FOOD CONSUMPTION, FEEDING HABITS, AND GROWTH OF WALLEYE (*Stizostedion vitreum*) AND SAUGER (*Stizostedion canadense*) IN THE OTTAWA RIVER NEAR OTTAWA - HULL, CANADA

by

Donald M. Osterberg

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To Sue, Kim, and Glen

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ABSTRACT

Food consumption and growth of walleye, Stizostedion vitreum (Mitchill) and sauger, Stizostedion canadense (Smith) were compared. Both the species were caught in the Ottawa River during 1967 to 1972. Their daily feeding periods, feeding behavior, and movement were studied from spring to fall in the field.

Growth of the walleye and sauger in the Ottawa River was the lowest recorded for any water of similar latitude. Slow growth was pronounced in fish older than three years. For example, the mean total lengths of six year old walleye and sauger were 40.2 cm and 29.4 cm respectively as compared to 49 cm (Balch, 1951) and 41 cm (Van Oosten, 1948) for walleye and sauger of the same age from the Great Lakes.

Sauger consume demersal prey due to their sensitivity to light intensity. However, in the Ottawa, River, a lack of sufficient prey in demersal waters caused the sauger to compete ineffectively for food with the walleye and non-Stizostedion predators in the littoral zone of the river. We observed that the emerald shiner (Notropis atherinoides) was the most abundant prey species in the littoral zone, accounting for more than 75% of the diet of the walleye and sauger. Yellow perch (Perca flavescens), also caught in the littoral zone, served as an important secondary food source during periods of low density of the emerald shiner.

Daily food consumption of walleye in the river

decreased from 4.3 to 3.0% of body weight in two to six year old fish. Daily food consumption of the sauger decreased from 3.3 to 2.9% of body weight in two to six year old fish. In the laboratory, two, three, and four year old walleye and sauger, when fed ad libitum, consumed more food per day (4-9% of body weight) than fish of the same age in the river.

Approximately two thirds of the total walleye and sauger moving into the feeding area in the river were caught between sunset and midnight. Most of the remaining one third were caught before 3 a.m.. Daily food consumption and growth of the fish in the river indicated that both species must have fed every night during the growing season. Feeding activity of the walleye peaked in late July and coincided with the highest prey density. Feeding activity of the sauger peaked in August.

In the laboratory, walleye and sauger differed very little with respect to food consumption, stomach and gut evacuation time, efficiency of food assimilation, and growth efficiency. Stomach evacuation at 19°C took an average of 18 hours, and food passed through the entire digestive tract in 48 hours. Ingested calories were assimilated with an efficiency of 92%. Food conversion efficiency for growth ranged between 13 and 15% for two and three year old fish fed at 4.0% of body weight and maintained at 19°C in the laboratory.

Continued disruption of their habitat, e.g. dam construction and increased eutrophication, threatens the balance between the two species and may cause the disappearance of the sauger in the Ottawa River as it did in the St. Lawrence River. Only good fishery management practices can avert this situation.

RESUME

La consommation de la nourriture et la croissance du doré, Stizostedion vitreum (Mitchell) et du doré noir Stizostedion canadense (Smith) de la rivière des Outaouais ont été comparées pour la période de 1967 à 1972. Aussi, les périodes quotidiennes d'alimentation et le comportement durant ces périodes, ainsi que le mouvement furent étudiés sur le terrain, du printemps à l'automne.

Dans les eaux situées à une même latitude, la croissance du doré et du doré noir dans la rivière des Outaouais fut parmi les plus basses enregistrées. Les poissons agés de plus de trois ans avaient une croissance lente; comme exemple, les longueurs totales du doré et du doré noir de six ans étaient 40.2 cm et 29.4 cm respectivement, comparativement à 49 cm et 41 cm pour ces mêmes espèces de la région des Grands Lacs.

Le doré et le doré noir consomment, de manière préférentielle, les proies des eaux profondes, plus particulièrement le doré noir à cause de sa plus grande sensitivité à la lumière. Cependant, dans l'Outaouais, la rareté des proies dans les eaux profondes place le doré noir en compétition pour la nourriture avec le doré et avec les prédateurs autre que Stizostedion dans la zone littorale. Le méné émeraude (Notropis atherinoides) était l'espèce la plus abondante comme proie dans la zone littorale; il composait plus de 75 pourcent de la diète du doré et du doré noir. La perchaude Perca flavescens), capturée aussi dans la zone littorale, sert d'importante source secondaire de nourriture durant les périodes de basse densité du méné émeraude.

La consommation quotidienne de nourriture du doré dans la rivière décroît de 4.3 à 3.0 pourcent du poids corporel, des poissons de deux à six ans. Chez le doré noir, cette consommation décroît de 3.3 à 2.9 pourcent du poids corporel chez les poissons du même âge. Au laboratoire, les dorés et les dorés noirs de deux, trois et quatre ans, nourris ad libitum, ont consommés plus de nourriture par jour (4 à 9 pourcent du poids corporel) que les poissons du même âge vivant dans la rivière.

A peu près deux tiers des dorés et des dorés noirs se déplaçant dans la zone d'alimentation de la rivière, ont été capturés entre le coucher du soleil et minuit. La plupart des autres spécimens furent capturés avant 3 heures a.m. La consommation quotidienne de nourriture des poisons dans la rivière indique que les deux espèces ont dû se nourrir tous les soirs durant la saison de croissance. La recherche la plus active de nourriture chez le doré, vers la fin de juillet, a coincidé avec la présence maximale de proies. Chez le doré

noir, cette période a eu lieu au mois d'août.

Au laboratoire la consommation de nourriture, le temps d'évacuation de l'estomac et des intestins, l'efficacité de l'assimilation de la nourriture, et l'efficacité de croissance diffèrent peu chez le doré et le doré noir. L'évacuation de l'estomac à 19°C prend environ 18 heures, et la nourriture traverse le système digestif entier en 48 heures. Les calories ingérées ont été assimilées avec une efficacité de 92 pourcent. L'efficacité de conversion de la nourriture pour la croissance variait de 13 à 15 pourcent pour les poissons de deux et trois ans, recevant 4 pourcent de leur poids corporel en aliments et maintenus à une température de 19°C dans le laboratoire.

Le boulversement continuel de leur habitat i.e. l'augmentation de l'eutrophication et la construction de barrages, menacent l'équilibre entre les deux espèces et peuvent causer la disparition du doré noir dans la rivière des Outaouais, comme ce fut le cas dans le fleuve Saint-Laurent. Seules de bonnes méthodes d'aménagement des pêcheries peuvent prévenir cette situation.

