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ACKNOWLEDGEMENTS

My thanks are due to many people for their assistance in the study. P. Rossignol and P. Rubec assisted in the field work in 1967 and 1968 respectively.

I am indebted to the Ontario Water Resources Commision for the chemical analyses of water samples, and the Ottawa Public Health Commission for coliform bacterial analyses. Mr. J.-P. Cuerrier, Canadian Wildlife Service, and Mr. J.A. Murphy, Ontario Department of Lands and Forests, read a number of yellow perch scales.

Mr. N.T. Gridgeman, National Research Council of Canada, suggested the method of statistical analysis, and supplied the N.R.C. computer program for polynomial regression. Dr. C.-J. Hughes, University of Ottawa Computer Centre, modified the original program, and wrote various computer sub-routines, for my data. To these people I am grateful.

My thanks are due to Dr. S.U. Qadri for his suggestions and supervision of the study, criticism of the manuscript, and financial aid in 1967-68. The constructive criticism and advice of Dr. S. Kerr has also been appreciated.

The present research was supported by National Research Council grant no. A-2386.

ABSTRACT

A detailed study of the effects of pollution on the fish fauna at six stations on the Ottawa River, near Ottawa, Ontario, was conducted from 1966-68. Bacterial and water chemistry analyses indicated the main areas of domestic and industrial pollution. Pollution below Britannia Bay (control station) is primarily due to two pulp and paper mills and the total domestic sewage from the city of Hull and the township of Gatineau, Quebec. Analyses of the growth of 2775 yellow perch indicated few statistical differences in growth above and below the sites of pollution. Examination of 1100 young-of-the-year perch indicated no inhibition of growth during the first year. However, the length curves and seasonal growth data indicate that perch from Britannia Bay exhibit faster growth after the third or fourth year than elsewhere. At the most polluted stations, the decreased growth rate noted in older perch, was greater than observed at moderately polluted stations. Back calculations of length also suggest a deterioration of growth conditions below the control station.

The fish fauna at Britannia Bay was more diverse with a greater number of 'clean-water' fish than elsewhere. Only 4 species of fish were found immediately below the C.I.P. paper mill, and the abundance and diversity were restricted for five miles downstream. Perch caged below the mill suffered 65-100% mortality near effluent outflows and sustained mortalities of 10-20% were observed for a distance of 1 mile downstream. Domestic pollution enhanced the growth of young perch in the first 2 year classes, although pollution tolerant fish predominated the area.

Analysis of stomach contents suggest a greater diversity of 'clean-water' food types at Britannia Bay, predominantly aquatic insect larvae, while pollution tolerant isopods and dipterans are prevalent elsewhere in the study area. The decreased rate of growth in older fish may result from the limited food size in the polluted areas.

A 56.5% recovery occurred on tagged perch suggesting a restricted home range. Two were recaptured the following year at the tagging site.

ABREGE

Une étude détaillée des effets de la pollution sur les poissons de six stations de la rivière Outaouais fut menée de 1966 à 1968. Des analyses bactériologiques et chimiques de l'eau déterminèrent les zones principales de pollution domestique et industrielle. En aval de la station de contrôle située dans la Baie Britannia, la pollution est due aux eaux rejetées par deux moulins à pulpes et papier et aux eaux-vannes de la ville de Hull.

Des mesures de croissance de 2775 perches communes démontrèrent peu de différences statistiques entre la croissance en amont et en aval des sites de pollution. L'examen de 1100 jeunes perches communes de l'année ne montre aucune inhibition de la croissance pendant la première année. Toutefois, les courbes de longeur et les données sur la croissance saisonnière indiquent que les perches communes de la station de contrôle ont une croissance plus rapide après la troisième ou quatrième année que celles des autres stations. Aux stations les plus polluées, la diminution du taux de croissance des perches plus agées, fut plus marquée qu'aux trois stations modérément polluées. L'interprétation de certaines mesures suggère une détérioration des conditions de croissance en aval de la station de contrôle.

Les espèces de poissons à la station de contrôle sont plus variées qu'ailleurs. Seulement quatre espèses de poissons furent trouvées immédiatement en aval du moulin à papier de la C.I.P. L'abondance et la diversité des espèces sont restreintes sur une distance de cinq milles en aval. Des perches communes mises en cages en aval du moulin, près de la zone d'arrivée des eaux en provenance de celui-ci, subirent un taux de mortalité de 65 à 100%. Ce taux est de 10 à 20% à un mille en aval.

Les eaux-vannes domestiques rehaussèrent la croissance chez les perches de trois ans ou moins et augmentèrent la productivité mais en favorisant aussi l'établissement de poissons plus tolérants à la pollution.

Une analyse des contenus stomacaux suggère qu'une plus grande variété de nourriture a été utilisée à la station de contrôle c'est-à-dire en "eau saine" où les larves d'insectes aquatiques dominent, alors que des isopodes et des diptères, plus tolérants à la pollution, forment les groupes dominants trouvés dans les estomacs des poissons capturés en eau plus polluée.

La diminution du taux de croissance chez les poissons plus âgés peut être causée par la petite taille des proies dévorées dans les endroits pollués. Les effets des produits chimiques en concentrations sublétales et ceux occasionnés par la présence de fibres de bois sont aussi discutés.

On a recapturé 56.5% des 46 perches étiquetées. Ceci suggère une zone d'activité (home range) restreinte. Deux perches furent reprises l'année suivante à l'endroit d'étiquetage. L'utilité des étiquettes de type "fléchette" sur les perches est aussi étudiée.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

Previous studies on the Ottawa River have primarily dealt with a bacterial and chemical analysis of water samples (Thomas, 1952; Piché, 1954; LeSauteur, 1967). These investigations have revealed a serious deterioration of the water quality below the cities of Ottawa and Hull, especially on the Quebec side, with little or no recovery occurring in the remaining 80 miles of the river. However, none of these studies have examined the effects of such pollution on the river fauna.

LeSauteur (1967) observed an absence of benthic macrofauna for 2000 feet below the Canadian International Pulp and Paper Company mill (C.I.P.) at Gatineau and a thick layer of decomposing wood fibres extending considerably further downstream though no qualitative data were presented.

The depletion of the macrofauna below paper mills, often accompanied by the occurence of thick layers of wood fibers, have been examined by several investigators (Trautman, 1933; Waldichuk, 1962; Colby and Smith, 1967).

A similar faunal depletion below domestic sewage outfalls has been noted by Gaufin and Tarzwell (1955), Tsai (1968) and Katz and Gaufin (1952). However the effect of domestic effluents often enhances the abundance and growth rate of pollution tolerant organisms (Katz and Howard, 1954).

The principal aim of the present study was to examine and compare growth in yellow perch _Perca flavescens_ (Mitchill) in six different areas of the Ottawa River and, if possible, relate differences in their growth to industrial or domestic pollution. The yellow perch was chosen as the study subject since it was relatively abundant in the Ottawa River system and considerable published data on its growth is available for comparison (Carlander, 1950; Jobes, 1952; Hile and Jobes, 1942; Eschmeyer, 1937; Grimaldi, 1967).

Dr g 1966-68, in addition to collecting data on growth, the water quality in the study area, the diversity and abundance of fishes, and the availability of food organisms for perch were examined. Much of the study was concerned with conditions in the vicinity of the C.I.P. mill since this area was considered the most polluted of those studied. The virtual absence of fish near the mill effluent outflows resulted in 'in situ' experiments on the acute effects of effluent on perch, plus an intensive fish distributional study extending five miles below the mill.

DESCRIPTIONS OF AREAS

The study is concerned with that portion of the Ottawa River between Britannia Bay and past the Canadian International Paper Company, a distance of about 14-15 miles (Fig. 1). Stream flow velocities in the Ottawa River subside to a seasonal low in summer; August flow speeds ranged between 0.7 and 0.8 feet per second (f.p.s.) at all stations except Britannia Bay and the Gatineau River (see below). Since industrial discharge from paper industries reaches maximum levels in summer, the relative effects on the aquatic environment could vary throughout the year.

The E.B. Eddy Pulp and Paper Company constituted the most westerly major source of pollution in my study area. The mill is located a short distance below the Chaudière Falls at Ottawa and Hull, and uses approximately 27,000,000 gallons (122,730,000 litres) of water daily (LeSauteur, 1967). No recent information concerning the amount of effluent released into the river was obtained, however Piché (1954) stated the wood wastes and residues include "the sulphite liquor from the cooking of approximately 450 tons of wood daily, the white waters from making some 160 tons of newsprint, 240 tons of specialty papers and 70 tons of panel board daily, bleach and various wash waters" plus wood debris and fibers.

Mainly, these wastes are released mid-river; the effluents are thus highly dispersed and exert a generalized effect on all stations downstream. Additional effluents are released along the Quebec shore.

Unfortunately stream flow and depth precluded successful sampling near the Eddy mill, however six sampling stations were selected as representative of conditions above and below various sources of pollution (Fig. 1). General descriptions of the six sampling stations are provided below.

Station 1: Britannia Bay (control)

Lac Deschênes is a large shallow expansion of the Ottawa River about five miles above the Chaudière Falls. The main currents occur in the deeper waters near the northern shore, those of the southern shore being wind directed. The bottom consists primarily of sand, with rocky shoals in some areas. Rooted vegetation appears to be sparse, except along the shores. Drifting aquatic plants, however, were often collected in our nets.

Relatively unaffected by man, this area exhibited little evi- of water pollution.[1] Most sampling was done in Britannia Bay, a part of Lac Deschênes.

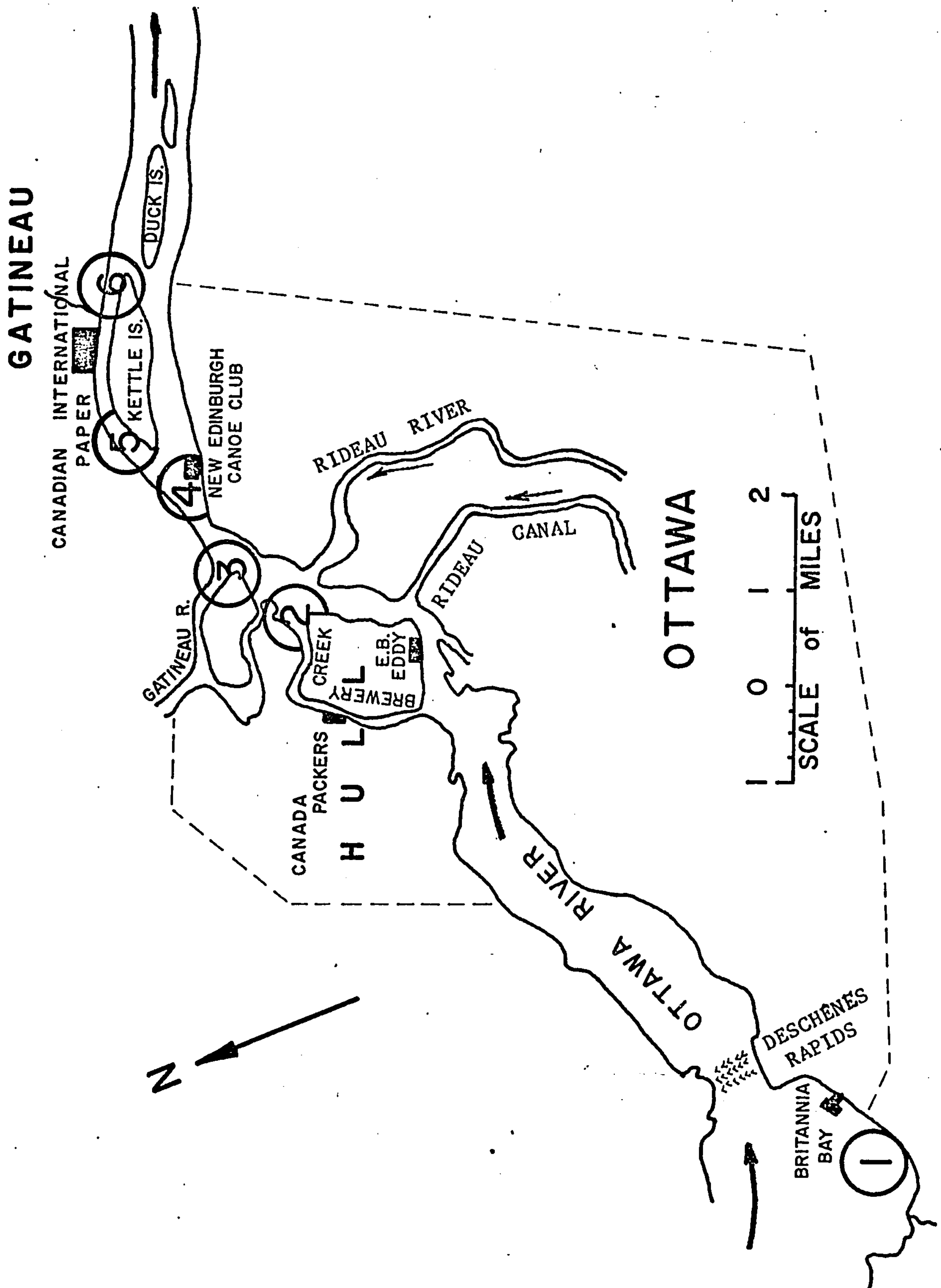
Station 2 : Brewery Creek

Brewery Creek, a tributary of the Ottawa River, encircles part of the city of Hull. It receives from 20-30% of the raw domestic sewage (sewage is chlorinated before being released) from the city of Hull. In addition, a large Canada Packers meat processing plant discharges wastes into the creek.

Maximum depth of the creek was 12 feet. The bottom consisted of fine silt, giving off large amounts of gas, probably methane. Wood fibers and chips were found only near the mouth of the creek where eddies are caused by the main stream of the Ottawa River; this debris originates from the E.B. Eddy mill. Considerable amounts of garbage and Sphaerotilus spp. also accumulated in our nets. Aquatic vegetation was prevalent only in the shallows along the northern shore. Collections were made a short

1 At Shirley's Bay, 4 miles upstream from Britannia Bay, Ottawa releases over 5 million gallons of primary treated sewage per day into Lac Deschênes.

Fig. 1. The section of the Ottawa River near Ottawa and Hull examined from 1966-68. The location of the sampling stations are indicated by circled numbers.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distance upstream from the counter current caused by an influx of Ottawa River water.

Station 3: Mouth of the Gatineau River

The Gatineau River is the main tributary of the Ottawa River, contributing about 30,000 cubic feet (850,000 l.) of water per second to the system annually. Although largely used as a means for transporting logs for the paper mills, it is otherwise subject to relatively little pollution.

Collections were made near the mouth of the Gatineau River; logging operations prevented sampling further upstream. Current speeds in August varied from 0.5 f.p.s. on the southeastern shore to 2.0 f.p.s. on the norwestern shore. Nets were set in the slower current at depths up to 16 feet. The bottom was primarily coarse sand, with considerable amounts of tree bark overlying it.

Station 4: New Edinburgh Canoe Club

Collections were made upstream from the New Edinburgh Club. This site was representative of the south side of the Ottawa River below Ottawa and Hull, receiving waters influenced by the effluents from the Eddy Paper Company, Brewery Creek, the Rideau River, and possibly the Gatineau River. The bottom consisted of shale and mud, with moderate amounts of wood chips and submerged vegetation. Fish collections were made at depths of up to 25 feet, although in 1968 some nets were set at depths of 30-40 feet.

Station 5: Kettle Island

This station, located at the western end of Kettle Island, is greatly influenced by the Gatineau River. It is a shallow sandy area, heavily vegetated with submerged aquatic plants in mid-summer. Gill nets were set at depths up to 15 feet but most perch were collected with seines. This was the only station below the Chaudière Falls which could be sucessfully seined.

Station 6: Canadian International Pulp and Paper Company (C.I.P.)

This station is located downstream from the Canadian International Pulp and Paper Company (Fig. 1.). The mill requires 45,600,000 gallons (207,275,000 l.) of water daily (LeSauteur, 1967), most being returned to the Ottawa River with the accompanying waste products. Piché (1954) included in the effluent "the sulphite liquor from the cooking of approximately 860 tons of wood daily and the white waters from the production of nearly 900 tons of newsprint and 250 tons of dissolved cellulose daily" and further that one-half of the weight of wood treated by the sulphite process is suspended in the discharged sulphite liquor. Some raw domestic sewage from the town of Gatineau also enters the River in this area.

The channel between Kettle Island and the Quebec shore is about 350 feet wide, with a maximum depth of 40 feet above the mill and 20 feet below. Although the substrate is primarily sand above the mill, below the discharge outlets the bottom is covered with a thick layer of decomposing wood chips. In addition, large amounts of wood fibers and Sphaerotilus spp. are suspended in the water mass and often accumulated in our nets. This situation existed for at least 5 miles downstream and suggests the extent to which the river bottom is being affected. Below the Kettle Island, currents from the main stream restrict the fiber load to the Quebec shore for about one mile; two miles below Kettle Island, mixing appears complete.

The collection area had to be extended to one mile below Kettle Island because few fish were caught by gill nets in the C.I.P. channel. Seine collections were attempted along the northern shore of Duck Island, but only a few young-of-the-year perch were obtained here in 1967 and none in 1968. Water depth and debris prevented seine collections in the C.I.P. channel, or along the Quebec shore.

MATERIALS AND METHODS

Collection of data for this study began in June, 1966, and terminated in November, 1968. Field work on the Ottawa River was conducted during the following periods: 28 June - 29 August, 1966; 29 May - 31 October, 1967; 25 May - 11 November, 1968.

Physico-chemical Methods

In order to investigate the water quality, 231 water samples, both surface and bottom, were collected: 166 for bacterial analysis (Table 3), and 65 for physical and chemical analysis (Table 4).

Surface and bottom water samples were obtained using a 4-liter Van Dorn Sampler. Bimonthly samples were collected for coliform bacterial analysis, while those for chemical analyses were collected bimonthly in 1966 and 1967 and monthly in 1968. Due to unstable ice conditions only one series of samples was collected in winter (February, 1968). A portable Hach Chemical kit (model AL-36-WR) was used for field analyses of pH, dissolved oxygen, and carbon dioxide; these 3 factors were also analysed each time nets were set. Chemical analyses were carried out by the Ontario Water Resources Commission on the following factors: 5-day Biochemical Oxygen Demand, turbidity, anionic detergents, phenols, nitrite, nitrate, phosphorus, alkalinity, chloride, sulphate, iron, calcium, copper, zinc, manganese, and conductivity. Estimates of the Most Probable Number (MPN) of coliform bacteria were performed by the Ottawa Public Health Department.

The transparency of the water was estimated with a Secchi disc, as described by Beeton (1957). Transparency measurements were taken only in 1966 and 1967.

Surface and bottom temperature readings were taken with a thermistor made by Allied Research Associates of Texas, and calibrated in degrees F. Temperature readings were taken concurrently with water sampling and net setting.

Currents were charted in June, 1968, using the 'float method' described by Waldichuk (1958). Flow speeds, measured as the time required for a float to extend a fifty foot length of cord, were later checked with a Price Type AA Current Meter supplied by Scientific Instruments of Wisconsin, Inc.

Fish Population Parameters

For the study of growth between 1966 and 1968 a total of 3875 yellow perch were collected from six locations in the Ottawa River (Table 1). The majority were taken in 1968 (1843 fish), with 222 and 1810 perch sampled in 1966 and1967 respectively. The samples from Britannia Bay and Kettle Island included 989 and 872 young-of-the-year respectively; 550 from each station were collected in 1968 to examine growth in the first summer. Few 0-year class fish were caught at the other locations, although 149 young-of-the-year perch were taken on the north side of Upper Duck Island below C.I.P. in 1967.

An additional 476 perch, seined from Britannia Bay and Kettle Island were used in other aspects of the project (Table 1): 350 perch collected in Britannia Bay were kept in cages below C.I.P. for the study of mortality and 126 perch collected at Kettle Island were used to examine aging techniques and tagging procedures.

Table 1. Number of yellow perch used in the growth and other studies in 1966-68. Fork length ranges (cm) indicated in parentheses under the number of fish.

Parameter Examined	Britannia Bay	Brewery Creek	Gatineau River	N. Edinburgh Club	Kettle Island	C.I.P.	Total
Growth curves and T.L.'/F.L.' ratio	651 (3.2-25.9)	570 (8.1-25.1)	196 (9.0-24.7)	619 (7.0-26.6)	451 (3.3-23.9)	288 (9.5-25.3)	2775 (3.2-26.6)
S.L.'/F.L. ratio and T.L./S.L. ratio	152 (3.2-25.9)	82 (8.1-25.1)	52 (9.0-24.7)	125 (7.0-26.6)	146 (3.3-23.9)	89 (9.5-25.3)	646 (3.2-26.6)
Stomach analysis	115 (3.3-24.2)	92 (8.4-23.8)	54 (9.9-21.9)	107 (8.1-23.6)	121 (3.4-23.0)	107 (9.7-22.6)	596 (3.3-24.2)
First season's growth	550 (1.6-9.1)				550 (2.5-8.3)		1100 (1.6-9.1)
Comparison of aging technique					60 (5.4-22.9)		60 (5.4-22.9)
Cage Experiments at C.I.P. +	350 (4.9-15.4)						350 (4.9-15.4)
Tagging ++							
Field study					46 (9.1-20.5)		46 (9.1-20.5)
Lab experiment					20 (9.4-19.8)		20 (9.4-19.8)

\+ Fish kept in cages in the C.I.P. channel.

++ Fish used in tagging investigation.

' F.L., S.L., and T.L. denote fork length, standard length, and total length respectively.

a) Collection of Specimens

Three methods were used to collect specimens : gill nets, seine nets, and Windemere traps. (Sheri and Power, 1968).

Multifilament nylon gill net gangs, 6 ft. deep and 200 ft. long were most extensively employed. Originally 50 ft. lengths of four different stretched mesh sizes (3/4, 1 1/2, 2 1/2, and 3 or 4 inch) were combined in each gang. The three and four inch mesh proved to be very inefficient in catching perch, and after July, 1967, were used only to obtain periodic samples of other species of fish. Thereafter, for catching perch, the amount of 1 1/2 inch stretched mesh was increased to 100 ft., thereby maintaining the length of the gangs at 200 ft..

During the study period, a total of 175 gill net gangs were set (Table 2). In 1967 and 1968, 20 and25 gill net sets were made respectively to investigate fish density in relation to distance from effluent outlets of the Canadian International Paper Company (C.I.P.). Seven locations, up to five miles from the mill discharge were examined, three locations being sampled on each collection date. Only yellow perch netted along the Quebec shore within a mile of the lower tip of Kettle Island were included with the growth data.

Nets were set in the afternoon and raised the following morning. Large amounts of debris: logs, wood chips, wood pulp, and "sewage fungus" (Mackenthun and Ingram, 1967) had to be removed from the nets after every setting, except in the control area. The worst fouling conditions were encountered below the paper mill discharge (Fig. 2).

The use of Windemere Minnow traps was generally unsuccessful. Seines were the only successful method of sampling young-

Table 2. Number of times gill nets (overnight sets), seines, and traps were used for collecting fish. Number of perch taken per net operation indicated in parentheses.

	Britannia Bay	Brewery Creek	Gatineau River	N. Edinburgh Club	Kettle Island	C.I.P.
Gill Nets						
1966	4	4	2	2	2	4
1967	36	14	17	14	3	20*
1968	15	4	3	4	2	25*
Total	55 (3.9)+	22 (25.9)	22 (8.9)	20 (25.0)	7 (18.4)	49 (5.9)
Seines++						
1967	11 (113.6)				4 (287.5)	
1968	11 (89.3)				11 (246.7)	
Windemere Traps						
1967				38 (2.1)		
1968	12 (0.4)	2 (6.5)			2 (5.5)	

* perch obtained at C.I.P. in 1967 and 1968 were mainly taken outside the C.I.P. collecting area (see appendix 2) for the distributional investigation. The average catch (5.9) does not include results from the distributional net sets.

\+ heavy predation on perch caught in gill nets occurred, likely by channel catfish. Yield value including fish remains in nets would be 8.6.

++ on each occasion four to six seine hauls were made to ensure a random collection.

of-the-year perch. The condition of the river bottom limited sampling with this method to three of the six study areas: Britannia Bay, Kettle Island, and Duck Island. A 60 ft. nylon seine, 6 ft. deep and with mesh size of 1/4 inch, was used in 1967. In 1968, a 120 ft. bag seine 6 ft. deep, with mesh sizes of 1/4 inch in the wings and 1/8 inch in the bag portion, was found to be more efficient.

