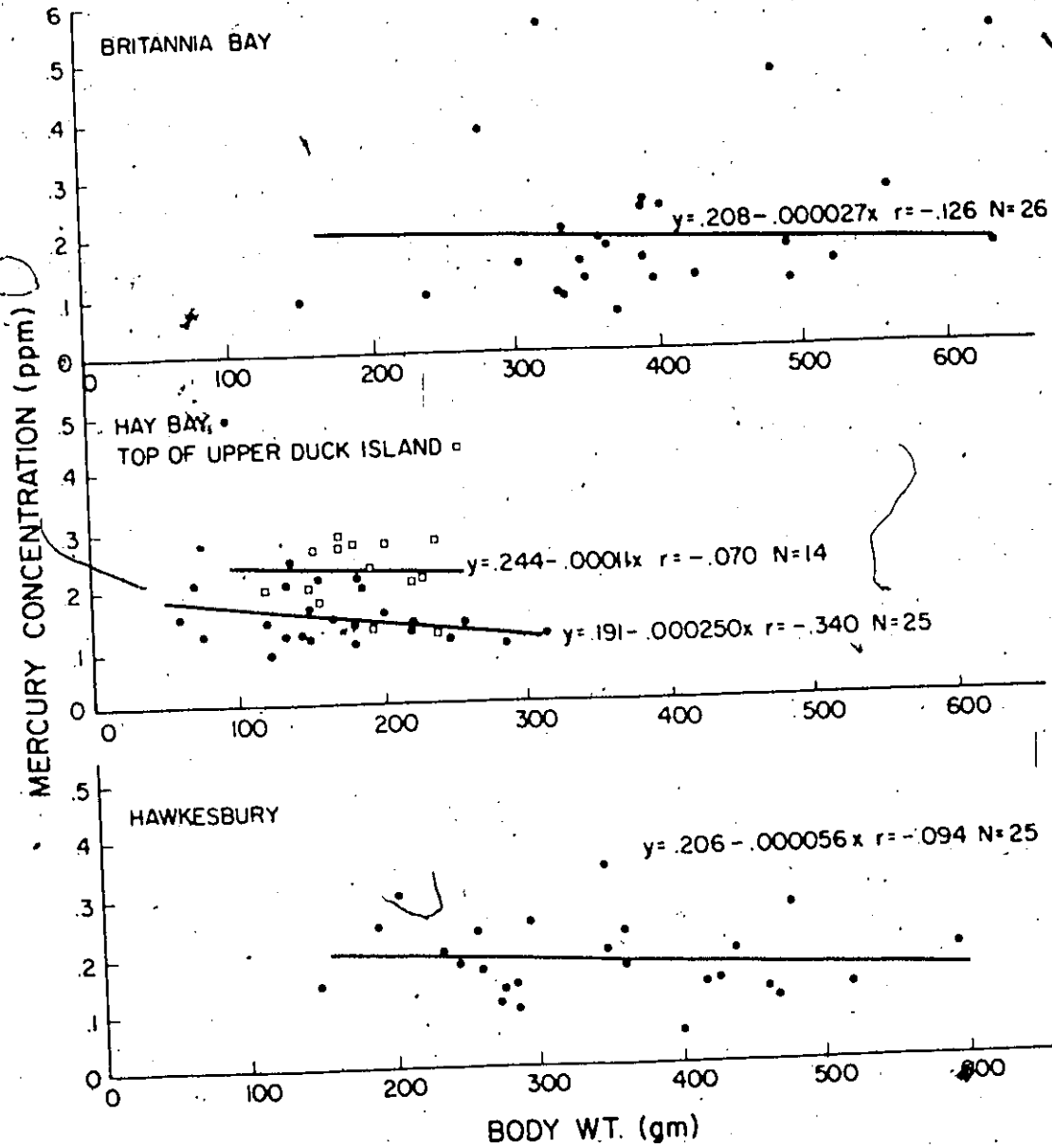
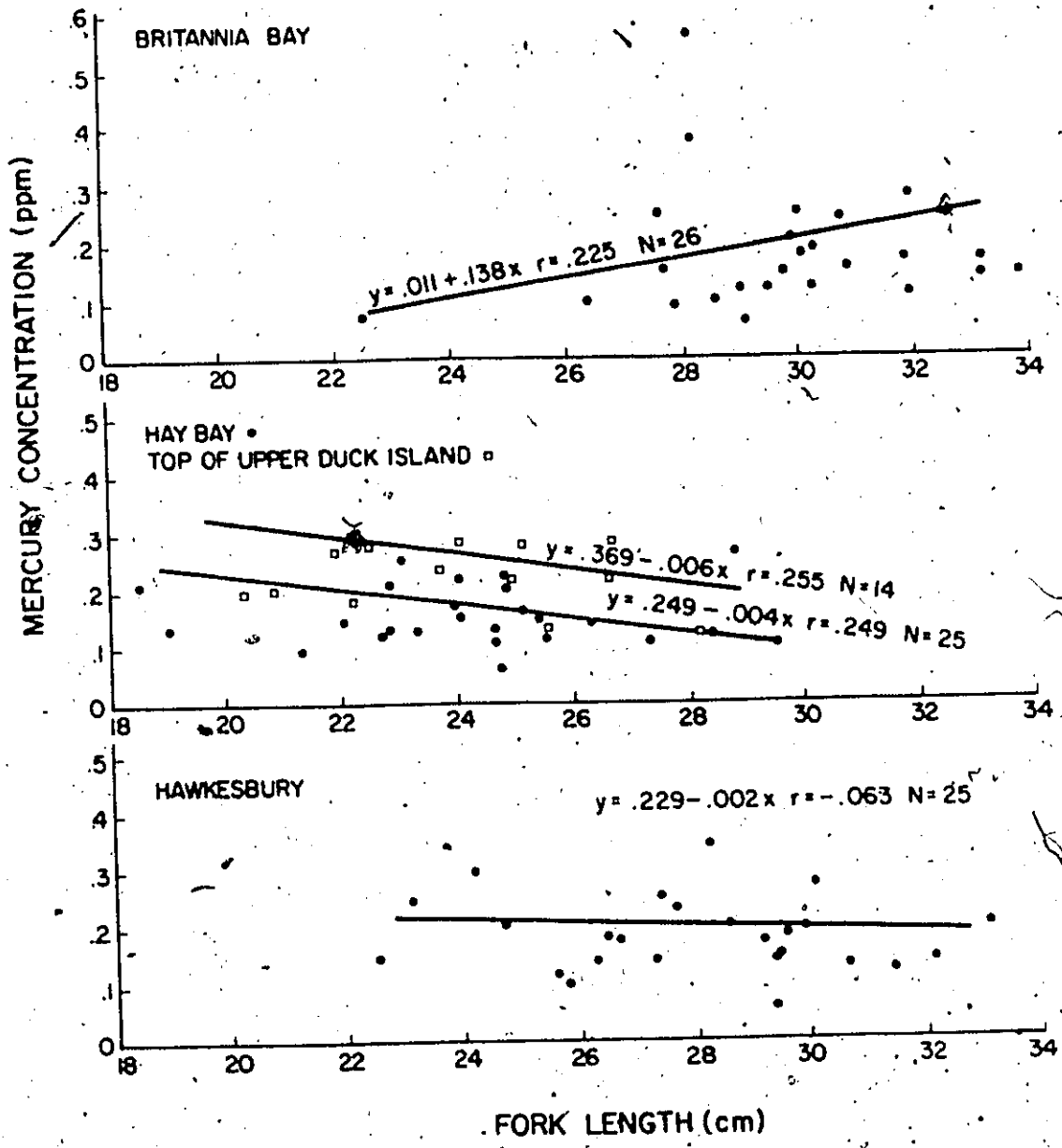


Figure 18. Total mercury concentration in bullhead muscle in relation to fork length of fish taken from Britannia Bay, Hay Bay, the top of Upper Duck Island and near Hawkesbury during 1971.



lake from which the fish were collected. Each lake contained different levels of Hg pollution which affected the net accumulation rate of Hg in muscle tissue of pike. Pike from Lake Snogeholm had the lowest concentration of Hg and showed only a slight net accumulation with age. This was interpreted to mean that the environmental level of biologically available Hg was apparently lowest in this lake and the elimination rate of Hg from the muscle was very similar to the uptake rate (Wallace et al. 1971).

Extensive studies by Scott and Armstrong (1972) demonstrated that within a species the relation between mercury concentration and length was not consistent. Most important from a practical viewpoint were the very large differences in Hg levels between various population samples. Statistical analyses showed the regressions ranged from complete lack of significance to strong correlations. The relation between Hg concentration and length was positively correlated in most samples, had weak or no correlation in others and a few were negatively correlated. Slopes greater than zero were believed to be indicative that the absorption of Hg was at a greater rate than the combined effects of excretion and growth. A slope equal to zero would not mean that there was no relation between size and total Hg content; rather, it indicates no change in the mercury concentration with size. The fish must absorb Hg at a rate which just matches their growth to produce this value. A negative relation occurred when there was a particular Hg content at the beginning of a growth period and no new Hg was absorbed by the fish. This results in dilution by growth.

Cross et al. 1973 found levels of Hg increased with increasing weight but levels of Mn, Fe, Cu and Zn stayed the same or decreased in fish

taken from the marine environment. The results indicated that fish residing in two different depth regions of the Atlantic Ocean were in a steady state with their environment with respect to the latter elements but not with Hg. This was thought to be related to uptake and elimination rates as well as the levels of the element biologically available.

DeFreitas (1973) has proposed that mercury uptake and clearance is primarily a function of metabolic rate. Growth dilution, rates of growth and maximum age were felt to be important and closely linked to metabolic rate. The trophic level and species specific differences may not play as important a role in Hg detoxification and clearance as metabolic rate. Depending on their rates of growth and metabolism within the same environment different species may be expected to exhibit different rates of uptake and excretion resulting in different mercury distributions. Such distributions would still be partially dependent on levels of biologically available Hg in the environment and may be expected to vary on an annual as well as a seasonal basis.

Since the levels of Hg in brown bullhead did not increase with increasing length or increasing weight, it may be concluded that bullhead from the various areas examined were in a steady state with their environment during 1971. The fact that the levels did not differ appreciably would tend to indicate that the levels of biologically available mercury in the environment were similar in the areas of the river examined.

One would expect that since the use of mercurials was only discontinued in the spring of 1970, that the levels of Hg in the lower river downstream of the outfalls would still have been high in 1971. It is

apparent that the levels of Hg in the sediments close to these paper mills had changed very little (Oliver and Kinrade, 1971). Jernelov (1969) believed that it would take many years for a river to clear itself of Hg deposits in sediments. Tests of water, fish and sediments in 1972 and 1973 would tend to indicate that the Ottawa River has been clearing itself of Hg at a much faster rate than was originally anticipated (Norstrom and Brownstein, 1973).

Contaminated fish, tested in 1969, were taken a considerable distance downstream of the paper mills near Orleans (OWRC-QWB, 1971). This would tend to indicate that the Hg pollution was quite widespread. With the cessation of the use of mercury it is possible that the areas of contamination have become restricted to the vicinity of the paper mills. Thus it is possible that bullhead taken in other areas are presently not being exposed to contamination. While such changes have been occurring over the last three years, it is doubtful that they can entirely explain the low levels of total mercury found in brown bullhead in 1971.

It seems more likely that low levels of total Hg in bullhead have resulted because brown bullhead have a low metabolic rate in comparison to other species. Experiments with radioactive tracers have shown that bullhead take up Hg directly from the water and from their food (deFreitas et al. 1972). Both factors are responsible for the levels found in bullhead in the Ottawa River. While it is not yet clear which factor is the more important, it appears that the levels of methyl mercury taken up from the food of bullhead are low in comparison to such species as sauger, walleye and northern pike. The levels of methyl mercury in the diet does not vary significantly with increasing size of the bullhead which continues to eat

Invertebrates. In contrast the ingestion of methyl mercury can be expected to change in such species as walleye which become piscivorous as adults. Thus, it seems likely that the brown bullhead in the Ottawa River never were seriously contaminated with Hg to the extent found in other species.

The levels of Hg in fish and in sediments in the Ottawa River are low in comparison to other areas with serious Hg pollution (Bligh, 1971; Voegelé, 1971; Fimreite et al. 1971). It would appear that brown bullhead from the Ottawa River were safe for human consumption in 1971 and possibly before this time.

The levels of Hg can be expected to vary in brown bullhead in different environments depending on the levels of mercury biologically available and the rates of uptake and elimination of the populations concerned. Brown bullhead are generally not a species containing high levels of Hg. However, high levels have been reported. Buhler et al. (1973) found levels of Hg from 0.22-1.78 ppm with a mean of 0.75 ppm in 13 brown bullhead collected in Oregon rivers. It was believed that three bullhead from the Rogue River with a mean of 0.89 ppm may have been contaminated due to high losses of Hg during gold mining in the latter part of the last century. Similarly, levels of 0.93 and 1.57 ppm Hg were found in bullhead from the Wisconsin River and Flambeau River respectively in Wisconsin (Kleinert and Degurse, 1972). The level of methyl mercury found in that study was 85-86% of the total mercury which compares with 83% determined in brown bullhead from the Ottawa River (Norstrom and Peter, 1972). Thus it would not be safe to assume that brown bullhead from other waters are safe for consumption.

## AGE AND GROWTH

## Introduction

Published data is not available concerning the age and growth of brown bullhead in Canada (Scott and Crossman, 1973). Detailed studies have been conducted in the United States by Redd (1970) and in Czechoslovakia by Frank (1955) and Hensel (1966). Most of what is known concerning growth in length of brown bullhead has been summarized by Carlander (1969).

Since North American catfishes lack scales, various other bony structures have been utilized for age determinations. Frank (1955), Lewis (1950) and Hensel (1966) have used vertebrae while Finnell et al. (1956), Sanderson (1958), Priegel (1966) and Redd (1970) have used pectoral spines to age brown bullhead.

From the standpoint of collection, preparation and readings, pectoral spines were preferred over vertebrae as they required the least effort in preparation and were more reliable for age determination because they showed fewer false annular marks (Marzolf, 1955). A comparison of vertebrae and sections of pectoral spines of channel catfish of known age indicated that the annular marks were true year marks.

The relationship between vertebral radius and fish length or between spine radius and length is not always consistent (Marzolf, 1955). Sneed (1951) found a linear relationship between posterior spine radius (Fig. 19) and total length (TL) of channel catfish. Marzolf (1955) compared channel catfish aged by vertebrae and pectoral

spine sections and found that the relationship of spine radius to TL was curvilinear while the relationship between vertebral radius and TL for small and large catfish was described by two intersecting straight lines. Frank (1955) found a linear relationship between TL and diameter of vertebra while Hensel (1966) in a similar study of brown bullhead found a curvilinear relationship. Redd (1970) found a linear relationship between TL and spine radius of brown bullhead.

Marzolf (1955) noted that growth was accomplished by a seasonal deposition of bone on the outside of the spine. As the spine grew the lumen of the basal groove enlarged at the expense of the earliest bone deposits. Because of the lengthening of the groove, the point of sectioning in successive years was moved distally along the spine. Posterior spine radius measurements from older fish were found to give back calculated lengths which were shorter than those lengths derived from measurements to the same annulus in younger fish. The first year mark was often obliterated. Marzolf noted a large variation in the posterior radius measurements and suggested that measurements of the anterior radius, might minimize the error and allow reasonably accurate calculations of growth from spine sections.