INTRODUCTION

Walleye, Stizostedion vitreum (Mitchill) and sauger, Stizostedion canadense (Smith) are two closely related members of the perch family that are found in many lakes and rivers throughout North America (Eddy and Surber, 1943). Although these two species have a common range, they do not necessarily occur in the same bodies of water within their range. Walleye usually inhabit large clear lakes, while sauger generally occur in shallow lakes and silty rivers (Hubbs and Lagler, 1947). Coexistence of the two species is not infrequent in lakes and rivers that are large enough to provide a sufficient diversity of hibitats (Nelson and Walburg, 1977; Vasey, 1967). The Ottawa River, once a mesotrophic habitat, had sufficient diversity to permit the walleye and sauger to feed at various depths and on a variety of food species (Dymond, 1939). However, as a result of recent impoundments in the river and other human activities, the Stizostedion spp. now compete for the same food species and these prey species are concentrated in the littoral zone.

Complete competition between two species is rarely tolerated in nature but can be demonstrated in the laboratory. Gause (1934) and Park (1948) found that when two species having exactly the same niche requirements were introduced into the same habitat under the same laboratory conditions, one species was excluded. This concept was later termed the "competitive exclusion principle" by Hardin (1960). Essentially, the principle states that if two non-interbreeding populations occupy the same ecological niche and the same geographic territory, the population which multiplies a little faster eventually will replace the other population. While the theoretical aspects of such a principle may be sound, the application of the principle to a natural situation is difficult because of the number of variables involved.

The Lotka-Volterra model for predicting the outcome of competition between species living in the same space and on the same food can be applied to natural interactions if the population sizes of the interacting species can be determined. However, in studies such as ours, where the relationships of the two species have not been quantified, characteristics of behavior, food consumption and growth have been used to establish the extent of the interaction between the species involved. Interspecific competition is an interaction between two or more species as a result of a need for a shared resource. It may occur between taxonomically distant species but may be more severe between closely related species because of their similar needs. Competition for food sometimes results in an equilibrium adjustment in the daily food consumption of the two species, but more frequently, in one species forcing the other to occupy a different habitat or or to use a different food refuge.

There are many examples in nature where similar species of fish or members of the same genus are able to coexist in the same habitat (Forney, 1974; Newman, 1956; Swenson and Smith, 1976; Winn, 1958). In such cases, ecological adaptations have permitted them to occupy different ecological niches, possess different feeding methods, utilize different foods, or if the food is the same, to feed at different times or places.

The walleye and sauger are somewhat similar in their morphology, behavior and geographic distribution. Their success when coexisting within the same habitat is dependent upon particular conditions, such as prey density, competition, eutrophication, and physical characteristics of the habitat. Walleye feed on pelagic prey in the shallower strata while the sauger feed in the deeper strata on the demersal prey (Swenson, 1977). Limitations in either prey density or habitat variation inhibit diversification in feeding of the two species and tends to increase interspecific competition (Carlander, 1942).

Greene (1934) suggested that some form of competition was the likely explanation for the absence of the sauger from large lakes in Wisconsin where both the walleye and sauger are believed to have once coexisted. It seems reasonable to assume that during the evolutionary divergence of the two species that the walleye gained certain advantages (e.g. feeding, spawning) over its close competitor, the sauger. These advantages probably allowed the walleye to dominate the habitats where the two fish coexisted. The sauger, threatened by exclusion, adapted to a slightly different area of the habitat. This diversity in habitat preference is particularly noticeable where the two species still coexist (Swenson, 1977).

Progressive eutrophication can affect the success of walleye and sauger by rendering preferred habitats unusable, producing a loss in preferred prey species, and affecting reproductive behavior due to the heavy sedimentation of organic matter (Leach _et al._, 1977). Walleye and sauger also show preference for certain but different physical conditions of the habitat such as specific substrate composition, water current, depth, and clarity (Ketchell *et al*., 1977; Nelson and Walburg, 1977). Abundance, growth and distribution of walleye and sauger in rivers can be significantly decreased as a result of cultural eutrophication and impoundments (Nelson and Walburg, 1977; Schmulbach, 1959; Raine, 1967).

Reports on distribution, food and growth of walleye and sauger from large lakes are numerous since these habitats support substantial populations of these fish, which are easily caught with a variety of gear (Forney, 1961). In addition, large lakes are abundant in North America, and research facilities are usually situated in close proximity to these bodies of water. Unless of a major size such as the Mississippi River, river habitats are less frequently reported in the literature with respect to the genus *Stizostedion* and, in particular, the sauger (Addison and Ryder, 1970). Walleye and sauger of certain rivers have been found to be dissimilar to those of lakes in the following: feeding behavior, diet preference, reproductive potential and growth (Schmulbach, 1959). Further investigation of river populations of walleye and sauger is warranted, especially with respect to their competitive interactions.

Five species of the genus *Stizostedion* have been distinguished by Collette (1963). Three species are European, *S. lucioperca*, *S. marina*, and *S. volgensis*, and two are found in North America, *S. vitreum* and *S. canadense*. In North America, each species has two subspecies. The blue walleye

(*S. vitreum glaucum* Hubbs) is a subspecies of the walleye and is found in lakes Erie and Ontario. Certain Montana specimens with very small eyes have been distinguished as *S. canadense boreum* Girard, a subspecies of the sauger.

Svetovidov and Dorofeeva (1963) proposed that the genus *Stizostedion* had its origin in Europe, and that the two North American species evolved from *S. marina*, which is restricted to brackish water. Svetovidov and Dorofeeva (1963) suggest that *S. marina* may have moved along the edges of the land bridge which theoretically occurred in the north Atlantic during the Oligocene and Pleistocene periods. From the coastal waters, the ancestral stock entered the area that is now the Gulf of St. Lawrence and spread throughout the Great Lakes where speciation occurred.

The walleye range is from Labrador and Hudson Bay westward to the MacKenzie River in British Columbia. Southward they are found from the western slopes of the Appalachian Mountains throughout the Great Lakes basin and portions of the Mississippi River drainage south to Alabama. The western boundary extends from Arkansas to Nebraska and north along the eastern slopes of the Rocky Mountains (Hubbs and Lagler, 1947). The sauger has a small geographic distribution and occurs within the range of the walleye. It is found from the Hudson Bay drainage east to Quebec and west to Nebraska. Southward, it ranges through the Great Lakes basin and most of the Mississippi River system (Hubbs and Lagler, 1947). They are scarce throughout most of Wisconsin, and Greene (1934) suggests that they have been unsuccessful in competition with the walleye in this area.

Walleye and sauger are members of the family Percidae. In North America, the walleye is the largest member of the family and is more robust and deeper-bodied than the sauger. Other than size, the walleye and sauger also differ in scale pattern and color. The spiny dorsal fin of the sauger has two or three rows of black dots, which are lacking in the walleye (Scott, 1967). The cheek of the walleye is smooth and mostly scaleless whereas the cheek of the sauger is covered with rough scales. Both species are piscivorous. Both have large eyes and mouths and numerous sharp teeth. The "canine" teeth of both the walleye and sauger are especially conspicuous. Anatomically, the fish differ only in the number of pyloric caecae, the walleye having three long caecae, whereas the sauger has four to seven small caecae (Eddy and Surber, 1943).