This larger seine was subsequently used to collect bimonthly samples of 50 young-of-the-year perch from Britannia Bay and Kettle Island. No 0-year class perch were found at Duck Island in 1968. The collection period extended from 14 June to 15 November at Kettle Island, however in Britannia Bay, no young perch were found until 21 June.

b) Measurements

Fresh weights, using a Mettler B5 Macro-balance, were taken from all perch used in the young-of-the-year study, following the third blotting procedure described by Parker (1963). To insure that only 0-year class perch were being considered, scales from the same area from several fish of each sample were examined under a Bausch and Lomb microprojector.

Measurements, and scales, from all other fish used in the growth comparisons were taken subsequent to preservation in 10% formalin for at least five months. These fish were weighed to the nearest 0.1 gram on a Gram-atic balance. Fork lengths, taken to the nearest millimeter, follow the methods of Lagler (1956) and Hubbs and Lagler (1964). Length conversion factors were also calculated to facilitate comparisons with other work. Factors for conversion of body lengths: total length (T.L.), fork length (F.L.), and standard length (S.L.):

Fig. 2. Wood fibers and Sphaerotilus spp. on gill net and on minnow trap placed 1 mile below C.I.P. Net condition shown was typical.

Conversion of length (cm)	Factor	Reciprocal Factor
F.L.to S.L.	0.837	1.199
F.L.to T.L.	1.051	0.951
S.L.to T.L.	1.250	0.800

Differences were not found in the conversion factors between males and females, or between sampling stations for the length interval examined (4.5-21.6 cm). Some authors (Jobes, 1952; Muncy, 1962), have however shown differences in growth between male and female yellow perch. Since such discrepancies could result in different growth parameters, I have treated the sexes separately whenever possible.

c) Age determination

Fish were aged by the scale method. No scale erosion was evident, although the scales were taken from preserved specimens. Impressions of four to eight dry scales from each specimen were made on cellulose acetate slides (0.002 or 0.003 inches thick) with a roller press (Smith, 1954). The impressions were twice examined under a Bausch and Lomb Tri-simplex Microprojector (40.7X). During the second reading, three scale impressions from each slide were measured and averaged for determination of the body length - scale length relationship, and for back-calculation of growth. The measurements were taken along the most anterior radius from the scale focus to each successive annulus and to the scale edge. The criteria outlined by Jobes (1952) were used to position the annuli.

To check possible errors in age determination and position of annuli, a series of 50 samples were examined first by Mr. J.-P. Cuerrier of the Canadian Wildlife Service, and then sent to Mr. J.A. Murphy of the Ontario Department of Lands and Forests for independent examination. Agreement between their age readings and the author's was 96% and 100% respectively, with only a few minor disagreements in annulus position. Since 40% of the submitted slides were specifically selected because I experienced some difficulty in aging them, the level of agreement is satisfactory. The instances of disagreement were related to false annuli; the difference in both cases did not exceed one year.

Although the scale annulus has been used as a year mark for yellow perch by several authors (Jobes, 1952; Muncy, 1962), a check was conducted using three aging techniques. Scale samples, opercular bones, and otoliths (Fig. 3) were prepared from 60 fresh yellow perch (5.4 - 22.9 cm in fork length) and three independent age determinations made on each.

The opercular bones were prepared and read according to Grimaldi (1967), using a Wild M5 stereo-miscroscope.

When removed from a fresh specimen, the otolith is easily cleaned by dipping it into warm water, then rubbing with a cloth. Fresh specimens were used since perch otoliths disintegrated after a two week period in formalin and were useless for age determination. The rings are most easily seen when the otolith is immersed in a creosote solution and viewed under reflected light. The clear winter zones appear dark and the opaque summer zones white under reflected light.

Although perch otoliths thicken with age, no additional treatment was required for aging purposes. Examinations were made along the long axis of the otolith because the increased thickness obscured annuli on the short axis (Fig. 3). Also, care must be exercised in designating the first annulus since ~~many~~ false annuli are formed in the first summer. False annuli were not prevalent in the otoliths examined after the first year of life.

The age determination by each method was consistent throughout the three readings. Results from the scale and opercular bone readings were identical. The ages estimated from the otoliths however, differed from the other two methods in 2 out of 60 cases examined, a percentage difference of 3.33. In both cases, the age determined from the otolith was one year greater than from the scales or opercular bones.

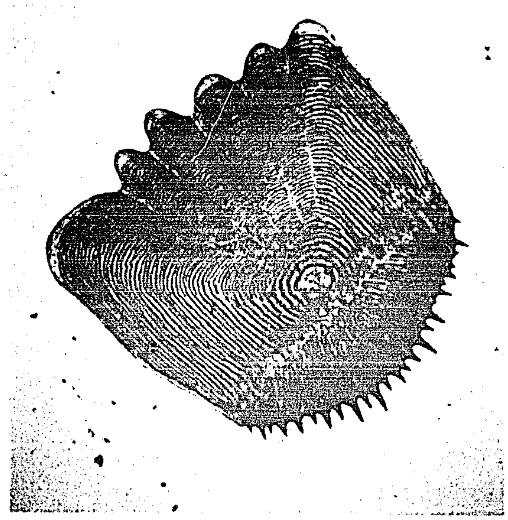
d) Statistical analysis

Regression lines were fitted by the method of least squares fit. The body-scale relationships were determined following Miller (1966). The growth curves were fitted using a National Research Council of Canada polynomial regression computer program (identification number CLPG00148 POLREG).

Both second and third order polynomials were fitted to the growth data; little difference was observed between the generated curves, thus only the second order curves ($y = A_0 + A_1x + A_2x^2$) are considered here. Significant differences between regression coefficients were checked using Student's t-test at $P = 0.05$ and $P = 0.01$ as outlined by Mather (1965).

When dealing with curvilinear regression, it is difficult

Fig. 3. Scales and bones showing the annuli, and therefore the ages, of yellow perch. The fish whose scales and bones are numbered 2, 3, and 4 were caught in June, 1968 and are 4, 5, and 7 years old respectively (fork lengths are 19.1, 21.8, and 24.0 cm). The no. 1 scale is from a young-of-the-year perch (7.6 cm) caught in September, 1968, and has no annulus.



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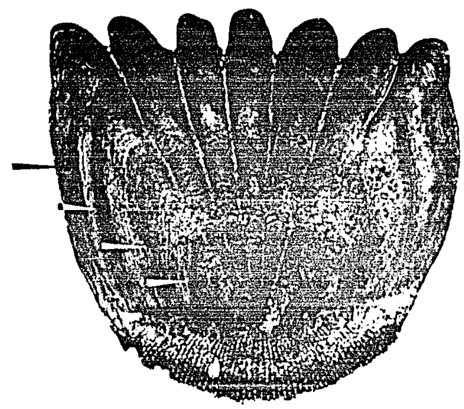

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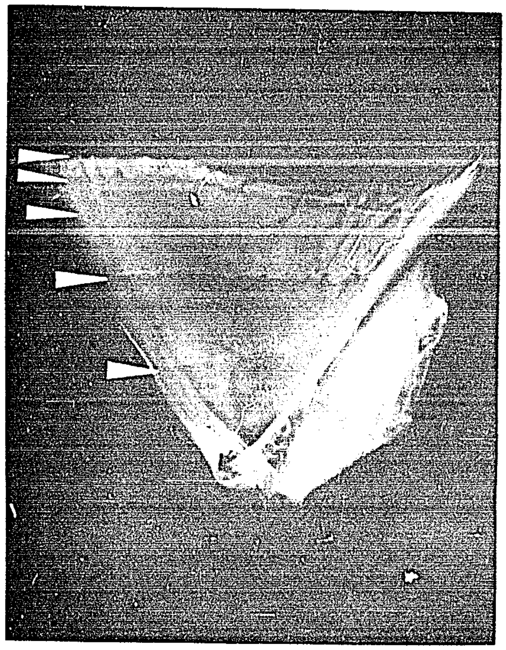

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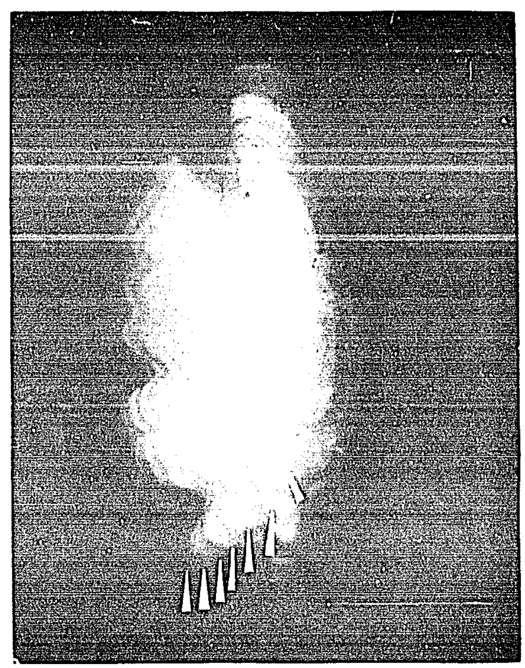

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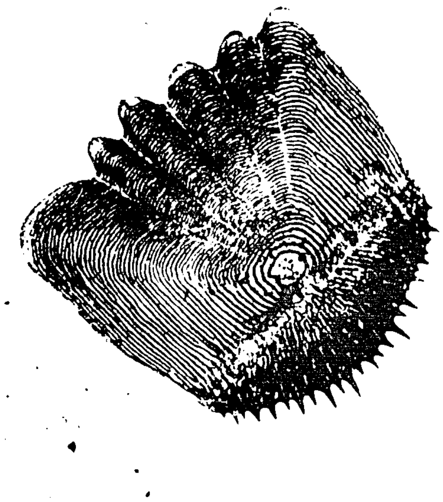

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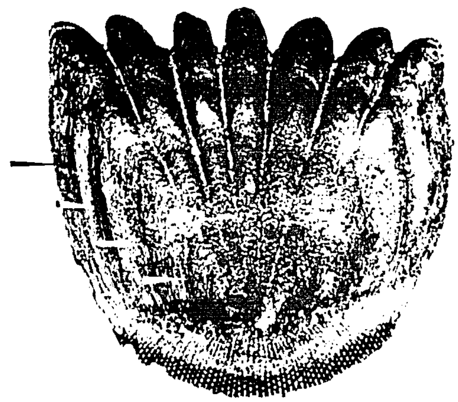

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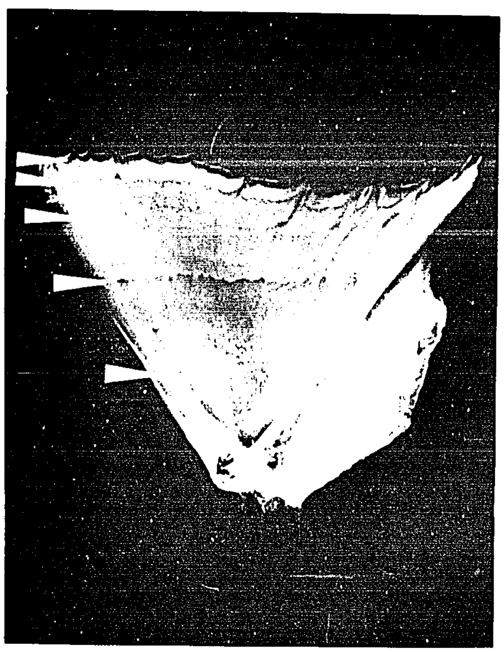

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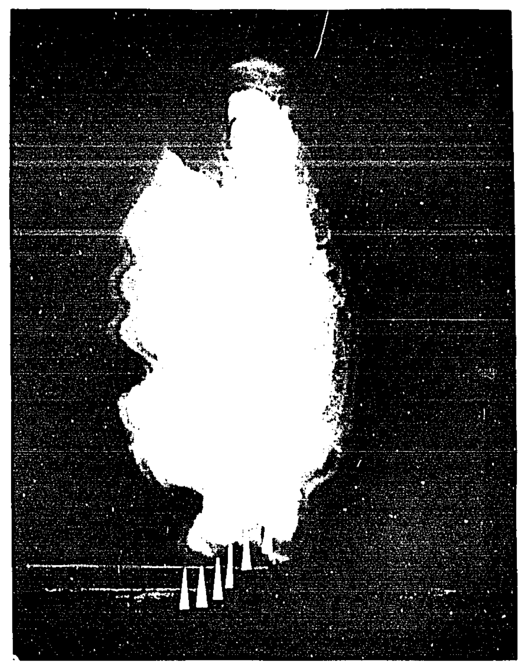


No. 4

to attribute a particular portion of the growth curve to any one coefficient. In any polynomial, the A_0 coefficient describes the slope of a straight line from which the curve is derived. Subsequent terms function to alter this line into the particular curve described by the data, the greater the number of additional coefficients, the greater the number of data points included in the curve.

However, in polynomial equations, the relative influences of the coefficients vary with the value of x. The value of the first coefficient, A_0, remains constant and exhibits greatest influence at small values of x. The effect of the A_1 and A_2 coefficients, on the value of y are directly proportional to the value of x, A_2 having the greatest effect on the latter part of the curve. Since all growth curves have the same origin, that is $y = 0$ when $x = 0$, growth differences are usually observed on the latter part of the curve. Therefore, when comparing curves it is possible to give biological meaning to significance shown between the various coefficients, the greatest weight being given to significance between corresponding coefficients in the order A_2, A_1, and A_0.

e) Sex determination

The gonads of all fish were examined to determine sex. The testes always appear as a pair of ribbon-like structures, and the ovaries as a single bilobed structure. Although in adults, the gonads decrease in size in mid-summer, the majority of males and females are easily separated by macroscopic examination of these organs. Microscopic examination was required only to determine the sex of the 0-year class fish.

f) Stomach analysis

Whole stomachs were removed from a representative sample of perch from each collection area, and stored in 5% formalin for subsequent examination. The contents of each stomach were separated according to taxonomic units, usually orders. The relative importance of food items was judged by estimating the volume composition visually, and by calculating the percentage frequency of occurrence. The visual method was considered an adequate method of estimation due to the inherent biasing factors in stomach samples: degree of digestion, unidentifiable debris resulting from digestive activity, and non-digestible components. The frequency of occurrence was obtained by counting the number of different organisms in a representative sample of the contents of each stomach. Every taxonomic unit present in a sample was accounted for by designating a minimum value of 0.1 percent.

g) Tagging of perch

To study fish movement, numbered FT-67 dart tags manufactured by the Floy Tag and Manufacturing Inc., of Seattle were used. The tags were inserted above the lateral line at the junction of the spiny and soft-rayed dorsal fins. The method followed was similar to that of Dell (1968), except that no anesthetic was used in the field.

The effects of this marking method were investigated in the laboratory over a three month period. Sixteen perch of various fork lengths (range 9.6 - 16.3 cm ; mean 13.2 cm) were divided into four similar groups. Prior to tagging, each group was treated according to one of the following methods:

1) No preliminary treatment (control)

2) Fish anesthetized using a solution of 8 ml ethyl ether per litre of water (Bell, 1964).

3) Fish anesthetized; tagging equipment dipped in 70% ethyl alcohol

4) Tagging equipment dipped in 70% ethyl alcohol; fish not anesthetized

h) Acute effects of industrial discharge on perch

In 1967 and 1968 five series of experiments, of three days duration, were conducted to test the toxicity of discharges from a pulp and paper mill on fish.

The experimental fish were perch (0 and 1 year classes) seined from Britannia Bay. The difficulties incurred in obtaining fish of sufficient size and transferring them to the cages prevented the use of more sensitive species or greater numbers of perch used. After being held in the laboratory for one week, groups of perch, each of similar size range (4.9 - 15.5 cm.), were placed in the river, in plastic minnow traps 18" long by 9" in circumference. In most instances, surface and bottom tests were conducted simultaneously.

Sites were chosen to enable comparison of mortality observed at various distances from the effluent outflows in the C.I.P. channel. A control site for this experiment was chosen in the C.I.P. channel above the discharge area. All traps were checked and dead fish removed at 900, 1300, and 1700 hours each day. Fork lengths of all fish were taken at the end of the experiment.

RESULTS

Bacterial Analyses

Many studies on water quality have used coliform bacterial levels as relative indices of domestic pollution. The Ottawa Public Health Department uses the value of 2400 total coliform organisms (MPN) as an index of polluted water,[2] however caution must be exercised when using such data in biological work since levels deemed hazardous to human health may be meaningless in application to aquatic organisms.

With these qualifications considered, coliform levels were examined in the present study (Table 3). Generally, Britannia Bay is the least domestically polluted section of the study area, having low levels of both total and fecal coliform organisms. All sites below Britannia Bay have much higher total and fecal coliform levels than at Britannia Bay. Brewery Creek and C.I.P. have the greatest levels of domestic organic pollution respectively. However, coliform levels at any station must be examined in view of the influence of the other stations upstream. Thus, coliform levels at Brewery Creek would tend to increase the coliform levels at all stations downstream, while the low levels at Kettle Island would tend to dilute the high concentration of coliforms near C.I.P. (Fig. 1).

Brewery Creek has consistently high coliform levels. Whereas at all other stations the upper limits of the range were obtained following a rain, the coliform levels at Brewery Creek were little affected by precipitation. Such coliform fluctuations suggest that increased water flow at most stations liberates bacteria not normally found in the water column. At Brewery Creek however, the stability of the

2 Since 1968, the number of total coliform organisms to be used as an index has been lowered to 1,000 per 100 cc of water tested.

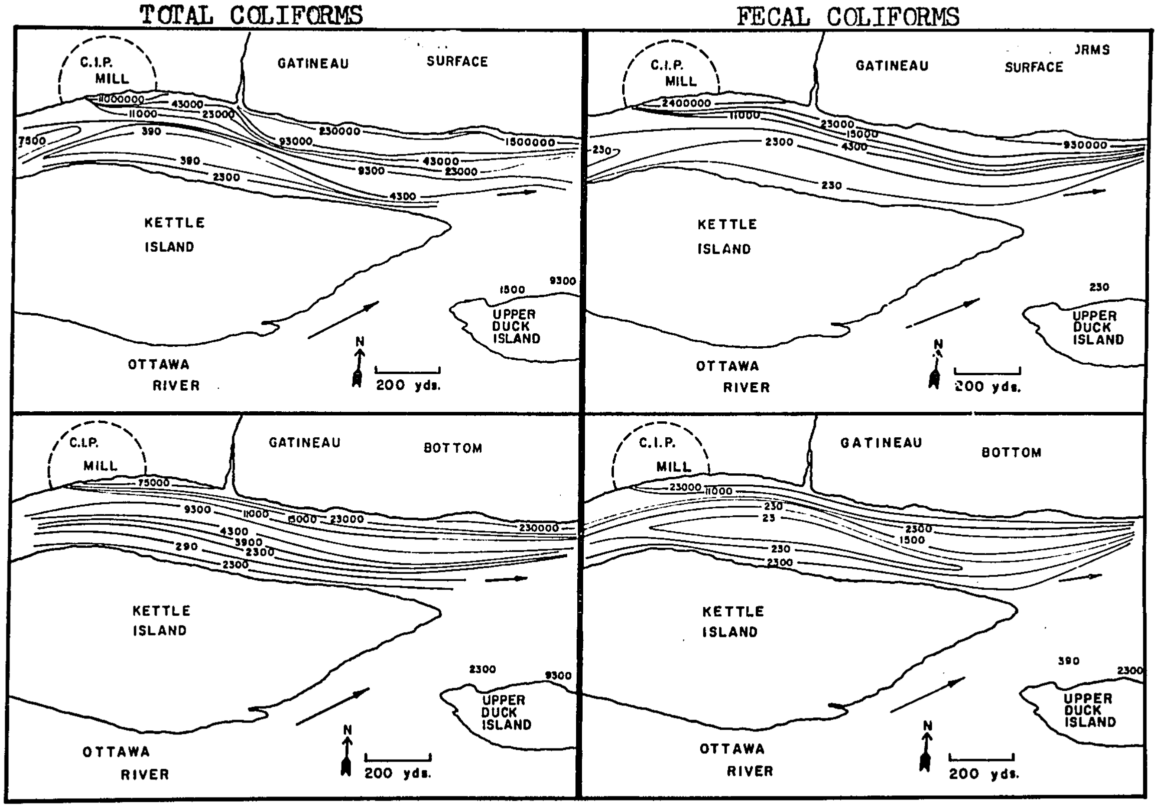
Table 3. Bacterial analysis of water samples taken from the Ottawa River, 1966-68. Both averages and ranges are given. The number of samples collected shown in brackets after each station. The five substations at C.I.P. were chosen to indicate differing levels of bacteria in the channel relative to distance from the mill.

Station	Total Coliform Bacteria (MPN)		Fecal Coliform Bacteria (MPN)	
	Surface	Bottom	Surface	Bottom
Britannia Bay (14)	748 23-2300	1232 21-9300	165 0-1500	295 0-2300
Brewery Creek (15)	197,067 11,000-430,000	242,067 11,000-930,000	56,189 3900-230,000	89,017 23-430,000
Gatineau River (14)	13,386 23-93,000	6470 75-39,000	1637 0-11,000	3177 0-23,000
N. Edinburgh Club (15)	17,966 230-93,000	14,868 390-46,000	4036 23-23,000	1331 23-2300
Kettle Island (6)	10,850 4300-23,000	8533 2300-23,000	3026 23-9300	2402 230-7500
C.I.P. Substations'				
Effluent outflows (3)	3,684,667 11,000-11,000,000	36,333 11,000-75,000	811,333 11,000-2,400,000	12,100 23-23,000
Quebec shore (6)	77,383 2300-230,000	14,317 9300-23,000	7,474 25-23,000	5060 230-23,000
Middle of channel (5)	6840 2300-23,000	11,820 290-43,000	5157 230-23,000	1013 210-2300
Kettle Is. shore (2)	2345 390-4300	2300 2300-2300	1265 230-2300	2300 2300-2300
Duck Island (3)	6700 1500-9300	7150 4300-15,000	690 230-2300	1248 390-2300

' See appendix 1 for location of substations.

Fig. 4. Distribution of total and fecal coliform bacteria (M.P.N.) at the surface and bottom in the Ottawa River below the Canadian International Pulp and Paper Co., 1966-68.

TOTAL COLIFORMS FECAL COLIFORMS



coliform levels indicate that the high counts are due to a constant influx of bacteria rather than flushing of the system.

C.I.P. exhibits a rapid decrease in coliform levels below the paper mill outlets at both surface and bottom (Fig. 4), relative to the values obtained at the effluent outflows. The Quebec shore is the most highly polluted area of the channel, receiving additional domestic waste from the small creek and the cottages along the shore, However, at least half the channel maintains coliform levels similar to that above the mill, and the main stream of the Ottawa River below Kettle Island restricts the high levels of coliform organisms to the Quebec shore.

Water Chemistry

Attempts have been made to determine the state of pollution in the Ottawa River (Thomas, 1952; Piché, 1954; Ontario Water Resources, 1961; LeSauteur, 1967), by a broad chemical assay. However, none have correlated their findings with investigations of the diversity, and abundance of aquatic organisms.

After establishing areas of high local pollution by chemical assay and bacterial analyses on a section of the river, I subsequently examined the growth, abundance, and diversity of fish in relation to these areas.

Generally the water chemistry suggests a low degree of water deterioration for all stations, except at Station 6 (C.I.P.). From Britannia Bay to Kettle Island, little variation in the chemistry of the water occurred between surface and bottom concentrations or among sites. For some factors, Britannia Bay had lower concentrations than the rest of the stations but exhibited no consistent pattern (Table 4).

Fig. 5. Distribution of B.O.D. (ppm) and phenols (ppb) at the surface and bottom in the Ottawa River below the Canadian International Pulp and Paper Co., 1966-68. Note that for phenols 5 ppb is the level toxic to many species of fish.