Redd (1970) compared measurements made along the anterior and posterior pectoral spine radii of brown bullhead. Both measurements were found to reliably measure the growth of brown bullhead. Measurements along the anterior radius were preferable since they were found to have less variation than measurements from the same fish made along the posterior radius.

## Materials and Methods

A total of 803 brown bullhead collected from the Ottawa River during 1971 were used for the age and growth study. Of this total, 163 were from Shirleys Bay and Britannia Bay in the upper river; 168 were from Hay Bay, 179 from Governor's Bay and 84 from the top of Upper Duck Island in the lower river; 112 were from above Hawkesbury and 97 from below Hawkesbury.

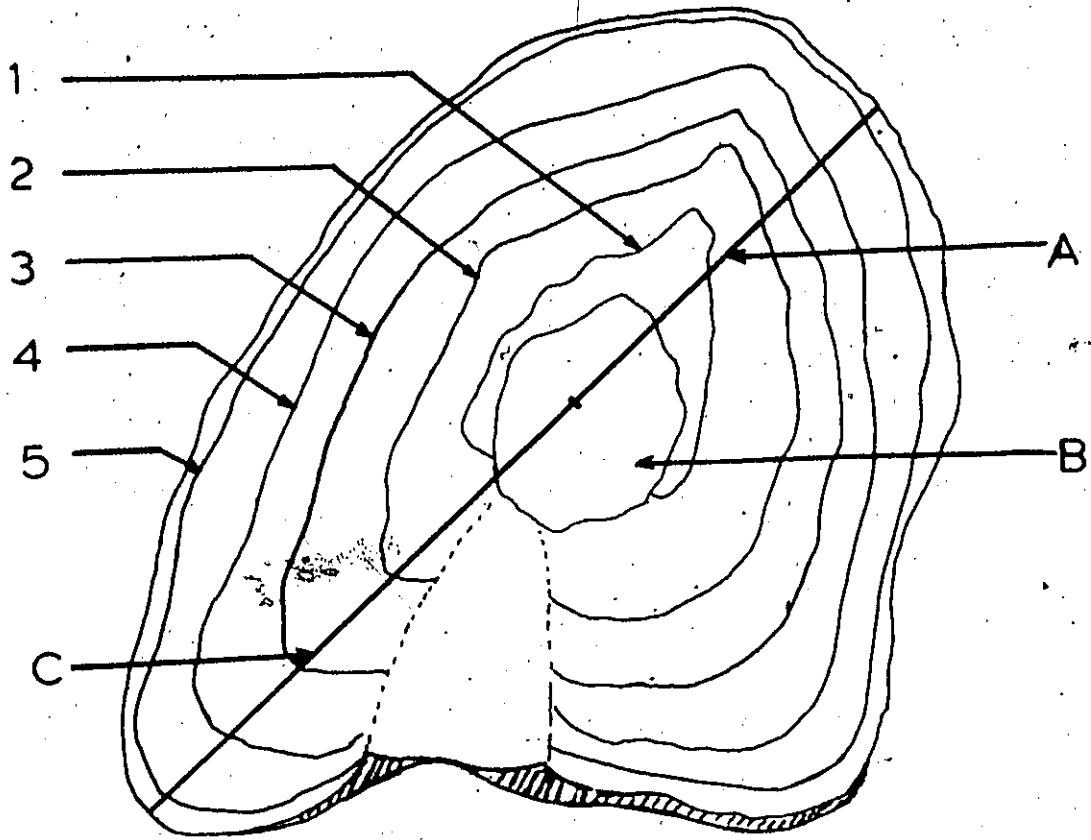
Most brown bullhead in this study were aged from pectoral spine sections. To check the validity of ages derived from spine sections the fifth unfused vertebra from thirty bullhead were examined and compared with spine readings from the same fish. Measurements for back calculations were made along the anterior radius of the spine which was situated 180 degrees opposite the posterior radius through the long arm of the spine (Fig. 19).

Spines were removed from bullhead which had been frozen about four months. The spines were air dried in coin envelopes, fixed in 10% non-buffered formalin for a minimum of 48 hours, and then placed in the decalcifying fluid Decal (Scholl, 1968). After a decalcification period of about three days the spines were rinsed in water for three hours. A single edged razor blade was used to cut sections from 0.1 to 0.2 mm thick from the distal end of the basal groove (Sneed, 1951) in a manner similar to Smith (1974).

Spine sections were read at least twice before an age was assigned to the fish. A drawing at 100X magnification was made of the anterior radius of the spine with the aid of a camera lucida. Since

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Figure 19. A typical pectoral spine cross section showing A - anterior radius, B - lumen, C - posterior radius, 1 - 5 the annuli for different ages.



the center of the lumen of the spine is difficult to determine (Muncy, 1959) thirty spines were measured to obtain an average factor by which one could estimate the spine radius. Spine measurements were made from the edge of the lumen to the anterior edge of the spine section along the anterior radius. This measurement was multiplied by the factor (1.3223) to obtain the spine radius.

To assess losses in weight and length due to freezing 30 brown bullhead varying from 23-35 cm total length were collected by trap netting in Shirleys Bay. These fish were weighed and measured while still alive and again after being frozen in groups of six in plastic bags for four months.

Growth determinations for this investigation were calculated according to the proportional method outlined by Whitney and Carlander (1956). The Lee-Lea formula used was calculated as:

$$L_n = a + \frac{S_n}{S} (L - a)$$

where  $L_n$  = calculated length when annulus 'n' was formed

$a$  = the intercept on the Y axis

$S_n$  = radius of spine section from lumen to annulus

$S$  = radius of spine section at capture

$L$  = total body length

The back calculated lengths at each annulus for each age group were obtained through the computerized age and growth program of Voightlander and Roohvarg (1967). This program derived back calculations for each sex as well as sexes combined at each of the six stations. In addition, calculations were derived for the lower river

stations combined and for above and below Hawkesbury combined. This program also gave monthly growth increments for each station during the period from May to October.

Associated with increases in length of fish are increases in weight. The relationship between length and weight may vary due to sex, season, suitability of habitat, food supply, degree of parasitism and age of the fish concerned (LeCren, 1951). Such relations as the condition factor and the length-weight relationship can be used to compare the relative well being of different fish populations in separate environments as well as to compare different segments of the same population.

The condition factor (K) has been used as a measure of the degree of plumpness or general well-being of a fish. It is generally believed that a long thin fish is inferior to a plump fish of the same length of the same species. Studies of the seasonal changes in condition factor or differences in the mean condition factor of different populations have been used to ascertain the suitability of the fish's environment. The condition factor was calculated according to the formula given by LeCren (1951).

$$K = \frac{(W) (100)}{L^3}$$

where W = total body weight (g)

L = total length (cm)

The length-weight relationship can be represented by the expression:  $\log W = \log c + n (\log L)$

An analysis of covariance (NRC computer program, Biomathematics Section) was used to compare the length-weight regressions according to sex and at the six collection stations (LeCren, 1951). The same program was also used to compare Walford plots (Ricker, 1958) derived from the back-calculated length data. The analysis of covariance (one-way classification) was used to determine whether significant differences in growth existed between sexes or between stations with the two sexes pooled together. This analysis was adequate in revealing where significant differences existed in the relations (Dr. S.D. Walter, personal communication).

### Results

#### Growth in Young-of-the-Year Bullhead

While seining was conducted in both the upper and lower river, it was only possible to capture young-of-the-year bullhead on a regular basis at Britannia Bay. Small bullhead from Britannia Bay grew most rapidly during June and July. A large variation in growth between individuals was evident. This became greater as the summer progressed. Thus bullhead taken on September 22, 1972 ranged from 4.9-8.9 cm. The growth over the summer was quite similar to that of young bullhead collected by Raney and Webster (1940) in New York State (Fig. 20).

#### Shrinkage Due to Freezing.

Grouping the frozen specimens into one cm intervals, the loss in weight and length of bullhead from Shirleys Bay was found to be a constant proportion of the original measurements for all sizes of bullhead examined. Averaging the percentage differences in length


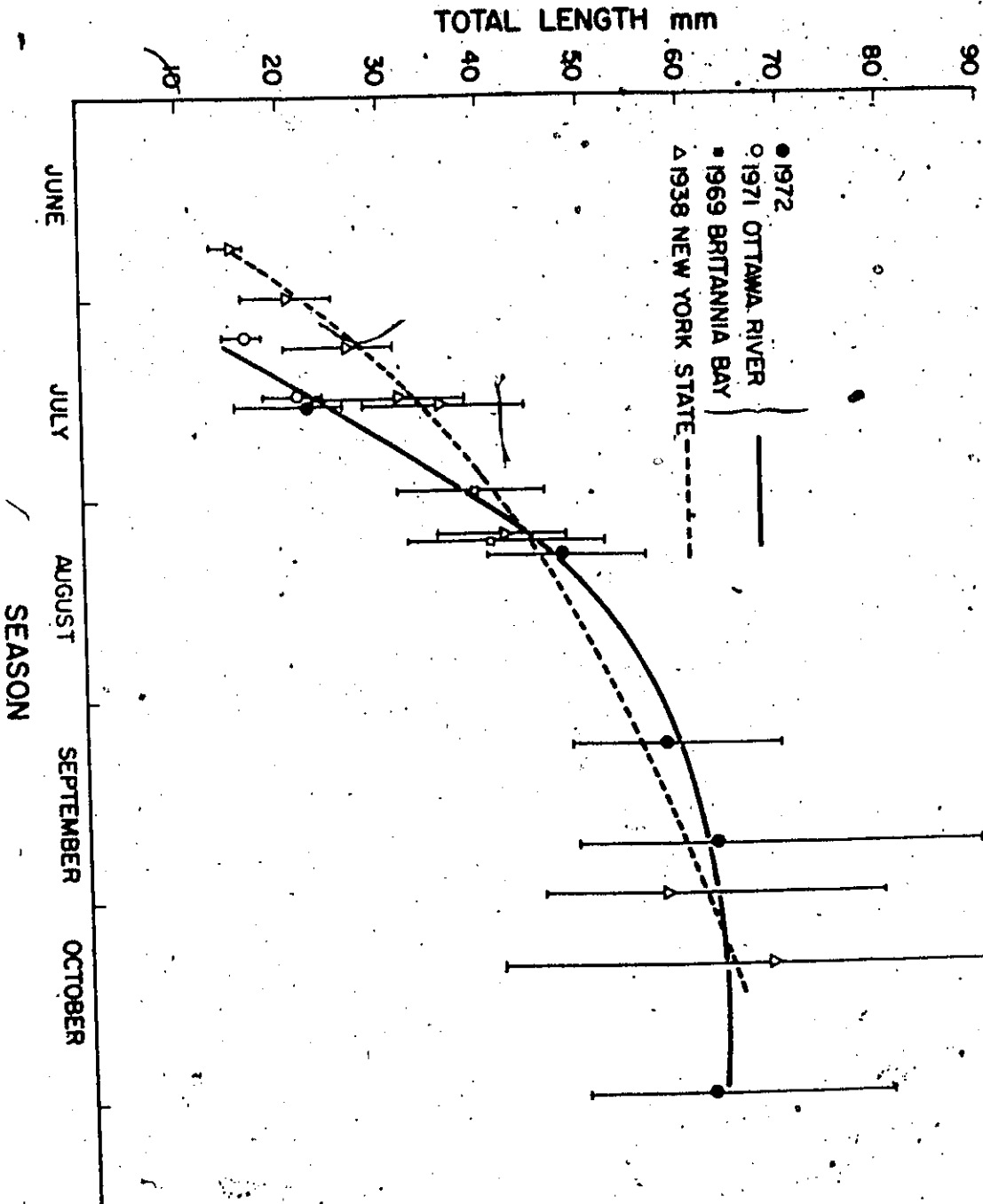


Figure 20. Comparison of the seasonal growth of young-of-the-year bullhead collected from the Ottawa River at Britannia Bay with those collected in Cayuga Lake, New York by Raney and Webster (1940). The range in total length is given by the vertical lines, the mean size by the point.



and in weight, it was determined that the bullhead had lost 1.4% of their total length and 8.7% of their original weight. Similar results were found for bullhead taken at Hay Bay and at the top of Lower Duck Is. The lengths of frozen specimens used in age and growth studies were corrected by multiplying the total length measurements by 1.0139. Body weights were multiplied by 1.0871.

#### Conversion Between Fork Length and Total Length

The relationship between total length (TL) and fork length (FL) was found to be constant for bullhead varying from 2.0-32.0 cm.

$$TL = 0.1145 + 1.0193 FL, N = 80, r = .997$$

$$FL = 0.0344 + 0.9750 TL, N = 80, r = .997$$

Averaging the measurements of TL and FL, the conversion ratio of FL/TL was calculated as 0.9764. The conversion ratio of TL/FL was calculated as 1.0241. Standard length (SL) was not measured. Carlander (1969) gave a conversion ratio TL/SL of 1.135.

#### Body Length-Spine Radius Relationship

Due to the large variation in the spine radius measurements for a given length of brown bullhead it was difficult to ascertain the body:spine relationship empirically. Since the age one and age two bullhead were inadequately sampled at most stations, calculation of the body:spine regressions at these stations yielded unrealistic y intercepts. By including young-of-the-year bullhead it was possible to obtain the relationship at Hay Bay and at Shirleys Bay by using the regression formula  $L = a + cs$ .

Hay Bay  $L = 43.8369 + 1.6102 S$ ,  $r = .883$ ,  $n = 181$

Shirleys Bay  $L = 39.5466 + 1.4167 S$ ,  $r = .930$ ,  $n = 178$

$L$  = total length (mm),  $S$  = spine radius (mm)

Both regressions showed a high measure of association between the two variables as indicated by the correlation coefficients which differed significantly from  $r = 0$ . This indicated that the relationships were linear and growth was calculated on this basis. Since the Lee-Lea formula is suitable for a linear body:spine relationship, it was used to derive back-calculated lengths at all six stations. This formula avoids the necessity of assuming a linear body:spine relationship having a zero intercept.

Carlander (1969) has pointed out the fallacy of assuming that the intercept derived from the body:scale regression represents the size of young fish when scales first form. Likewise the intercepts derived from the body:spine regression do not represent the size of the bullhead when spines first form since this occurs during larval development before the fry become free swimming (Smith and Harron, 1904). Young bullhead which hatched in an aquarium at the university were 13.0 mm when they became free swimming. The mean size of newly free swimming bullhead collected in the field was 15.2 mm at Brewery Creek and 16.2 mm at Shirleys Bay. It is possible that the fish collected in the field had grown a little after becoming free swimming.

To more accurately ascertain the body:spine relationship at Hay Bay and Shirleys Bay, log-log regressions of the data were made.