Walleye inhabit the larger lakes and rivers throughout its range. Moyle (1954) found the most successful "walleye waters" to be the mesotrophic lakes with total dissolved solids between 50 and 100 ppm. The more fertile eutrophic waters produced populations which were slower growing and were sporadic in their reproductive success. Regier et al. (1969) summarize their discussion of the walleye habitat by noting that they are not very tolerant of oligotrophic or advanced eutrophic conditions, but frequent waters with turbidity between 1 and 3 ppm, summer temperatures between

16 and 27°C and prefer a bottom substrate that is mostly clean rock and sand. Whether or not sauger once inhabited the same large lakes and rivers now occupied by walleye is not known. Sauger populations are now most frequently found in small, shallow lakes, and in silty rivers and their tributaries. Carufel (1963) describes the habitat of the sauger as early eutrophic, having dissolved solids between 300 and 500 ppm and turbidity as high as 18 ppm.

Walleye and sauger spawn in the spring, usually in April or May (Eschmeyer, 1950). The spawning site is either in fast moving water at the base of waterfalls or along rock or gravel covered shoals. Eggs hatch in approximately two weeks and receive no parental care. Except for a short pelagic stage following hatching, the young-of-the-year inhabit the deepest portions of the littoral zone. By the end of the first year of growth, the fish forage either in the littoral zone during periods of darkness or in the sublittoral zone where they remain during daylight. Maturity is reached by both species between 3 and 5 years of age. Walleye reach an average weight of 1.5 to 2.5 kg and sauger seldom average more than 1.0 kg.

When walleye and sauger coexist in the same body of water, their interaction is not necessarily competitive. Habitats in which both species occur are frequently classified as being more favorable to the walleye than to the sauger. For example, walleye were an abundant commercial species in Lake Nipigon, a large northern lake with little turbidity. Sauger were also present in the lake but occupied those portions of the habitat not frequented as often by the walleye (Hart, 1928). Both species also coexist in the Lake-of-the-Woods, but have a different relationship to one another. Carlander (1942) demonstrated a high degree of similarity in the diets and distribution of the walleye and sauger in this lake. He later concluded that competition for food between the two species along with the selective commercial fishing for walleye was causing a decline in the walleye population (Carlander, 1948).

The Ottawa River is a large tributary of the St. Lawrence River. Both rivers have natural and man-made barriers which prevent the movement of fish throughout the system. Although walleye are still found in some areas of the St. Lawrence River, sauger are scarce (Moore, 1934). Walleye and sauger still coexist in the Ottawa River even though the habitat characteristics are more favorable to the walleye. A decrease in the size of the walleye since 1950 has been cause for concern. With possible changes in the productivity of the river brought about by continued modification of the shoreline (e.g. dredging weed-beds and filling in marshlands) the biotic community is no doubt being affected. Cultural eutrophication and impoundments may also be affecting the stability of the habitat and the continued coexistance of the walleye and sauger.

The objectives of this study were to examine food consumption, growth, and behavior of the walleye and sauger in the Ottawa River and to determine whether or not the two species are competing for the same resources. An attempt was also made to determine what effect competition has on the growth and behavior of the two species and the causes for the competitive interaction of the two species in this river environment.

The study was approached primarily from the standpoint of growth and food consumption of the walleye and sauger. Considering all the parameters that can be obtained from a population of fish, age and growth data probably give the broadest indication of the success of its individuals. From age-length and age-weight measurements, values can be derived for condition, age of maturity, life span, mortality, growth and production (Ricker, 1968).

Age and growth measurements can indicate environmental instabilities (Lagler, 1956). The growth of a fish reflects its ability to cope with space restrictions, fluctuations in available food, interactions with other members of the same species, and interactions with other species of the community with which it shares available resources. Since the success of an individual is based on its ability to obtain food energy, anything that might hamper food-getting, e.g. competition, should be reflected in the growth of the individual and should be studied.

Food relationships, in part, determine population levels, rates of growth, and condition of fish. Food also serves as a basis for determining the status of various predatory or competing forms (Lagler, 1956). Food consumption may be a factor which influences the extent to which the Ottawa River walleye and sauger interact. A limited food supply shared by the two similar species could produce subnormal growth rates. Beamish and Dickie (1967) stated that simultaneous studies on distribution and feeding success of fish, in conjunction with metabolic and food conversion measures (in the laboratory and, if possible, in the natural habitat) provide valuable insights into the production processes of the ecosystem.

Although walleye and sauger were observed in the laboratory, an analysis of the food habits for this study is based primarily on observations made in the field. Stomach contents were examined for food types, quantity of food, and the energy content. Feeding behavior was recorded with respect to movement, foraging, and fluctuations in feeding during the growing season.

Our laboratory investigations were designed to determine food consumption, rate of digestion, assimilation, rate of gut clearance, respiration, and growth in the walleye and sauger, and allow for a complete comparison of the two species. These data can then be used to determine whether or not one species gains any advantage through its energetics that might aid in its competitive interaction with other species. Even though food and energetics of walleye have been previously reported to a degree (Hofmann, 1972; Kelso, 1972; Swenson and Smith, 1973), laboratory analysis has been necessary because energetics of the sauger have not been examined and certain relationships between the two species have not been critically compared.

DESCRIPTION OF THE STUDY AREA

Walleye and sauger were collected from the Ottawa River between Lac Deschênes and Lower Duck Island, a distance of approximately 29 km. The Chaudière Falls located at Ottawa probably prevent fish from moving up river into Lac Deschênes (Fig. 1). The study area above the falls is referred to as the upper river and that portion below the falls as the lower river.

The Ottawa River has an average yearly flow of 1236 m^3 per second at the Chaudière Falls (700-2880, range for 30 years). Below the junction of the Gatineau River, the primary tributary of the Ottawa, the average yearly flow is increased by approximately twenty-two percent (personal communication - Dr. R. Warnock, University of Ottawa).

Water temperature of the river is monitored by the Britannia Bay Water Works located two miles west of the Chaudière Falls. Temperature records show a high of 23.0°C and a low of 1.2°C for the three year period between January, 1971, to December, 1973. Mean temperatures for the three years were lowest in February at 1.2°C. By April the mean temperature increased to 4.1°C, and by June to 18.9°C. The highest temperatures were in July and August (mean, 22.1°C) followed by a drop to 14.0°C in October and to 2.9°C in December.