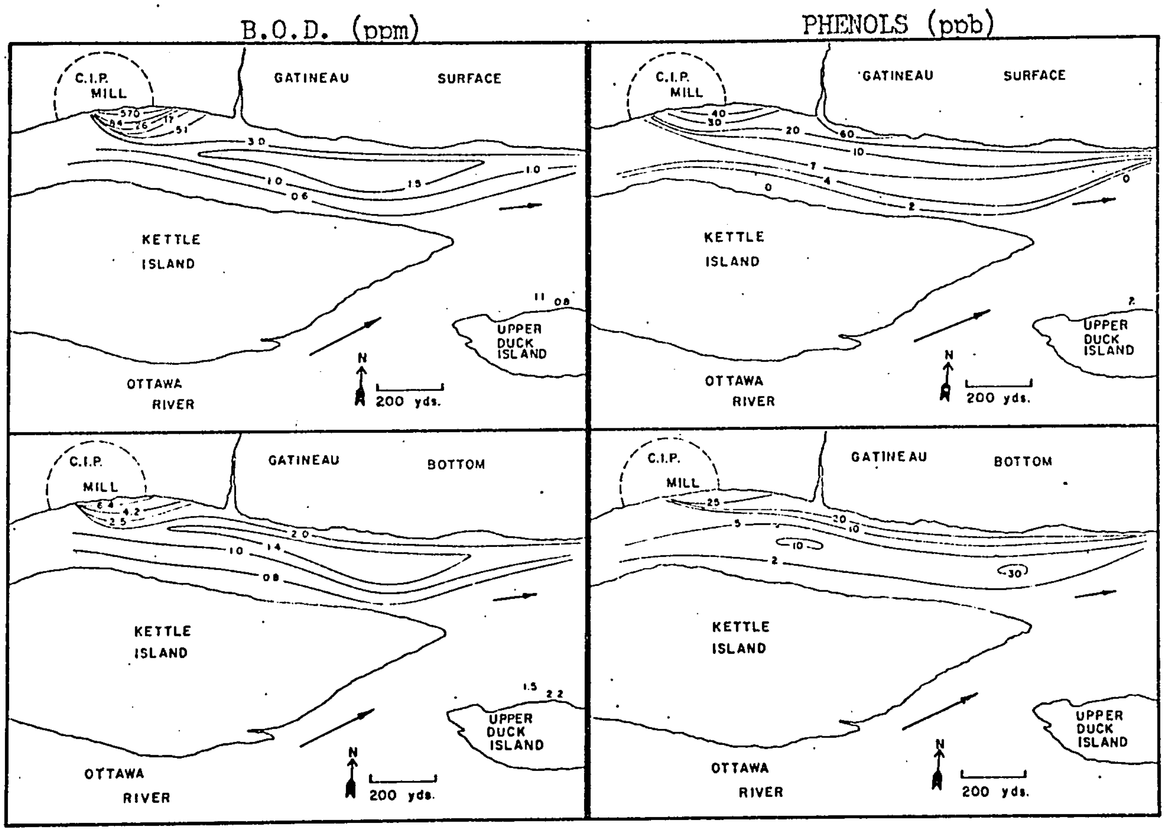

B.O.D. (ppm)
PHENOLS (ppb)
C.I.P. MILL
GATINEAU
SURFACE
BOTTOM
KETTLE ISLAND
UPPER DUCK ISLAND
OTTAWA RIVER
N
200 yds.

Table 4. Selected parameters of water quality of the Ottawa River, 1966-68. Averages and ranges of both surface (S) and bottom (B) samples are given. Number of samples analysed are given in parentheses after each station. All analyses are in ppm. except where indicated.

Station		Dissolved O_2	Dissolved CO_2	5-day B.O.D.	Phenols (ppb)	Iron	Sulphate
Britannia Bay (9)	S	8.5 8.0-9.0	6.9 5.0-10.0	0.7 0.2-1.2	3.8 0 - 8.0	0.73 0.14-3.50	20.7 6-80
	B	8.0 7.0-9.0	6.6 5.0-10.0	0.7 0.5-1.2	6.0 0 -15.0	0.44 0.23-0.92	28.5 5-84
Brewery Creek (13)	S	8.3 7.0-11.0	6.5 5.0-10.0	1.4 0.8-4.2	5.3 0 -15.0	0.45 0.24-0.75	11.6 8-17
	B	8.2 5.5-10.0	8.1 5.0-15.0	1.5 0.6-4.6	4.4 0 -15.0	0.61 0.30-1.10	11.7 4-17
Gatineau River (11)	S	8.8 7.0-11.0	7.1 5.0-15.0	0.9 0.4-2.7	1.8 0 - 8.0	0.59 0.28-1.40	8.3 4-14
	B	8.7 7.3-10.0	6.8 5.0-15.0	1.2 0.3-3.0	2.2 0 - 8.0	0.67 0.30-1.30	8.2 5-12
New Edinburgh Club (13)	S	8.9 7.5-11.0	7.3 5.0-15.0	0.9 0.3-2.0	4.9 0 -15.0	0.40 0.22-0.60	10.7 5-16
	B	8.7 7.0-11.0	5.4 3.0-10.0	1.0 0.3-1.8	4.0 0 - 8.0	0.65 0.23-3.65	11.6 5-17

Table 4 (con't).

Station		Dissolved O_2	Dissolved CO_2	5-day B.O.D.	Phenols (ppb)	Iron	Sulphate
Kettle Island (3)	S	8.7 8.0-10.0	10.0 10.0-10.0	0.7 0.4-1.2	4.3 0 - 8.0	0.33 0.28-0.36	21 21-21
	B	8.0 7.0- 9.0	10.0 10.0-10.0	0.8 0.5-1.3	5.0 3.0- 8.0	0.35 0.30-0.45	19 19-19
C.I.P. Substations*							
Effluent (7)	S	4.7 0.0- 8.0	25.0 5.0-65.0	104.5 1.3-570.0	28.3 0.0-40.0	1.14 0.76-2.42	38 9-76
	B	7.4 5.2- 9.0	9.0 5.0-14.0	3.7 1.5-6.4	14.0 3.0-30.0	0.92 0.35-1.70	17 9-40
Quebec Shore (4)	S	8.3 7.0- 9.0	7.5 5.0-10.0	2.7 1.8-3.2	23.0 2.0-60.0	0.47 0.38-0.59	10 8-12
	B	8.5 7.0-10.0	6.9 5.0-10.0	1.7 1.0-2.0	8.5 0.0-20.0	0.44 0.23-0.63	9 6-13
Middle of Channel (3)	S	9.0 8.0-10.0	6.0 5.0- 8.0	0.9 0.6-1.3	5.0 4.0- 6.0	0.55 0.54-0.56	12 10-13
	B	10.0 10.0-10.0	5.5 5.0-6.0	1.2 0.9-1.4	16.5 3.0-30.0	0.51 0.42-0.62	12 12-13

Table 4 (con't).

Station		Dissolved O_2	Dissolved CO_2	5-day B.O.D.	Phenols (ppb)	Iron	Sulphate
C.I.P. Substations*							
Kettle Island Shore (4)	S	8.5 7.0-11.0	7.5 5.0-10.0	1.0 0.5-1.6	4.5 0 - 8.0	0.42 0.32-0.60	11 12-20
	B	8.4 7.0-11.0	7.5 5.0-10.0	1.0 0.7-1.6	6.0 2.0-12.0	0.34 0.27-0.40	13 11-17

* See appendix for location of substations.

The high coliform levels at Brewery Creek were not reflected in the levels of dissolved oxygen or in the biochemical oxygen demand (BOD). This lack of variation I believe is due to the high flushing rate of the system.

The water quality of C.I.P. is heterogeneous (Table 4). In the area immediately below the mill discharge, high surface levels of dissolved CO_2, BOD, and phenols (Fig. 5) are accompanied by low levels of oxygen (0.0 ppm in some samples), and pH. These concentrations quickly decrease with distance from the effluent outlets and with depth (Fig. 5). However, the combination of these factors close to the mill, in addition to possible synergistic affects, may possibly reach levels lethal to fish (Doudoroff and Katz, 1953; Van Horn et al., 1949; Herbert, 1962; Trahms, 1950). This deterioration of water quality could, in part, explain the virtual absence of fishes in the C.I.P. channel below the mill.

Fish Movement

Many of the conclusions to be drawn from this study require that the perch obtained at the six sampling stations represent essentially discrete populations. A tagging program was therefore instituted to provide the necessary assurance that frequent movement did not occur between stations during the period of study. Due to the difficulties in obtaining large numbers of yellow perch at any time in the Ottawa River only a small tagging program was feasible. All fish were originally captured, and subsequently recaptured with a seine.

At Station 5, on June 14 and 21, 1968, a total of 46 perch were tagged and of these 20 had their anal fins clipped. In the following

3 1/2 month period 26 specimens (56.5%) were recaptured: twenty specimens were recaptured once, five were recaptured twice, and one taken three times (Table 5). Two of the tagged fish were also recaptured again in June, 1969. All fish were recaptured at the point of release. None were recaptured at the other stations. Subsequent seining yielded no evidence of tag loss. That is,no recaptured fish exhibited a clipped anal fin and/or a tagging scar but no tag, thus tag loss was not considered significant during the study period.

The recaptures in 1968, and especially those in 1969, strongly suggest that perch have a restricted home range in this section of the river, a tendency Gerking (1953) found prevalent in many stream fishes, Rodoheffer (1941) found true for yellow perch in Michigan, and Worthington (1950) for European perch. In the Ottawa River, the fast stream flow may enhance this tendency, as Muncy (1962) suggests for Severn River perch.

Laboratory Study for the Reliability of Tagging

Although relatively high rates of tag recovery prevailed, the tagging method caused large open wounds (Fig. 6) at the point of attachment. No infection was apparent. If tagging, or the method used in tagging increased the chances of mortality in those fish tagged, then the differential mortality could affect the significance of the tagging program results. Accordingly, a laboratory experiment was designed to determine whether the tagging method could elicit significant mortality or tag loss during a period of time comparable to that of the previous experiment.

The results of the lab study were similar to the field

Table 5. Number of yellow perch tagged, dart tags used, and recaptured from the Ottawa River, June 14 - Sept. 29, 1968. All fish recaptured are represented under 'Total Recaptures', but fish captured two or three times are also presented separately, with the dates of successive recaptures indicated by an * .

Date Tagged	Number of Fish	Recapture Dates: 21 June	3 July	2 August	9 August	2 Sept.	24 Sept.	1 Oct.	Total Recaptures
					Recaptures				
14 June	36	10	3	4	3	1	1	1	23
21 June	10	0	1	1	1				3
					Double Recaptures				
14 June		*	*						1
		**		**					2
		*			*				1
21 June			*		*				1
					Triple Recaptures				
14 June			*		*		*		1

results. The wounds, however, were smaller (Fig. 6). All fish survived till the end of the study. No consistent difference in wound size or state of health was observed in the four groups of experimental perch. Thus the amount of mortality of tagged perch was not increased by the presence of tags, or the tagging methods used. Also, the appearence of a wound in both the laboratory and field tested perch indicates that the tagging procedure is not responsible for the occurrence of a wound.

A shallow open wound was first observed two weeks after tagging. The wound had become deeper at the end of the study. The wound formation seemed to be due to the design of the tag. The exposed portion used the T-bar as an axis and moved constantly as the fish swam. This movement slowly increased the size of the wound.

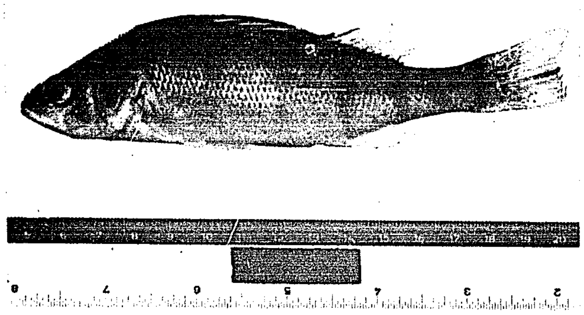
Dell (1968) found the dart tag satisfactory for trout, and these tags do no appear to adversely affect perch. The fact that two tagged perch, in good condition, were recaptured a year later attests this conclusion.

Thus the tagging method is satisfactory for perch, and the experiment indicates that tag loss, and mortality due to tagging was insignificant during my study. Therefore legitimate comparisons can be made between sampling stations.

Gross Effects of Pollution Upon the Fish Fauna

We collected 34 species of fishes previously recorded for the Ottawa Drainage System (Dymond, 1939; 1947), but not necessarily for the Ottawa River. The abundance and diversity of these species (Appendix 4) at various stations of the Ottawa River may provide an index of the effects of pollution on the fish populations.

Fig. 6. Comparisons of wounds which developed in laboratory-kept (no. 1) and field tagged (no. 2) yellow perch three months after tagging Dart tags were used in both cases. Nos. 3 and 4 are close-ups of nos. 1 and 2 respectively.



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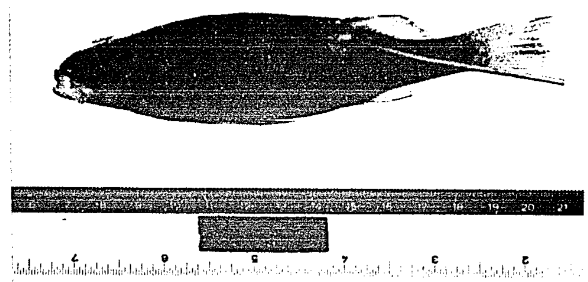

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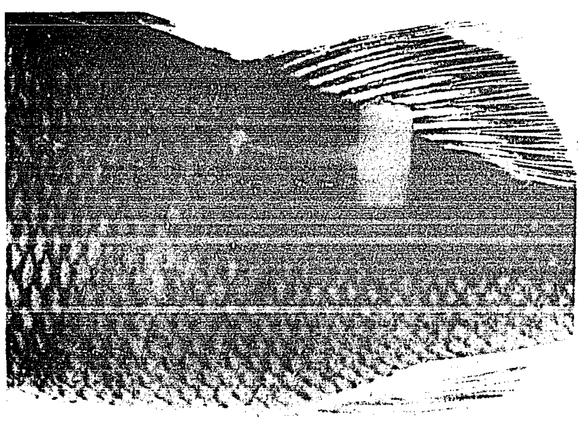

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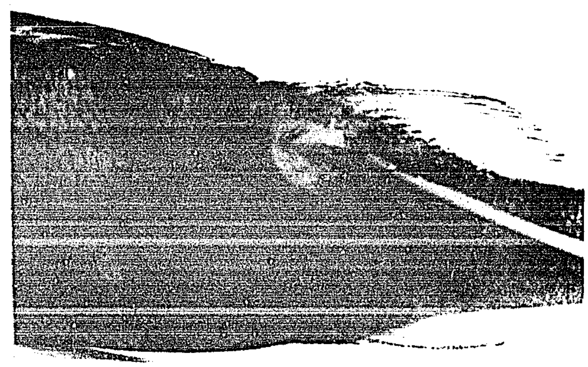

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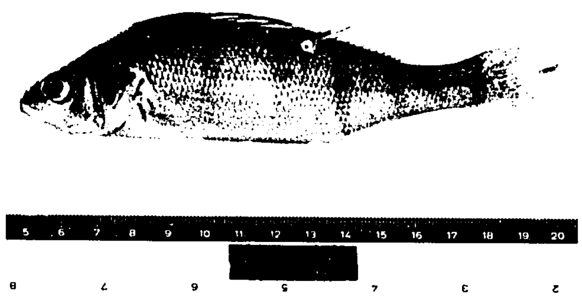

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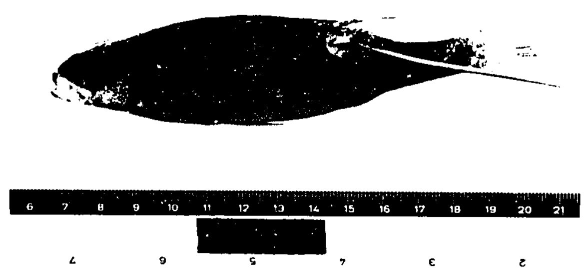

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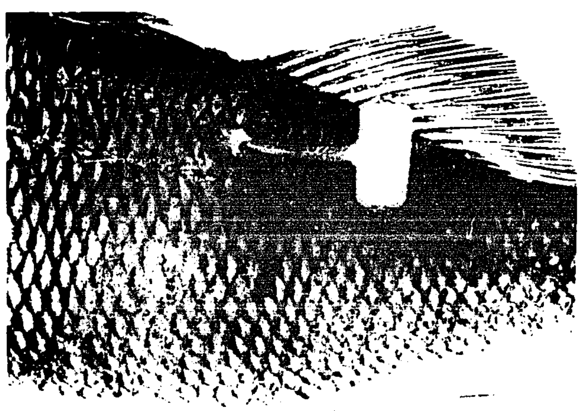

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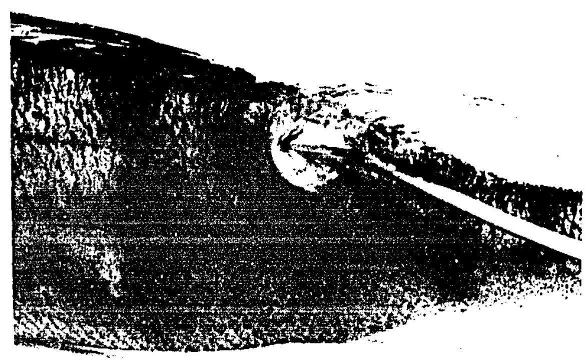


No. 4

Seine collections indicate both a greater diversity and abundance of darters (Etheostoma spp.) and cyprinids (Notropis spp.), and greater numbers of log perch (Percina caprodes, Rafinesque) and killifish (Fundulus diaphanus, LaSueur) at station 1, than at the other seining area, Station 5.

Gill net collections indicate changes in relative abundance of species, but little effect on species diversity.. Tsai (1968) found similar results caused by chlorinated sewage effluents..

As noted previously, the majority of fish listed for the C.I.P. station were taken 1.5 - 5 miles below the mill discharge, few fish being found near the mill. The indices listed for this station therefore do not adequately indicate the impoverished conditions occurring there. Only four species of fishes, the Northern shorthead redhorse (Moxostoma macrolepidotum), yellow perch (Perca flavescens), Northern brown bullhead (Ictalurus nebulosus), and Northern rock bass (Ambloplites rupestris) were netted in the C.I.P. channel at Station 6. This extremely reduced fauna indicates strong local effects of pollution upon fish.

Although gill net results are subject to gear selectivity, they are similar within themselves and comparisons can therefore be made. Gar pike (Lepisosteus osseus) and Mooneye (Hiodon tergisus), both clean water species common to Station 1, are rare or absent at most other stations. The Northern channel catfish (I. punctatus), the most prevalent fish at Station 1, was netted only twice below the Chaudiere Falls; and the single specimen taken from Station 6 was netted over four miles below the mill discharge. The reverse is essentially true for I. nebulosus; rarely taken in gill nets at Station 1, and found mainly as young-of-the-year in seine collections, the brown bullhead ranked second in abundance to perch below the Chaudiere Falls.

Yellow perch were abundant at all sites. Although the average catch per unit of effort was only 3.9 at Britannia Bay (Table 2), a high predation rate occurred on perch caught in the gill nets. The counts provided in Table 2 are of whole fish only, though the abundance of perch remains in the nets suggest a much larger population. The predator was likely I. punctatus.

Fish Distribution at Station 6 (C.I.P.)

As noted in the previous section, fish distribution and abundance was found to be very irregular in the area of Station 6, suggesting local effects of the paper mill effluent within this station. I therefore selected 6 substations (Fig.7), to determine whether a correlation could be obtained between concentrations of mill discharge and abundance of fishes. Station 5, upstream from the C.I.P. mill, was chosen as a control station for this part of the study to enable comparison of the substation catches with that of an area unaffected by the mill. The effect of the E.B. Eddy mill on Station 5 was considered to be negligible. All fish found in the gill nets were considered; yellow perch and brown bullheads were the most abundant at all substations, comprising 43.6 - 74.4% and 13.3 - 25.0% of the catch respectively.

Of the 6 substations, the three (A_1, A_2, and A_3) along the Quebec shore yielded catches per standard gill net gang which were markedly lower than either the remaining substations (A_4, A_5, and A_6), or the unaffected Station 5 above the effluent (Table 6).

Although pollution affects are evident, it is obvious that the hypothesis of increased abundance of fish with distance from the mill is inadequate to fully explain my data. The additional complicating factor of current flow effects upon downstream dispersal of mill wastes must be considered.

The substations A_1 and A_2, in the C.I.P. channel are subjected to the highest concentrations of mill discharge, and have the lowest catch rates. Below Kettle Island, the currents from the main stream initially restrict the effluent along the Quebec shore. However, dispersal of mill effluent begins below area A_2 and increased turbidity is quickly observed along the Lower Duck Island and Ontario shores. Mackenthum and Ingram (1967) note that the fouling of gill nets by wood pulp and slime growths can lower net efficiency, Although decreased net efficiency may partially explain the decreased catch along the Quebec shore, the condition of the nets retrieved from A_1, A_2, and A_3 were much the same as those from A_6, where yields were considerably higher. In fact, nets from A_1, where the yield was lowest (Table 6), were less clogged than in the other three areas; this additional clogging at A_2, A_3, and A_6 was likely due to slime build-up below A_1, the greatest factor in net fouling. Also nets set at Station 5 and areas A_4 and A_5 were not subject to the effluent effects from the C.I.P. mill due to the water current effect, and were seldom clogged with debris, but the yields were similar to those of area A_6. Thus it is clear that decreased net efficiency is not responsible for the large differences in yield and the data, although inferential, suggest a definite correlation between mill pollution and fish distribution and abundance. However, caution must be exercised in extrapolating further downstream than considered in the study. Chemical analyses in 1969 (Mackie, unpublished) indicate high

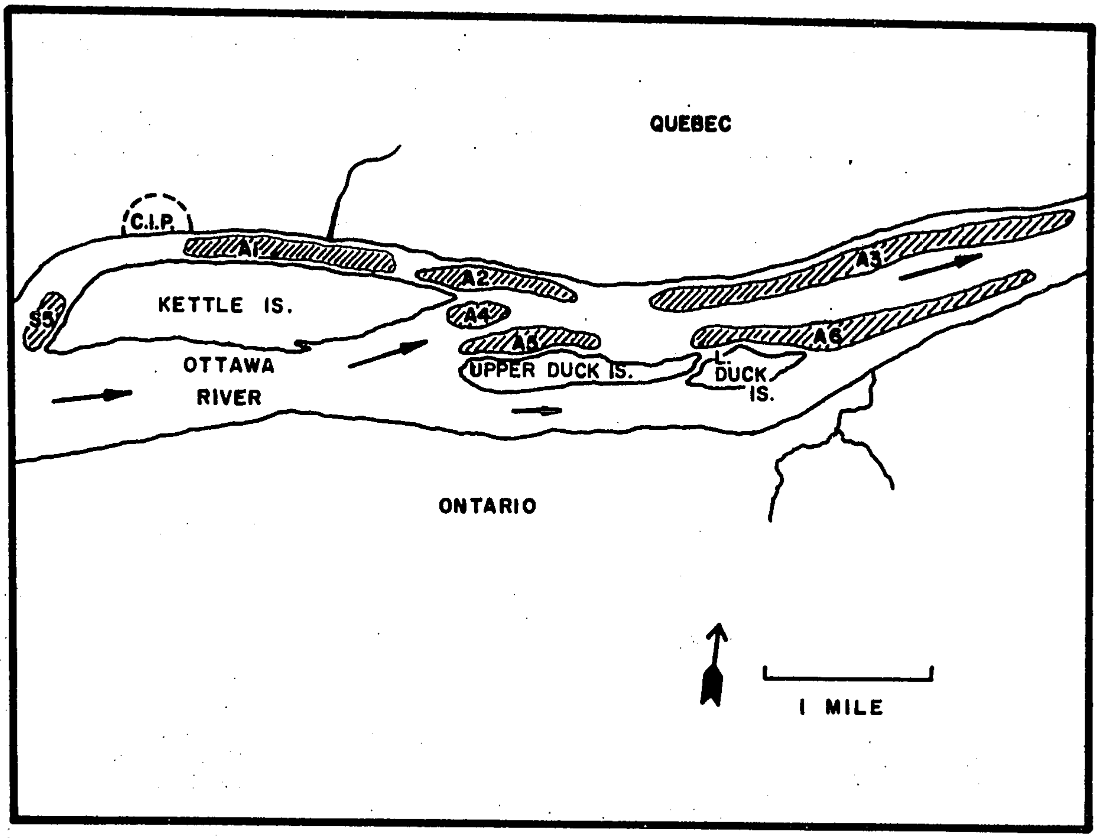
Table 6. Number of fishes (all species) netted at varying distances (Fig. 7) from the C.I.P. mill between May 30 and Sept. 9, 1967, and July 7 and August 8, 1968, per standard gill net gang.