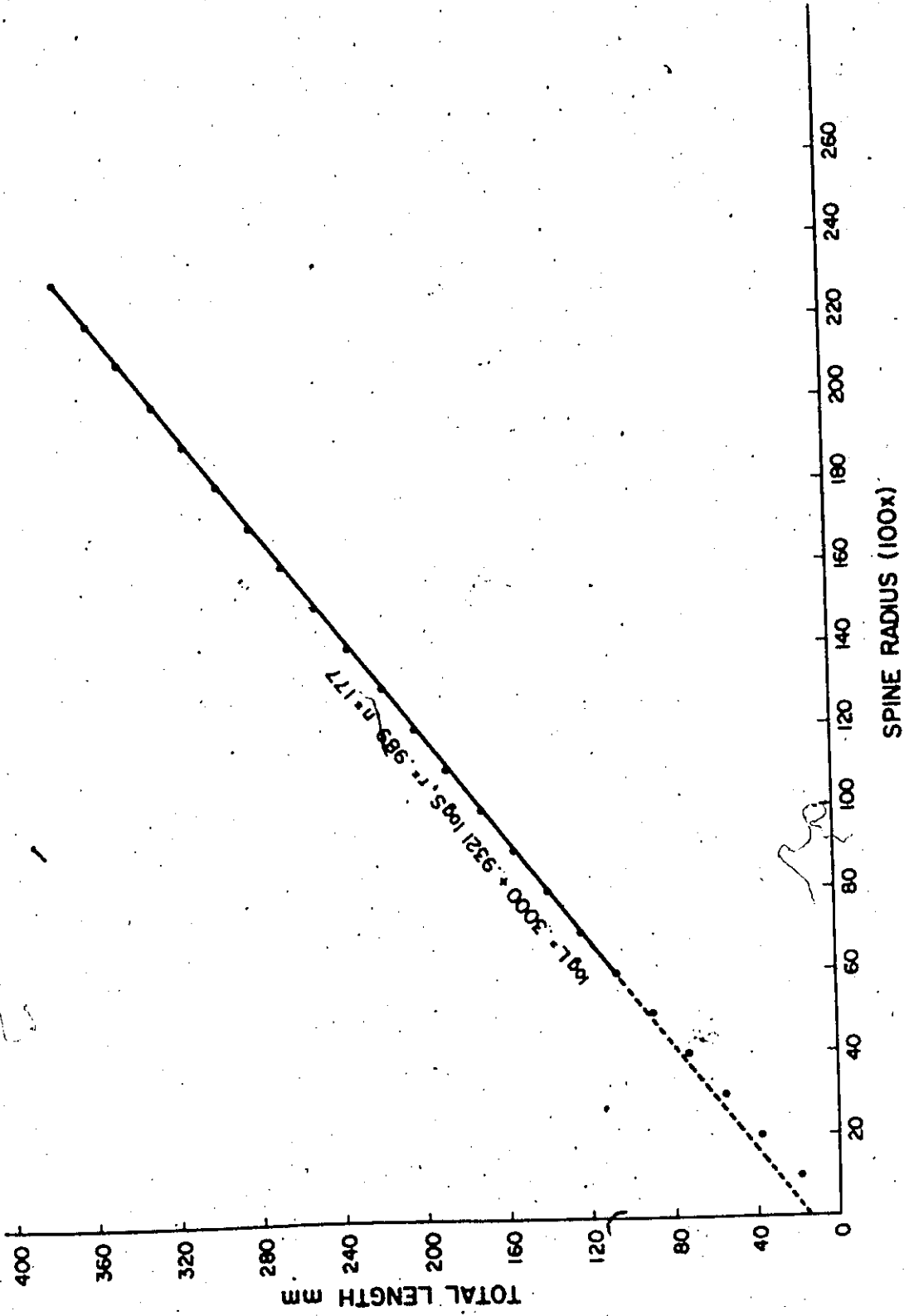
Substituting known spine radius values into the logarithmic equations equivalent total lengths were obtained from each regression. Plotting these values on ordinary graph paper (Figs 21 and 22) the true relationship between total length and spine radius was obtained for the two stations (Frost and Brown, 1967). While slight deviations near the ends of the lines were noted the graphs were essentially straight lines. These graphs more accurately described what was actually observed. From the logarithmic regressions one can predict that newly freeswimming bullhead should be close to 15 mm in length, rather than near the 40 mm predicted from the simple body: spine regressions.

A common intercept (a) was chosen on the assumption that newly freeswimming bullhead, prior to the beginning of active feeding should be close to the same size at all stations. An intercept of 13 mm was chosen, based on the size of newly free swimming bullhead observed in the aquarium, for substitution into the Lee-Lea formula in order to derive back-calculations.

#### Back-Calculations

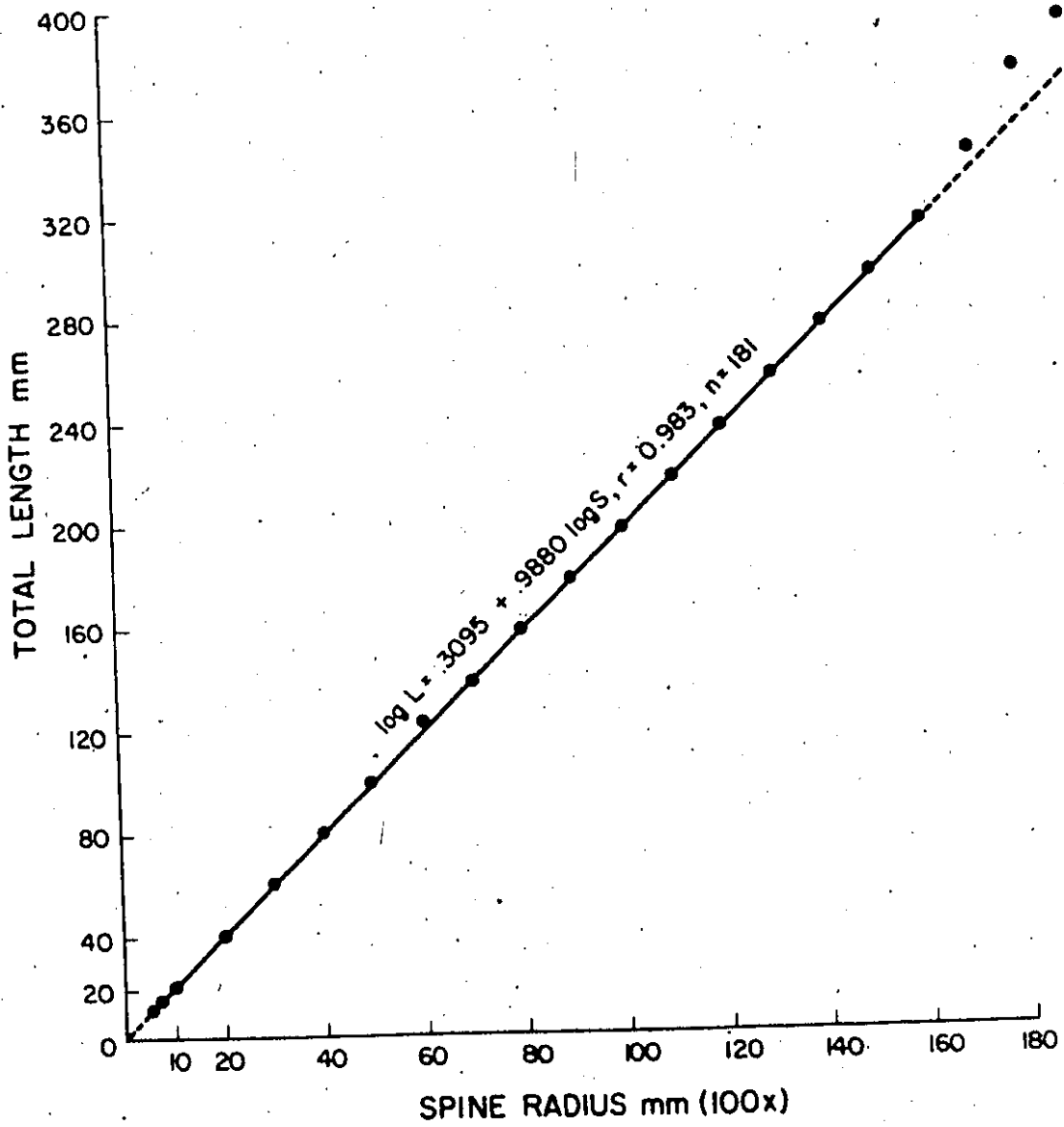
The yearly growth for each age group has been indicated in Tables 17 through 32. The back-calculated lengths of male bullhead at each annulus were slightly greater than those of females from the same station. The growth of bullhead was greatest in the upper river at Shirleys Bay and Britannia Bay. Growth rates at the stations in the lower river were much less than that observed in the upper river. Growth rates intermediate between those observed in the upper and

Figure 21. Body:spine relationship of brown bullhead collected from Britannia Bay and Shirleys Bay during 1971 based on measurements of the anterior spine radius.



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Figure 22. Body:spine relationship of brown bullhead collected from Hay Bay during 1971 based on measurements of the anterior spine radius.



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Table 17. Average calculated total length at the end of each year of life of male and female brown bullhead collected from Shirleys Bay and Britannia Bay in 1971. (\*Collected 1968)

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus							
				1	2	3	4	5	6	7	8
Male											
I	*1967	2	142	129							
II	1969	5	259	139	228						
III	1968	23	298	143	201	267					
IV	1967	34	311	145	200	254	290				
V	1966	8	321	133	174	215	262	301			
VI	1965	2	348	142	198	250	299	329	342		
VII	1964	1	355	154	197	218	227	299	312	346	

Weighted mean length	142	199	253	284	306	332	346
Average annual growth increment	142	57	54	31	22	26	14
Number of fish	75	73	68	45	11	3	1

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus							
				1	2	3	4	5	6	7	8

## Female

I	*1967	2	148	131							
II	1969	0									
III	1968	27	288	132	190	249					
IV	1967	41	300	129	172	230	276				
V	1966	15	310	132	167	218	261	293			
VI	1965	2	315	148	180	203	257	282	299		
VII	1964	0									
VIII	1963	1	348	125	185	229	253	278	329	340	345

Weighted mean length	131	177	223	271	291	309	340	345
Average annual growth increment	131	46	46	48	20	18	31	5
Number of fish	88	86	86	59	18	3	1	1

Table 18. Average calculated total length at the end of each year of life of male and female brown bullhead collected from Hay Bay in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus							
				1	2	3	4	5	6	7	8
Male											
II	1969	7	204	122	168						
III	1968	19	228	118	156	204					
IV	1967	29	262	132	175	219	246				
V	1966	28	282	131	170	210	243	266			
VI	1965	16	287	132	167	202	233	254	273		
VII	1964	1	296	135	152	170	184	224	276	286	
VIII	1963	1	254	133	144	155	176	191	200	209	236
Weighted mean length				128	168	209	240	259	264	248	236
Average annual growth increment				128	40	41	31	19	5	-16	-12
Number of fish				101	101	94	75	46	18	2	1
Female											
II	1969	4	197	129	174						
III	1968	11	217	100	142	191					
IV	1967	12	252	112	154	194	233				
V	1966	21	273	124	160	197	231	255			
VI	1965	12	274	128	159	191	222	241	262		
VII	1964	5	293	118	149	176	207	234	258	282	
VIII	1963	2	278	114	133	169	191	219	246	257	270
Weighted mean length				118	155	192	226	246	259	275	270
Average annual growth increment				118	37	37	34	20	13	16	-5
Number of fish				67	67	63	52	40	19	7	2

Table 19. Average calculated total length at the end of each year of life of male and female brown bullhead collected from Governor's Bay in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus							
				1	2	3	4	5	6	7	8
Male											
II	1969	1	230	131	193						
III	1968	16	232	128	169	211					
IV	1967	36	244	126	166	201	231				
V	1966	46	259	127	159	191	221	246			
VI	1965	13	273	127	151	183	208	238	262		
VII	1964	2	252	118	147	161	187	203	224	242	
Weighted mean length				127	162	196	222	243	257	242	
Average annual growth increment				127	35	34	26	21	14	-15	
Number of fish				114	114	113	97	61	15	2	
Female											
II	1969	1	186	105	150						
III	1968	9	226	118	157	208					
IV	1967	21	250	128	161	199	230				
V	1966	17	265	125	163	196	224	248			
VI	1965	10	272	134	158	185	217	240	259		
VII	1964	4	259	122	144	169	194	218	240	253	
VIII	1963	3	289	133	167	190	216	237	255	270	281
Weighted mean length				126	160	195	222	241	254	260	281
Average annual growth increment				126	34	35	27	19	13	6	21
Number of fish				65	65	64	55	34	17	7	3

Table 20. Average calculated total length at the end of each year of life of male and female brown bullhead collected from the top of Upper Duck Is. in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus								
				1	2	3	4	5	6	7	8	
Male												
III	1968	11	226	114	158	200						
IV	1967	10	256	126	164	200	239					
V	1966	21	250	120	151	180	206	229				
VI	1965	3	248	119	155	167	187	217	238			
VII	1964	1	293	155	182	219	239	266	279	289		
Weighted mean length				121	156	189	215	229	248	289		
Average annual growth increment				121	35	33	26	14	19	41		
Number of fish				46	46	46	35	25	4	1		
Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus								
				1	2	3	4	5	6	7	8	
Female												
III	1968	7	231	115	166	208						
IV	1967	15	256	121	154	194	218					
V	1966	9	250	122	149	179	202	226				
VI	1965	7	248	123	152	183	207	232	246			
Weighted mean length				121	155	191	211	229	246			
Average annual growth increment				121	34	36	20	18	17			
Number of fish				38	38	38	31	16	7			

Table 21. Average calculated total length at the end of each year of life of male and female brown bullhead collected from above Hawkesbury in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus									
				1	2	3	4	5	6	7	8		
Male													
II	1969	1	202	120	177								
III	1968	1	208	120	176	194							
IV	1969	6	284	146	184	226	259						
V	1968	24	308	157	204	240	266	287					
VI	1967	12	328	161	204	236	274	301	318				
VII	1966	4	314	156	189	211	234	263	284	301			
VIII	1965	2	345	133	171	210	258	279	303	323	338		
Weighted mean length				154	198	233	264	288	309	308	338		
Average annual growth increment				154	44	35	31	24	21	-1	30		
Number of fish				50	50	49	48	42	18	6	2		
Female													
Age group													
Year class													
Number of fish													
Total length at capture													
Calculated length (mm) at each annulus													
1													
2													
3													
4													
5													
6													
7													
8													
III	1968	4	221	123	155	189							
IV	1969	6	271	128	164	202	234						
V	1968	26	291	143	187	226	253	273					
VI	1967	13	293	138	172	208	238	261	277				
VII	1966	11	318	159	190	220	248	269	287	303			
VIII	1965	2	327	150	190	230	252	270	283	303	325		
Weighted mean length				142	180	217	247	269	282	303	325		
Average annual increment				142	38	37	30	22	13	21	22		
Number of fish				62	62	62	58	52	26	13	2		

Table 22. Average calculated total length at the end of each year of life of male and female brown bullhead collected below Hawkesbury in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus							
				1	2	3	4	5	6	7	8
Male											
III	1968	12	294	157	206	263					
IV	1967	10	299	141	183	230	276				
V	1966	15	306	149	195	227	262	288			
VI	1965	12	334	149	191	232	272	300	321		
VII	1964	0									
VIII	1963	1	336	128	172	228	262	301	314	319	327
Weighted mean length				149	194	237	269	294	320	319	327
Average annual growth increment				149	45	43	32	25	26	-1	8
Number of fish				50	50	50	38	28	13	1	1
Age group	Year class	Number of fish	Total length at capture (mm)	Calculated length (mm) at each annulus							
				1	2	3	4	5	6	7	8
Female											
III	1968	9	266	138	188	240					
IV	1967	9	271	139	180	220	252				
V	1966	14	295	144	190	227	255	279			
VI	1965	11	309	141	180	220	252	276	296		
VII	1964	3	331	146	180	229	271	294	314	324	
VIII	1963	1	294	126	139	149	174	203	238	261	284
Weighted mean length				141	184	225	253	277	296	308	284
Average annual growth increment				141	43	41	28	24	19	12	-24
Number of fish				47	47	47	38	29	15	4	1