The upper river (Lac Deschênes) is comparatively free of industrial and human wastes, and the water is seldom

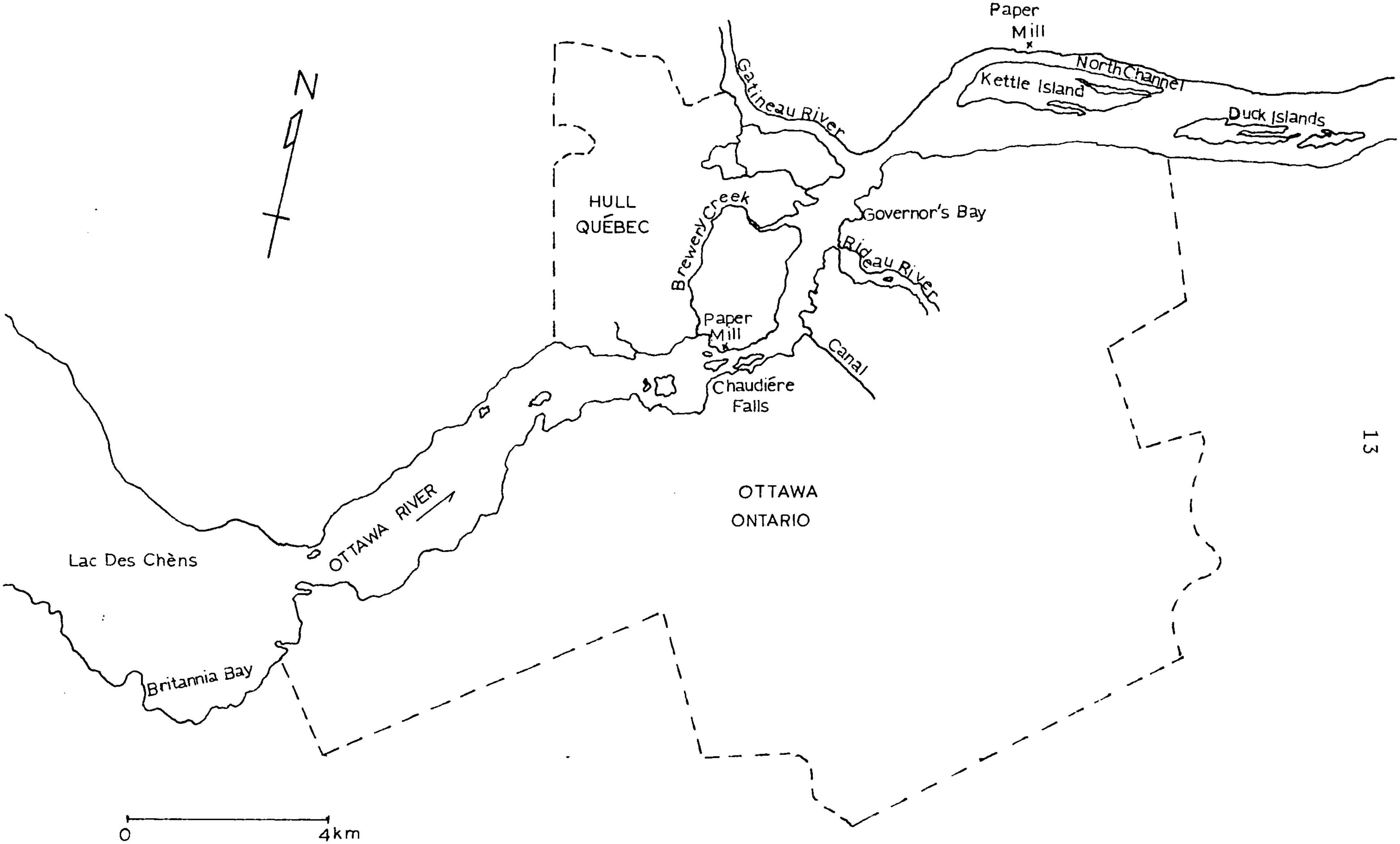


Figure 1. The Ottawa River study area at Ottawa - Hull, Canada.

turbid, with Secchi disc readings ranged from 1.5 m to 1.8 m. Colored by organic plant matter, the water is distinctly yellow brown (color range from 40 to 60 A.P.H.A. units) with a hardness equivalent to approximately 24 to 48 ppm of calcium carbonate (Pichè, 1954). During the summer months, dissolved oxygen in the river is 7-9 ppm, CO_2 between 10 and 15 ppm, and the pH ranges from 6.7 to 7.0. The substrate of Lac Deschènes is primarily silt-covered gravel with few rocky shoals and sparse vegetation.

The lower river once received wastes from two sulphite paper mills and primary and secondary sewage from the cities of Ottawa and Hull. The smaller of the two paper mills was located at the base of the Chaudière Falls. Operations at this plant were suspended in 1972. The second mill is located 8 km downstream from the first on the north shore of the river at Gatineau, Quebec (Fig. 1). The wastes from these two mills were mainly sulphite liquor from the cooking of 1200 to 1400 tons of wood pulp daily, plus the "white waters" from making newsprint, specialty paper, and panel board.

The substrate of the lower river is shale covered with mud, wood fibers, chips and bark. Vegetation is moderate along the inlets and bays and is lacking in the main channel. This section of the river is cluttered with sunken and partially submerged logs which have become detached from log booms.

Governor's Bay, an area used in this study, is located

3.6 km east of Chaudière Falls along the south shore of the lower river (Fig. 1). The bay, approximately 225 by 350 m in size, is 5 to 6 m in depth at its deepest point (Fig. 2). The bottom or substrate of the bay slopes gradually from the shoreline to the main channel and is generally covered with silt, decaying leaves, wood fiber, and chips. Vegetation is moderate, consisting primarily of *Anacharis canadensis* and *Vallisneria americana* in the shallow waters. The bay, like the river, is heavily cluttered with submerged tree stumps and sunken logs. The water of the bay is not affected by the main current of the river, and its movement is partly the result of slower eddy currents.

MATERIALS AND METHODS

Field Studies

Capture and Data Handling

Fishing gear for the study was selected for its capability to function as efficiently as possible for capturing both the walleye and sauger in a river cluttered with debris. Although trap nets and trawls would have been preferred, gill nets had to be used in most areas.

A sixty-one meter gill net was set on the bottom of the sampling area for a twenty-four hour period which provided the standard unit of effort. Nets were usually set in water eight meters or less in depth and were placed across the mouth of a bay or inlet. Each sixty-one meter gill net was composed