	Station 5	Station 6						Total
		Substations						
	S5	A1	A2	A3	A4	A5	A6	
Total Number	175	39	84	82	71	211	69	731
Total Effort+	7	8	12	6	3	6	3	45
Catch per Unit Effort++	25	5	7	14	24	35	23	16
Range per Unit Effort	7-54	0-12	1-25	2-34	12-34	11-69	5-52	0-69

+ No. of times gill net gangs were set.

++ Catch per gill net gang.

Fig. 7. Substations (shaded areas A_1 to A_6) of the C.I.P. station demarcated to show the effects of effluents on fish distribution. The Kettle Island station (S5) served as a control for this phase of the study.


QUEBEC
C.I.P.
A1
A2
A3
A4
A5
A6
S5
KETTLE IS.
OTTAWA
RIVER
UPPER DUCK IS.
DUCK
IS.
ONTARIO
I MILE

B.O.D. and low O_2 levels further downstream which would likely reduce fish abundance even more.

Acute Effects of Industrial Effluent

The preceding section provided some evidence supporting the hypothesis that effluent from the C.I.P. mill exerts an influence on fish distribution at Station 6. Presumably, the greatest effect on the fishes would be exerted near the effluent outflows, where concentrations of pollutants are highest. To test the extent and degree of the effluent effect on fishes, I performed 5 series of mortality experiments in the C.I.P. channel using yellow perch as the experimental fish. Mortalities in the channel were compared with those at a control station located about 150 yds. upstream of the mill (Appendix 2).

Mortality rates at the surface and bottom differed somewhat, although the highest mortalities always occurred near the Mainland shore (Fig, 8). The 5 series of experiments gave similar results; within 2 feet of the bottom and within 100 yards of the mill discharge, 100% mortality was incurred. But 600 yards downstream, the bottom mortality had dropped to about 10%, similar to that at Kettle Island. Areas along the Kettle Island shore suffered mortalities ranging from 0 - 13% (Fig. 8). Control mortalities averaged 4.5%. Surface mortalities followed a similar trend, although mortalities of 20% were common to the channel 600 yards below the discharge. The control mortality was about 5%.

Data concurrently collected on temperature, pH, dissolved oxygen, and carbon dioxide indicated no abnormal fluctuation during the experiments and thus are not considered as contributory to the mortalities obtained (Appendix 3).

The high initial mortality near the bottom is likely due to the fact that 5 of the 7 effluent outlets are submerged in concrete caissons. Consequently, the greatest concentration of effluent would be found there. Assumably, the majority of the effluent rises to the surface where ultimate dispersal occurs, resulting in a consistently higher mortality rate there.

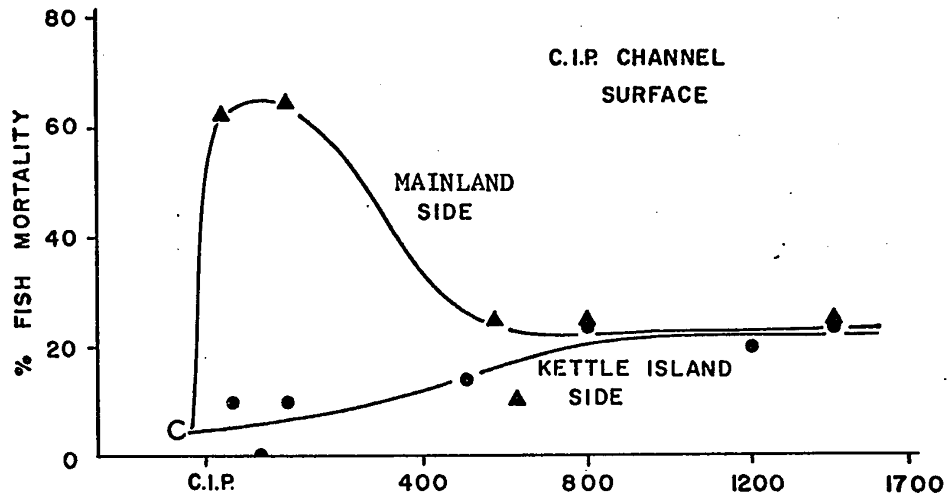
The results indicate that the mill effluents exert a lethal effect on a large percentage of fishes 200 to 300 yd. below the mill outflows. This mortality remains high for some distance along the Quebec shore. The consistent 20% mortality near the surface further suggests that conditions exist which would directly deter fishes from remaining in the C.I.P. channel.

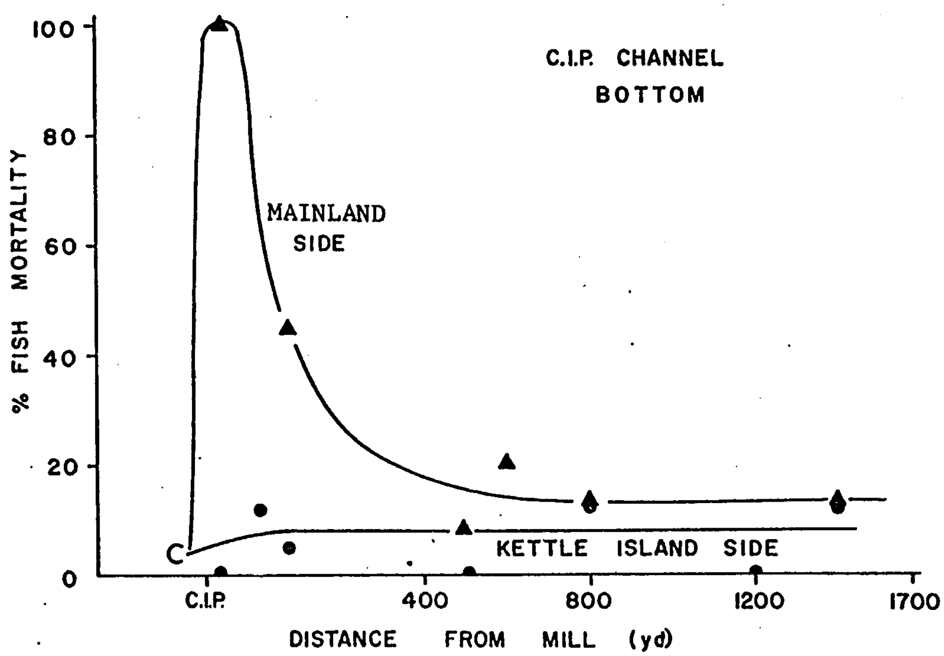
Growth of Yellow Perch

The preceding sections indicate that the waters of the Ottawa River are highly polluted, in localized areas, by industrial and domestic effluent. Industrial pollution has practically eliminated the fish from the C.I P. channel, and limited the abundance and diversity downstream.

Domestic effluents reduce species diversity although the abundance of fish is not necessarily affected. The highest yield of perch, per unit of effort, occurred at Brewery Creek (Table 2), which is highly polluted with domestic wastes. Also, changes in abundance and diversity do not necessarily mean that the growth of species present in the area is inhibited. Some species of fish thrive on moderate amounts of sewage effluent (Katz and Howard, 1954; Trautman, 1933;

Fig. 8. Perch mortality in a series on 'in situ' cage experiments conducted near the Canadian International Pulp and Paper Company (C.I.P.) on the Ottawa River in the fall of 1967 and 1968. The data was averaged where more than one value was obtained. The symbol 'C' indicates the mortality at the control substation. Note the decreasing scale used for the distance below the mill.


C.I.P. CHANNEL
SURFACE
% FISH MORTALITY
80
60
40
20
0
MAINLAND
SIDE
KETTLE ISLAND
SIDE
C
C.I.P.
400
800
1200
1700


C.I.P. CHANNEL
BOTTOM
% FISH MORTALITY
100
80
60
40
20
0
MAINLAND
SIDE
KETTLE ISLAND SIDE
C
C.I.P.
400
800
1200
1700
DISTANCE FROM MILL (yd)

Allen and O'Brien, 1967). The Ottawa River project was primarily concerned with determining the effect of industrial and domestic effluent on yellow perch by comparing various aspects of growth from different areas of the River.

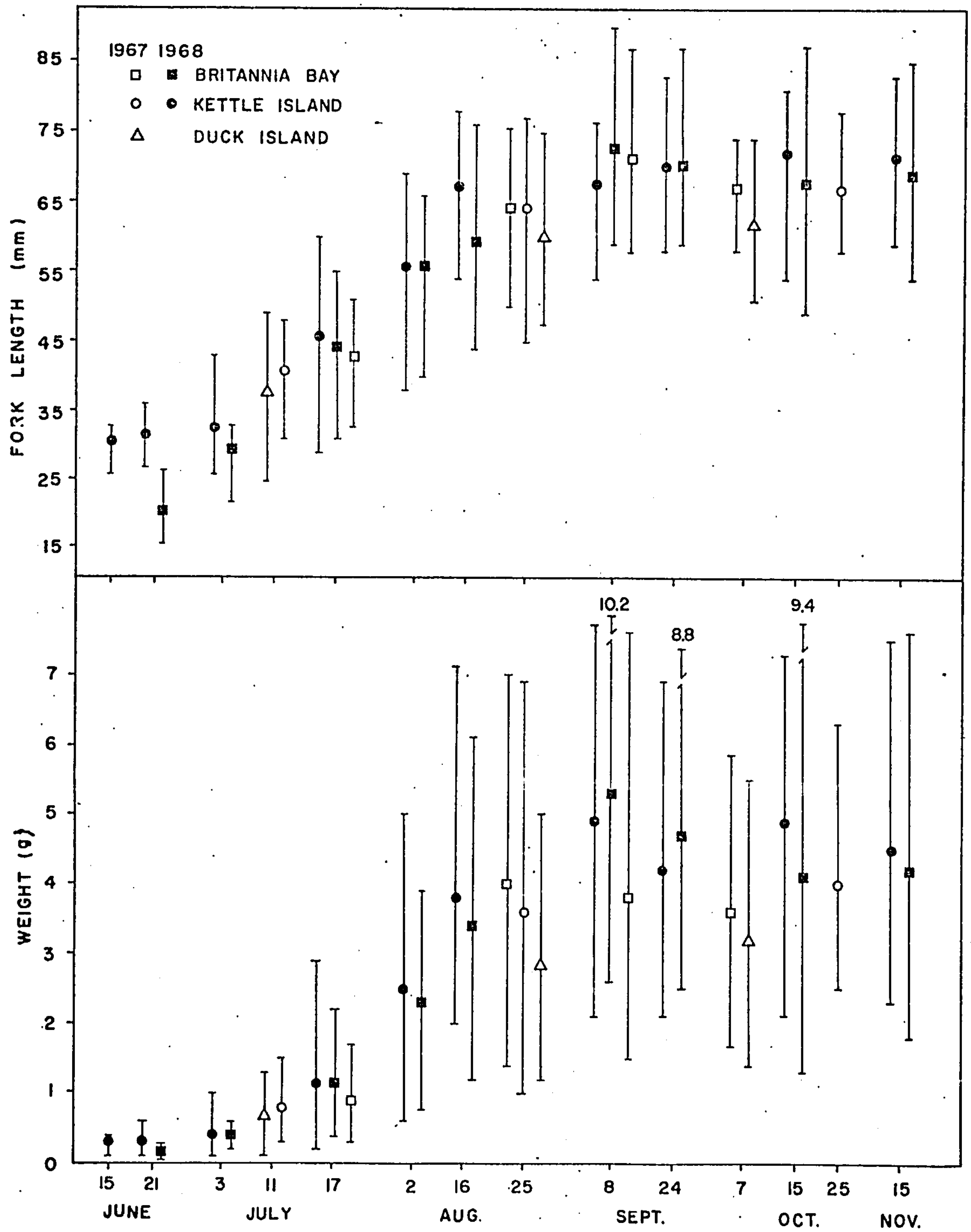
Growth in Young-of-the-Year Perch

Industrial and domestic pollution could influence the growth in length and weight at any stage during the life history of the fish. Consequently, I examined the growth of the 1968 year class from June to November. Figure 9 presents the growth of young-of-the-year perch form Britannia Bay and Kettle Island; young-of-the-year perch could not be caught at the other stations. Included in the figure are the 1967 data from Britannia Bay, Kettle Island, and Upper Duck Island. The 1967 samples contained at least 50 fish for all dates except in October when the sample sizes were 23, 19, and 18 respectively.

In 1968, efforts to sample young-of-the-year perch at all stations began in early June. No 0-year-class perch were found at Upper Duck Island. The first successful collection in 1968 was made at Kettle Island on June 15, almost a week earlier than at Britannia Bay.

Although the magnitude of the size difference is reduced by mid-July, the young perch from Kettle Island retain a slight growth advantage throughout the summer. The majority of growth occurred between June and mid-September, then levelled off in late September. The decrease in the length and weight in later collections were likely caused by migration of the larger young into deeper water, thus

Fig. 9. Growth of young-of-the-year perch in the Ottawa River, 1967 and 1968. The symbols represent the means and the bars, the size range in each sample.


1967 1968
BRITANNIA BAY
KETTLE ISLAND
DUCK ISLAND
FORK LENGTH (mm)
85
75
65
55
45
35
25
15
WEIGHT (g)
7
6
5
4
3
2
1
0
10.2
8.8
9.4
15
21
3
11
17
2
16
25
8
24
7
15
25
15
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.

making them unavailable for seine collections in October and November.

On comparison, the 1967 data suggest that the growth rate in the 0-year-class was slightly better in 1968. The differences were most noticeable at the end of the summer. Again Kettle Island fish had initially faster growth than at Britannia Bay. The relative sizes of perch collected early in the seasons and the dates of the first successful collections suggest that normally perch from Britannia Bay hatch later than in the lower river.

It should be noted that the data from Duck Island revealed a slower growth rate than either Kettle Island or Britannia Bay. Since the Duck Island seining station was influenced by the waters from the C.I.P. mill, the industrial effluent may have influenced this decreased growth rate.

Growth History

If the growth of young-of-the-year perch can be inhibited by industrially polluted water, important information on the present populations of the River may be obtained by examining their growth history. Any inflections in the growth histories of perch from the six stations may well explain any differences in the growth of the present populations.

Body Length-Scale Length Relationships

The body length - scale length relationships were found by regressing fork length against the antero-medial radius of selected scales of the fish. Regression coefficients, length intercepts, and correlation coefficients as determined by the formula from Miller (1966) are presented in Table 7, where:

Table 7. Body-scale relationships of yellow perch from six areas of the Ottawa River.

Station	Sex	Sample Size	Length Intercept	Regression Coefficient	Correlation Coefficient
Britannia	♀	349	2.824	0.099	0.98
Bay	♂	302	2.835	0.101	0.99
Brewery	♀	298	3.148	0.082	0.96
Creek	♂	272	2.906	0.085	0.96
Gatineau	♀	64	2.656	0.088	0.93
River	♂	132	3.137	0.084	0.96
New Edin-	♀	263	3.421	0.083	0.96
burgh Club	♂	356	3.115	0.086	0.97
Kettle	♀	246	2.961	0.084	0.97
Island	♂	205	2.826	0.086	0.95
C.I.P.	♀	131	2.435	0.089	0.97
	♂	157	2.507	0.089	0.97

$$L = a + cS$$

where L = body length

S = anterior scale length

a and c = constants

The results were essentially straight line regressions as evidenced by the correlations obtained.

Back Calculations

The back calculated lengths of the fish were obtained from the body-scale relationships, following the method outlined by Miller (1966), and shown in Tables 8 to 13. The back calculations show that the mean calculated length of the females exceed those of the males by at least 1 mm in the second year of life, and this difference tends to increase with age.

Historically, as seen in the length increments (Tables 8 to 13), perch from Britannia Bay are slower growing in the first year than at the other stations. This was also observed in the young-of-the-year data. However, after the second year, the mean yearly length increments, and thus the growth rates of Britannia Bay perch generally exceed the growth at the other stations. The Brewery Creek and C.I.P. perch exhibit the greatest decrease in growth rate in the older year classes.

Many fish studies have exhibited the Rosa Lee phenomenon (see Chugunova, 1963; p. 79) in which body lengths calculated from the scales of older fish tend to be shorter than the lengths calculated from younger fish. However it was not observed in the Ottawa River perch. In most cases, the calculated lengths from the older year classes were greater than the lengths calculated from year classes I and II. This situation could be the result of net selectivity (catching small young fish and large old fish). But this

Table 8. Summary of the mean calculated fork length (mm) at each annulus of female (top) and male (bottom) yellow perch collected in Britannia Bay, Ottawa River, for 1967.

Age Group	Number of Fish	Fork Length at Capture, (mm)	Calculated Length at End of Year of Life (mm) 1	2	3	4	5	6
Females								
1	64	91	58					
2	14	128	61	108				
3	12	171	60	113	155			
4	18	200	62	112	157	189		
5	14	211	64	111	155	184	205	
6	5	246	64	114	161	188	206	221
Averages			60	111	156	187	205	221
Growth Increments			60	51	45	31	18	16
Total Number of Fish			127	63	49	37	19	5
Males								
1	55	88	58					
2	15	127	61	106				
3	5	152	57	109	139			
4	5	176	62	104	145	168		
5	5	203	67	108	143	170	187	
Averages			61	106	142	169	187	
Growth Increments			61	45	36	27	18	
Total Number of Fish			85	30	15	10	5	

Table 9. Summary of the mean calculated fork length (mm) at each annulus of female (top) and male (bottom) yellow perch collected at Brewery Creek, Ottawa River, for 1967.

Age Group	Number of Fish	Fork Length at Capture (mm)	Calculated Length at End of Year of Life (mm) 1	2	3	4	5
Females							
1	64	105	69				
2	80	138	77	117			
3	92	166	78	128	155		
4	57	185	75	127	161	178	
5	5	234	72	130	164	190	204
Averages			75	124	157	179	204
Growth Increments			75	49	33	22	25
Total Number of Fish			298	234	154	62	5
Males							
1	37	103	68				
2	69	132	73	111			
3	90	162	80	128	154		
4	67	182	73	119	154	172	
5	9	189	69	111	139	162	176
Averages			74	120	153	171	176
Growth Increments			74	46	33	18	5
Total Number of Fish			272	235	166	76	9

Table 10. Summary of the mean calculated fork length (mm) at each annulus of female (top) and male (bottom) yellow perch collected at the C. I. P. station, Ottawa River, for 1967.

Age Group	Number of Fish	Fork Length at Capture (mm)	Calculated Length at End of Year of Life (mm)					
			1	2	3	4	5	6
Females								
1	39	87	59					
2	24	128	71	111				
3	21	172	78	129	159			
4	42	187	75	129	164	197		
5	4	198	79	129	152	177	192	
6	1	253	92	157	191	209	220	227
Averages			71	125	163	195	201	227
Growth Increments			71	54	38	32	6	26
Total Number of Fish			131	92	68	47	5	1
Males								
1	45	86	63					
2	39	130	70	111				
3	30	156	76	122	148			
4	33	184	74	118	153	173		
5	10	182	65	101	132	155	171	
Averages			70	114	147	169	171	
Growth Increments			70	44	33	22	2	
Total Number of Fish			157	112	73	43	10	

Table 11. Summary of the mean calculated fork length (mm) at each annulus of female (top) and male (bottom) yellow perch collected in the Gatineau River, Ottawa River , for 1967.

Age Group	Number of Fish	Fork Length at Capture (mm)	Calculated Length at End of Year of Life (mm)					
			1	2	3	4	5	6
Females								
1	9	106	68					
2	15	139	73	118				
3	20	162	69	117	152			
4	17	176	72	117	151	170		
5	2	252	59	101	152	176	192	
6	1	247	64	111	164	190	203	211
Averages			70	117	152	172	198	211
Growth Increments			70	47	35	20	26	13
Total Number of Fish			64	55	40	20	3	1
Males								
1	27	102	69					
2	36	132	67	107				
3	40	158	75	122	151			
4	29	181	73	118	151	170		
Averages			71	116	151	170		
Growth Increments			71	45	35	19		
Total Number of Fish			132	105	69	29		

Table 12. Summary of the mean calculated fork length (mm) at each annulus of female (top) and male (bottom) yellow perch collected at the New Edinburgh Club station, Ottawa River, for 1967.

Age Group	Number of Fish	Fork Length at Capture (mm)	Calculated Length at End of Year of Life (mm) 1	2	3	4	5	6	7
Females									
1	40	96	67						
2	29	127	76	112					
3	49	160	81	127	153				
4	116	188	80	128	161	179			
5	21	205	79	129	162	183	196		
6	6	229	73	110	137	170	193	203	
7	2	266	87	131	170	191	211	223	232
Averages			78	125	158	180	196	207	232
Growth Increments			78	47	33	22	16	11	25
Total Number of Fish			263	223	194	145	29	8	2
Males									
1	44	92	70						
2	24	125	74	108					
3	93	159	77	123	153				
4	136	183	77	126	159	176			
5	47	195	75	118	151	173	188		
6	9	231	70	109	143	165	193	209	
7	2	220	70	102	138	165	181	195	206
Averages			75	122	155	175	188	204	206
Growth Increments			75	47	33	20	13	16	2
Total Number of Fish			355	311	287	194	58	11	2

Table 13. Summary of the mean calculated fork length (mm) at each annulus of female (top) and male (bottom) yellow perch collected at the Kettle Island station, Ottawa River , for 1967.

Age Group	Number of Fish	Fork Length at Capture (mm)	Calculated Length at End of Year of Life (mm.) 1	2	3	4	5
Females							
1	23	81	72				
2	17	114	66	101			
3	15	155	78	120	143		
4	15	182	78	128	162	179	
5	4	225	75	134	179	200	212
Averages			73	117	155	185	212
Growth Increments			73	44	38	30	27
Total Number of Fish			74	51	34	19	4
Males							
1	20	85	71				
2	15	115	70	103			
3	11	148	72	113	135		
4	6	167	83	136	162	172	
5	3	197	79	128	159	175	184
Averages			72	112	145	173	184
Growth Increments			72	40	33	28	11
Total Number of Fish			55	35	20	9	3

general decrease in the growth rate at all stations between 1964 and 1967 could also indicate deterioration of the environment. If such a condition exists, then the uniform growth rate at Britannia Bay suggests that the growth in length below the control station is deteriorating more quickly than above. The greatest effect is exhibited at Brewery Creek and C.I.P.

Growth in Length and Weight

Comparison of Males and Females

In most growth studies, some reference is made to the sex ratio of the population. In the yellow perch, extreme variations occur. Schneberger (1935) found a predominance of male fish in Nebish Lake, Wisconsin, with the reverse situation occurring in Weber and Silver Lakes nearby, while Hile and Jobes (1941) and Jobes (1952) found no distinct trend.

Tables 14 and 15 contain the sex ratios in actual numbers and percentages, for each age group of the fish sampled. Great variation occurred between samples, but no general trends appeared. The mean ratios of three stations, Britannia Bay, Brewery Creek, and Kettle Island show a preponderance of females, while at the Gatineau River the New Edinburgh Club, and C.I.P., the reverse occurs. Britannia Bay, the Gatineau River, and Kettle Island exhibit a greater relative abundance of females with increase in age, while Brewery Creek exhibits the reverse. The reasons for the sex ratio differences are not known.

Since the growth in length and weight and the length-weight

Table 14. Sex ratio of yellow perch in the Ottawa River, 1966-68. Some older fish not included.

Year Class and Station	Number of Males	Number of Females	Total	Percentage Males	Percentage Females
Britannia Bay					
1	55	64	119	46	54
2	15	14	29	52	48
3	5	12	17	29	71
4	5	18	23	22	78
5	5	14	19	26	74
6	0	5	5	0	100
Totals and Averages	85	127	212	40	60
Brewery Creek					
1	37	64	101	37	63
2	69	80	149	46	54
3	90	92	182	49	51
4	67	57	124	54	46
5	9	5	14	64	36
Totals and Averages	272	298	570	48	52
Gatineau River					
1	27	9	36	75	25
2	36	15	51	71	29
3	40	20	60	67	33
4	29	17	46	63	37
5	0	2	2	0	100
Totals and Averages	132	63	195	68	32

Table 15. Sex ratio of yellow perch in the Ottawa River, 1966-68. Some older fish not included.