Table 23. Average calculated total length at the end of each year of life of male and female brown bullhead collected from above and below Hawkesbury in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus									
				1	2	3	4	5	6	7	8		
Male													
II	1969	1	202	120	177								
III	1968	13	288	154	204	258							
IV	1967	16	294	143	183	228	270						
V	1966	39	307	154	201	235	264	287					
VI	1965	24	331	156	197	234	273	300	320				
VII	1964	4	314	156	189	211	234	263	284	301			
VIII	1963	3	342	132	171	216	259	286	307	322	335		
Weighted mean length				152	196	235	266	290	314	310	335		
Average annual growth increment				152	44	39	31	24	24	-4	25		
Number of fish				100	100	99	86	70	31	7	3		
Female													
III	1968	13	252	134	178	225							
IV	1967	15	271	135	174	213	245						
V	1966	40	292	143	188	226	254	275					
VI	1965	24	300	139	176	214	244	268	286				
VII	1964	14	320	157	188	222	253	274	293	308			
VIII	1963	3	316	142	173	203	226	248	268	209	312		
Weighted mean length				142	182	220	249	272	287	305	312		
Average annual growth increment				142	40	38	29	23	15	8	7		
Number of fish				109	109	109	96	81	41	17	3		

Table 24. Average calculated total length at the end of each year of life of male and female brown bullhead collected from Hay Bay, Governor's Bay and the top of Upper Duck Is. in the lower river in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus									
				1	2	3	4	5	6	7	8		
Male													
II	1969	8	208	123	161								
III	1968	46	229	120	161	206							
IV	1967	75	252	128	169	208	238						
V	1966	95	264	127	161	195	224	248					
VI	1965	32	278	129	160	191	219	244	265				
VII	1964	4	273	131	157	177	199	224	251	265			
VIII	1963	1	254	133	144	155	176	191	200	209	236		
Weighted mean length				126	163	200	228	246	262	254	236		
Average annual growth increment				126	37	37	28	18	16	-8	-18		
Number of fish				261	261	253	207	132	37	5	1		

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus									
				1	2	3	4	5	6	7	8		
Female													
II	1969	5	195	124	169								
III	1968	27	224	110	153	201							
IV	1967	48	246	122	157	196	227						
V	1966	47	264	124	159	193	223	247					
VI	1965	29	269	129	157	187	217	238	257				
VII	1964	9	278	120	147	173	201	227	250	269			
VIII	1963	5	285	125	154	182	206	230	252	265	276		
Weighted mean length				122	157	193	221	241	255	268	276		
Average annual growth increment				122	35	36	28	20	14	13	8		
Number of fish				170	170	165	138	90	43	14	5		

Table 25 Average calculated total length at the end of each year of life of brown bullhead, sexes combined, from Shirleys Bay and Britannia Bay in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus									
				1	2	3	4	5	6	7	8		
I	1967	4	145	130									
II	1969	5	259	139	228								
III	1968	50	292	137	195	257							
IV	1967	75	305	136	184	241	282						
V	1966	23	313	133	170	217	261	296					
VI	1965	4	332	145	189	227	278	306	321				
VII	1964	1	359	154	197	218	227	299	313	346			
VIII	1963	1	348	125	185	229	253	278	329	340	345		
Weighted mean length				136	187	242	276	297	321	343	345		
Average annual growth increment				136	51	55	34	21	24	22	2		
Number of fish				163	159	154	104	29	6	2	1		

Table 26 Average calculated total length at the end of each year of life of brown bullhead, sexes combined, from Hay Bay in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus									
				1	2	3	4	5	6	7	8		
II	1969	11	202	125	170								
III	1968	30	224	111	151	200							
IV	1967	41	259	126	169	212	242						
V	1966	49	278	128	166	205	238	261					
VI	1965	28	281	130	164	197	228	249	269				
VII	1964	6	293	121	150	175	203	232	261	282			
VIII	1963	3	270	120	137	164	186	210	231	241	259		
Weighted mean length				124	163	203	234	253	265	268	259		
Average annual growth increment				124	39	40	31	19	12	3	-9		
Number of fish				168	168	157	127	86	37	9	3		

Table 27 Average calculated total length at the end of each year of life of brown bullhead, sexes combined, from Governor's Bay in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus									
				1	2	3	4	5	6	7	8		
II	1969	2	208	118	171								
III	1968	25	230	125	164	210							
IV	1967	57	250	127	164	200	231						
V	1966	63	264	127	160	193	222	247					
VI	1965	23	273	130	154	184	212	239	260				
VII	1964	6	257	120	145	166	192	213	235	249			
VIII	1963	3	289	133	167	190	216	237	255	270	281		
Weighted mean length				127	161	196	223	243	255	256	281		
Average annual growth increment				127	34	35	27	20	12	1	25		
Number of fish				179	179	177	152	95	32	9	3		

Table 28 Average calculated total length at the end of each year of life of brown bullhead, sexes combined, from the top of Upper Duck Is. in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus									
				1	2	3	4	5	6	7	8		
III	1968	18	228	114	161	203							
IV	1967	25	245	123	158	196	227						
V	1966	30	248	120	150	180	205	228					
VI	1965	10	254	122	153	178	201	227	244				
VII	1964	1	293	155	182	219	239	266	279	289			
Weighted mean length				120	155	190	213	229	247	289			
Average annual growth increment				120	35	35	23	16	18	42			
Number of fish				84	84	84	66	41	11	1			

Table 29 Average calculated total length at the end of each year of life of brown bullhead, sexes combined, from above Hawkesbury in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus									
				1	2	3	4	5	6	7	8		
II	1969	1	202	120	177								
III	1968	5	218	122	159	190							
IV	1967	12	278	137	174	214	247						
V	1966	50	299	150	195	232	259	280					
VI	1965	25	311	149	187	222	256	280	297				
VII	1964	15	317	159	190	218	244	267	286	303			
VIII	1963	4	333	142	181	220	255	274	293	313	332		
Weighted mean length				148	188	224	255	278	293	305	332		
Average annual growth increment				148	40	36	31	23	15	12	27		
Number of fish				112	112	111	106	94	44	19	4		

Table 30 Average calculated total length at the end of each year of life of brown bullhead, sexes combined, from below Hawkesbury in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus									
				1	2	3	4	5	6	7	8		
III	1968	21	282	149	199	233							
IV	1967	19	286	140	182	221	265						
V	1966	29	301	146	193	227	259	284					
VI	1965	23	322	145	186	227	262	289	309				
VII	1964	3	331	146	180	229	271	294	314	324			
VIII	1963	2	315	127	156	188	218	252	276	290	306		
Weighted mean length				145	189	231	261	285	307	310	306		
Average annual growth increment				145	44	42	30	24	22	3	-4		
Number of fish				97	97	97	76	57	28	5	2		

Table 31 Average calculated total length at the end of each year of life of brown bullhead, sexes combined, from Hay Bay, Governor's Bay, and the top of Upper Duck Is. in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus									
				1	2	3	4	5	6	7	8		
II	1969	13	203	122	168								
III	1968	73	227	115	156	201							
IV	1967	123	252	124	162	201	230						
V	1966	142	265	124	158	191	221	244					
VI	1965	61	274	127	156	187	215	238	258				
VII	1964	13	276	122	148	172	198	223	247	264			
VIII	1963	6	280	125	150	175	198	220	240	252	266		
Weighted mean length				123	158	194	222	240	255	260	266		
Average annual growth increment				123	35	36	28	18	15	5	6		
Number of fish				431	431	418	345	222	80	19	6		

Table 32 Average calculated total length at the end of each year of life of brown bullhead, sexes combined, from above and below Hawkesbury in 1971.

Age group	Year class	Number of fish	Total length at capture	Calculated length (mm) at each annulus									
				1	2	3	4	5	6	7	8		
II	1969	1	202	120	177								
III	1968	26	270	144	191	241							
IV	1967	31	283	139	179	221	258						
V	1966	79	300	149	194	230	259	281					
VI	1965	48	316	147	186	224	259	284	303				
VII	1964	18	319	156	188	220	249	272	291	306			
VIII	1963	6	327	137	172	209	243	267	287	306	323		
Weighted mean length				147	188	227	257	280	299	306	323		
Average annual growth increment				147	41	39	30	23	19	7	17		
Number of fish				209	209	208	182	151	72	24	6		

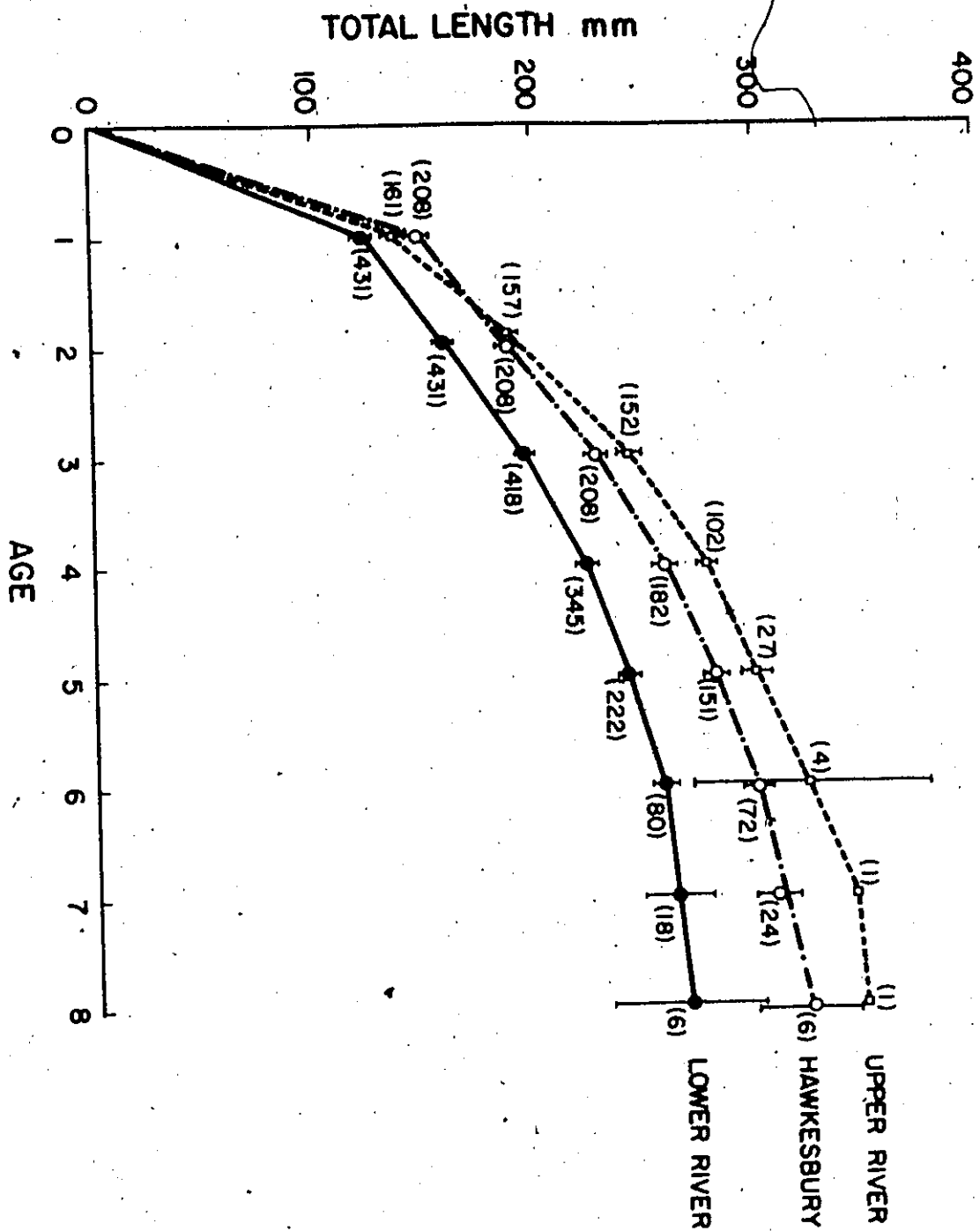
lower river were found above and below Hawkesbury.

Analysis of covariance showed no significant difference in growth between the sexes at the six individual Ottawa River stations. Similarly, no significant difference was found in the growth between sexes for the lower river stations combined or for above and below Hawkesbury combined. An analysis of the data for the sexes pooled was used to compare the growth of bullhead between stations. No significant difference was found in the growth of the sexes combined between Hay Bay, Governor's Bay and the top of Upper Duck Is. Similarly no significant difference was found in the growth of the sexes combined above and below Hawkesbury. Significant differences ( $P < .01$ ) were found in the growth between stations in the upper river, lower river and near Hawkesbury. The back-calculated growth for the stations combined within the three sections of the river have been depicted in Fig. 23.

The Rosa Lee phenomenon whereby, each successively older age group tends to give smaller values for the calculated lengths for corresponding years of life, was evident at four of the six stations (Hile, 1936). A reversal of Lee's phenomenon was noted among males and the sexes combined at the top of Upper Duck Island and for both sexes above Hawkesbury (Tables 20 and 21).

The back-calculated lengths at each annulus varied between different year classes of the same population as well as between the six stations. In all cases the growth was characterized by rapid growth during the first year followed by smaller growth increments in

Figure 23. Back-calculated average length at each annulus for brown bullhead, sexes combined, collected from the upper river, lower river and near Hawkesbury during 1971. The squares represent the upper river, open circles the section near Hawkesbury, closed circles the lower river. The vertical lines about each point represent 95% confidence limits about the mean. The number of bullhead at each annulus is given in parentheses.



succeeding years. Tables 18, 19, 21, 22, 23, 24, 26 and 30 show negative growth increments due to the fact that the samples of age seven and eight bullhead were too small to be representative.

The back-calculations from the three sections of the Ottawa River have been compared to studies elsewhere (Table 33). The maximum age and rate of growth observed in Czechoslovakia was less than that noted for brown bullhead in North American waters. The growth in the lower Ottawa River was similar to that calculated for West Virginia reservoirs (Redd, 1970). The growth observed among the older age classes in the upper Ottawa River and near Hawkesbury was greater than that observed in West Virginia. The rate of growth recorded in these latter sections of the Ottawa River was only exceeded by bullhead aged in Oklahoma (Finnell et al., 1956). It is believed that the rate of growth observed by populations of brown bullhead in the Ottawa River are not exceptionally high. Brown bullhead reach a larger size in Alabama and Florida (Carlander, 1969).

The largest brown bullhead captured in this study was 395 mm total length and approximately 800 g in weight. The individual was taken in Kettle Island Bay in the lower river. No gonads were discernable in this fish when it was dissected. This is close to the maximum theoretical size attainable ( $L_{\infty}$ ) for the Ottawa River derived from Walford plots (Table 34). Using the procedure outlined by Ricker (1958), Bertalanffy equations were derived from the growth data for the three sections of the Ottawa River.