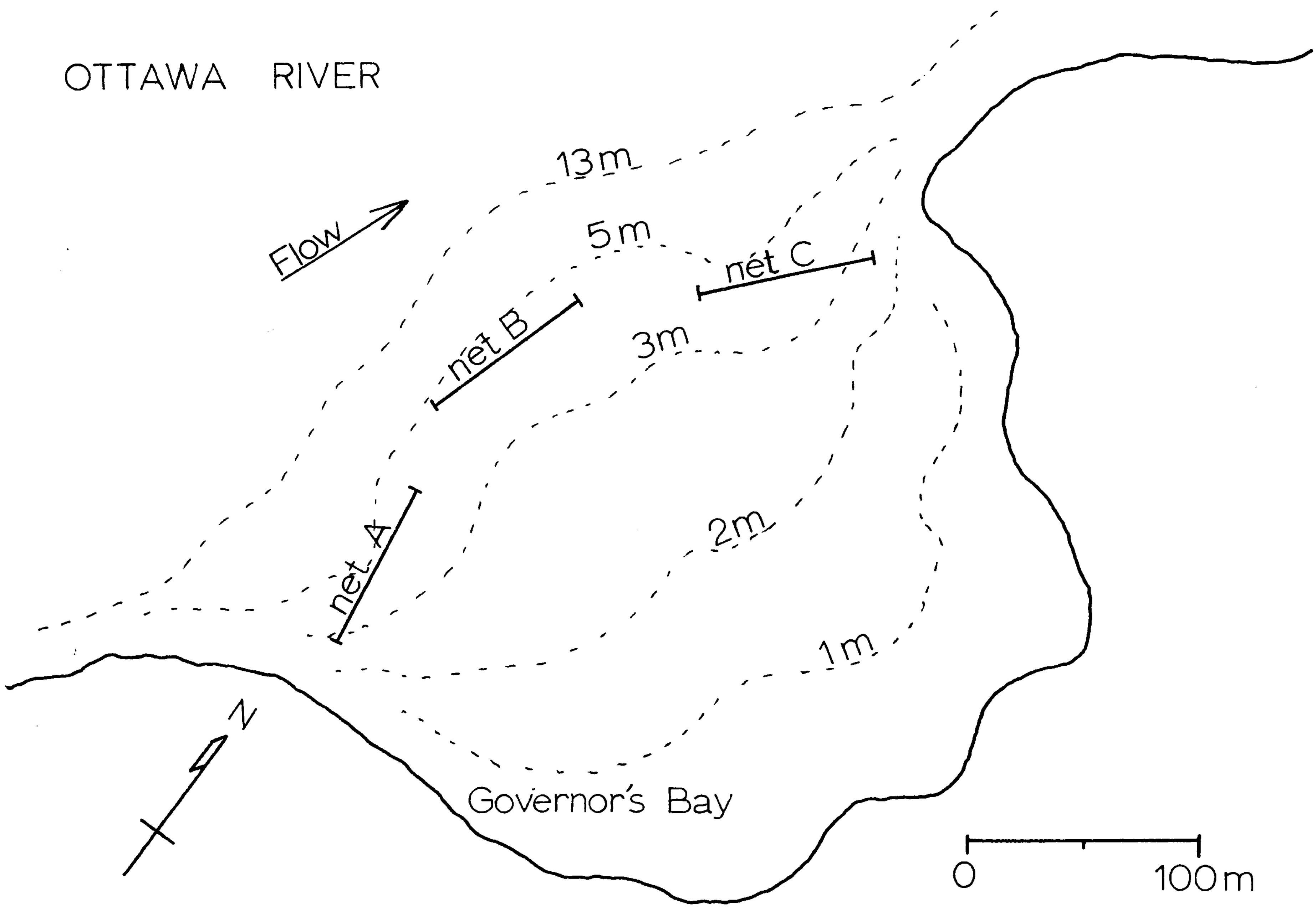


Figure 2. Governor's Bay, showing depth contour and net positions.

of four, fifteen by two meter nylon panels composed of four, five, seven, and ten centimeter stretched mesh respectively. The different mesh sizes caught walleye and sauger from 2 to 8 years old and minimized the size selection as discussed by Carlander (1953).

Creel censuses conducted by the Ontario Ministry of Natural Resources and the Quebec Department of Fish and Game showed a decrease in the size of walleye and sauger caught in the river since 1955. Therefore, netting efforts for this study were restricted to quantities of fish which would provide sufficient data but not unnecessarily reduce the number of older individuals.

Although no records have been kept on illegal fishing, this activity affects the balance of mature individuals in the Ottawa River. As many as twenty walleye were removed from the base of the Chaudière Falls in a four hour angling period during the spawning in 1971. Anglers at this time told me that they felt that the size of the spawning individuals had decreased during the past ten to twenty years.

Fish were weighed to the nearest gram and total length and fork length were measured to the nearest millimeter. Fish not killed or injured by the gill nets were scale sampled, tagged and released. Fish were marked with two inch yellow spaghetti tags manufactured by the Floy Company (Seattle, Washington). The tags were inserted to the left of the midbase of the first dorsal fin by using a tagging gun. All tags carried numbers (series A0-A500) and a forwarding address. Dead fish and fish too weak to recover were frozen for later processing in the laboratory at which time otoliths, scales, stomachs and intestines were removed and the sex determined. Total lengths were recorded unless otherwise noted.

The data were recorded on tape and programmed in Fortran IV language. Location, weight, total length, fork length, sex, maturity, net mesh size (capture), age, scale annuli measurements and identification number were recorded for each fish.

To correct lengths and weights of all preserved fish (caught in 1967-1969) to their measurements prior to preservation, samples of fresh walleye and sauger were measured, weighed, and placed in 8% formalin solution for one to two years. The fish were then remeasured and weighed and the correction factors were determined and applied to all preserved fish.

A minimum of ten scales were removed from each fish to determine age. The scales were taken from the left side in an area below the lateral line posterior to and adjacent to the distal end of the pectoral fin. Impressions were made of six to eight of the scales on a clear acetate slide using a roller press as described by Smith (1954). Scale impressions were examined on a microprojector at a magnification of 40x. The positions of the focus, annuli, and anterior margin of the scale closest to the mid radius were recorded on paper strips for measurement to the nearest millimeter.

Criteria as described by Vassey (1967) were used to determine the validity of the annuli. The false annulus also described by Vassey was frequently present during the first year of growth and was commonly observed in both species. The age of each fish was determined from two readings of the clearest scale impression. If these two readings did not coincide, a third reading was made. Fish for which ages could not be correctly determined were removed from the study. The Mann-Whitney U-test and the Wilcoxon two-sample test were used for all total length comparisons because normality was not assumed in the distribution of each age class.

Governor's Bay

The gill nets used in Governor's Bay were composed of four, fifteen meter panels (two of 5 cm and two of 7 cm stretched mesh). The four and ten centimeter stretched mesh nets used in the other areas of the river were not used because of their low catch per unit effort. Three net gangs were set in the bay so that they were equidistant from the shoreline and from each other (Fig. 2). These were set to sample fish moving both in and out of the bay. Fish were removed from the nets at sunset, midnight, 3 a.m. and sunrise.

The efficiencies of different net positions were evaluated during the study. On five different occasions during 1972, nets were set in the deeper water of the main channel near Governor's Bay (Fig. 2). These nets were set parallel to the direction of the current in 9-12 m of water and as close to the bottom as possible. Nets were also suspended in three positions in the water column of the bay (1.5, 3 and 4.5 m) to determine the most efficient fishing depth for walleye and sauger. These nets were set for 24 hours and checked at sunset and sunrise. To determine whether nets which were clogged with wood fiber retained the same ability to catch fish as a clean net, a third series of nets were set in the north channel to collect wood fiber and then were reset in the bay along with clean nets for periods of 24 hours.

The number and time of capture of all species of fish caught in the nets in Governor's Bay during 1972 were recorded (Appendix A). Weight and length measurements were taken for walleye and sauger only. Walleye and sauger were kept alive in floating net baskets which were attached to the side of the boat. Before any fish was removed from the net, it was noted whether it was entering or leaving the bay.