Year Class and Station	Number of Males	Number of Females	Total	Percentage Males	Percentage Females
New Edinburgh Club					
1	44	40	84	52	48
2	24	29	53	45	55
3	93	49	142	65	35
4	136	116	252	54	46
5	47	21	68	69	31
6	9	6	15	60	40
7	2	2	4	50	50
Totals and Averages	356	263	619	58	42
Kettle Island					
1	20	23	43	47	53
2	15	17	32	47	53
3	13	17	30	43	57
4	6	15	21	29	71
5	1	2	3	33	67
Totals and Averages	55	74	129	43	57
C. I. P.					
1	45	39	84	54	46
2	39	24	63	62	38
3	30	21	51	59	41
4	33	42	75	44	56
5	10	4	14	71	29
Totals and Averages	157	130	287	55	45

relationships were studied differences in growth between males and females for these three aspects were examined. Table 16 contains the values of Student's t-test applied to the coefficients of the polynomial equations describing the growth curves. As in the back calculated lengths, the calculated growth curves suggest that female perch grow faster than males (Fig.10).

The significance of these differences for each station, however, are not always consistent for the three parameters analysed. The Gatineau River, C.I.P. and the total lower river samples show significant differences between male and female perch for weight gains, the length-weight relationship, and to some extent for length increments. Britannia Bay and Kettle Island perch show significance only for the length-weight relationships, but not for increase in length or weight. Significant differences between male and female perch from Brewery Creek occur for weight gains and for length increases, while in the New Edinburgh Club samples only significantly different weight gains were found.

Nevertheless, the significance found in the growth differences between sexes at the majority of stations justified the separate analysis of the growth curves.

Comparison of Growth at the Six Stations

The calculated curves for growth in length and weight, and the length-weight relationships are presented in Figures 10 and 12. The coefficients of each regression and their standard deviations are included in Appendix 5, and the associated t-values in Tables 17, 18, and 19.

Table 16. Results of Student's t-test applied to the coefficients of the computed curves comparing male and female yellow perch. Significance at P = 0.05 and P = 0.01 are indicated by the symbols * and ** respectively.

Length Curves	A_0	A_1	A_2
Britannia Bay	0.444	0.724	0.255
Brewery Creek	1.345	1.204	1.645*
Gatineau River	2.091*	1.939*	1.908*
New Edinburgh Club	0.848	0.943	1.404
Kettle Island	1.225	1.027	0.408
C.I.P.	0.912	1.323	1.868*
Total (lower river)	1.181	1.125	2.181*
Length-Weight Relationships			
Britannia Bay	2.141*	2.330**	2.573**
Brewery Creek	0.214	0.482	0.803
Gatineau River	1.554	1.874*	2.178*
New Edinburgh Club	0.055	0.336	0.168
Kettle Island	2.405**	2.824**	3.316**
C.I.P.	3.645**	4.186**	4.556**
Total (lower river)	2.196*	2.726**	3.424**

Table 16 .(con't).

Weight Curves	A_0	A_1	A_2
Britannia Bay	1.554	1.631	0.606
Brewery Creek	1.650*	2.057*	2.919**
Gatineau River	2.108*	2.404*	2.679**
New Edinburgh Club	1.166	1.646*	2.512**
Kettle Island	0.613	0.307	0.689
C.I.P.	2.284*	3.114**	3.950**
Total (lower river)	2.770**	3.824**	5.872**

Growth in Length

Analysis of the length curves adds little evidence in detecting the harmful effects of industrial and domestic effluent to fish growth. Few differences were observed between stations. The length curves for males and females at all stations are presented in Figure 10.

The absence of gross differences in the growth curves necessitated graphic comparisons, to be made only of Britannia Bay (control), with Brewery Creek and C.I.P., the two most polluted stations (Fig.11).

If we compare the lengths of perch from all stations (Fig. 10), in year classes I and V, they would be in the following order of magnitude respectively from the best to the poorest: for males and females of year class I, Brewery Creek, Gatineau River, New Edinburgh Club, Britannia Bay, C.I.P. and Kettle Island; for males in year class V, Kettle Island, New Edinburgh Club, Britannia Bay, Gatineau River, Brewery Creek, C.I.P., while for year class V females the order would be Britannia Bay, Kettle Island, Brewery Creek, New Edinburgh Club, Gatineau River and C.I.P.

The greatest shift in length increases occurs in the male perch (Fig. 10 and 11). Males from Kettle Island have the slowest growth in year class I, but the fastest in year classes IV and V. Male perch from Brewery Creek reveal the opposite trend, from the fastest to the second slowest growth in year class V. The differences between these two most divergent growth curves are not statistically significant (Table 17).

A similar situation occurs in the growth of female perch. Females from Britannia Bay and Kettle Island exhibit the best length increases after year class I, fish from Britannia Bay being the longest in age classes III to V (Fig. 10 and 11).. Although growth at both

Table 17. Results of Student's **t**-test applied to the coefficients of the computed **length** curves of male and female yellow perch. Significance at P = 0.05 and P = 0.01 are indicated by the symbols * and ** respectively.

MALES	Brewery Creek	Gatineau River	N. Edinburgh Club	Kettle Island	C.I.P.	Total lower river
Britannia Bay	1.894 0.289 0.266	1.835 0.532 0.020	0.639 0.140 0.021	0.559 1.202 1.069	1.377 1.799 1.995*	0.740 0.060 0.110
Brewery Creek		0.202 0.529 0.572	1.500 0.280 0.577	1.001 1.219 1.571	3.425** 2.765** 2.442*	
Gatineau River			1.448 0.761 0.273	1.058 0.708 0.949	3.202** 2.746** 2.414*	
N. Edinburgh Club				0.064 1.419 1.385	2.174* 2.747** 3.090**	
Kettle Island					1.787 3.019** 3.055**	
FEMALES						
Britannia Bay	4.097** 2.379* 1.400	4.035** 3.458** 2.664**	2.019* 1.867 1.330	0.356 1.265 1.416	0.036 0.191 0.013	2.164* 1.738 1.204
Brewery Creek		1.704 1.959 1.762	1.786 0.593 0.168	4.047** 0.818 0.261	2.896** 1.696 1.131	
Gatineau River			2.663** 2.310 1.942	4.100** 7.333** 1.313	3.460** 2.890** 2.338*	
N. Edinburgh Club				2.201* 0.352 0.403	1.503 1.297 1.056	
Kettle Island					0.316 0.891 1.206	

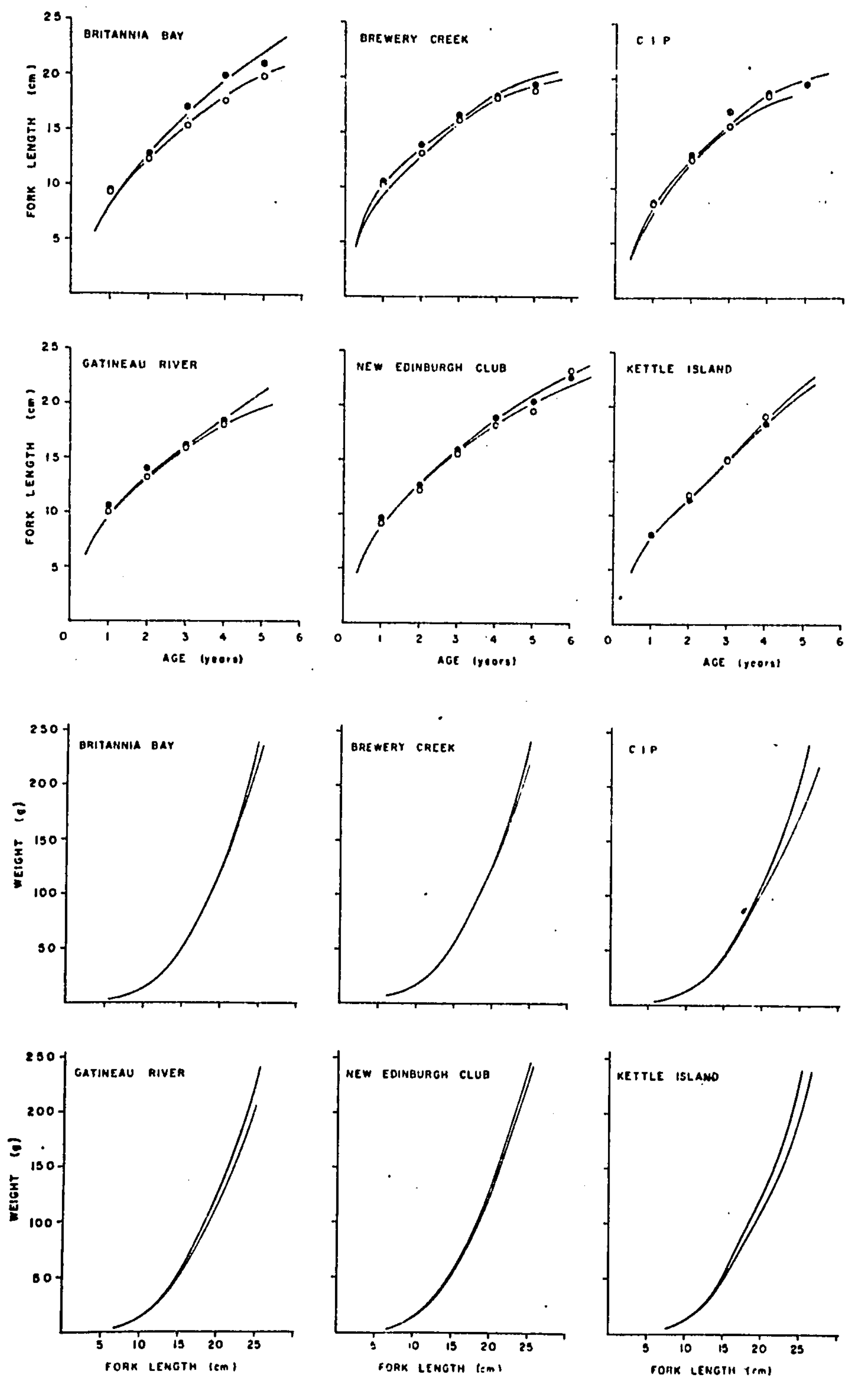
stations is significantly different from that at Brewery Creek, the Gatineau River, and the New Edinburgh Club, in the youngest year classes (Table 11), no significance occurs between older fish. This lack of consistent significance in the differences between growth curves suggests few chronic growth differences between the control population and those of the lower river, or between stations having varying degrees of pollution in the lower river.

Although the growth curves indicate some statistical significance, the lack of consistency makes the significance questionable from a biological aspect. However, some obdervations are notable. The growth of male perch from Britannia Bay is not significantly different from that of the combined samples of the lower river samples (Table 17).. Females from Britannia Bay have significantly slower growth in the younger year classes than the total lower river samples (Table 17) but this is likely due to the quantitative effect of the samples from Brewery Creek and the New Edinburgh Club which combined represent 58.8% of the lower river sample.

After the first year, perch from Britannia Bay and Kettle Island exhibit the best growth curves; Brewery Creek and the Gatineau River exhibit the poorest length increases. Perch from the New Edinburgh Club have length increments intermediate between the extremes. C.I.P. fish also exhibit an intermediate growth in length for year classes I and III, but these increments decrease in subsequent years.

Perch from Brewery Creek and C.I.P. exhibit the poorest growth increases . after year class III. A convergence of the growth curves for the lower river stations occurs in year class III for males, and in year class IV for female perch. Subsequently, growth at

Fig. 10. Calculated length curves (upper half) and length-weight relationships (lower half) for male and female yellow perch in the Ottawa River. Curves were fitted by eye. The circles represent mean length of fish in each year class, females (•) and males (o). In the length-weight relationships, the curves representing the female perch were always the highest.


BRITANNIA BAY
BREWERY CREEK
C I P
GATINEAU RIVER
NEW EDINBURGH CLUB
KETTLE ISLAND
FORK LENGTH (cm)
AGE (years)
BRITANNIA BAY
BREWERY CREEK
C I P
GATINEAU RIVER
NEW EDINBURGH CLUB
KETTLE ISLAND
WEIGHT (g)
FORK LENGTH (cm)

Brewery Creek and C.I.P. is slower than at the other stations.

The length curve for male perch at C.I.P. is significantly different than all other stations (Table 17). However, there is insufficient divergence from the length curves of the other stations (Fig. 11) to imply significantly faster or slower growth of the C.I.P. sample. Possibly there is significantly slower growth at C.I.P. in the older age classes. But the nature of the growth at C.I.P. requires interpretation of such significance as indicating only that the perch sample from C.I.P. is a population distinct from the other stations.

A similar situation exists for the growth of female perch from the Gatineau River. The statistical analysis again can only be interpreted as indicating that the Gatineau River sample has a growth curve distinct from the other stations, not necessarily faster or slower.

Growth in Weight

The comparison of the weight curves at the six stations adds only to the inferential data already obtained. The lack of data on one-year old females at Gatineau River required truncation of that curve for statistical analysis. As in the preceding section, for the sake of simplicity, graphic comparisons of only Britannia Bay, Brewery Creek and C.I.P. are made (Fig. 13). The weight curves of all stations comparing sexes are shown in Figure 12.

If the males from all stations are compared, Brewery Creek perch exhibit the best weight increases although those of the New Edinburgh Club and the Gatineau River are similar to it and not significantly different (Table 18). However neither is the weight curve at Kettle Island, the poorest of the six stations (Fig. 12), significantly different

Brewery Creek and C.I.P. is slower than at the other stations.

The length curve for male perch at C.I.P. is significantly different than all other stations (Table 17). However, there is insufficient divergence from the length curves of the other stations (Fig. 11) to imply significantly faster or slower growth of the C.I.P. sample. Possibly there is significantly slower growth at C.I.P. in the older age classes. But the nature of the growth at C.I.P. requires interpretation of such significance as indicating only that the perch sample from C.I.P. is a population distinct from the other stations.

A similar situation exists for the growth of female perch from the Gatineau River. The statistical analysis again can only be interpreted as indicating that the Gatineau River sample has a growth curve distinct from the other stations, not necessarily faster or slower.

Growth in Weight

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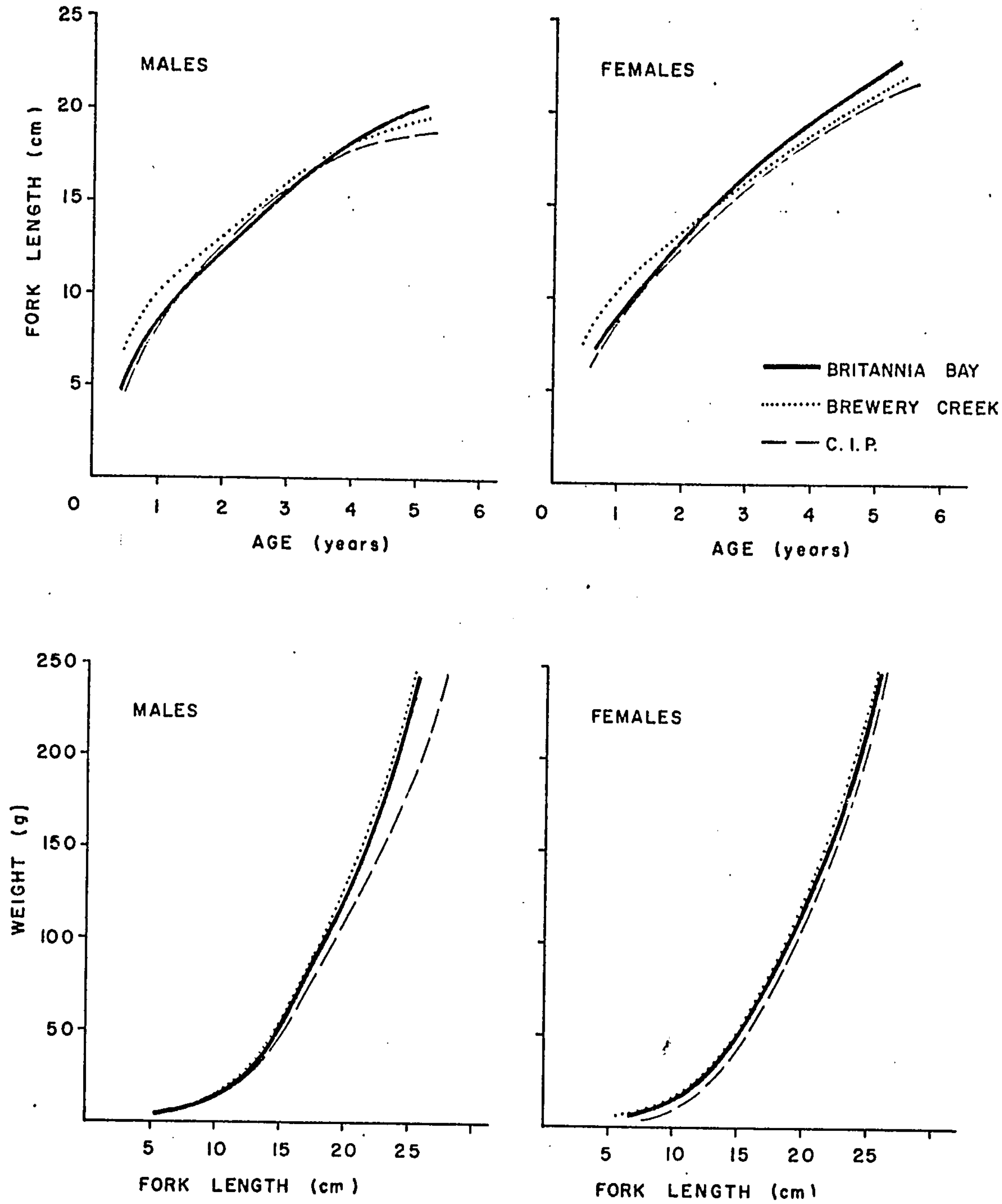
Fig. 11. Comparison of the calculated curves of yellow perch from Britannia Bay, Brewery Creek, and C.I.P. Curves were fitted by eye. Length curves compared in upper part, length-weight relationships in lower section.


MALES
FEMALES
FORK LENGTH (cm)
AGE (years)
BRITANNIA BAY
BREWERY CREEK
C. I. P.
WEIGHT (g)
FORK LENGTH (cm)
25
20
15
10
5
0
1
2
3
4
5
6
250
200
150
100
50

from that of Brewery Creek or the Gatineau River (Table 18). The weight curve of Britannia Bay male perch exhibits slower growth than the curves of Brewery Creek, the New Edinburgh Club, the Gatineau River, and C.I.P. till the third year class, but higher in the fifth year class, and is significantly different from all stations except the Gatineau River and Kettle Island. The weight increases of C.I.P. male perch drop off drastically in the fourth year but differs significantly only from Kettle Island, Britannia and the Gatineau.

Weight differences in female perch are slightly different. By the second and third years, Britannia Bay females exhibit respectively the second highest, and subsequently the best weight gains, though the growth curve is very similar to that at Brewery Creek. Kettle Island females again exhibit the poorest weight gains but the curve does not differ significantly from the other stations (Table 18). The relative positions of the female weight curves from the New Edinburgh Club, the Gatineau River, and C.I.P. are found in the above order, though the curve for the New Edinburgh Club sample drops off after the fourth year and is significantly different from that of the Gatineau River sample (Table 18). The Gatineau River and C.I.P weight curves of female perch are very similar (Fig. 12).

Similar to the length curves, the statistical analyses show neither significantly faster nor slower growth rates. For both sexes, significant differences are found between the two extremes, but statistically there is no difference between the weight curves of the fastest and slowest growing samples. The weight gains of male perch at C.I.P. may be significantly slower than at Britannia Bay in older fish, but generally significance indicated between the growth curves must be inter-

Table 18. Results of Student's t-test applied to the coefficients of the computed weight curves of male and female yellow perch. Significance at $\underline{P} = 0.05$ and $\underline{P} = 0.01$ are indicated by the symbols * and ** respectively.

	Brewery Creek	Gatineau River	N. Edinburgh Club	Kettle Island	C.I.P.	Total lower river
MALES						
Britannia Bay	0.721 2.097* 2.198*	0.418 1.173 1.234	2.308* 3.647** 3.977**	0.101 0.137 0.623	2.414* 3.313** 3.934**	3.047** 4.009** 4.141**
Brewery Creek		0.237 0.635 0.553	1.380 1.043 0.935	0.539 1.844 1.206	1.475 1.317 1.785	
Gatineau River			1.589 1.629 0.689	0.265 1.110 0.546	1.681 1.805 2.082*	
N. Edinburgh Club				1.872 2.965** 2.193*	0.097 0.517 1.284	
Kettle Island					1.965* 2.926** 2.737**	
FEMALES						
Britannia Bay	2.315* 1.767 1.453	2.556* 2.761* 2.233*	0.631 0.576 0.048	0.489 1.190 0.678	1.818 2.213* 1.922	1.348 1.198 0.634
Brewery Creek		1.281 1.549 1.108	1.401 1.304 1.704	1.574 0.387 0.662	0.381 1.082 0.932	
Gatineau River			2.122* 2.454* 2.462*	2.239* 1.696 1.565	1.395 1.265 1.353	
N. Edinburgh Club				0.136 0.726 0.794	1.284 1.894 2.075*	
Kettle Island					1.395 1.265 1.353	

Fig. 12. Calculated weight curves for male and female yellow perch in the Ottawa River. Curves fitted by eye. The circles represent the mean weight of the fish in each year class, females (●) and males (o).