Table 33. Comparison of back-calculated total lengths at each annulus of brown bullhead, sexes combined, from various localities.

Location	No. of specimens	Mean calculated length at each annulus									Citation	
		1	2	3	4	5	6	7	8	9		
CANADA												
Upper Ottawa River	163	136	187	242	276	297	321	343	345			present study
Lower Ottawa River	431	123	158	194	222	240	255	260	266			ibid
Hawkesbury	209	147	188	227	257	280	299	306	323			ibid
CZECHOSLOVAKIA												
pond Zehun	63	93	145	187	239	271						Frank (1955)
pond	222	81	124	160	211	272						Frank (1959)*
backwater Poltruba	159	75	116	152	178							Frank (1955)
Elbe River	107	96	131	160	178	198						Hensel (1966)
backwater Poltruba	101	81	119	160	201							Frank (1959)*
Elbe River (near Hradec?)	46	102	143	176	203	226	254					Hensel (1966)
backwater Prochaskova, Elbe River												
UNITED STATES												
Little River	41	91	180	259	312	361						Finnell et al. (1956)*
Oklahoma												
Monocacy River	—	147	203	239								Sanderson (1958)
Maryland												
Monogahela Reservoir	214	141	167	192	215	239	258	274	280	284		Redd (1970)
West Virginia												
Tygart Valley Reservoir, West Virginia	97	173	202	222	239	250	255	258	253	242		ibid

\*cited from Carlander (1969)

The von Bertalanffy equation is expressed as:

$$l_t = L_\infty [1 - e^{-K(t-t_0)}]$$

$l$  is the length of the fish in mm

$L_\infty$  is the asymptotic length of the fish

$K$  is the rate at which length reaches the asymptote

$t$  is time

#### Seasonal Growth

The number of bullhead sampled at any one station on a monthly basis from May to October was too small to give a reliable picture of seasonal growth at any one station. By combining the three lower river stations a more reliable picture of seasonal growth was obtained. The percentage gain on a seasonal basis was obtained from the computed growth increments derived from measurements between the last annulus and the edge of the spine (Fig. 24).

The seasonal growth pattern was similar to the annular growth increments, with the greatest gains being made by the younger year classes. Most of the growth was noted to occur early in the season prior to June. Little or no growth occurred among bullhead four years and older during July and August. There was another spurt of growth in these year classes, with the exception of age five, during September and October. It is believed that enhanced growth in the fall may be related to food supply. This is discussed in the section concerning food habits.

Table 34 Walford plots of brown bullhead growth data in various sections of the Ottawa River, followed by Bertalanffy growth equations.

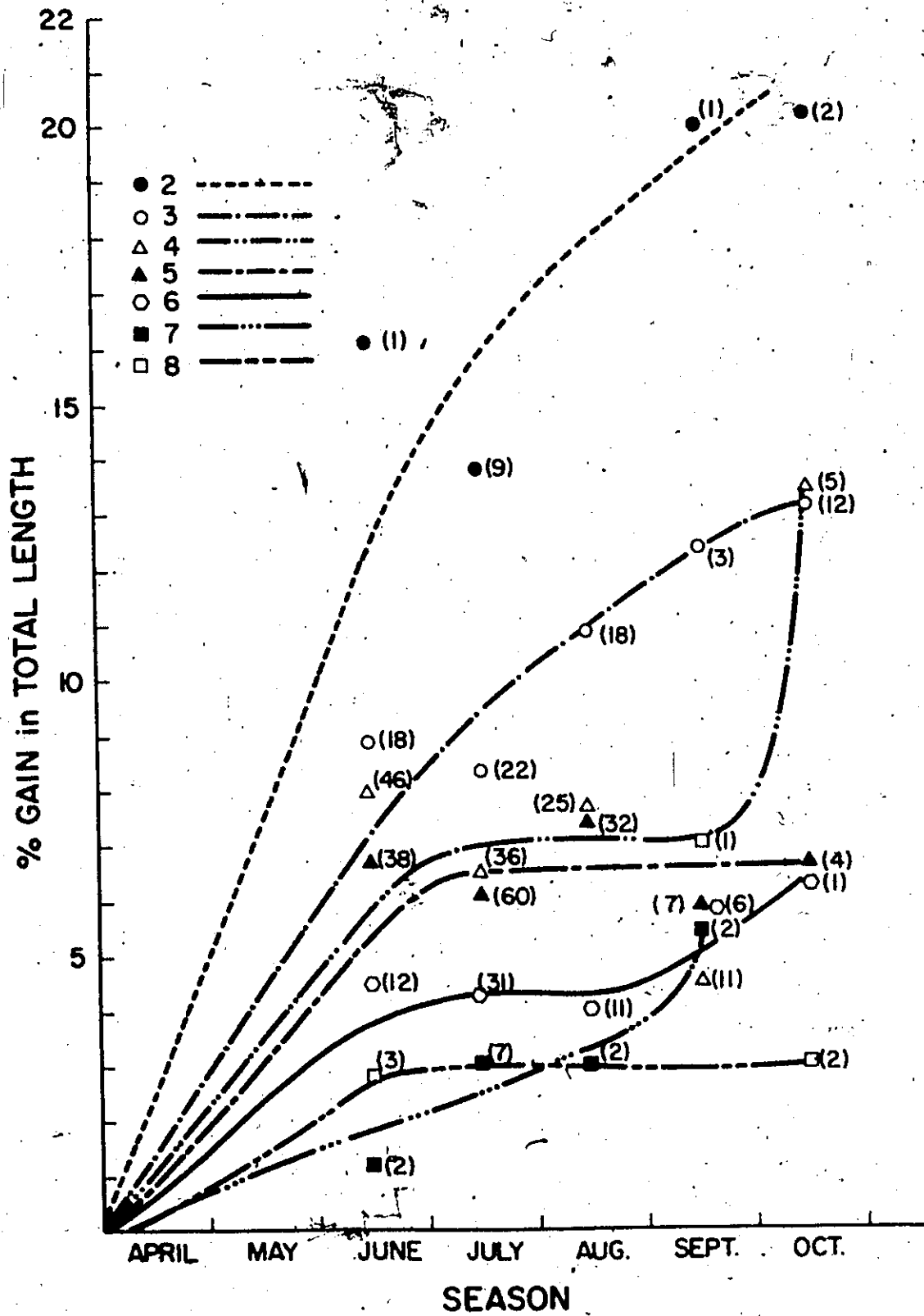
WALFORD PLOTS  $l_t + 1 = Y, l_t = X, L_\infty = TL, mm$

	Males	Females	Sexes Combined
Upper Ottawa River	Y = 94.14 + .7620 X r = .996, n = 6, L <sub>∞</sub> = 395.5	Y = 77.88 + .8099 X r = .989, n = 7, L <sub>∞</sub> = 409.7	Y = 89.39 + .7688 X r = .993, n = 7, L <sub>∞</sub> = 386.6
Lower Ottawa River	Y = 65.04 + .8036 X r = .997, n = 5, L <sub>∞</sub> = 331.2	Y = 63.39 + .8023 X r = .998, n = 6, L <sub>∞</sub> = 320.6	Y = 62.05 + .8098 X r = .996, n = 5, L <sub>∞</sub> = 326.2
Hawkesbury	Y = 78.55 + .7919 X r = .984, n = 7, L <sub>∞</sub> = 377.5	Y = 71.53 + .8004 X r = .998, n = 7, L <sub>∞</sub> = 358.4	Y = 72.85 + .8040 X r = .997, n = 7, L <sub>∞</sub> = 371.7

BERTALANFFY GROWTH EQUATIONS

Upper Ottawa River	$l_t = 395.5 [1 - e^{-.2723(t+.63)}]$	$l_t = 409.7 [1 - e^{-.2279(t+.51)}]$	$l_t = 386.6 [1 - e^{-.2839(t+.40)}]$
Lower Ottawa River	$l_t = 331.2 [1 - e^{-.2204(t+.17)}]$	$l_t = 320.6 [1 - e^{-.2648(t+.64)}]$	$l_t = 326.2 [1 - e^{-.2139(t+.20)}]$
Hawkesbury	$l_t = 377.5 [1 - e^{-.2242(t+.05)}]$	$l_t = 358.4 [1 - e^{-.2259(t+.22)}]$	$l_t = 371.7 [1 - e^{-.2159(t+.26)}]$

Figure 24: Seasonal growth of brown bullhead collected from the lower river during 1971, expressed as the % gain in total length since the formation of the last annulus.



### Condition Factor

Examining seasonal changes in condition, females exhibited a characteristic decline over the summer attributable to spawning (Table 35). The condition of males stayed about the same. A significant drop in condition occurred among males taken from Governor's Bay and Hay Bay during October, but it is not known whether this is a general situation.

Comparing condition for the sexes combined between different areas, bullhead from two parts of the lower river, Governor's Bay-Hay Bay and Kettle Island Bay had the poorest condition. These differed significantly ( $P < .05$ ) from the upper river and near Hawkesbury. The same situation was noted among males and among females. Hawkesbury bullhead were generally in the best condition, followed by the upper river and then the lower river stations. Male bullhead from the upper river differed significantly from those near Hawkesbury during July and August, while no significant difference was noted among females between the same areas.

### Length-Weight Relationship

An analysis of covariance was used to compare length-weight regressions calculated on a log-log scale. No significant difference in slopes or intercepts were found in a comparison of the regressions according to sex at each station. Consequently, the data were pooled and the stations were compared with the sexes combined. The regressions derived were the following:

Table 35 Seasonal changes in total length condition factor (KTL) of brown bullhead in various sections of the Ottawa River. Condition factor, followed by number of fish in parenthesis and 95% confidence limits beneath.

Location	May	June	July	August	September	October
FEMALES						
Britannia Bay & Shirleys Bay	1.50 (4) 1.27-1.73	1.56 (17) 1.50-1.62	1.44 (5) 1.27-1.61	---	1.34 (62) 1.30-1.38	---
Governor's Bay & Hay Bay	---	1.31 (53) 1.26-1.36	1.18 (56) 1.10-1.26	1.18 (13) 1.10-1.26	1.19 (14) 1.11-1.27	1.13 (12) 1.08-1.18
Above & below Hawkesbury	---	1.53 (64) 1.48-1.58	1.52 (9) 1.42-1.62	1.46 (38) 1.42-1.50	---	---
MALES						
Britannia Bay & Shirleys Bay	---	1.41 (11) 1.33-1.49	1.38 (10) 1.29-1.47	1.39 (2) 1.33-1.45	1.39 (46) 1.34-1.44	---
Governor's Bay & Hay Bay	---	1.24 (83) 1.19-1.29	1.25 (111) 1.21-1.29	1.25 (12) 1.10-1.40	1.15 (18) 1.10-1.20	1.05 (15) 1.01-1.09
Above & below Hawkesbury	---	1.47 (49) 1.43-1.51	1.55 (16) 1.50-1.60	1.53 (35) 1.49-1.57	---	---
SEXES COMBINED						
Britannia Bay & Shirleys Bay	1.50 (4) 1.27-1.73	1.49 (28) 1.43-1.55	1.40 (15) 1.33-1.47	1.39 (2) 1.33-1.45	1.36 (108) 1.32-1.40	---
Governor's Bay & Hay Bay	---	1.27 (136) 1.23-1.31	1.23 (167) 1.20-1.26	1.21 (25) 1.13-1.29	1.18 (32) 1.14-1.22	1.09 (27) 1.04-1.14
Kettle Is. Bay	---	1.38 (100) 1.34-1.42	1.27 (100) 1.24-1.30	1.11 (100) 1.09-1.13	1.09 (100) 1.07-1.13	---
Above & below Hawkesbury	---	1.49 (113) 1.45-1.53	1.53 (25) 1.46-1.60	1.49 (73) 1.46-1.52	---	---

Shirleys Bay and Britannia Bay	$\log W = -5.503 + 3.260 \log TL, r = .922, n = 163$
Hay Bay	$\log W = -5.306 + 3.159 \log TL, r = .962, n = 169$
Governor's Bay	$\log W = -5.145 + 3.100 \log TL, r = .943, n = 181$
Top of Upper Duck Island	$\log W = -3.062 + 2.222 \log TL, r = .870, n = 85$
Above Hawkesbury	$\log W = -4.930 + 3.042 \log TL, r = .938, n = 113$
Below Hawkesbury	$\log W = -5.299 + 3.191 \log TL, r = .961, n = 98$

Since significant differences in condition had been found between the upper river, lower river and Hawkesbury, it was not surprising to find that these areas had significantly different length-weight regressions. Shirleys Bay, Hay Bay, Governor's Bay, the top of Upper Duck Island and the combined stations near Hawkesbury were all significantly different from one another ( $P \leq .01$ ). All stations, except the top of Upper Duck Island, had similar slopes indicating that the differences found between them were due to significant differences in their intercepts.

Above Hawkesbury did not differ significantly from below Hawkesbury indicating that a common regression could apply to the two stations. The significant difference in intercepts between Hay Bay and Governor's Bay probably resulted from the bullhead being sampled from the two stations at different times. The top of Upper Duck Island had the lowest intercept and slope in comparison to the other stations, which might indicate that the bullhead from that area were in the poorest condition.

In addition to the regressions made from frozen specimens, corrected for shrinkage, data was taken from live specimens in the

lower river during 1973. The regressions were the following.

Hay Bay	$\log W = -5.210 + 3.121 TL, r = .963, n = 100$
Kettle Island Bay	$\log W = -4.093 + 2.654 TL, r = .962, n = 100$
Top of Lower Duck Island	$\log W = -4.893 + 2.983 TL, r = .899, n = 100$

The regression based on field data from Hay Bay shows close agreement with the regression based on frozen data of bullhead collected at the same station. The Kettle Island Bay regression had a slope less than 3.0 which would indicate that the bullhead in the NRC section were in poor condition. The Kettle Island Bay regression being based on a field data may be a better representation of the length-weight relationship of bullhead in the NRC section than the regression derived from frozen data at the top of Upper Duck Island.

#### Discussion

The rates of growth among brown bullhead in the Ottawa River were usually better than those observed in the United States and Czechoslovakia. Although brown bullhead in the Ottawa River are close to the northern edge of their range, their growth did not appear to be adversely affected by such a northern distribution.

Factors such as population density and food supply appear to be more important in determining growth rates than latitude. Population density is so often the most significant factor affecting growth that fishery biologists consider slow growth and low condition factors as indicators of overpopulation (Carlander, 1969). Carlander has pointed out that the problem is further complicated by the fact that

there is no absolute population density of the fish which has such a dominant effect on growth, but it is the population density in relation to carrying capacity of the body of water. Growth is a function of the degree to which biomass is below carrying capacity.

Most studies of bullhead have been on overcrowded and stunted populations (Carlander, 1969). Within the Ottawa River, one can interpret the high growth rates and condition factors of bullhead in the upper river and near Hawkesbury as indications that the bullhead have not exceeded the carrying capacity of these areas. The lower river data would tend to indicate that the species has overpopulated that section of river.