Stomach contents were examined for all live walleye and sauger. Each fish was either injected with tartar emetic and placed in a metal wash tub filled with river water to collect the regurgitated stomach contents (Jernejcic, 1969), or the stomach contents were pumped out with a device similar to that described by Seaburg (1956). The regurgitation technique was only moderately successful, so the stomach pump was used during most of this study. The stomach contents were placed in vials with 8% formalin solution for later analysis. The fish was then tagged, scales were taken, and it was then returned to the river.

The contents of each stomach were examined and each organism was identified to species in the laboratory. Food had been in the stomach for usually less than five hours and was only slightly digested. The stomach contents of those fish leaving the bay were considered to be a daily meal for the fish. Standard lengths of prey fish found in the stomachs were compared to standard lengths of the same species that were obtained in seine samples taken every two weeks during the summer in or near Governor's Bay.

Winter and Spring Capture

Between December and February of 1971 and 1972, walleye and sauger captured by fishermen through the ice were examined for stomach contents. Because of swift river currents and unpredictable ice conditions, angling with live minnows was the only method that was successful for catching fish during this time of the year.

In April 1971 and 1972, following the clearance of ice from the river, the stomach contents of fish caught by anglers were examined to establish the feeding habits of the fish before and during spawning. Examination of fish caught by anglers was the best means of obtaining data on food consumption at this time of the year since the high water level and fast currents made it impossible to set gill nets. Most of the fish examined were captured with spears, hand nets or treble hooks. Stomach contents were usually analyzed on the spot and where possible, other data were taken.

Spawning

Following hatching, larvae of the walleye and sauger remain at the surface of the water for a short period of time and can be sampled. To establish the occurrence of spawning by both species in the Ottawa area, and to study the effect that the river currents have on the pelagic larvae, surface tows using coarse plankton nets (363 micrometers) were made following the spawning periods of 1971 and 1972. The tows caught few fish since the mesh quickly became clogged with wood fiber and wood chips.

A second method for sampling the larval stages proved to be more successful. Larval walleye and sauger were recovered from stomachs of perch captured by seins or gill nets (2.5, 4, and 5 cm stretched mesh) below the spawning areas. The stomachs of the perch were pumped and the contents examined for the presence of walleye and sauger larvae. Post-larval stages of the genus Stizostedion were identified to species by use of morphological characteristics described by Nelson (1968a-b).

Laboratory Studies

Facilities

Studies were conducted at both the waterfront laboratory of the National Research Council of Canada, located on the south shore of the Ottawa River 2 km east of the Chaudière Falls, and at the Department of Biology, University of Ottawa. The waterfront laboratory is equipped with several 170 liter fiberglass tanks with a continuous flow of river water allowing a complete water turnover in each tank every hour. Six tanks were used for both holding and experimentation on fish that were three years and older.

Work with young-of-the-year, yearlings and two year old fish took place at the university laboratory. The fish were held individually in forty or eighty liter tanks kept in constant temperature rooms. Dechlorinated, aerated city water was generally used in these tanks. On a few occasions river water was used. One third of the water in each tank was replaced daily, and glass wool and activated charcoal filters ran continuously in each tank.

Water temperature at both laboratories was the same, the temperature being determined by the temperature of the river water which remained between 19-21°C during the summer. Light at the surface of all tanks was maintained below 10 foot-candles during the day and was reduced to less than 1 foot-candle between sunset and sunrise.

Fish were transported to the laboratory in 19 liter glass containers with portable aerators. Since the distance traveled was minimal, the fish were not anesthetized. Upon arrival at the laboratory, all fish were treated with a fungicide (0.75% solution of malachite green, one drop in four liters of water).

Care of Fish

Laboratory fish were acclimated for two weeks under the experimental conditions (nine hours of darkness, water temperature 20°C ± 1°C, O_2 at 9 ppm.). The fish were fed once during a 24 hour period, six days a week. Food was not given on the seventh day. Fish weights were taken on the first day of the new week just prior to feeding.

The method of weighing the experimental fish and the live fish used as fish food was the same. Each fish was removed from the tank by a dip net and sandwiched between two soft polyurethane sponges which were large enough to completely contain the specimen. The sponges were held together by wire clips. The unit was then placed on a top loading balance and weighed to the nearest tenth of a gram. Following the weighing, the fish was returned to the tank and the sponges and clips were reweighed. The tare weight was subtracted from the initial weight. This procedure not only eliminated the need for anesthetizing the fish but also made it unnecessary to blot the fish dry. Repeated weighings of the same fish assured the precision of this procedure to 0.1 g.

Three types of food were fed to laboratory fish; processed trout pellets, emerald shiners (*Notropis atherinoides*) or yellow perch (*Perca flavescens*), and perch muscle. The trout pellets were those used by the Ontario Ministry of Natural Resources at the White Lake Hatchery. All live food-fish were kept under the same conditions as the experimental fish and they were fed trout pellets. Live food was seined from the Ottawa River twice a month. The larger perch taken by the seine were filleted, frozen, and used as the third food source.

Digestion and Calorimetry

Walleye and sauger were fed live emerald shiners which were dyed with undiluted red or blue vegetable dye. This was done to determine the time required for the completion of digestion. Two to three ml of dye were injected directly into the abdominal cavity of an adult emerald shiner and the shiner was released into the tank. The shiners continued to swim long enough (10-20 mins.) to attract and be consumed by the predator. Once the dye was released in the stomach of the predator, the bony and cartilaginous portions of the food became lightly stained. Many of the undigestible bones and scales remained stained in the gut of the predator, and were identifiable in the feces.

Caloric values of fecal material were determined within one or two hours following defecation after collecting the feces from the tanks by means of large pipettes. Following a two or three day period of regulated feeding, the times of defecation were predictable. The threadlike feces were transferred to weighed evaporation dishes and dried at 105°C.

The caloric value of the laboratory fish foods (whole perch and shiners, trout pellets and perch muscle) and feces were evaluated by means of a Parr, plain jacket oxygen bomb calorimeter. Samples (except feces) were dried at 60°C until a constant weight was attained and then stored in a desiccator with silica gel. Prior to burning, all samples were ground to a fine powder with a porcelain mortar and pestle and then reheated to assure complete dryness.

Samples of one gram (dry weight) were burned in the calorimeter. The calorimeter was standardized with benzoic acid before each set of tests. Two or three tests were run on each sample and values did not vary more than 1%. Determination of the percent ash content was made for feces by completely burning the material in a muffle furnace at 550°C.