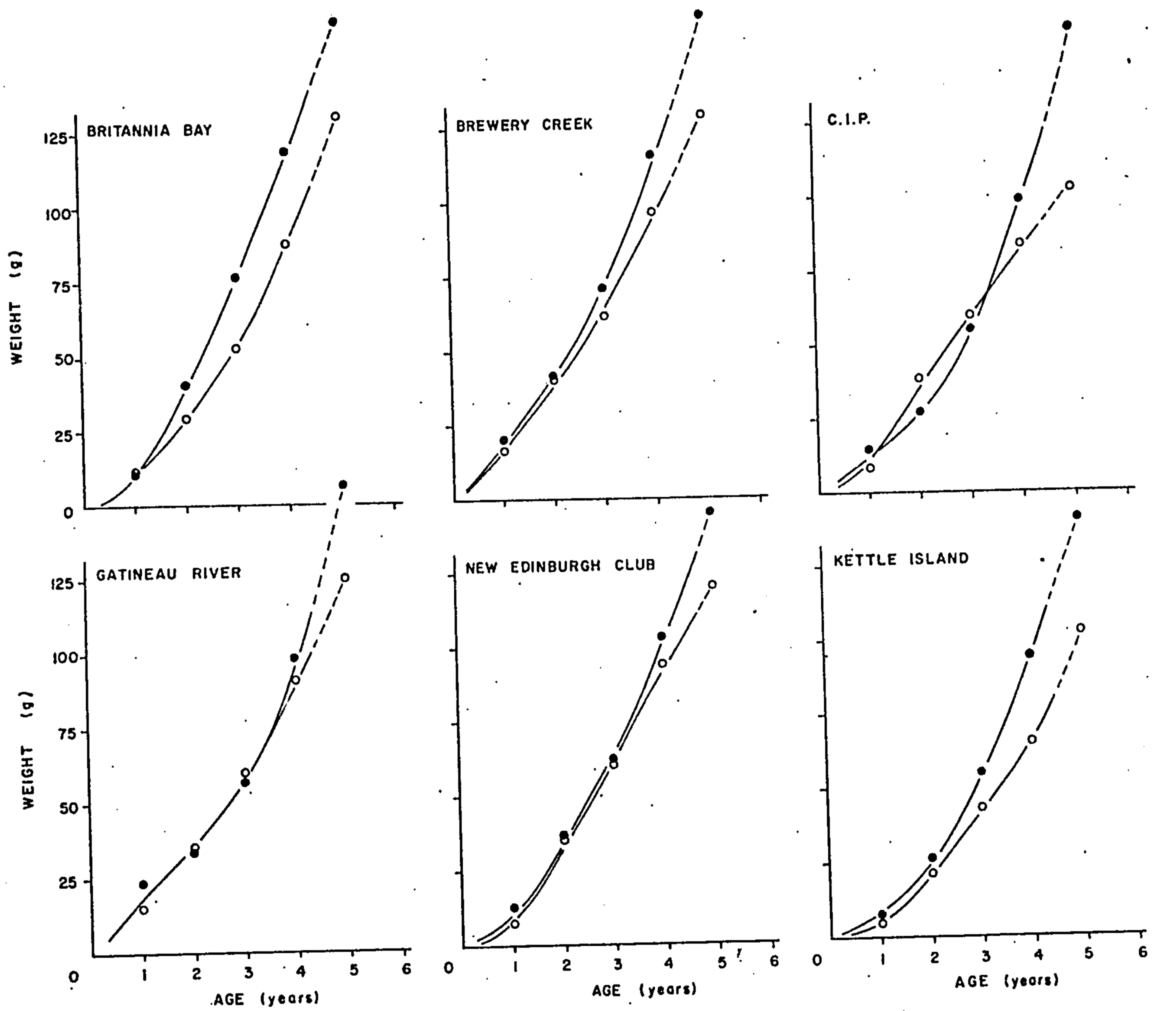
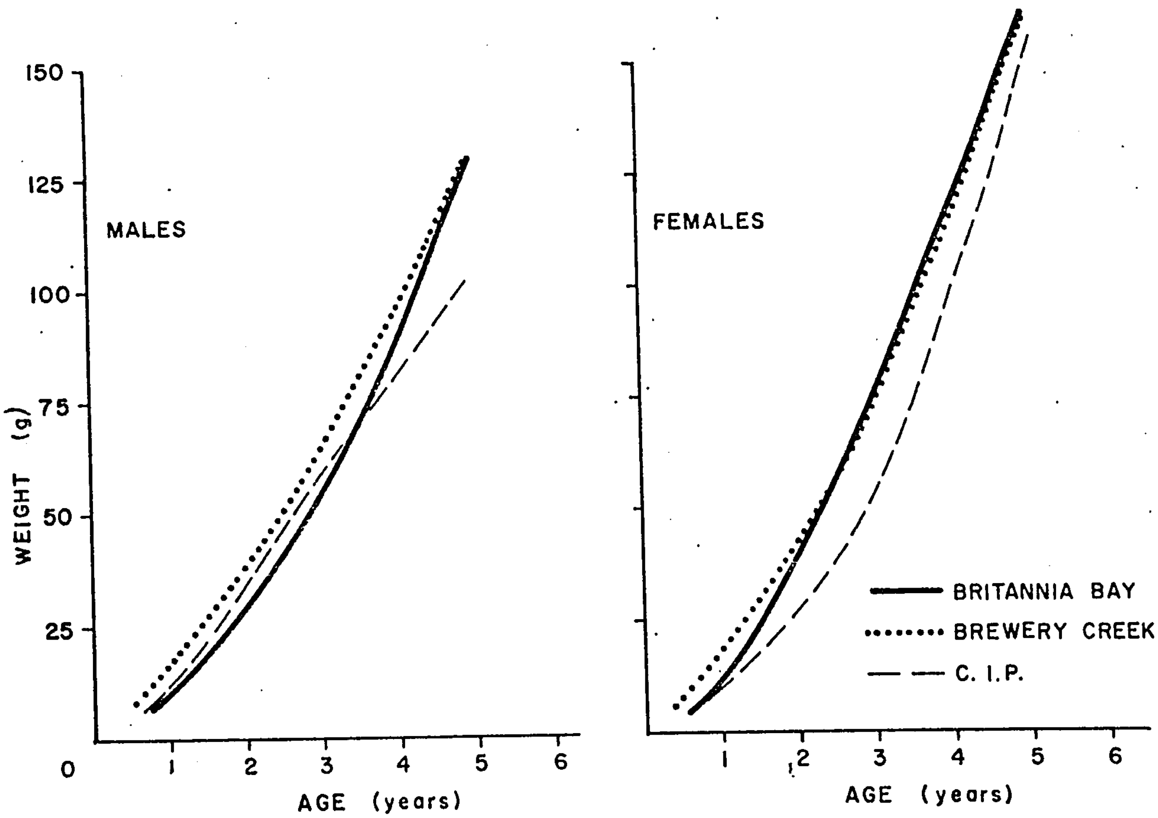

BRITANNIA BAY
BREWERY CREEK
C.I.P.
GATINEAU RIVER
NEW EDINBURGH CLUB
KETTLE ISLAND
WEIGHT (g)
0
25
50
75
100
125
AGE (years)
1
2
3
4
5
6

Fig. 13. Comparison of the calculated weight curves of male and female perch from Britannia Bay, Brewery Creek, and C.I.P. Curves were fitted by eye.



MALES
FEMALES
WEIGHT (g)
150
125
100
75
50
25
0
1
2
3
4
5
6
AGE (years)
BRITANNIA BAY
BREWERY CREEK
C. I. P.

preted as indicating discrete populations only not faster or slower growing ones.

Length-Weight Relationship

The length-weight relationship, and the condition factor are interpreted as expressing the relative well-being of fishes and facilitates comparing fish populations. The calculated curves for the length-weight relationships of all stations are presented in Figure 10. As with the length curves, the similarity of these growth curves necessitated comparing only three: Britannia Bay, Brewery Creek and C.I.P. in Figure 11 to avoid confusion in the graphic presentation.

The length-weight realtionships show few irregularities throughout the size range studied. The perch from Brewery Creek have the best length-weight relationship, while that at the other sites in decreasing order are: Britannia Bay, New Edinburgh Club, Gatineau River, C.I.P., and Kettle Island.

The length-weight relationships on male perch split into two different groups. Statistically, Britannia Bay, Brewery Creek, and the New Edinburgh Club were not different, but all three have significantly better growth than at Kettle Island and C.I.P. (Table 19). Brewery Creek and New Edinburgh Club also differ signficantly from the Gatineau River. The differences between female perch are even less revealing. The Britannia Bay and Brewery Creek length-weight relationships are significantly different from that of the Gatineau River and Kettle Island for older fish. No significant differences occur between the other stations.

Male and female perch from Britannia Bay do not have a

Table 19. Results of Student's t-test applied to the coefficients of the computed length-weight relationships of male and female yellow perch. Significance at P = 0.05 and P = 0.01 are indicated by the symbols * and ** respectively.

MALES	Brewery Creek	Gatineau River	N. Edinburgh Club	Kettle Island	C.I.P.	Total lower river
Britannia Bay	1.486 1.182 1.124	1.735 1.937 1.879	1.445 1.279 1.048	2.556* 2.858** 3.395**	1.725 2.095* 2.532*	0.079 0.303 0.434
Brewery Creek		2.584** 2.610** 2.818**	0.330 0.183 0.317	3.123** 3.326** 2.499*	2.526* 2.699** 3.125**	
Gatineau River			2.740** 2.992** 3.138**	0.387 0.677 1.185	0.121 0.640 0.232	
N. Edinburgh Club				3.515** 3.965** 4.522**	2.564* 2.896** 3.262**	
Kettle Island					0.116 0.163 0.121	
FEMALES						
Britannia Bay	0.284 0.120 0.123	1.154 1.681 2.288*	0.518 1.067 1.526	1.946 2.141* 2.616**	1.475 1.186 1.421	1.161 1.528 1.809
Brewery Creek		1.299 1.513 2.024*	0.738 0.886 1.314	2.014* 1.915 2.447*	1.595 1.016 1.255	
Gatineau River			0.732 0.814 0.966	0.275 0.169 0.255	0.094 0.598 0.716	
N. Edinburgh Club				1.328 1.150 1.310	0.869 0.203 0.139	
Kettle Island					0.511 0.872 0.998	

length-weight relationship significantly different from the total lower river population.

Although some significance is shown between some sites, I doubt that it has much interpretive value. Schneberger (1935) found that fish having a good length-weight relationship (XXXXXXXXXXXXXXXXXX) does not necessarily mean that it is growing rapidly. This appears to be true for Ottawa River fish. Brewery Creek consistently has the best length-weight relationship but the rate of growth in length decreases in older fish. Kettle Island has the best growth rate after year class I, but consistently exhibits the poorest length-weight relationship.

Consequently, if the length-weight relationships are used to indicate the suitability of an environment, then any detrimental effects which pollution may cause in the Ottawa River are obscured. Only the result of increased growth at Brewery Creek due to domestic pollution can be observed.

The results obtained from the condition factor are somewhat more revealing.

Condition Factor

The condition factor differs from the length-weight relationship in that the formula for condition approximates the relationship between length and weight. Consequently, the value of K tends to increase with age (Rounsefell and Everhart, 1953). The formula used for calculating K was taken from Bennett (1962):

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

where W = weight (gm.)

and L = total length (cm.)

Although Ottawa River female perch from some stations exhibit a significantly better length-weight relationship than the males, this difference was not similarly observed in the condition factor. Jobes (1952), and LeCren (1951) found that sex or state of maturity had little effect on the value of K. Consequently, the data are combined in Table 20. The Britannia Bay sample exhibits the greatest improvement in the condition factor, stabilizing at 1.46 in the fourth year class. The coefficients for the samples from the Gatineau River, New Edinburgh Club and Kettle Island tend to level off in the second to third year class at 1.30 - 1.35. Perch from Brewery Creek and C.I.P. exhibit the highest (1.40) and lowest (1.22) mean coefficients of condition respectively.

Seasonal Growth

In the previous section, overall growth curves were presented to compare growth between male and female yellow perch, and among various habitats. In order to better understand variations in growth at various ages, it is important to study the seasonal growth of the various year classes.

The summer's growth of Ottawa River perch, examined as increments in scale length, are shown in Figure 14. Insufficient data for some dates necessitated combining results for the sexes. No data is presented for the Gatineau River since most specimens from this station were collected in July. The young-of-the-year data, previously presented, are included for comparison.

At all stations the growth increments, as also observed by Pycha and Smith (1954), decreases progressively with age. The data from Kettle Island and the New Edinburgh Club, suggest that growth

Table **20.** Coefficients of condition for yellow perch from the Ottawa River 1967-68. Sexes combined.

SITE	YEAR CLASS							AVERAGE*
	0	1	2	3	4	5	6	
Britannia Bay	1.02	1.15	1.26	1.34	1.46	1.46	1.46	1.30
Brewery Creek		1.31	1.46	1.40	1.41	1.47		1.40
Gatineau River		1.21	1.28	1.35	1.34			1.30
N. Edinburgh Club		1.22	1.30	1.33	1.33	1.34	1.40	1.30
Kettle Island	1.08	1.19	1.25	1.30	1.28			1.26
C.I.P.	0.96	1.12	1.29	1.22	1.23	1.29		1.22

* Since the value of K increases with age, the averages include only year classes 1-4.

resumes at the same time for most year classes between mid-May and early June. However, the younger fish experience a longer growing season, the majority of growth occuring between June and mid-September, while growth occurs mainly form June to early August for older fish. Jobes (1952) found that in 1928, Lake Erie perch in the I and II year classes had completed 80% of the year's growth by Sept 5, while age class III had stopped growing prior to this date; he presented no data on older fish.

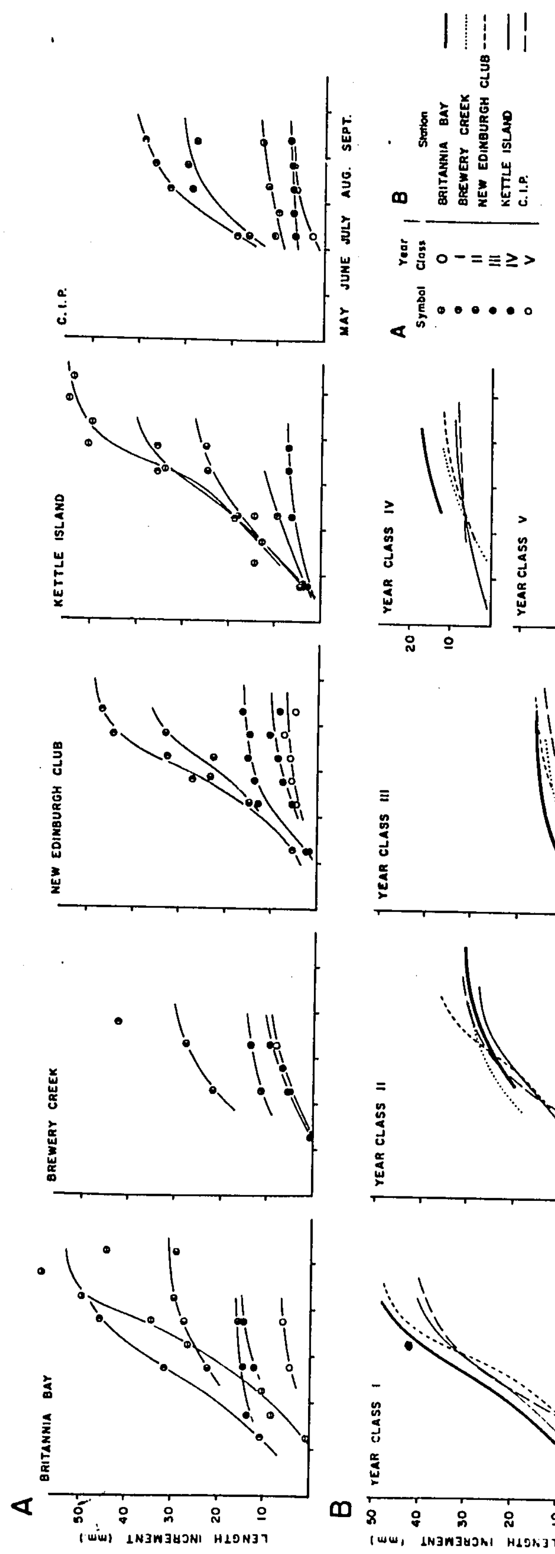
At Britannia Bay growth in the 0-year class started later in the season than that obtained for older fish, though the total summer increment was larger. Subsequent increments at Britannia Bay do not reflect this later hatching date however, the summer increment being greater for most years than at most stations.

Perch from the C.I.P. station exhibit the smallest growth increments for most year classes. These results are similar to those reflected in the calculated growth curves, that is, similar growth increments to the other stations in year classes I and II, but a poorer growth in older fish.

The growth increments of Brewery Creek perch, though greater than at C.I.P., follow a similar trend. Larger than at Britannia Bay in year class II, and likely in class I, the increments at Brewery Creek tend to decrease in subsequent years relative to growth at Britannia Bay. This also was reflected in the calculated growth curves.

The size of the growth increments at the New Edinburgh Club and Kettle Island tend to lie between the largest and smallest increments for the other stations, those at the New Edinburgh Club being generally larger than at Kettle Island.

Fig. 14. Summer growth of Ottawa River yellow perch from May to September, 1967, expressed as increments in scale length (40.7X). The points in part A represent the averagedgrowth over periods of 15 days. The growth of all year classes for each station is given in part A, comparisons of growth between stations in part B. A single dot, above the curve for Britannia Bay, represents the data for Brewery Creek in year class I, part B. Sexes are combined.


A
BRITANNIA BAY
BREWERY CREEK
NEW EDINBURGH CLUB
KETTLE ISLAND
C.I.P.
LENGTH INCREMENT (mm)
50
40
30
20
10
MAY JUNE JULY AUG. SEPT.
B
YEAR CLASS I
YEAR CLASS II
YEAR CLASS III
YEAR CLASS IV
YEAR CLASS V
A
Symbol
Year Class
O
I
II
III
IV
V
B
Station
BRITANNIA BAY
BREWERY CREEK
NEW EDINBURGH CLUB
KETTLE ISLAND
C.I.P.

Stomach Contents

An examination of the stomach contents was primarily conducted to give some indication of food preferences and the availibility of food organisms. However, the results (Tables 21 to 26) may also be helpful in explaining some trends in the growth rates of perch from the various sampling areas.

The stomach contents are considered in relation to year class to determine any shifts in feeding habits throughout the life of the fish. Insufficient data precluded analysis of seasonal variations.. The "debris' category includes wood pulp, other plant material, pieces of mollusc shells and the unidentifiable remains of organisms, in that order of importance. The percentage of debris in the samples from Britannia Bay and the Gatineau River was low for all year classes, the mean values being 4.7% and 3.6% respectively. Fish from all other stations exhibited an increase of debris with age, C.I.P. reaching the highest proportion of debris at 27.7%. In fact, many C.I.P. fish in year classes II to V had greatly distended stomachs due to the amount of wood fibers contained. The accumualtion of such material in the stomach indicates that either the wood fibers are essentially indigestible, or the fish are continually ingesting it. In either case, I doubt that stomachs full of wood fibers could function efficiently, and thus could adversely affect growth.

Although there seems to be basic food types common to all stations on the Ottawa River, there were differences in preference with age, and the availibility of food items. Generally, it was found that chironomid larvae and other dipterans, cladocerans, amphipods, and hemipteran larvae decrease as principal food item with age.

Table 21. Stomach contents of Ottawa River yellow perch showing variations by year class, 1967-68.

Britannia Bay	0		I		II		III		IV		V		TOTAL	
	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample
No. of stomachs	11		20		19		21		15		7		93	
% empty stomachs	18.2		20.0		15.8		14.3		20.0		14.3		17.2	
FOOD ITEM														
Fish	11.1	11.0	18.8	8.2	-	-	50.0	19.0	50.0	30.8	33.3	29.5	27.3	14.6
Arthropoda														
Crustacea														
Amphipoda	55.6	38.6	81.3	28.5	100.0	38.2	83.3	14.3	75.0	17.1	33.3	0.8	79.2	24.5
Cladocera	44.4	15.5	62.5	17.1	-	-	-	-	-	-	16.7	15.7	19.5	6.6
Isopoda	-	-	18.8	3.3	50.0	3.0	33.3	1.6	-	-	-	-	22.1	1.7
Ostracoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Insecta														
Hemiptera	55.6	33.1	6.3	0.4	100.0	20.8	83.3	8.2	-	-	-	-	48.1	10.3
Coleoptera	-	-	-	-	25.0	1.4	-	-	-	-	-	-	5.2	0.3
Odonata	-	-	-	-	-	-	82.0	8.7	25.0	6.8	16.7	0.9	24.7	3.2
Trichoptera	-	-	-	-	25.0	10.4	100.0	34.5	50.0	34.2	66.7	34.5	41.6	18.3
Ephemeroptera	-	-	75.0	33.1	75.0	9.5	50.0	7.1	25.0	1.1	-	-	46.8	10.8
Diptera (misc.)	22.2	1.2	25.0	2.6	-	-	33.3	1.6	-	-	16.7	0.2	16.9	1.1
Chironomidae	-	-	18.8	2.0	-	-	-	-	-	-	-	-	3.9	0.4
Other Arthropods	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mollusca														
Gastropoda	-	-	6.3	0.1	25.0	9.3	-	-	25.0	0.9	-	-	10.4	2.2
Pelecypoda	-	-	-	-	-	-	-	-	-	-	16.7	12.6	1.3	1.0
Annelida														
Oligochaeta	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Debris	11.1	0.6	56.3	4.7	50.0	7.5	50.0	5.0	100.0	8.8	83.3	5.8	57.1	4.7

Table 22. Stomach contents of Ottawa River yellow perch showing variations by year class, 1967-68.

Brewery Creek	YEAR CLASS I % Occurrence	I % Vol. in Sample	II % Occurrence	II % Vol. in Sample	III % Occurrence	III % Vol. in Sample	IV % Occurrence	IV % Vol. in Sample	TOTAL % Occurrence	TOTAL % Vol. in Sample
No. of stomachs	22		15		17		15		69	
% empty stomachs	18.2		13.3		17.7		20.0		17.4	
<u>FOOD ITEM</u>										
<u>Fish</u>	-	-	-	-	-	-	-	-	-	-
<u>Arthropoda</u>										
<u>Crustacea</u>										
Amphipoda	-	-	15.2	2.2	-	-	-	-	1.8	0.5
Cladocera	100.0	78.7	100.0	63.9	35.7	0.8	25.0	7.8	68.4	41.3
Isopoda	-	-	23.0	1.3	35.7	6.2	8.3	1.6	15.8	2.2
Ostracoda	-	-	46.1	0.7	-	-	8.3	0.5	12.3	0.3
<u>Insecta</u>										
Hemiptera	-	-	-	-	-	-	-	-	-	-
Coleoptera	-	-	-	-	7.1	4.5	8.3	0.3	3.5	1.2
Odonata	-	-	-	-	-	-	-	-	-	-
Trichoptera	-	-	-	-	7.1	0.2	-	-	1.8	0.1
Ephemeroptera	-	-	-	-	-	-	-	-	-	-
Diptera (misc.)	77.8	5.8	76.9	9.0	64.3	10.1	50.0	7.7	68.4	8.0
Chironomidae	33.3	5.3	61.5	3.7	78.6	31.8	100.0	28.9	64.9	16.4
<u>Other Arthropoda</u>	11.1	0.1	-	-	-	-	-	-	3.5	0.1
<u>Mollusca</u>										
Gastropoda	11.1	0.7	23.0	1.0	64.3	7.8	75.0	15.4	40.4	5.6
Pelecypoda	-	-	-	-	7.1	0.1	-	-	1.8	0.1
<u>Annelida</u>										
Oligochaeta	44.4	0.4	23.0	0.4	35.7	0.6	33.3	1.5	35.1	0.7
<u>Platyhelminthes</u>	-	-	-	-	-	-	8.3	0.3	1.8	0.1
<u>Debris</u>	89.0	8.9	100.0	17.7	100.0	37.9	100.0	36.3	96.5	23.8

Table 23. Stomach contents of Ottawa River yellow perch showing variations by year class, 1967-68. The 0-year class sample was collected at Duck Island.

C.I.P.	YEAR CLASS 0 % Occurrence*	0 % Vol. in Sample	I % Occurrence	I % Vol. in Sample	II % Occurrence	II % Vol. in Sample	III % Occurrence	III % Vol. in Sample	IV % Occurrence	IV % Vol. in Sample	V % Occurrence	V % Vol. in Sample	TOTAL % Occurrence	TOTAL % Vol. in Sample
No. of stomachs	15		13		14		10		16		4		72	
% empty stomachs	26.7		30.8		14.3		11.1		18.8		25.0		20.8	
FOOD ITEM														
Fish	-	-	-	-	-	-	22.2	11.5	15.2	10.5	-	-	7.0	4.5
Arthropoda														
Crustacea														
Amphipoda	72.8	19.1	66.7	27.6	8.3	0.2	33.3	3.7	-	-	-	-	31.6	8.7
Cladocera	72.8	6.4	55.6	9.6	8.3	0.4	22.2	0.2	-	-	-	-	28.1	2.9
Isopoda	9.1	3.5	22.2	2.5	-	-	11.1	1.5	15.2	0.6	-	-	10.5	1.4
Ostracoda	9.1	0.7	11.1	0.5	-	-	-	-	-	-	-	-	3.5	0.2
Insecta														
Hemiptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera	18.1	9.6	33.3	9.6	-	-	-	-	-	-	-	-	8.8	3.5
Odonata	-	-	11.1	7.6	-	-	-	-	-	-	-	-	1.8	0.1
Trichoptera	-	-	-	-	8.3	0.6	33.3	9.0	38.5	17.9	-	-	15.8	5.6
Ephemeroptera	9.1	1.7	11.1	1.0	-	-	-	-	-	-	-	-	3.5	0.5
Diptera (misc.)	36.4	11.7	22.2	3.0	41.6	3.7	22.2	4.4	23.0	5.9	100.0	16.7	33.3	6.4
Chironomidae	90.9	22.4	77.8	8.7	83.3	32.7	22.2	0.2	61.5	6.8	100.0	24.3	70.2	15.4
Other Arthropods	27.3	3.0	44.4	1.7	8.3	0.1	-	-	-	-	-	-	14.0	0.9
Mollusca														
Gastropoda	36.4	11.5	55.6	7.6	41.6	12.2	77.8	26.9	53.7	22.7	33.3	0.7	50.9	15.5
Pelecypoda	18.1	4.8	11.1	1.0	16.7	1.9	22.2	3.8	15.2	4.3	-	-	15.8	3.3
Annelida														
Oligochaeta	18.0	1.7	22.2	10.2	16.6	0.1	22.2	7.7	-	-	-	-	14.0	3.2
Debris	36.4	4.1	66.7	9.4	91.7	48.1	100.0	31.1	92.3	31.3	66.7	58.3	77.2	27.7

Table 24. Stomach contents of Ottawa River yellow perch showing variations by year classes, 1967-68.