Carrying capacity is a difficult parameter to measure being both a function of habitat and food supply. It can generally be assumed that the lotic environments of the upper river and near Hawkesbury because they have more shallow water area produce a greater food supply and are potentially capable of supporting a larger biomass of invertebrates and fish. This is reflected by the higher diversity and biomass of benthic invertebrates supported in the upper river over the lower river (Mackie, 1971). Most invertebrates are found in the very narrow littoral zone ( $0.25-2.16 \text{ g/m}^2$ ) of the lower river while the deep fast flowing areas support smaller standing crops ( $0.07 \text{ g/m}^2$ ) of benthos (Qadri et al., 1973). The high organic load from local paper mills coupled with morphometry and current severely limit the size of those areas which are productive habitat for brown bullhead in the lower river.

Since no significant differences in growth in length were found between stations in the lower river and between stations near Hawkesbury, it must be concluded that the conditions affecting growth were similar at the different stations within each section of river. It was not possible to demonstrate any effect on growth in body length due to localized conditions such as effluents from paper mills or municipalities. Stobo (1971) found a similar situation with yellow perch in the lower Ottawa River. Therefore it seems likely that general conditions, which apply to the whole section of river, such as the distribution of the food supply in relation to morphometry and current, play an important role in determining growth. These differences in conditions between sections of river may explain the significant differences in growth of brown bullhead in the upper river, lower river and near Hawkesbury.

Brown bullhead in the upper river were not generally abundant but exhibited the highest growth rate of the three sections of the Ottawa River examined. It is likely that the combined biomass of the two most abundant species in the upper river, channel catfish and brown bullhead, is higher than the biomass of brown bullhead in the lower river. While the high C/f of brown bullhead (Table 4) near Hawkesbury implies a high population density, their high growth rates also imply a very high carrying capacity for this section of the Ottawa River.

One factor often not considered in the interpretation of growth data is the variation in growth exhibited by members of the

population. Brown bullhead within any age group exhibited a wide variation in growth, indicating that the population consisted of both fast and slow growing individuals. This was exemplified by the ranges in TL of bullhead sampled for this study (Appendices 2-7). A wide range of overlap in TL was noted for bullhead of different ages.

Differential mortalities between bullhead in relation to their growth rates may account for Lee's phenomenon observed in this study (Carlander, 1969). The trap net because it had a two inch mesh tended to select only the larger fish in the younger age groups. Fast-growing fish are frequently shorter-lived than the slow growing fish which may explain why fish in the older age groups exhibited poor growth.

## FOOD HABITS

### Introduction

Young-of-the-year brown bullhead initially feed on planktonic crustaceans such as cladocerans and ostracods. In Czechoslovakia, by far the most important was the cladoceran Chydorus (Frank, 1955b; Hensel, 1964). By the end of July the young bullhead shift to a diet of benthic invertebrates primarily composed of chironomids (Raney and Webster, 1940). In Lake Opinicon Ontario, brown bullhead 30-60 mm TL feed on chironomid larvae (up to 50% volume), Cladocera (60%), Ostracoda, Amphipoda, Hemiptera, and small Ephemeroptera (Keast and Webb, 1966).

Adult brown bullhead are heterogeneous in their feeding habits. While it is generally assumed that bullhead feed heavily on aquatic invertebrates many authors have noted that brown bullhead ingest large quantities of algae and detritus (Cable, 1929; Emig, 1966; Klarberg and Benson, 1973). The quantity and type of food consumed depends largely on the habitat. Under exceptional circumstances brown bullhead have been found to have consumed fish (Jepson and Platts, 1959; Moore, 1972; Massengill, 1972) and fish eggs (Emig, 1966). This study elucidates the food habits of adult brown bullhead in the lower Ottawa River.

#### Materials and Methods

The presence of algae, detritus and small fragmented organisms made it impractical to obtain stomach content estimates by the numerical or volumetric displacement methods. The points method of Hynes (1950) was utilized to estimate the percentage volume of organisms and other debris. Stomachs of specimens, collected and preserved in 10% formalin, were removed and points allotted on the basis of the wet weight of stomach contents. Thus stomach contents weighing 0.5 gm were allotted 5 points. The allotted number was then subdivided and points given to the various food items. A per cent volume per food item was derived by summing the points allotted to that item for all the stomachs collected at that station according to the following formula:

$$\% \text{ Volume} = \frac{\text{Sum of points allotted for item B in all stomachs} \times 100}{\text{Sum of points allotted for all items in all the stomachs}}$$

The per cent frequency of occurrence was calculated on the basis of the number of times a food item occurred out of the total number of stomachs examined which had food contents.

The per cent composition was calculated on the basis of the number of times a food item occurred out of the total number of occurrences of all food items.

### Results

The data from stomach analyses on the brown bullhead collected from the lower Ottawa River are given in Tables 36 to 39. Although a wide size range of bullhead were sampled most of the fish were close to the mean sizes indicated in Table 36. No discernable differences in food habits according to size were apparent from the data. The results for all five stations have been arranged according to the time of the year collected. The percentage of empty stomachs and the number of points allotted per stomach at the various stations may be partly related to seasonal changes in food consumption in relation to temperature; but it can be noted that even during the warmer months of July and August large differences between stations occurred (Table 36). The abundance of benthic invertebrates varies widely between different areas of the lower river (Mackie, 1971). Casual inspection of data (Tables 36-39) suggests that this probably accounts for most of the differences in food consumed by brown bullhead at the various stations.

Examining the stomach contents by order of most importance on a % volume basis (Table 37), one can see that filamentous algae, debris, isopods, chironomids, amphipods, and sphaerids were ingested.

On a % frequency of occurrence basis (Table 38) debris, plant material, filamentous algae, chironomids, isopods, Helisoma, amphipods, sphaeriids and trichopterans were important. A similar situation to the % frequency of occurrence data was noted with the % composition data (Table 39).

Brown bullhead taken at more lotic stations such as the top of Upper Duck Island and below CIP had ingested large amounts of filamentous algae (Spirogyra, Ulothrix, Hydrodictyon and Lyngbya) while those in bays such as Kettle Island Bay, Governor's Bay and Hay Bay had ingested large quantities of fine organic debris mixed with fragments of plant material. Wood fiber comprised most of the debris found in the stomachs of bullhead taken in the CIP channel.

Below the CIP mill several bullhead had ingested large numbers of corn kernels. Six of the 14 fish taken in this area had ingested fish scales. Some of the scales resembled those of a sucker while others most resembled whitefish scales. It is possible the scales came from the bullhead feeding on dead fish remains. Whitefish (Coregonus sp.) are not a fish which have been captured in the lower river leading me to suspect that not all the wastes, viz. kernels of corn, entering the CIP channel originate from the paper mill.

An examination of some 500 stomachs of bullhead used for age and growth studies showed that fish removed from the nets during the day had empty stomachs. Special efforts were made to collect bullhead at night for food studies. Most bullhead used for food analysis were collected using trap nets and hoop nets between 0200 and 0500 hr. At

Table 36. Size range, number of specimens and collection locations of brown bullhead taken from the lower Ottawa River for stomach analysis during 1973.

Location	A Kettle Is. Bay	B Kettle Is. Bay	C Hay Bay	D Governor's Bay	E top of Upper Duck Is.	F CIP channel transect 2
Collection Date	February 21	July 24	July 25	August 22	August 23	October 6
No. of fish examined	25	54	30	36	33	36
No. of fish with stomach contents	4	48	27	35	25	14
% of empty stomachs	84.0	11.1	10.0	2.8	24.2	61.1
TL range (cm) of bullhead	18.8-32.2	18.2-31.4	16.1-29.3	22.0-33.9	20.5-27.8	21.3-33.9
Mean TL	26.1	19.8	24.1	25.0	23.9	27.4
Range in points allotted per stomach	3-5	2-10	1-54	1-26	1-82	2-15
Mean points per stomach	4.5	5.5	21.3	3.8	13.8	6.1

Table 37. Stomach contents of brown bullhead taken at various stations in the lower Ottawa River during 1973.

Station	% Volume (Points Method)						$\bar{X}$
	A	B	C	D	E	F	
STOMACH CONTENTS							
Porifera	---	---	0.04	---	---	---	.007
Filamentous algae	---	11.89	28.31	37.41	70.33	27.91	29.31
Seeds-plants	9.09	7.36	4.45	0.23	0.67	11.63	5.57
MOLLUSCA							
Campelema	---	---	0.87	2.67	---	---	0.59
Helisoma	---	---	1.48	2.06	0.55	---	0.68
Physa	---	---	2.34	---	---	---	0.39
Sphaeriidae	---	9.81	1.30	2.44	0.87	2.33	3.35
CRUSTACEA							
Amphipoda	---	0.38	14.94	1.37	3.47	---	3.36
Cladocera	---	0.19	1.23	0.08	3.53	---	0.84
Isopoda	72.72	7.17	21.63	1.30	---	---	17.14
Ostracoda	---	---	0.09	---	1.48	---	0.26
ARACHNIDA							
Hydracarina	---	---	0.91	0.08	0.72	---	0.29
INSECTA							
Coleoptera	---	0.38	0.15	0.38	---	1.16	0.52
Diptera (chironomids)	---	25.47	4.78	10.31	6.95	---	11.88
Ephemeroptera	---	---	---	---	2.89	---	0.48
Hemiptera	---	---	0.39	0.76	---	---	0.19
Odonata	---	---	0.87	---	0.14	---	0.17
Megaloptera	---	---	0.35	---	---	---	0.06
Trichoptera	---	5.66	1.91	0.84	0.06	4.65	2.19
ANNELIDA							
Oligochaeta	---	0.75	0.03	---	---	---	0.13
Hirudinea	---	---	0.10	0.15	---	---	0.04
TREMATODA							
Platyhelminthes	---	---	0.52	---	---	---	0.09
Fish remains	---	---	---	0.15	---	10.46	1.77
Debris	18.18	30.94	12.59	39.77	10.94	41.86	25.71

Table 38. Stomach contents of brown bullhead taken at various stations in the lower Ottawa River during 1973.

Station	% Frequency of Occurrence						$\bar{X}$
	A	B	C	D	E	F	
STOMACH CONTENTS							
Porifera	---	---	7.41	---	---	---	1.24
Filamentous algae	---	30.60	44.44	27.78	45.16	---	24.66
Seeds-plants	50.00	26.50	25.93	2.78	6.45	7.14	19.80
MOLLUSCA							
Campelema	---	---	25.93	11.11	---	---	6.17
Helisoma	---	---	29.63	13.89	9.68	---	21.76
Physa	---	---	40.74	---	---	---	6.79
Sphaeriidae	---	38.80	33.33	11.11	32.26	---	17.92
CRUSTACEA							
Amphipoda	---	2.04	77.78	11.11	32.26	---	20.53
Cladocera	---	2.04	37.04	2.78	29.03	---	11.82
Isopoda	100.00	26.50	48.15	8.33	---	---	30.49
Ostracoda	---	---	3.70	---	9.68	---	2.23
ARACHNIDA							
Hydracarina	---	---	37.04	2.78	6.45	---	7.71
INSECTA							
Coleoptera	---	2.04	11.11	2.78	---	7.14	5.77
Diptera (chironomids)	---	85.70	77.77	38.89	48.39	---	41.79
Ephemeroptera	---	---	---	---	3.23	---	0.54
Hemiptera	---	---	14.81	2.78	---	---	2.93
Odonata	---	---	18.52	---	3.23	---	3.63
Megaloptera	---	---	3.70	---	---	---	0.62
Trichoptera	---	32.65	37.04	5.56	3.23	21.43	16.65
ANNELIDA							
Oligochaeta	---	2.04	7.41	---	---	---	1.58
Hirudinea	---	---	3.70	2.78	---	---	1.08
TREMATODA							
Platyhelminthes	---	---	18.52	---	---	---	3.09
Fish remains	---	---	---	2.78	---	35.71	6.42
Debris	100.00	97.96	85.19	97.20	83.90	92.86	92.85

Table 39. Stomach contents of brown bullhead taken at various STATIONS in the lower Ottawa River during 1973.

Station	% Composition of the Diet						$\bar{X}$
	A	B	C	D	E	F	
STOMACH CONTENTS							
Porifera	---	---	1.03	---	---	---	0.17
Filamentous algae	---	8.88	6.15	10.63	16.47	17.24	9.90
Seeds-plants	20.00	7.69	3.59	1.06	2.35	3.45	6.36
MOLLUSCA							
<u>Campeloma</u>	---	---	3.59	4.26	---	---	1.31
<u>Helisoma</u>	---	---	4.10	5.32	3.52	---	2.16
<u>Physa</u>	---	---	5.64	---	---	---	0.94
Sphaeriidae	---	11.24	4.62	6.98	4.71	3.45	5.07
CRUSTACEA							
Amphipoda	---	0.59	10.77	4.26	11.76	---	4.56
Cladocera	---	0.59	5.13	1.06	10.59	---	2.90
Isopoda	40.00	7.69	6.67	3.19	---	---	9.59
Ostracod	---	---	0.51	---	3.53	---	0.67
ARACHNIDA							
Hydracarina	---	---	5.13	1.06	2.35	---	1.42
INSECTA							
Coleoptera	---	0.59	1.54	1.06	---	3.45	1.11
Diptera (chironomids)	---	24.85	14.86	18.08	17.65	---	12.57
Ephemeroptera	---	---	---	---	1.18	---	0.20
Hemiptera	---	---	2.05	1.06	---	---	0.52
Odonata	---	---	2.56	---	1.18	---	0.62
Megaloptera	---	---	0.51	---	---	---	0.09
Trichoptera	---	9.47	5.13	2.18	1.18	10.34	4.72
ANNELIDA							
Oligochaeta	---	---	0.59	1.03	---	---	0.27
Hirudinea	---	---	1.02	1.06	---	---	0.35
TREMADOTA							
Platyhelminthes	---	---	2.56	---	---	---	0.43
Fish remains	---	---	---	1.06	---	17.24	3.05
Debris	40.00	27.81	11.79	36.17	23.53	44.83	30.69