Metabolism

The metabolic rates were measured for young-of-the-year, yearling and two year old walleye and sauger by means of a gravity fed respirometer (Fig. 3). Various sized clear rectangular plastic boxes with tightly fitting lids were used to hold the fish to be tested. The boxes were designed so that the length was at least one and one half times the length of the fish and the volume was at least ten times the water displacement of the fish. The box was placed in a 38 liter tank of aerated water (9 ppm of oxygen; saturation at 19°C). Water from the tank entered the box through a hole near the head of the fish, and was siphoned off through a tube which was attached to a hole near the tail. A valve was placed on the excurrent tube below the tank to regulate the flow of water through the respirometer. The flow was adjusted

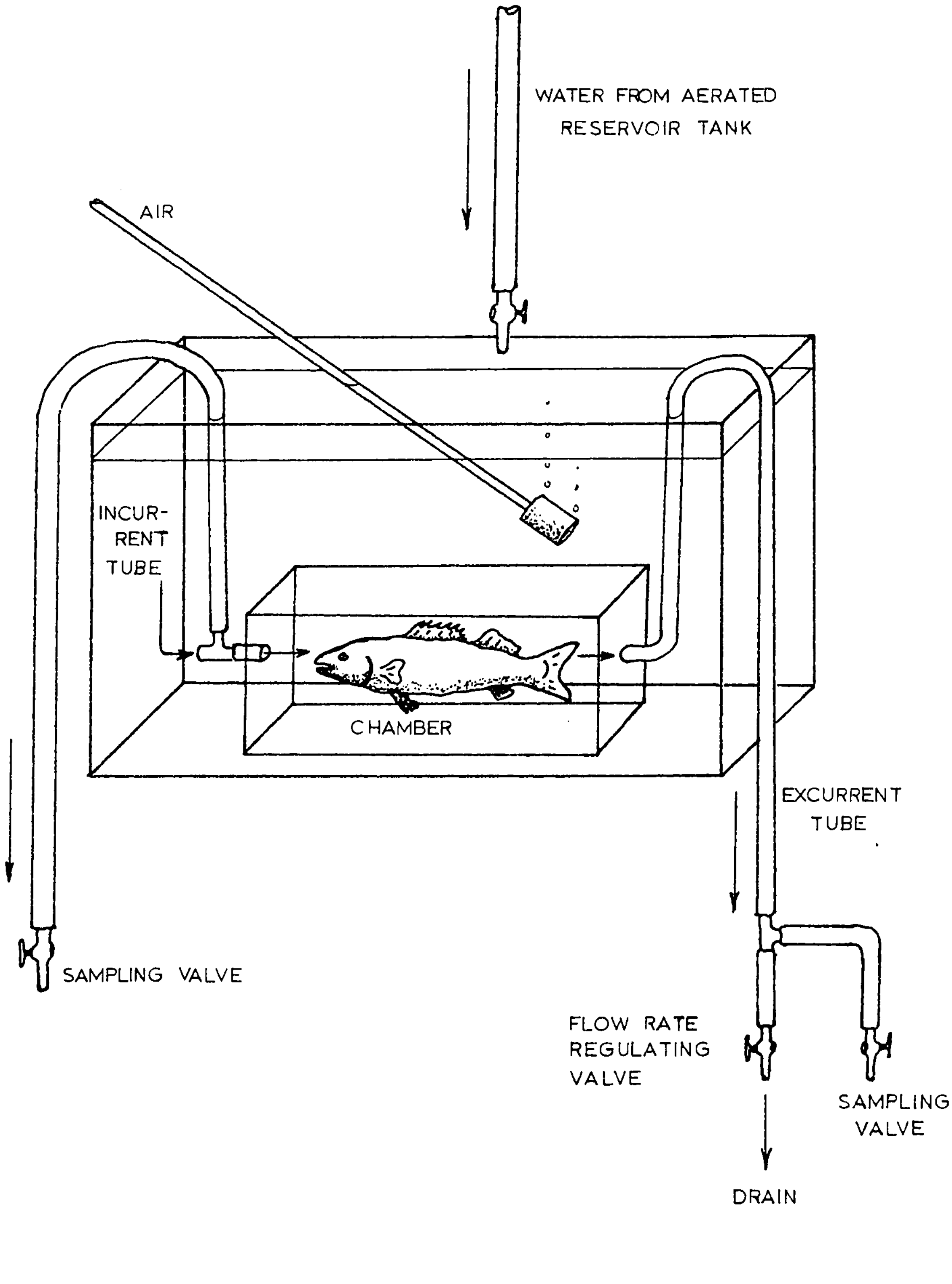


Figure 3. Gravity fed respirometer.

to approximately one $ml \cdot min^{-1} \cdot g^{-1}$ of fish and was measured accurately each time an oxygen reading was taken. Seventy-six liters of oxygen-saturated water were stored in a reservoir tank above the respirometer. The water was gravity fed to the respirometer tank to maintain a constant level.

Once the starved fish (unfed for 48 hours) had been placed in the respirometer, a black plastic cover was placed over the tank to prevent visual disturbance of the fish. The apparatus was allowed to run for an hour at the rate of one ml $H_2O \cdot min^{-1} \cdot g^{-1}$ of fish before oxygen readings were recorded. Water entering and leaving the respirometer was analyzed for the oxygen concentration by the Winkler method (Cox, 1967). Readings were taken every hour for all tests and were conducted between June and August. Fourteen to eighteen hours were required to test each fish and to allow for readings to level off. A total of seventeen fish, ages 1 to 4, were tested separately.

RESULTS

Field Studies

Growth

Growth, as defined by an increase in length and weight, was faster for the 261 walleye caught in the Ottawa River than for the 352 sauger (Table 1). At age 5, for example, the average walleye was 37 cm in length and weighed 481 g. The average 5 year old sauger was 29 cm long (78% of the 5 year old walleye length) and weighed 186 g (39% of the 5 year

Table 1. Mean Total Lengths and Weights of all Walleye and Sauger Caught in the Ottawa River Between 1967 and 1972

	Age	Number of Fish	Mean Total Length (cm)	Range	Mean Weight (g)	Range
Walleye	1	20	17.96 ±2.01*	11.9-22.0	48.17 ±15.8*	11.2-94.0
	2	49	25.53 ±1.64	22.0-29.5	136.44 ±23.3	83.0-213.0
	3	33	29.96 ±2.11	25.1-34.5	231.28 ±49.9	123.0-394.0
	4	57	33.73 ±1.89	29.9-38.5	349.37 ±57.1	225.0-531.0
	5	43	37.26 ±2.06	32.5-41.7	481.09 ±89.3	291.0-751.0
	6	35	40.19 ±1.93	33.4-44.0	596.09 ±106.7	326.0-853.5
	7	12	42.83 ±1.38	39.2-45.8	750.64 ±97.2	510.0-971.2
	8	12	45.38 ±2.04	41.0-50.4	913.07 ±94.3	604.0-1166.0
Sauger	1	7	15.70 ±1.94	10.0-19.6	29.5 ±9.6	7.0-52.0
	2	42	22.70 ±2.36	15.4-27.7	88.67 ±27.3	23.0-150.4
	3	75	26.20 ±2.28	19.0-31.1	135.14 ±39.1	43.0-224.0
	4	72	27.88 ±2.52	21.1-33.3	161.45 ±40.7	72.0-268.0
	5	54	29.14 ±2.81	24.1-34.3	186.03 ±44.0	95.0-306.0
	6	49	29.38 ±1.66	26.0-35.1	182.72 ±32.4	119.0-333.0
	7	32	31.62 ±1.84	27.9-39.2	236.66 ±53.3	133.2-468.0
	8	21	32.44 ±1.92	29.0-39.6	266.74 ±50.1	167.0-471.1

*One standard deviation of the mean

old walleye weight). The longest 8 year old walleye caught (50 cm) exceeded the longest sauger of the same age by 10.8 cm. The average 6 year old sauger showed the least increase in length over the previous year, gaining only 0.24 cm.