	YEAR CLASS									
	I		II		III		IV		TOTAL	
Gatineau River	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample
No. of stomachs	22		21		14		12		69	
% empty stomachs	31.8		40.0		28.6		58.3		34.8	
FOOD ITEM										
Fish	20.0	6.4	20.0	2.9	-	-	20.0	6.1	15.6	3.9
Arthropoda										
Crustacea										
Amphipoda	26.7	2.9	80.0	5.8	20.0	2.8	20.0	2.4	42.2	4.0
Cladocera	86.7	44.5	86.7	21.3	-	-	-	-	57.8	21.9
Isopoda	13.3	1.0	60.0	1.9	70.0	24.2	80.0	12.3	48.9	7.9
Ostracoda	-	-	-	-	-	-	-	-	-	-
Insecta										
Hemiptera	-	-	-	-	-	-	-	-	-	-
Coleoptera	-	-	-	-	20.0	0.9	40.0	1.4	6.7	0.6
Odonata	-	--	-	-	20.0	0.6	40.0	14.2	8.9	1.6
Trichoptera	26.7	5.9	66.7	8.5	100.0	42.8	80.0	46.6	62.2	19.8
Ephemeroptera	20.0	1.0	73.3	10.7	50.0	12.5	20.0	2.0	44.4	6.9
Diptera (misc.)	73.3	24.8	100.0	31.8	40.0	2.4	-	-	66.7	19.7
Chironomidae	80.0	7.5	100.0	14.0	30.0	2.2	20.0	0.2	68.9	7.8
Other Arthropods	-	-	-	-	-	-	-	-	-	-
Mollusca										
Gastropoda	-	-	-	-	-	-	40.0	5.9	4.4	0.1
Pelecypoda	-	-	-	-	20.0	4.7	20.0	6.9	6.7	1.8
Annelida										
Oligochaeta	20.0	5.9	-	-	-	-	-	-	6.7	0.1
Debris	66.7	2.2	66.7	3.0	70.0	7.0	40.0	2.0	64.4	3.6

Table 25. Stomach contents of Ottawa River yellow perch showing variations by year class, 1967-68.

New Edinburgh Club	YEAR CLASS I		II		III		IV		V		TOTAL	
	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample
No. of stomachs	14		17		18		16		11		76	
% empty stomachs	21.4		17.6		22.2		25.0		18.2		21.1	
FOOD ITEM												
Fish	-	-	-	-	-	-	8.3	7.1	11.1	8.7	3.3	2.7
Arthropoda												
Crustacea												
Amphipoda	27.2	12.4	-	-	-	-	-	-	-	-	5.0	2.3
Cladocera	18.1	15.2	28.5	2.6	-	-	8.3	1.5	-	-	11.7	3.7
Isopoda	45.0	6.3	57.1	6.3	42.8	16.5	33.3	10.8	-	-	38.3	8.6
Decapoda	-	-	-	-	-	-	-	-	11.1	8.2	1.7	1.2
Insecta												
Hemiptera	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera	-	-	-	-	-	-	-	-	-	-	-	-
Odonata	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera	9.0	0.4	57.1	17.5	71.4	30.0	66.7	30.1	11.1	3.4	46.7	17.7
Ephemeroptera	18.1	8.9	-	-	14.2	5.8	16.7	8.2	-	-	10.0	4.6
Diptera (misc.)	100.0	20.7	71.4	21.8	50.0	7.4	50.0	7.2	33.3	5.3	61.7	12.8
Chironomidae	100.0	31.9	85.7	17.4	64.2	14.2	25.0	4.1	44.4	19.5	65.0	17.0
Other Arthropoda	-	-	-	-	-	-	8.3	0.4	-	-	1.7	0.1
Mollusca												
Gastropoda	18.1	2.2	42.8	20.8	42.8	16.5	50.0	20.2	66.7	31.7	43.3	17.9
Pelecypoda	-	-	28.5	5.2	-	-	-	-	11.1	1.3	8.3	1.4
Annelida												
Oligochaeta	-	-	-	-	-	-	-	-	-	-	-	-
Debris	27.2	1.8	71.4	8.6	64.2	9.6	66.6	10.4	66.7	22.0	60.0	10.0

Table 26. Stomach contents of Ottawa River yellow perch showing variations by year class, 1967-68.

	YEAR CLASS											
	0		I		II		III		IV		TOTAL	
Kettle Island	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample	% Occurrence	% Vol. in Sample
No. of stomachs	20		14		19		15		11		79	
% empty stomachs	20.0		14.4		15.8		20.0		54.5		22.8	
FOOD ITEM												
Fish	-	-	-	-	-	-	30.7	27.2	40.0	28.1	9.8	7.8
Arthropoda												
Crustacea												
Amphipoda	43.7	12.9	33.3	2.9	12.5	1.2	7.6	0.5	-	-	23.0	4.5
Cladocera	56.2	17.9	33.3	3.1	37.5	1.8	23.0	1.2	40.0	0.5	39.3	6.3
Isopoda	31.2	12.5	33.3	8.4	62.5	1.9	30.7	10.1	20.0	1.7	39.3	7.9
Ostracoda	-	-	-	-	-	-	-	-	-	-	-	-
Insecta												
Hemiptera	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera	18.7	4.5	8.3	4.7	-	-	7.6	0.1	-	-	8.2	2.3
Odonata	6.2	0.5	16.7	5.6	37.5	2.9	15.3	0.8	-	-	18.0	2.2
Trichoptera	6.2	0.1	50.0	10.8	75.0	11.2	38.4	8.6	40.0	20.8	42.6	8.6
Ephemeroptera	6.2	3.4	8.3	0.8	25.0	7.0	15.3	5.2	20.0	0.8	14.8	4.0
Diptera (misc.)	6.2	0.3	-	-	-	-	-	-	-	-	1.6	0.1
Chironomidae	68.7	34.1	91.6	19.9	87.5	17.6	30.7	7.0	40.0	18.3	68.9	20.6
Other Arthropods	-	-	33.3	1.6	12.5	1.2	7.6	0.4	-	-	11.5	0.7
Mollusca												
Gastropoda	13.3	3.4	41.6	9.5	87.5	39.1	23.0	23.0	80.0	10.5	54.1	15.9
Pelecypoda	-	-	-	-	-	-	-	-	60.0	2.2	4.9	0.2
Annelida												
Oligochaeta	-	-	8.3	0.1	-	-	7.6	0.1	20.0	0.3	4.9	0.1
Debris	100.0	11.6	91.6	32.5	100.0	16.2	69.2	15.9	100.0	17.0	93.4	18.4

Cladocerans are the most universal food of the O and I year classes, representing as much as 78% of the stomach contents. Isopods, gastropods, trichoptera larvae, and fish increase in importance with age. The main transition occurs between the second and third years.

It is notable that chironomid and other dipteran larvae, which are taken by all year classes and contribute as much as 20% each to the total stomach contents of perch in the lower river, have a negligible contribution at Britannia Bay. Gastropods, a principal food item in older fish, and also contributing to all year classes in the lower river were seldom consumed in Britannia Bay, or the Gatineau River. Amphipods and hemiptera nymphs, representing almost 25% and 10% respectively of the total stomach contents at Britannia Bay, were seldom taken at most lower river stations. Mayfly and damsel fly nymphs were regularly found in Britannia Bay stomach samples, to a lesser extent at the Gatineau River, Kettle Island, and the New Edinburgh Club, and were essentially absent in C.I.P. and Brewery Creek stomach contents. Fish or fish larvae were utilized as food items by most year classes at Britannia Bay and the Gatineau River, but only taken by older fish at other stations.

If we can infer that the percentage volume of a food item in the stomachs of fish reflects the abundance and thus diversity of organisms in an area, then pollution effects are evident. Britannia Bay fish exploit a greater variety of organisms as major food sources than any other station. This indicates a greater diversity and relative abundance of organisms in Britannia Bay. The major food sources found at the other stations: dipterans, chironomids, and gastropods, are negligible as food items in Britannia Bay. The diversity of food items in the lower river is related to the degree of pollution at each station, the extreme cases being Brewery Creek and C.I.P., each having only 2 or 3 major food sources. The other stations, which are less affected by pollution than Brewery Creek and C.I.P. have a diversity intermediate between them and Britannia Bay.

The feeding habits of Brewery Creek and C.I.P. perch may account for their decreased growth rate in year classes IV and V. Perch from C.I.P. feed mainly on chironomids and the largely indigestible gastropods;[3] they also tend to accumulate large amounts of wood pulp in their stomachs. Brewery Creek perch rely mainly on the relatively small cladocerans and chironomids for food. Searching and feeding on such small organisms, though beneficial to growth of young fish in Brewery Creek, may be energetically inefficient for older perch. The small body size of prey organisms would necessitate a greater energy expenditure by large fish in obtaining a sufficient amount of food. Consequently, the amount of energy available for growth would decrease. At the other stations, availability of more diverse food items may allow the fish to prey on larger food items such as other fish, tricoptera, ephemeroptera, and odonata nymphs. If this is so, the energy expenditures would be less for the volume of food obtained and would not result in such a decrease in growth rate.

[3] That gastropods are largely indigestible was indicated by the predominance of intact shells found in the intestinal tract.

DISCUSSION

The Ottawa River carries a heavy organic load at all times (LeSauteur, 1967). However, severe pollution of the river does not occur above the cities of Ottawa and Hull (Piché, 1954; LeSauteur, 1967). The great quantities of industrial and domestic effluent entering the river at this point and further downstream (Thomas, 1952; Piché, 1954) obviously affect the ecological situation of the whole system. Since an intensive examination of the whole system would be extremely difficult, it is imperative that localized studies relate water quality data with more informative biological criteria, such as the abundance, distribution and diversity of the river fauna above and below various pollution points, and the effects on the life history of a single species of organism.

This I have tried to do for six locations on the Ottawa River near Ottawa and Hull, using the growth of yellow perch as an index for comparison. In pursuing this aim I have examined the following: growth of the young-of-the-year perch for possible effects on the juveniles, the growth history of the perch, seasonal growth, and diet variations by analysing stomach contents. Other aspects of the effects of pollution were noted in the general distribution and abundance of fishes in the area, and in distributional and experimental investigations below the C.I.P. mill.

The discussion will be primarily devoted to the Brewery Creek and C.I.P. stations, since these are the most polluted. Reference will be made to the other lower river stations only to clarify an observation or to indicate gross difference from the control station at Britannia Bay.

Water Quality

My coliform data generally agrees with the results of LeSauteur (1967): Britannia Bay is relatively unpolluted compared to the lower river stations; the Quebec side of the Ottawa River has higher coliform counts than the Ontario side; high levels of pollution persist on the Quebec side for some distance below Kettle Island.

Previous studies on the water chemistry (Thomas, 1952; Piché, 1954; LeSauteur, 1967) indicated a decrease in dissolved oxygen level accompanied by an increase in the biochemical oxygen demand (B.O.D.) as they sampled downstream from Ottawa and Hull. Their records of dissolved oxygen levels as low as 3.0 ppm and B.O.D. values up to 5.0 ppm are similar to results obtained by Mackie in 1969 (pers. comm). The present study however, was designed to examine the pollution effects closer to the effluent origin and thus did not reveal such extremes below the mill. The 1967-68 data on the water chemistry reveałled little deterioration of the water quality except at the C.I.P. station (Table 4). In the vicinity of the mill effluents especially high levels of CO_2, B.O.D., and phenols occurred, but these were quite localized in occurrence (Fig. 5). A short distance below the mill the levels of all factors analysed were within the range of the other stations.

A bacterial and chemical evaluation of the area then, would suggest that Brewery Creek is heavily polluted by domestic waste, while the C.I.P. channel is industrially polluted in a restricted area around the mill. However, such water quality analyses do not necessarily give a proper perspective of the extent and effects of pollution. The seriousness of domestic pollution is determined by human health standards which may or may not, be relevant to aquatic organisms. The addition of domestic sewage to a water system may enhance productivity due to the increased nutrients available (Smith, 1960). Although domestic pollution can reduce the species diversity or alter the relative numbers of each species present (Trautman, 1933; Jones, 1964; Tsai 1968), the depletion of fish has been attributed mainly to reduction of dissolved oxygen (Katz and Gaufin, 1952; Hynes, 1960). Also fish in domestically polluted areas often exhibit accelerated growth (Katz and Howard, 1954). Chemical analyses are similarly unreliable as the sole criterion since it may underestimate the degree of pollution. Deleterious substances released periodically from industrial mills may not be present during the period of sampling. Often high levels of chemical pollutants are analytically evident only in localized areas near effluent outflows (Waldichuk, 1956; Taylor, 1965). In addition, laboratory studies on pollutants (Doudoroff and Katz, 1950, 1953) seldom indicate synergistic or antagonistic effects of chemicals on the fauna (Cairns, 1966), nor examine sublethal toxicological effects. Consequently, pollution studies should be concerned with the kinds of species present in the area and the relationship between the resident organisms and their environment. Water quality data should be used to supplement the information gathered from biological investigations.

Fish Distribution and Abundance

The fishing suggest low population levels of most fish species thus suggesting a low productivity in the study area. In 175 gill net sets, a total of 3256 fish of 24 species were collected. Although some net selectivity may have occurred since small mesh nets were used on many occasions, the relative low numbers of the smaller forage fishes taken still indicate low productivity. Only approximately 1800 yellow perch specially fished for, were taken by this method. The remainder of the yellow perch along with 10 additional fish species were taken with seine nets. Of the 34 species found in the lower river only 6 species occurred more than twice per unit effort while 10 such species occurred in the Britannia Bay samples. The collections from Britannia Bay (Appendix 4) indicate a greater diversity and abundance of 'clean water' fish, notably Notropis spp., Pimephalus notatus, Percina caprodes, and Etheostoma spp. (Krumholz and Minckley, 1964) than on the lower river. Collections from the three lower river stations of Gatineau River, New Edinburgh Club, and Kettle Island also contained pollution sensitive species not found at Brewery Creek or C.I.P. (Appendix 4). The presence of Micropterus d. dolomieui, and Micropterus s. salmoides suggests lower pollution levels at these stations (Katz and Gaufin, 1952).

Brewery Creek collections differ little from the other stations in the total number of species present (Appendix 4);XXX the highest yields of perch per unit effort (Table 2) occurred here. Although pollution tolerant species predominated the fauna, the addition of organic wastes appears to have enhanced the productivity of this station. The situation at the C.I.P. station is reversed. The faunal depletion is much more severe and extensive than the chemical analysis would suggest. Although no fish were found in the vicinity of the effluent outflows, only 4 species of fish, M. macrolepidotum, P. flavescens, I. nebulosus, and A. rupestris occurred, in limited numbers, in the C.I.P. channel below the mill.

The species diversity increased to 14 types in the 5 mile section below Kettle Island with a considerable increase in abundance (Table 6). But a high level of pollution still was evident since the abundance of most species was low; yellow perch and bullheads comprised 93.9% (73.6% perch, 20.3% bullheads) of the collections. Bullheads, which are highly pollution tolerant (Trautman, 1933; Tsai, 1968; Rounsefell and Everhart, 1953) represented a greater proportion of the C.I.P. catch than at any other station.

The toxicity experiments in the C.I.P. channel help to interpret the significance of both the chemical and distributional work. The high levels of localized pollution indicated by the chemical analyses (Fig. 5), proved lethal to 65-100% of the test perch near the effluent outflows (Fig. 8). These mortality levels explain the absence of fish in the immediate vicinity of the mill. The relatively constant mortality rate of 20-25% observed near the surface as far as 1 mile below the mill were not suggested by the chemical analyses, however, the depleted fish fauna did indicate some inhibiting factor. The relative abundance of fish species further downstream suggests that this factor persists for a considerable distance below the mill. The factor involved is likely chemical in nature, but would be very difficult to isolate due to the complicated interrelationships involved. It is also possible that the component may be present in concentrations too low for detection by the analytical methods used. In addition, the concentration of wood fibers may exert an effect on the life history of various fishes. Smith and Kramer (1963), Kramer amd Smith (1965), and Smith et al. (1965, 1966) found that the respiration of walleye fingerlings and fathead minnows was impaired by various concentrations of fiber suspensions and suggest deleterious effects on the hatching of eggs in the natural environment by Sphaerotilus natans growth. Cairns (1966) and Mackenthum and Ingram (1967) suggest that the blanketing of the substrate by wood fibers may severely reduce the number of benthic organisms, thus eliminating the food supply for fish. Heavy concentrations of suspended wood fibers, as observed in the C.I.P. channel, may also inhibit the feeding of fishes which rely on sight to find prey. The amount of wood fibers found in the stomachs of C.I.P. perch (Table 23) indicates a large degree of nutritiously poor feeding; the slow breakdown rate of the wood fibers in the stomach could inhibit additional feeding.

Growth of Yellow Perch

Home Range

In order to compare the growth of yellow perch between areas of the Ottawa River, some separated by distances of less than 1 mile, it was necessary to establish that I was not dealing with one large mobile population in the lower river. In the tag-release-recapture program in 1968 at Kettle Island, 56.5% recovery occurred. In addition, 6 perch were recaptured more than once and 2 were captured at the same site in the summer of 1969.. These results suggest a restricted home range for Ottawa River Perch. Rodoheffer (1941) found that yellow perch in Michigan lakes exhibit a small home range. Muncy (1962) found that fast stream flow of the Severn River inhibited the movement of yellow perch. Although conceivably the perch could migrate along the shore as Hasler and Bardach (1949) found for perch in Lake Mendota, Wisconsin, two aspects make such movement of doubtful importance in the present study: 1) frequent shoreline migrations could hardly result in such a high recovery rate at Kettle Island; 2) if such movement occurred, the only stations in which interchange would be likely are Brewery Creek and Gatineau River. The virtual absence of fish in the C.I.P. channel and the high mortality of perch caged in the channel should preclude migrations along this section of the Quebec shoreline. Thus we can assume that I was dealing with discrete, and thus comparable yellow perch populations.

Comparison of Growth With Other Areas

I have compared the growth of perch in the Ottawa River with that of other waters in the United States and Canada. Table 27 gives the average calculated length of yellow perch at the end of each year of life by Jobes (1952) for Lake Erie; Hile and Jobes (1942) for Green Bay, Lake Michigan; Carlander (1950) for Lake of the Woods, Minnesota; Grimaldi (1967) for two locations in the St. Lawrence River; and the data for Britannia Bay, Brewery Creek and C.I.P. for the present study. To avoid possible bias in the calculated lengths due to net selectivity, the combined male and female back calculated lengths, corrected to total length, for Ottawa River perch are presented. With reference to the other waters, it is sufficient to say that the published average lengths of the age groups show tremendous variation in the size of fish of the same age. The yellow perch were larger in Lake Erie than in the other areas. Growth of Ottawa River perch is somewhat similar to growth in the St. Lawrence River and Lake of the Woods, although Britannia Bay has the smallest growth increment in the first year. The growth of Ottawa River perch therefore, is comparable to that in some other lakes and rivers.

Growth History of Ottawa River Perch

If, in the history of an aquatic environment, habitat deterioration occurs, the growth history of the fish from that environment will reflect such changes as long as that change affects growth.

Table 27. Comparison of total lengths of yellow perch from several localities with Britannia Bay, Brewery Creek, and C.I.P.

Locality	Average Calculated Length in mm. at each annulus						Reference
	1	2	3	4	5	6	
Lake Erie	94	170	216	241	264	279	(Jobes, 1952)
Green Bay	71	117	160	201	229	259	(Hile and Jobes, 1941)
Lake of the Woods	88	112	161	188	211	230	(Carlander, 1950)
St. Lawrence River							(Grimaldi, 1967)
La Grand Anse	72	122	157	184	214	243	
Iles de la Paix	77	123	156	177	188	205	
Ottawa River							
Britannia Bay	63	115	161	192	211	232	
Brewery Creek	79	128	163	184	195		
C.I.P.	74	125	164	192	195		

All stations on the Ottawa River indicate a decrease in the back-calculated length of perch from 1962 to 1967 (Tables 8 to 13). If we consider the trend to be real, then the relative growth of perch has decreased in that 5-year period. We have already seen that over-population cannot be the cause of the slower growth, thus the effects of pollution are the most likely causes for such deterioration. This hypothesis gains force by the fact that the greatest decreases occur at the C.I.P. station (Table 10). Not being affected by pulp mill wastes from the Eddy mill or domestic sewage from Brewery Creek, the Gatineau River would be expected to be similar to Britannia Bay in growth history, providing pollution is the inhibiting factor. Such is the situation in the present study. Perch in Brewery Creek, the New Edinburgh Club and Kettle Island generally exhibit a greater decrease in length increments than either the Gatineau River or Britannia Bay. Britannia Bay perch exhibit relatively stable growth throughout the study period.

Growth in Yellow Perch

The results of the comparison of growth between male and female yellow perch (Figs. 10 and 12) agree with those of several workers (Carlander, 1950; Hile and Jobes, 1941, 1942; Muncy, 1962), who also observed that female perch grow faster than males. Their data also indicate that this differential generally occurs when perch reach the age of three or four years. The Kettle Island data deviate from this pattern in that male perch show the faster rates (Fig. 10); however, the difference was not significant. Females also exhibited greater weight gains (Fig. 12), significant differences occurring at Brewery Creek, Gatineau River, New Edinburgh Club and C.I.P.

Few other differences were found between the growth of yellow perch from the six stations. Statistical analyses of the curves for length, weight, and length-weight relationship do not show consistent differences. No statistical significance was found for the differences between the most divergent calculated length or weight curves of the six stations. Although significance was found between some of the growth curve coefficients (Tables 17, 18, and 19), many of these same calculated curves overlap or intersect each other at various places throughout the growth of the populations (Fig. 11 and 13). Thus the statistics have indicated only that I am dealing with discrete populations, most exhibiting fluctuations in growth such that each perch population has a distinct growth pattern, but none of which are significantly faster or slower growing than that of the other populations.

Although some consistent significant divergence occurred among the length-weight relationships, this parameter may not be used in indicating differences in the relative growth of perch populations. Schneberger (1935), working with three perch populations in Wisconsin, found that populations having the best length-weight relationship did not necessarily have the fastest growth rate, rather he found an inverse relationship.

Biologically therefore, the differences in the growth curves have little significance relating to the overall growth of the six perch populations. However the growth data does indicate certain trends.

The growth history (Table 8), and the growth curves (Fig. 10) agree that growth of young yellow perch (0 and I year classes) is slower in Britannia Bay than at the lower river stations. But generally, the growth at Britannia Bay in year classes III and IV exceeds that of the lower river. The young-of-the-year data indicate that Britannia Bay perch hatch later than in the lower river (Fig. 9). The definite reason for this later hatching date is not know, but thermal effects of the industrial and domestic pollutions may speed embryonic development in the lower river. Although these data suggest that little growth discrepancy exists by the end of the first summer, the growth history and the growth curves suggest that some difference occurs until the III or IV year classes. The seasonal growth data (Fig. 14) show that the relative growth increments at Britannia Bay exceed that of the other stations in the third and fourth year classes. Therefore, the seasonal growth data enforce the evidence that perch from Britannia Bay grow faster than perch from the lower river in the older year classes. The reasons for this increase in growth at Britannia Bay over that of the other stations could be related indirectly to the degree of pollution. The fact that the greater diversity of fish species in Britannia Bay (Appendix 4) results in greater numbers of perch predators such as _E. lucius_ and _C. v. vitreum_ (Seaburg and Moyle, 1964), _I. punctatus_ (Busbee, 1968; Scott, 1967) and _L. o. oxyurus_ (Scott, 1967). Eschmeyer (1937) and LeCren (1958) have found a close relationship between population density and rate of growth. Thus, as the predation rate of our nets suggest, these predators may limit the population size in Britannia Bay, thus reducing competition and maintaining a good growth rate for perch.

The type and availibility of food organisms could also affect the growth rate. Galbraith (1967) found that yellow perch selectively preyed upon the large size classes of _Daphnia_, thus implying that perch have preferential foods and are capable of selecting such food types. Jobes, (1952), Langford and Martin (1940), Pycha and Smith (1954) and

Tharratt (1959) observed that increase in size of perch was paralleled by an increase in food size. Eschmeyer (1937) and Paloheimo and Dickie (1966) suggest that in the absence of proper food size, the growth of fishes decreases. Such may be the situation in the Ottawa River. Perch from Britannia Bay appear to have a more diverse food supply than the lower river stations, and exhibit a shift from the small crustacea to a diet predominantly of fish and the larger aquatic insect larvae (Table 21). The pollution tolerant isopods and dipterans (Hynes, 1960) prevalent in the lower river, are minor items in the food of Britannia Bay perch. Thus, having a relatively large size range of food organisms, Britannia Bay perch may adjust the size of their prey to their own size increase, thereby maintaining a good growth rate. Lower river perch lack such diversity of food types and the accompanying limitation on the size of prey organisms may prevent similar rates of growth in older fish.