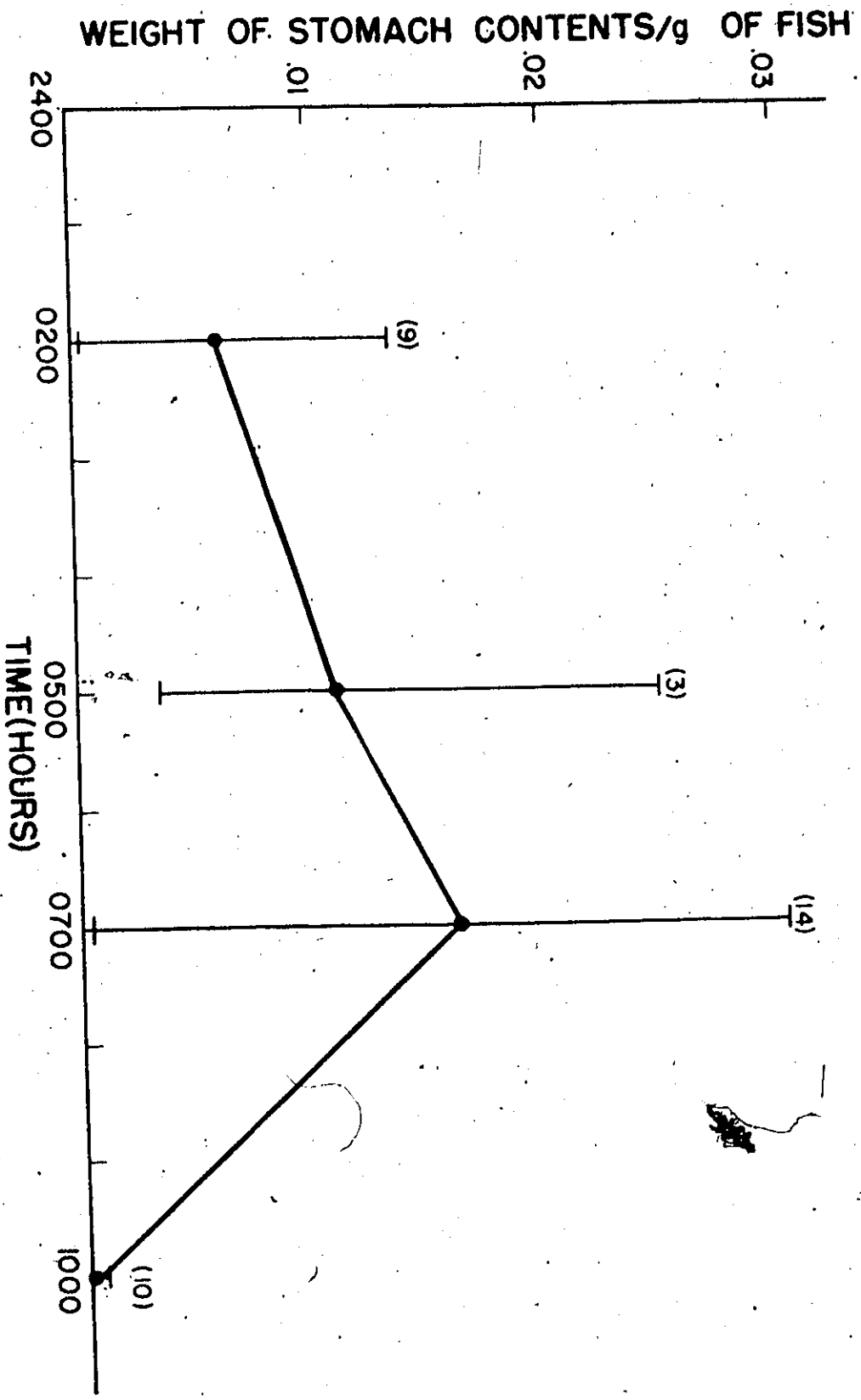
Hay Bay gill nets and hoop nets were used to collect specimens during three time periods, 2400-0200, 0200-0500 and 0500-0700 hr. The mean weight of stomach contents per gm of fish (Fig. 25) was highest just after sunrise during the 0500-0700 period. The stomach of 96% of the bullhead removed from nets between 0900 and 1000 hr were empty. The remainder were in an advanced state of digestion.

Most of the increase at Hay Bay during 0500-0700 hr can be attributed to the bullhead ingesting large quantities of isopods and amphipods. Isopods rose from 0.94% volume at 0200-0500 hr to 39.34% at 0500-0700 hr. Amphipods went from 10.54% to 18.70% while filamentous algae declined from 59.86% to 1.29% during the same period.

#### Discussion

The findings of this study are similar to those of Keast and Welsh (1968) who observed that only brown bullhead collected at dawn and in the very early morning have full stomachs; those taken later in the day or in the very early part of the night were empty or near empty. While there is no published data on the feeding chronology of brown bullhead, Darnell and Meiorotto (1962, 1965) have studied the feeding chronology and activity of juvenile black bullhead (Ictalurus melas). Juveniles exhibited peak feeding periods about dawn and dusk. Adult black bullhead were noted to have a single feeding period just after dark, but whether a dawn feeding peak also exists was not determined. Darnell and Meiorotto noted differences in the activity between adult and juvenile black bullhead which may indicate that feeding patterns also differed. Detailed studies of the feeding chronology of brown

Figure 25. Feeding periodicity of brown bullhead expressed as the weight of stomach contents per gram of fish. The specimens were collected at Hay Bay on July 25, 1973. The number of bullhead examined is given in parenthesis.



bullhead are currently being conducted by another student Mr. John Gunn.

Brown bullhead show some activity even during the winter and my February samples indicate that at least part of the population was feeding. Keast (1968) has similarly shown that all brown bullhead taken in April, at a water temperature of 6.5 C, contained moderate amounts of food in the stomach and intestine.

Experiments by Keast (1970) would tend to indicate that while bullhead may feed at lower temperatures growth only occurs at higher temperatures. At 15 C the food uptake of fish in aquaria quadrupled and there was a 45% increase in body weight, but no increase in length. At 20 C and 25 C caloric intakes amounting to about twice that at 15 C produced mean length increases of 12.5% and 14% and weight increases of 80% and 88% respectively. At 30 C it required a rather greater energy intake to achieve equivalent increases, indicating a higher cost of body maintenance at this temperature.

From the above data one would expect brown bullhead to feed the most and exhibit the most growth when optimum temperatures are achieved in mid-summer. Seasonal growth data (Fig. 24) would tend to indicate that adult brown bullhead grew most in length in the spring but showed little or no growth during July or August. This is consistent with studies on other warm-water species (Seaburg and Moyle, 1964; Keast 1970) where it has been shown that a rapid rise in feeding in early summer is followed by a decline in midsummer. Keast explains this phenomenon by stating that a high level of feeding is to be expected in animals that have been largely starved during the winter,

just as is a tapering off as their physiological needs are satisfied. Initial hunger and the stimulating effect of increased temperature may induce the bullhead to feed at a high rate during the spring.

It is also probable that feeding intensity changes in relation to variations in the food-supply. It seems likely that the growth of bullhead in the spring and fall (Fig. 24) may coincide with the seasonal peaks in abundance of such food organisms as chironomids, isopods and amphipods noted by Mackie (1971). Further studies on seasonal changes in feeding habits are needed to investigate such relationships.

The presence of large quantities of detritus and filamentous algae in the stomachs raises the question whether bullhead can derive any food energy from these sources. Cable (1929) noted that bullhead had consumed large quantities of plant material and made the following statement.

"If it were not for the fact that the plant tissue was digested, at least partly so, and that there was such a large proportion of it, it might be supposed that the fish had not eaten it for food, but rather by accident when browsing about for larvae, pupae, snails, and crustaceans crawling about over the Ruppia and Potamogeton (not many were found on the algae). The writer is inclined to believe that bullhead do not take food in any such haphazard manner, but they deliberately select certain foods and reject others ... As the bullheads consumed a large per cent of plant material, it would appear that they are able to choose this food as an alternative to animal tissue under certain conditions."

Aquatic vegetation and filamentous algae contain higher quantities of proteins and minerals than do terrestrial plants (Boyd, 1968). It is interesting to note that the types of algae consumed by the brown bullhead were among the kinds of algae tested which were found to have the highest protein content. On a dry weight basis, the protein content was 31.3% for Lyngbya, 23.8% for Hydrodictyon, and 17.1% for Spirogyra. It would appear that the bullhead were selecting these species of algae in their diet. This would only be advantageous to the bullhead if it could assimilate such materials.

Stickney and Shumway (1974) have demonstrated that a wide variety of fishes including the channel catfish have cellulase digesting enzymes present in the gut. The cellulase activity in catfish results from alimentary tract microflora rather than from cellulase secreting cells within the fish. The ability to utilize plant and algal materials may help explain why channel catfish and brown bullhead are more abundant than other fish species in the Ottawa River.

Because brown bullhead often become very abundant, interspecific competition for food between it and other fish species has been suggested by a number of authors including Scott and Crossman (1973). There appears to be little data to support such an assertion. Frank (1955b) could not find any evidence of competition for food between brown bullhead and other fish species. Hensel (1964) concluded that food competition between brown bullhead and other fish species in the Elbe River was attributable only to adult fish for larval insects, principally chironomid larvae.

Keast and Webb (1966) found that the three species in Lake Opinicon (Fundulus diaphanus, Percina caprodes and I. nebulosus) which fed heavily on chironomid larvae, were exploiting different habitats.

Smith (1974) suggested competition for food, territory or spawning sites between channel catfish and brown bullhead might account for the scarcity of channel catfish in the lower river. In the upper river where both channel catfish and brown bullhead are common both species were found to have high growth rates. Channel catfish while scarce in the lower river appeared to have better growth than those in the upper river. If numbers are the criterion of success it is as difficult to explain the success of brown bullhead in the lower Ottawa River as it is to explain the failure of channel catfish. The bullhead's preference for mud bottomed backwaters, its ability to tolerate polluted conditions and to feed under turbid conditions on more pollution tolerant food items may tend to favour bullhead in the lower river. The absence of such conditions and a wider spectrum of food resources in the upper river may tend to favour channel catfish. It is probable that brown bullhead and channel catfish occupy different niches. Thus differences in habitat requirements rather than interspecific competition may explain the differences in abundance of these two species in the upper and lower river.

## DISCUSSION

A large amount of data has been presented in the various chapters of this thesis. It is necessary to draw together the pertinent data to see how it relates to ecological theory. Some of the theories of Wynne-Edwards (1962) provide a conceptual framework which may apply to the findings of this study.

It is generally accepted by ecologists that there is a tendency for self-regulation (homeostasis) at the population and community levels. A population is regulated by a set of negative and positive controls which cause the population to attain a dynamic equilibrium with its environment mediated by genetic feedback (Odum, 1971).

Wynne-Edwards (1962) believed that populations of birds and other animals are ultimately limited by the availability of food. The food supply is usually not exceeded, with resultant overpopulation and starvation, because the populations regulate themselves intrinsically through social conventions such as territoriality, social hierarchy and other epideictic displays. Behavioural conventions are part of the homeostatic machinery that automatically prevents the population from departing too far from an optimum density. This upper asymptote of the sigmoid population growth curve beyond which no major increase in numbers can occur has been called the carrying capacity (Odum, 1971).

Wynne-Edwards considered that behaviour of this type must have evolved through 'group-selection' which acts to ensure that the population utilizes the food resources to the fullest extent possible without depletion. Such group-selection means that some individuals

in the population usually those lower in the social hierarchy or peck-order, must at intervals starve or emigrate, or refrain from breeding, even though there is enough food for them at the time, if circumstances are such that their consumption of food would tend to lead to overpopulation.

Wynne-Edwards has been criticized for his concept of group-selection by such authors as Lack (1966) and Chapman (1966) who maintained that many of his examples can be explained by natural selection acting upon the individual. Lack took the traditional view that extrinsic factors such as predation, parasitism and food supply were the most important mechanisms regulating bird populations. Chapman while recognizing the importance of these factors reviewed the literature on fish and concluded that competition for space and (or) food was the underlying cause of density regulation in salmonids. Social behaviour, both territorial and hierarchial, tends to replace direct competition for food with competition for space or social position.

Group-selection appears to apply to brown bullhead as exemplified through their social behaviour. The care given to the eggs and young by the parents tends to ensure that a large percentage of the young survive. Studies by Bowen (1931,1932) have established that aggregations of young black bullhead form because the young-of-the-year obtain visual and tactile stimulation from one another. A social appetite appears to cause the young bullhead to school during daylight hours. This behaviour may act as a protection against predators, but is not linked to feeding which occurs at dawn and dusk (Darnell and

Meieriotto, 1965). In the latter part of the season the young conceal themselves during the day. I found that large numbers of small bullhead could be taken by seining through fine detritus near the base of the pier at Britannia Beach. Concealment of schools of young bullhead in restricted areas may explain why bullhead become difficult to locate late in the season.

Adult brown bullhead also move about and feed in schools (Harlan and Speaker, 1956). This was evident from hoop netting where the nets would often go empty for several days and then catch large numbers of bullhead. Groups of bullhead exhibit higher respiratory rates and are more active than bullhead kept individually (Bowen, 1932). The bullhead, unlike the goldfish, appears to be stimulated to feed more intensively in shoals than in isolation (Nikolsky and Kukushkin, 1943).

Todd (1968) has demonstrated that yellow bullhead in aquaria establish a social hierarchy. Todd noted that each bullhead, irrespective of sex or season, defended a territory if provided with a shelter in the form of a clay pot. The size of such territories appeared to be mediated by the individual's position in the social hierarchy. Todd (1971) suggested that in a lake or pond a bullhead may occupy as its territory a hole in the bank or a space under a log or a burrow dug in the soft lake bed. This appears to be the case, since I have observed brown bullhead in elliptical depressions similar to spawning depressions in the soft mud in 8-10 ft (3 m) of water in Fairburn Lake Quebec near the town of Alcove. Schiche (1921) noted

that brown bullhead make "living holes" or depressions in the substratum to which they return at intervals.

Social hierarchy and the acquisition of breeding territory may be the social conventions by which brown bullhead regulate their population density close to the carrying capacity of the environment. The territories occupied by bullhead in 200 and 1200 liter aquaria in Todd's work were quite small in size and probably only functioned as home sites. Breeding territories with a diameter of 20 ft or more in areas suitable for spawning may tend to restrict the number of breeding pairs due to the scarcity of suitable spawning sites. But social hierarchy rather than territoriality would appear to be the most important density regulating mechanism.

Through extensive tagging studies I have been able to establish that distinct populations of brown bullhead are present in Hay Bay, Kettle Island Bay and Lower Duck Island Bay in the lower Ottawa River. Extensive recaptures of tagged bullhead indicated that the bullhead remain close to their home bay from one year to the next. Population estimates indicated that very large densities of adult bullhead (>2500 per ha) exist in the bays, while seasonal fluctuations in abundance occur the C/f tends to indicate that densities stay about the same from year to year.

Large aggregations of adults in certain bays prior to the spawning season may be related to a process by which only the larger more dominant bullhead in the social hierarchy obtain mates and spawning territory. Two pairs of bullhead were observed dominating other

bullhead in aquaria and defending spawning territories. One of these pairs successfully spawned when placed in a separate aquarium. The observations confirmed that there is severe aggression among bullhead prior to spawning. The bullheads inflicted serious wounds on one another particularly on the dorsum, caudal peduncle and caudal fin. Bullhead taken in trap nets at three stations in the lower river had fresh scars on 5-17% of the fish during the spawning period in late June. While such aggression resulted in the death of bullhead in aquaria, only a few dead were noted in the field. There was nothing to suggest any significant mortality due to aggression. Dead black bullhead with similar wounds have been noted in May and June in Clear Lake, Iowa (Forney, 1955).

An examination of selected areas for young bullhead schools and an examination of the gonads of mature female fish would tend to indicate that only a limited number of the potential spawners succeeded in reproducing. Although bullhead were noted to become sexually mature by age three in the sections of the Ottawa River under study, it is suspected that the age when they actually spawn may vary in different areas depending on the population concerned. All bullhead which were observed guarding young in the field were larger individuals above 30 cm TL. The pair of bullhead taken from the lower river which spawned in the aquarium were age five and six respectively. If reproduction only occurs among the larger bullhead then the smaller mature bullhead represent a surplus of non-breeders according to the theory of Wynne-Edwards.

Overpopulation of bullhead in the lower river was indicated by their having significantly lower growth rates and condition factors than the bullhead taken from the upper river and near Hawkesbury. Crowding appears to have had an inhibitory effect on growth. The number of individuals was large (>2500 per ha) and their mean body size was correspondingly reduced (0.17 kg vs 0.25kg in the upper river). It appears likely that the total biomass per unit volume reaches a constant ceiling regardless of the total number of individuals present. It has been shown in other studies that exploitation of overcrowded fish stocks can result in improved growth of the population.

Lee's phenomenon noted in this study appears to be a mechanism by which the population reacts to crowded conditions. Fast and slow growing individuals were noted within each age group. This may allow a better exploitation of food resources through selection of a wider food spectrum. The faster growing individuals in any age group are the first to die, so that the older age-groups are composed of the slower growing individuals.

Exclusion through density dependent mortality is difficult to demonstrate under field conditions. It should be noted however that very emaciated individuals with condition factors (KTL) between 0.6 and 0.9 made up about 0.2% of the catch. Depending on the rate of shedding of tags, total annual mortality of bullhead in the lower Ottawa River would appear to be between 30 and 50% of the adult population each year. Studies on other fish species have not indicated

any significant predation on bullhead in the Ottawa River. Exploitation by commercial fishermen near Hawkesbury and predation on the young-of-the-year by birds, especially in the upper river, may account for some mortality. In the lower river the bullhead are believed to be largely unexploited, which may account for their overpopulation and poor growth. The poor condition of bullhead in the lower river may cause appreciable overwintering mortalities among the slower growing individuals. Forney (1955) noted mass mortalities of young-of-the-year black bullhead in the late fall and winter, indicating that this is a critical period for their survival.

Food analysis of brown bullhead from the lower Ottawa River have demonstrated the importance of chironomids, isopods and amphipods in the diet. Large quantities of organic detritus, plant fragments and filamentous algae were also ingested, possibly as an alternate source of food due to the scarcity of invertebrates. Further studies presently being conducted by another student should elucidate the bioenergetics of brown bullhead on a daily and seasonal basis and clarify the importance of such materials in the diet.

Mercury analysis of brown bullhead from the upper river, lower river and near Hawkesbury revealed that brown bullhead were safe for human consumption. This is based on their being below the 0.5 ppm level set as being acceptable by the World Health Organization. Since brown bullhead are of considerable commercial importance it was gratifying to note that they posed no hazard to public health. It was ascertained that the levels of mercury in the muscle of brown

bullhead did not increase with increasing size of the fish. Studies by the National Research Council have shown that the early concepts of mercury contamination in fish as a function of size were too simplistic. De Freitas (1973) has shown the importance of uptake and clearance rates of mercury as a function of metabolic rate. Mercury is taken up directly from the water and from the fish's food, but which pathway is the more important remains to be determined.

#### MANAGEMENT IMPLICATIONS

This study has demonstrated that large numbers of brown bullhead inhabit bays in the Ottawa River while foraging over the section of river nearby to obtain an adequate food supply. The affinity of bullhead populations for a home bay and their social behaviour allows large numbers of bullhead to be captured in the bays with a minimum of effort. The sedentary nature of the bullhead means that the bullhead will remain in the vicinity of their home bay throughout the year. The commercial fisherman can therefore harvest the bullhead whenever he wishes according to fluctuating prices and market demand.

While further studies are needed to determine optimum rates of harvest it is likely that large numbers of bullhead can be removed without adversely affecting the population. Assuming an over wintering mortality of close to 40%, this amount of the adult population might be harvestable each year. Since only a small percentage of the population actually breeds each year there would appear to be a surplus of nonbreeders which could be harvested. Exploitation of brown bullhead in areas where they are overpopulated and exhibit poor growth, such as

the lower river, should result in improved growth.

Brown bullhead represent a highly palatable fish resource, which was retailing in local supermarkets at 58 cents per lb during the fall of 1973. Being naturally produced it is very competitive with alternative protein sources. Tests for mercury and other environmental pollutants in brown bullhead have indicated that the catch from the Ottawa River is safe for human consumption. Brown bullhead in the Ottawa River are so abundant that the supply far exceeds present demand. A rising demand for fish products has occurred over the last few years and is anticipated to continue. It is to be hoped that brown bullhead will gain greater public acceptance as a food source and that the stocks of this species in the Ottawa River will be exploited in a rational manner to their full potential.

## SUMMARY

1. High densities of brown bullhead were found to occur in bays with abundant aquatic vegetation and soft mud bottoms in the lower Ottawa River. Densities from 2500 to 7,800 adult bullhead per ha were estimated to occur in Kettle Island Bay. The abundance of bullhead was found to increase downriver towards Hawkesbury.
2. Different populations of brown bullhead were found to inhabit three bays in the lower Ottawa River. Extensive tagging showed that while a few bullhead moved as much as 17.6 km (10 miles) downstream the majority of bullhead remained near their home bay from one year to the next.
3. The fecundity of brown bullhead ranged from 2,200 - 8,800 eggs per female. The Gonadal-somatic Index rose dramatically in the spring reaching a peak during the second and third week of June. About equal sex ratios were found in the upper river and near Hawkesbury. In the lower river males were more prevalent in the catch than females. The bullhead were sexually mature at age three.
4. Aggressive behaviour was noted among bullhead in aquaria. Fighting resulted in dead bullhead bearing severe wounds. This appeared to be a prespawning behaviour linked to obtaining spawning territory. From 5-17% of the bullhead taken in trap nets during the spawning period bore fresh wounds.
5. The reproductive behaviour of brown bullhead was observed in aquaria. A spawning embrace which continued to be elicited at intervals 24 hr following the laying of eggs was noted. It was

the male rather than the female which incubated the eggs. Both parents co-operate to protect the young.

6. Total mercury concentrations in the muscle of brown bullhead ranged from 0.063-0.560 ppm. No significant difference in mercury levels were found between the stations examined in the upper river, lower river and near Hawkesbury. The mean mercury levels at the four stations ranged from 0.148-0.225 ppm. Mercury levels did not increase with increasing size of brown bullhead taken in this study.
7. Male bullhead were noted to grow at a slightly faster rate than females but the difference was not significant. Brown bullhead from the upper river grew the fastest, followed by those from near Hawkesbury while those taken from the lower river showed the poorest growth. The growth in these three sections of river were significantly different from one another. No significant differences in growth were found in comparing the growth between stations in individual sections of river.
8. The bullhead from near Hawkesbury exhibited higher condition factors than those from the upper river but the two were not significantly different. Bullhead from both of the latter sections of river had higher condition factors which were significantly different from those exhibited by bullhead in the lower river.
9. A large variation in the growth of individuals in any age group was noted. This may have resulted from overpopulated conditions and could possibly account for Lee's phenomenon which was noted at four out of six stations.

10. A depression in the growth of older bullhead taken from the lower river in mid-summer was evident. This may be related to the scarcity of benthic invertebrates at that time.
11. Brown bullhead taken at various sites in the lower river had ingested large quantities of organic detritus, filamentous algae, chironomids, isopods and amphipods. A peak in feeding of bullhead at Hay Bay was noted to occur just after dawn between 0500-0700 hr.

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## Appendix 1

Seasonal changes of the Gonadosomatic index of brown bullhead from the Ottawa River during 1973.

Month	Sex	95% confidence limits		$\bar{X}$	SD	SE	N
21 Feb	F	1.10	- 1.54	1.32	.4218	.1054	16
8 March	F	1.17	- 1.49	1.33	.0830	.0744	15
7 April	F	1.02	- 1.60	1.31	.4562	.1317	12
15 May	F	1.28	- 3.20	2.24	.6941	.3470	4
3 June	F	2.22	- 3.62	2.92	1.7007	.3401	25
	M	0.09	- 0.17	.13	.0914	.0191	23
10 June	F	9.08	- 10.92	10.00	2.4730	.4515	30
	Mat.	0.99	- 1.61	1.30	.4046	.1349	9
	Immat.	0.20	- 0.26	.23	.0695	.0127	30
29 June	F	1.86	- 5.60	3.73	2.4357	.8119	9
	Atretic	0.39	- 0.67	.53	.1647	.0582	8
	Spent	0.05	- 0.08	.06	.0349	.0063	31
28 July	F	0.50	- 0.82	.66	.3137	.0739	18
	M	0.11	- 0.15	.13	.0562	.0103	30
5 Aug	F	0.60	- 0.70	0.65	.1333	.0232	33
	M	0.10	- 0.14	0.12	.0504	.0092	30
28 Aug	F	0.55	- 0.81	0.68	.1431	.0541	7
	M	0.17	- 0.21	0.19	.0259	.0091	8
18 Sept	F	0.77	- 0.98	0.87	.1768	.0490	13
	M	0.07	- 0.16	0.12	.0899	.0212	18
23 Sept	F	0.90	- 1.37	1.14	.2844	.1005	8
	M	0.13	- 0.24	.19	.0501	.0204	6
7 Oct	F	1.11	- 1.59	1.35	.3147	.1049	9
	M	0.09	- 0.14	.12	.0439	.0122	13

## Appendix 2

Size range of brown bullhead collected at Shirleys Bay and  
Britannia Bay during 1971.

Age	N	Sex	TL Range (mm)	Mean	SD	SE
I	2	F	144-152	148.03	32.44	4.05
	2	M	126-159	142.45	23.65	1.67
	4	F&M	126-159	145.24	14.42	7.21
II	0	F				
	5	M	197-306	259.15	45.98	2.06
	5	F&M	197-306	259.15	45.98	2.06
III	27	F	233-319	287.53	19.67	3.78
	23	M	218-330	298.05	25.33	5.28
	50	F&M	218-330	292.37	22.83	3.23
IV	41	F	261-325	300.44	12.81	2.00
	34	M	287-351	311.27	15.95	2.74
	75	F&M	261-351	305.35	15.21	1.76
V	15	F	274-333	309.51	14.92	3.85
	8	M	304-336	320.65	10.59	3.74
	23	F&M	274-333	313.39	14.39	3.00
VI	2	F	288-343	315.32	38.71	2.74
	2	M	335-362	348.27	19.36	1.37
	4	F&M	288-362	331.80	31.41	1.57
VII	0	F				
	1	M		354		
	1	F&M		354		
VIII	1	F		343		
	0	M				
	1	F&M		343		

## Appendix 3

Size range of brown bullhead collected at Hay Bay during 1971.

Age	N	Sex	TL Range (mm)	Mean	SD	SE
II	4	F	188-212	197.46	10.48	5.24
	7	M	166-229	204.37	21.48	8.12
	11	F&M	166-229	201.86	17.95	5.41
III	11	F	187-244	217.07	20.19	6.08
	19	M	193-285	227.65	26.21	6.01
	30	F&M	187-285	223.77	24.36	4.45
IV	12	F	219-280	251.87	27.57	4.83
	29	M	219-311	261.76	20.88	3.87
	41	F&M	219-311	258.87	39.71	3.13
V	21	F	237-308	272.50	19.31	4.21
	28	M	201-329	281.50	27.06	5.11
	49	F&M	201-329	277.53	24.32	3.48
VI	12	F	259-290	274.01	11.58	3.34
	16	M	265-319	287.00	13.41	3.35
	28	F&M	259-319	281.43	14.05	2.66
VII	5	F	273-355	292.61	35.11	15.70
	1	M		296.06		
	6	F&M	273-355	293.19	31.44	12.83
VIII	2	F	257-299	278.32	29.39	20.78
	1	M		254.49		
	3	F&M	254-299	270.37	24.92	14.39

## Appendix 4

Size range of brown bullhead collected at Governor's Bay during 1971

Age	N	Sex	TL Range (mm)	Mean	SD	SE
II	1	F		185.54		
	1	M		230.16		
	2	F&M	186-230	207.85	31.55	22.31
III	9	F	210-250	226.10	13.68	4.56
	16	M	205-261	231.93	12.40	3.10
	25	F&M	205-261	229.83	12.91	2.58
IV	21	F	209-279	250.38	20.40	4.45
	36	M	203-291	244.15	44.74	7.45
	57	F&M	203-291	250.29	22.65	3.00
V	17	F	217-331	264.87	25.14	6.10
	46	M	219-340	258.70	44.20	6.52
	63	F&M	217-340	264.21	26.46	3.33
VI	10	F	225-316	272.03	27.54	8.71
	13	M	216-334	273.36	33.77	9.37
	23	F&M	216-334	272.78	30.54	6.37
VII	4	F	233-271	259.30	17.53	8.77
	2	M	234-270	251.95	25.09	17.74
	6	F&M	233-271	256.85	18.02	7.36
VIII	3	F	257-311	288.96	28.75	16.60
	0	M				
	3	F&M	257-311	288.96	28.75	16.60

## Appendix 5

Size range of brown bullhead collected at the top  
of Upper Duck Island during 1971.

Age	N	Sex	TL Range (mm)	Mean	SD	SE
III	7	F	212-249	230.88	16.18	6.11
	11	M	198-262	226.47	18.30	5.52
	18	F&M	198-262	228.18	17.16	4.04
IV	15	F	221-275	235.77	16.78	4.33
	10	M	218-287	255.60	23.74	7.51
	25	F&M	218-287	245.28	21.80	4.36
V	9	F	226-260	240.86	11.67	3.89
	21	M	208-314	250.43	25.87	5.65
	30	F&M	208-314	247.56	22.79	4.16
VI	7	F	233-283	257.53	19.56	7.39
	3	M	242-293	248.41	5.37	3.10
	10	F&M	233-293	254.49	16.76	5.30
VII	0	F				
	1	M		293		
	1	F&M		293		

## Appendix 6

Size range of brown bullhead collected above Hawkesbury during 1971.

Age	N	Sex	TL Range (mm)	Mean	SD	SE
II	0	F				
	1	M		201.77		
	1	F&M		201.77		
III	4	F	211-230	221.03	10.04	5.02
	1	M		207.85		
	5	F&M	211-230	218.39	10.50	4.70
IV	6	F	236-295	271.39	21.53	8.79
	6	M	232-344	284.23	38.55	15.74
	12	F&M	232-344	277.81	30.52	8.81
V	26	F	239-340	290.83	26.63	5.22
	24	M	210-360	308.14	37.24	7.60
	50	F&M	210-360	299.14	33.01	4.67
VI	13	F	216-336	293.44	31.72	9.16
	12	M	262-360	327.57	28.79	7.98
	25	F&M	216-360	311.19	34.33	6.87
VII	11	F	281-349	317.54	22.12	6.67
	4	M	291-331	314.31	16.70	8.35
	15	F&M	281-349	316.67	20.29	5.24
VIII	2	F	314-340	326.98	17.92	12.67
	2	M		344.72		
	4	F&M	314-345	332.90	16.30	9.41

## Appendix 7

Size range of brown bullhead collected below  
Hawkesbury during 1971.

Age	N	Sex	TL Range (mm)	Mean	SD	SE
III	9	F	233-287	266.43	17.02	5.67
	12	M	269-318	294.20	15.16	4.38
	21	F&M	233-318	282.30	20.99	4.58
IV	9	F	242-312	271.39	24.19	8.06
	10	M	240-312	299.10	20.92	6.62
	19	F&M	240-312	285.97	26.09	5.99
V	14	F	266-324	294.90	17.72	4.74
	15	M	271-349	306.13	24.40	6.30
	29	F&M	266-349	300.71	21.82	4.05
VI	11	F	290-327	308.69	12.96	3.91
	12	M	304-361	334.08	14.78	4.27
	23	F&M	290-361	321.94	18.81	3.92
VII	3	F	320-339	331.21	9.58	5.53
	0	M				
	3	F&M	320-339	331.21	9.58	5.53
VIII	1	F		294		
	1	M		336		
	2	F&M	294-336	314.82	29.39	20.78



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