Perch in the Gatineau River, New Edinburgh Club and Kettle Island stations exhibit a somewhat similar situation to Britannia Bay. Although the growth of perch at these stations in the older year classes is slower than in Britannia Bay, they do not exhibit the drop off in growth as do Brewery Creek and C.I.P. perch. It is possible that this intermediate growth in the older fish is correlated with the food availibility at the three stations. Although less diverse than Britannia Bay, a greater variety of food items were taken at these stations than at Brewery Creek or C.I.P. The Kettle Island sample exhibits the poorest growth in length and weight in the I, II, and III year classes (Figs. 10 and 12). The condition factor at Kettle Island is also the second poorest of those areas examined (Table 20). This situation was not predicted by the water quality or distributional data.

However, the slow rate of growth may be an artifact of sampling since most Kettle Island perch were collected with seine nets. Or, the heavy growth of vegetation at this station may have caused poor growth (Swingle and Smith, 1941).

The Brewery Creek station appears to have benefited from the influx of domestic sewage. In Brewery Creek the numbers of perch caught are higher than at the other areas studied (Table 2). The perch exhibit the highest weight gains (Fig. 12), the best length-weight relationship (Fig. 10) and condition factor (Table 20), and the longest perch in the first three or four years of growth. However, a drop-off is observed in the length increases of the older fish. As discussed earlier, the addition of sewage may enhance the growth of fish (Katz and Howard, 1954). Usually, small invertebrate organisms such as chironomids and oligochates and isopods (Rounsefell and Everhart, 1953; Hynes, 1960; Jones, 1964) predominate such areas. Metcalf (1942) also noted that large numbers of cladocera and copepods occurred in domestic sewage which attracted fishes. The stomach contents of Brewery Creek perch illustrate this tendency (Table 22). The dominate food items are cladocera and chironomids with little or no shift to larger prey with age. Although the numbers of such organisms could facilitate fast growth in young perch, the size limitations of these prey could inhibit growth in larger perch. The increase is debris found in the stomachs of older perch (Table 22) may indicate the effects of such food limitations. In the absence of suitably sized prey, the larger perch may be forced to feed indiscriminately to reduce the energy expended in obtaining food. Thus, the amount of debris in the stomach would increase. If such feeding methods did not balance the decrease in energy obtained per organism with the increase in number, then less energy would be available for further growth. These circumstances may explain the decreased growth at Brewery Creek.

At the Canadian International Paper (C.I.P.) station circumstances similar to those at Brewery Creek may explain the decreased growth rate in older fish. As mentioned earlier, the growth of perch at the C.I.P. station is not much different than at the other stations, although length and weight gains tend to be poorer in older fish, and the length-weight relationship (Fig. 11) and condition factor are poorer than at Britannia Bay and Brewery Creek. The reason for the decreased growth in older perch may be due to restricted food size with gastropods, chironomids and amphipods being the main food types (Table 23). The amount of debris in the stomachs again may indicate the feeding methods employed.

However, other factors must be considered in relating growth at C.I.P. station to the other stations. Long-term exposure to sublethal concentrations of chemicals may reduce the growth rate of fishes (Cairns, 1966). Smith, Kramer and Oseid (1966) and MacLeod and Smith (1966) found that prolonged exposure to wood fibers affected the respiratory system, thus possibly decreasing the growth rate of walleyes and fathead minnows (Pimephalus promelas).

SUMMARY

1) Data on several biological parameters were collected during the summers of 1966-68 from the following stations in the Ottawa River: Britannia Bay, Brewery Creek, Gatineau River, New Edinburgh Club, Kettle Island and Canadian International Pulp and Paper Co. All stations were in the vicinity of Ottawa and Hull.

2) Coliform bacterial analyses indicate greater pollution in the lower river than at Britannia Bay. Brewery Creek and localized areas at C.I.P. have the highest bacterial levels.

3) Chemical analyses indicate few differences in water quality between Britannia Bay and the lower river stations. At C.I.P. high concentrations of effluent components exist near the mill outflows but were not so observed further downstream.

4) The distribution and diversity of fish and invertebrates, from stomach contents, show Britannia Bay to be the area least affected by pollution. The Brewery Creek and C.I.P. stations are the most affected. The Gatineau River, New Edinburgh Club and Kettle Island exhibit an intermediate degree of pollution.

5) The C.I.P. station is the most polluted. High mortalities were incurred by perch caged near the mill outflows and continued to be abnormal for some distance downstream. Very few fish were netted in the C.I.P. channel in the three years of the study.

6) The effects of the mill effluent and wood fibers were noticeable for at least 5 miles further downstream.

7) A total of 4351 yellow perch were collected during the three summers. A tagging study suggests that perch have a restricted home range and possibly that the 6 populations are distinct..

8) Dart tags are suitable for tagging yellow perch.

9) The scales were used for age determination and back calculation of growth. Little discrepancy in ages of perch from scales, operculars or otoliths occurred.

10) Back calculations do not indicate the presence of Lee's phenomenon. In Britannia Bay, the growth of yellow perch has been uniform, however, at Brewery Creek and C.I.P. growth over the past 4 years suggests deterioration of the growing conditions.

11) The sex ratio fluctuates and indicates no tendency for the predominance of either sex.

12) Female perch tend to grow faster than male perch beyond the III-year class at most stations. At Kettle Island the reverse occurs, but it is not statistically significant.

13) The inconsistencies observed in the statistical differences between the growth curves suggest a discrete population at each station, not faster or slower growth.

14) Britannia Bay perch exhibit the best growth after the III-year class. This better growth may be correlated with the greater variety of food organisms.

15) Brewery Creek perch exhibit the best growth in the I-III-year classes, but slower growth in older fish. Domestic sewage may enhance the growth of young and inhibit the growth of older perch by altering the type of food organisms available.

16) C.I.P. perch also exhibit a reduction in growth in older perch. But this decrease could be due to chemical and/or physical factors.

17) Gatineau River, New Edinburgh Club, and Kettle Island perch do not exhibit such growth decreases in older perch. This may be correlated with the lesser degree of pollution at all three sites than at Brewery Creek or C.I.P.

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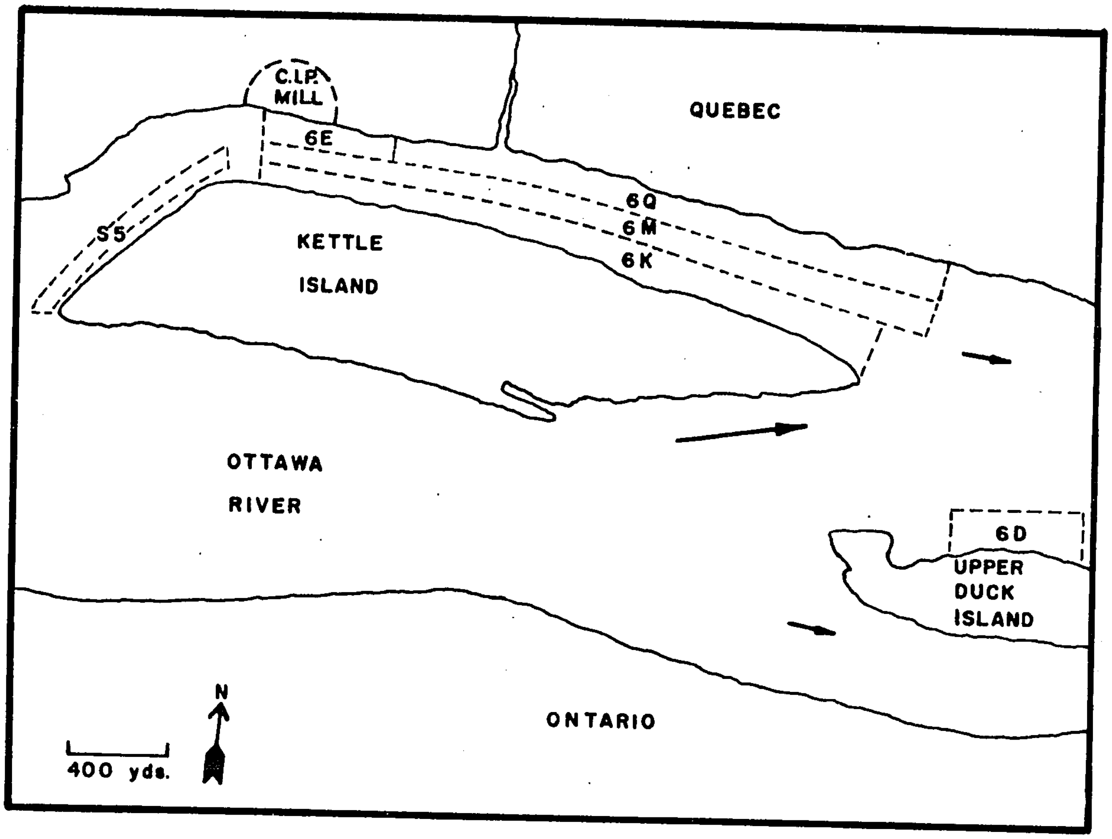
Appendix 1. Subdivisions of the C.I.P. station for water quality analysis: Kettle Island Station - S5; Effluent - 6E; Quebec Shore - 6Q; Middle of Channel - 6M; Kettle Island Shore - 6K; Duck Island - 6D.


C.I.P.
MILL
QUEBEC
6E
S5
6Q
6M
6K
KETTLE
ISLAND
OTTAWA
RIVER
6D
UPPER
DUCK
ISLAND
N
400 yds.
ONTARIO

Appendix **2**. **Yellow** perch mortality in 5 series of overlapping experiments near the C.I.P. mill, Ottawa River, in the fall of 1967 and 1968. Each series was run for a period of 3 days with cumulative daily mortality given below. Series I, II, and III were run on Aug. 29, Sept. 6, and Oct. 11, 1967, series IV and V, on Aug. 16 and Sept. 11, 1968, respectively. The number of fish used per cage in each series is shown in parentheses. The symbols D_0, D_1, and D_2 **show** respectively, the distance (yd.) above the mill, below the mill, and from the nearest shore. No mortality and no additional mortality are indicated by 'N' and 'NA' respectivley.

	Day	Series				
		$I_{(10)}$	$II_{(10)}$	$III_{(12)}$	$IV_{(5)}$	$V_{(8)}$
Control						
D_0			50		50	50
D_2			50		50	25
Mortality						
Surface	1		N		N	1
	2		N		N	NA
	3		N		N	NA
Bottom	1		N		N	1
	2		N		N	NA
	3		N		N	NA

Appendix 2 (con't).

	Day	Series I(10)	Series II(10)		Series III(12)			Series IV(5)			Series V(8)		
Kettle Island Shore													
D_1		150	25			150	500	500	1200	1700	100	800	1500
D_2		30	10			50	40	20	50	50	30	50	50
Mortality													
Surface	1	2	1			N	1	N	N	1	N	N	1
	2	NA	NA			N	NA	N	1	3*	N	1	2
	3	NA	NA			N	NA	1	NA	NA	N	2	NA
Bottom	1	1	N			N	N	N	N	N	N	1	1
	2	NA	N			N	N	N	N	N	N	NA	NA
	3	NA	N			N	N	N	N	N	1	NA	NA
Quebec Shore													
D_1		150	25	600	100	150	500				100	800	1500
D_2		30	10	15	25	50	40				30	50	50
Mortality													
Surface	1	4	N	N	11	4	N				1	1	1
	2	7	N	1	12	5	2				NA	2	NA
	3	9	N	NA	NA	NA	NA				2	NA	2
Bottom	1	4	2	1	6	2	1				2	N	1
	2	NA	10	2	9	5	NA				6	1	NA
	3	NA	NA	NA	12	6	NA				8	NA	NA

* not included in Fig. 8 since value abnormally high.

Appendix 3. Water quality parameters examined during fish toxicity experiments below the C.I.P. mill in 1967 and 1968. Control station was 50 yd. above the mill near the Kettle Island shore. Readings taken twice daily.

Date	Distance below C.I.P. (yds.); Shore	Surface: Temp. °C	Surface: pH	Surface: Dissolved O_2 (ppm)	Surface: Dissolved CO_2 (ppm)
Sept. 6/67	Control	18.3-18.3	6.9-6.9	8.0-8.5	10-11
	50 Quebec	19.2-19.4	6.8-6.9	8.0-8.5	12-15
	550 Quebec	18.3-18.6	6.6-6.7	7.5-7.5	11-12
	550 Kettle	18.3-18.6	6.8-6.8	8.5-8.5	10-10
Oct. 11/67	100 Quebec	10.6-11.1	6.5-6.6	7.0-8.0	10-10
	150 Quebec	10.6-11.7	6.8-6.8	8.0-8.0	5- 7
	150 Kettle	10.6-11.7	6.7-6.8	8.0-9.0	5- 5
	550 Quebec	11.1-11.7	6.6-6.8	8.0-9.0	5- 5
	550 Kettle	11.1-11.1	6.7-6.8	9.0-9.0	5- 5
August 16/68	Control	20.0-20.3	7.0-7.0	7.5-8.0	10-10
	500 Kettle	21.1-21.1	6.7-6.8	7.0-7.5	10-10
	1200 Kettle	20.3-21.1	6.7-6.8	7.5-7.5	10-11
	1700 Kettle	20.0-21.1	6.7-6.8	7.8-7.8	10-11

Appendix 3 (con't).

Date	Distance below C.I.P. (yds.); Shore	Surface Temp. °C	pH	Dissolved O_2 (ppm)	Dissolved CO_2 (ppm)
Sept. 11/68	Control	17.8-18.9	7.0-7.1	7.0-8.0	10-11
	100 Quebec	19.4-20.0	6.8-6.9	7.0-8.0	12-15
	100 Kettle	17.8-18.3	7.0-7.1	7.0-7.5	9-11
	800 Quebec	17.8-18.3	6.8-6.9	7.0-7.5	11-12
	800 Kettle	17.8-18.3	6.9-7.0	7.0-7.5	11-12
	1500 Quebec	17.8-18.3	6.7-6.8	7.0-7.5	10-12
	1500 Kettle	17.8-18.3	6.7-6.8	7.0-8.0	10-12
		Bottom			
Sept. 6/67	Control	18.3-18.3	6.9-6.9	8.5-8.5	10-11
	50 Quebec	18.3-18.3	6.2-6.3	7.0-7.5	11-13
	550 Quebec	18.3-18.6	6.6-6.6	7.0-7.5	11-12
	550 Kettle	18.3-18.3	6.9-6.9	8.0-8.5	11-11

Appendix 3 (con't).

Date	Distance below C.I.P. (yds.);	Shore	Bottom Temp. °C	pH	Dissolved O_2 (ppm)	Dissolved CO_2 (ppm)
Oct. 11/67	100	Quebec	10.8-11.1	6.6-6.7	7.0-8.0	10-10
	150	Quebec	10.6-11.4	6.8-6.9	8.0-9.0	5- 5
	150	Kettle	11.1-11.4	6.7-6.7	9.0-9.0	7- 8
	550	Quebec	11.1-11.4	6.6-6.7	8.0-8.0	5- 5
	550	Kettle	11.1-11.7	6.8-6.8	8.0-8.0	5- 5
August 16/68	Control		20.0-20.3	7.0-7.0	7.0-8.5	10-12
	500	Kettle	20.3-21.7	6.7-6.7	7.0-7.5	10-11
	1200	Kettle	20.0-21.1	6.7-6.7	7.5-8.0	10-11
	1700	Kettle	20.0-21.1	6.8-6.8	7.5-7.5	11-11
Sept. 11/68	Control		17.2-17.8	6.9-7.0	7.0-7.5	10-12
	100	Quebec	17.8-18.3	6.2-6.4	6.5-7.0	10-13
	100	Kettle	17.2-17.8	6.9-7.1	7.0-7.5	10-12
	800	Quebec	17.8-18.3	6.7-6.9	7.0-7.5	11-12
	800	Kettle	17.8-18.3	6.8-6.9	7.0-7.5	11-12
	1500	Quebec	17.8-18.3	6.7-6.8	6.5-7.5	10-12
	1500	Kettle	17.8-18.3	6.7-6.8	7.0-7.5	10-12

Appendix 4. Abundance of fish species at six stations on the Ottawa River, 1966-68. Average abundance per unit effort is grouped into three categories: R (< 1); C (1-2); A (> 2). Seine nets were used only at Britannia Bay and Kettle Island, and these results are separated in the table.

Scientific Name	Common Name	Station+ 1a	1b	2	3	4	5a	5b	6
Icthyomyzon unicuspis	Silvery lamprey								R*
Acipenser fulvescens	Lake sturgeon				R	R			R
Lepisosteus osseus oxyurus	N. longnose gar	R	C	R	R	R			
Osmerus mordax	American smelt	R							
Hiodon tergisus	Mooneye		C	R	R	C			
Carpiodes cyprinus cyprinus	N. quillback carpsucker			R			R	R	
Catostomus commersonii commersonii	Common white sucker		R	C	R	R	R	R	R
Moxostoma anisurum	Silver redhorse		R						R
Moxostoma macrolepidotum macrolepidotum	N. shorthead redhorse		C	C	R	R	R	R	R*
Semotilus corporalis	Fallfish				R		A	R	
Notemigonus crysoleucas crysoleucas	E. golden shiner	A		R	R	R	A	R	

Appendix 4 (con't).

Scientific Name	Common Name	Station+							
		1 a	1 b	2	3	4	5 a	5 b	6
Notropis rubellus	Rosyface shiner	A					C		
Notropis hudsonius	Great Lakes spottail shiner	A							
Notropis heterolepis	N. blacknose shiner	C							
Pimephalus notatus	Bluntnose minnow	R							
Ictalurus punctatus punctatus	N. channel catfish	R	A					R	R
Ictalurus nebulosus nebulosus	N. brown bullhead	C	R	A	R	A	A	A	A*
Esox lucius	N. pike	R	R	C	R	C	C	R	R
Esox masquinongy masquinongy	Great Lakes muskellunge		R		R		R		
Lota lota	Burbot				R	R			
Fundulus diaphanus	E. banded killifish	A					R		
Perca flavescens	Yellow perch	A	A	A	A	A	A	A	A*
Stizostedion canadense	Sauger	R	A	C	C	C		R	R
Stizostedion vitreum	Walleye	R	C	R	R	R		R	R

Appendix 4 (con't).

Scientific Name	Common Name	Station+ 1 a	1 b	2	3	4	5 a	5 b	6
Percina caprodes	N. logperch	A					R		
Etheostoma nigrum nigrum	Central Johnny darter	A							
Etheostoma nigrum olmsteadi	Tessellated Johnny darter	R					R		
Etheostoma exile	Iowa darter	R							
Micropterus dolomieui dolomieui	N. smallmouth bass		R			R	R	R	
Micropterus salmoides salmoides	N. largemouth bass		R				C	R	
Lepomis gibbosus	Pumpkinseed	A	R	C	R	C	A	C	C
Lepomis macrochirus macrochirus	Common bluegill			R		R			
Ambloplites rupestris rupestris	N. Rock bass		R	R	R	R	C	R	R*
Pomoxis nigromaculatus	Black crappie			R	R	R	A	R	R

+ station numbers: 1 - Britannia Bay; 2 - Brewery Creek; 3 - Gatineau River; 4 - New Edinburgh Club; 5 - Kettle Island; 6 - C.I.P.; a - seines; b - gill nets.

* species netted in the C.I.P. channel proper. Single specimen of *I. unicuspis* found in wood pulp and slime accumulated in gill nets.

Appendix 5. Second degree polynomials of the form $y = A_0 \quad A_1x \quad A_2x^2$ were fitted by the method of least squares separately for males and females from each station, and also to the combined samples of each sex from all stations below the control station. The coefficients A_0, A_1, and A_2 respectively, and their standard deviations, are given for the calculated growth curves of length, weight, and the length-weight relationship.

	MALES		FEMALES	
	Polynomial coefficients	Standard deviations	Polynomial coefficients	Standard deviations
Length Curves				
Britannia Bay				
	4.7129	0.7206	4.3036	0.5756
	4.3909	0.7478	5.0558	0.5372
	-0.2639	0.1373	-0.3055	0.0887
Brewery Creek				
	6.3531	0.4799	7.2039	0.4120
	4.1503	0.3687	3.5362	0.3526
	-0.3043	0.0656	-0.1493	0.0676
Gatineau River				
	6.5200	0.6714	9.1178	1.0451
	4.1503	0.5970	1.9595	0.7237
	-0.2273	0.1176	0.0911	0.1185
New Edinburgh Club				
	5.2835	0.5274	5.9436	0.5730
	4.2796	0.2769	3.8410	0.3737
	-0.2609	0.0366	-0.1643	0.0583

Appendix 5 (con't).

MALES		FEMALES	
Polynomial coefficients	Standard deviations	Polynomial coefficients	Standard deviations
Kettle Island			
5.3490	0.8805	3.9860	0.6803
4.2796	0.8076	4.0779	0.5606
-0.2609	0.1509	-0.1184	0.0980
C.I.P.			
3.2682	0.7622	4.3426	0.8982
6.1320	0.6148	4.8861	0.7136
-0.6117	0.1074	-0.3075	0.1224
Lower River Total			
5.2701	0.2179	5.6621	0.2505
4.3451	0.1485	4.0717	0.1924
-0.2792	0.0236	-0.1917	0.0327
Length- Weight Relationships			
Britannia Bay			
33.8230	5.3243	51.4560	6.2819
-8.6065	0.8852	-11.6130	0.9388
0.6527	0.0336	0.7698	0.0308
Brewery Creek			
51.4730	10.6200	54.2880	7.7644
-10.5930	1.4284	-11.4450	1.0385
0.7178	0.0470	0.7642	0.0339
Gatineau River			
17.3770	7.8277	37.5110	10.3210
-5.8420	1.1285	-8.9914	1.2459
0.5448	0.0395	0.6625	0.0371

Appendix 5 (con't).

	MALES		FEMALES	
	Polynomial coefficients	Standard deviations	Polynomial coefficients	Standard deviations
New Edinburgh Club				
	47.1680	7.5454	46.6080	6.9379
	-10.2790	0.9623	-10.2350	0.8861
	0.7001	0.0301	0.7069	0.0274
Kettle Island				
	13.5910	5.8582	34.2030	6.2578
	-4.8292	0.9811	-8.7243	0.9694
	0.4798	0.0383	0.6495	0.0342
C.I.P.				
	12.0960	11.4110	38.6350	6.0057
	-4.5031	1.7469	-9.9588	1.0312
	0.4708	0.0635	0.7003	0.0388
Lower River Total				
	33.3333	3.2480	43.2920	3.1656
	-8.3045	0.4604	-10.0320	0.4355
	0.6367	0.0157	0.7085	0.0150
Weight Curves				
Britannia Bay				
	0.3451	4.0101	-13.6260	8.0455
	5.9276	4.1613	20.6950	7.4455
	3.9878	0.7640	3.1055	1.2398
Brewery Creek				
	-5.5087	7.0601	10.3250	6.5038
	20.2600	5.4233	4.2636	5.5668
	1.2813	0.9654	5.4824	1.0678

Appendix 5 (con't).

MALES		FEMALES	
Polynomial coefficients	Standard deviations	Polynomial coefficients	Standard deviations
Gatineau River			
-3.1142	7.2348	30.0850	13.9930
14.9160	6.4332	-13.0470	9.6893
2.1618	1.2667	7.6012	1.5866
New Edinburgh Club			
-20.1550	7.9252	-5.7798	9.4831
27.3890	4.1615	15.1190	6.1849
0.2427	0.5504	3.0309	0.9640
Kettle Island			
-0.4612	6.9204	-7.5932	9.3469
4.8858	6.3472	7.9449	7.7027
3.1096	1.1860	4.3452	1.3457
C.I.P.			
-21.2450	7.9963	16.3390	14.3830
31.3590	6.4497	-9.4924	11.4260
-1.3684	1.1271	7.5630	1.9599
Lower River Total			
-14.6560	2.8555	-1.6805	3.7144
24.3430	1.9457	11.1410	2.8522
0.5741	0.3097	3.9500	0.4844

END OF REEL

30