The average back-calculated total lengths for walleye and sauger (Tables 2 and 3) based upon body length and scale radius, and were determined from the measurement of all walleye and sauger caught in the Ottawa River between 1967 and 1972. The mean body length for each two centimeter length group was plotted against the corresponding mean lengths of the anterior scale radii (X 40) and the relationship for both species was determined as follows:

Walleye - $L = 3.54 + 2.53\,(R)$

Sauger - $L = 3.25 + 1.85\,(R)$

where L = total length in centimeters

and R = anterior scale radius X 40.

The intercepts of the ordinate (walleye - 3.54 cm and sauger - 3.25 cm) approximate the length of the fish at the time of scale formation. Comparisons between total lengths of walleye and sauger of the same age classes were significantly different at the 0.05% level unless otherwise stated.

Total length was not altered when the fish were preserved; however, the weight of the preserved fish did decrease, and corrections were made on all preserved fish. The corrections increased the weight of the preserved fish from 1 to 5% depending on its period of preservation.

Table 2. Mean Back-Calculated Total Lengths in cm for Walleye Caught in the Ottawa River Between 1967 and 1972.

Age Group	Sex	No. in Group	Mean Total Lengths at Capture (cm)	Range of Lengths at Capture (cm)	Mean Back-Calculated Total Lengths (cm)						
					1	2	3	4	5	6	7
2	M	25	25.15 ±1.46*	22.00-28.70	12.66	21.13					
2	F	24	25.92 ±1.66	22.20-29.50	12.73	21.67					
3	M	13	29.99 ±1.25	25.10-32.70	12.62	20.46	26.10				
3	F	20	29.49 ±1.62	26.00-34.50	12.65	20.89	26.65				
4	M	23	33.84 ±1.59	30.40-37.60	12.10	20.05	25.16	30.08			
4	F	34	33.65 ±1.74	29.90-38.50	12.44	20.19	25.57	30.78			
5	M	22	37.28 ±1.63	34.00-41.70	12.26	19.90	26.62	31.48	35.09		
5	F	21	37.24 ±1.95	32.50-41.20	12.32	20.16	26.66	31.57	35.17		
6	M	18	39.13 ±2.01	33.40-43.30	11.91	18.86	25.01	30.37	34.27	37.20	
6	F	17	41.31 ±1.31	38.00-44.00	12.18	19.47	25.95	31.75	36.60	39.38	
7	M	6	41.90 ±1.33	39.20-45.10	12.33	19.50	25.77	31.95	35.95	38.79	40.42
7	F	6	43.77 ±1.01	41.00-45.80	13.69	21.45	27.67	32.74	36.97	39.92	42.50
GRAND AVERAGE (Combined Sexes)					12.53	20.41	26.19	31.38	35.63	39.05	42.24
MEAN ANNUAL INCREMENT (Combined Sexes)					12.53	7.92	6.02	5.24	4.00	3.75	2.84
GROWTH BASED ON SUM OF INCREMENTS					12.53	20.45	26.47	31.71	35.71	39.46	42.30

*One standard deviation of the mean.

Table 3. Mean Back-Calculated Total Lengths in cm for Sauger Caught in the Ottawa River Between 1967 and 1972.

Age Group	Sex	No. in Group	Mean Total Lengths at Capture (cm)	Range of Lengths at Capture (cm)	Mean Back-Calculated Total Lengths (cm) 1	2	3	4	5	6	7
2	M	15	22.92 ±1.96*	16.90-27.10	10.65	19.51					
2	F	27	22.59 ±2.38	15.40-27.70	11.12	19.11					
3	M	33	25.24 ±2.72	19.00-31.10	10.96	18.33	22.87				
3	F	42	26.95 ±1.90	22.10-30.80	11.06	18.68	24.16				
4	M	35	27.29 ±1.97	23.30-31.70	11.01	17.67	22.36	25.49			
4	F	37	28.44 ±2.36	22.10-33.30	10.85	17.80	23.10	26.64			
5	M	28	28.61 ±2.09	24.10-33.50	10.84	17.70	21.75	25.48	27.38		
5	F	26	29.71 ±2.24	25.00-34.30	10.89	17.21	21.94	25.54	28.20		
6	M	28	28.96 ±1.28	26.20-32.60	10.41	16.44	20.27	24.18	26.40	27.93	
6	F	21	29.94 ±1.63	26.00-35.10	10.56	16.01	20.66	24.27	27.06	28.73	
7	M	20	30.96 ±1.58	27.90-36.80	11.51	17.33	21.24	25.54	26.39	27.59	28.89
7	F	12	32.71 ±1.67	29.50-39.20	10.70	16.50	21.98	25.85	28.30	30.20	31.64
GRAND AVERAGE (Combined Sexes)					10.93	17.74	22.54	25.77	28.17	30.22	30.72
MEAN ANNUAL INCREMENT (Combined Sexes)					10.93	6.81	5.01	3.55	2.53	1.87	1.19
GROWTH BASED ON SUM OF INCREMENTS					10.93	17.74	22.75	26.30	28.83	30.70	31.89

*One standard deviation of the mean

Estimates of general growth are given in Tables 2 and 3. One estimate is based on the grand average of back calculated total lengths, and the second estimate is based on the summation of the grand average annual increments of length. Neither set of estimates differs significantly from the other.

Growth increments of walleye (Table 2, Figure 4) exceeded those of sauger (Table 3, Figure 4) by 1.60 cm at age 1 and a difference of 10.41 cm was recorded for age 7. The mean annual increment or calculated rate of annual growth of walleye exceeded that of the sauger for each year of growth by a minimum of 1.01 cm at age 3 and a maximum of 1.88 cm at age 6.

Mean back calculated total lengths of walleye (Table 2), separated by sexes, showed that females surpassed the males in length in all age groups. The largest differences between the walleye sexes appeared in the older age groups, the females exceeded the males by 2.18 cm and 2.08 cm at ages 6 and 7 respectively. Mean total lengths of male and female sauger were similar at age 1 and 2, but among older age groups, the length of female sauger exceeded the males (Table 3).

Both walleye and sauger in the lower river grew faster than the upper river fish (Table 4). The length for each year class of lower river walleye caught between 1967 and 1972 exceeded, with one exception (age 2), the length of the upper river walleye by a minimum difference of 0.39 cm for 1 year old fish and by a maximum difference of 2.97 cm for 8

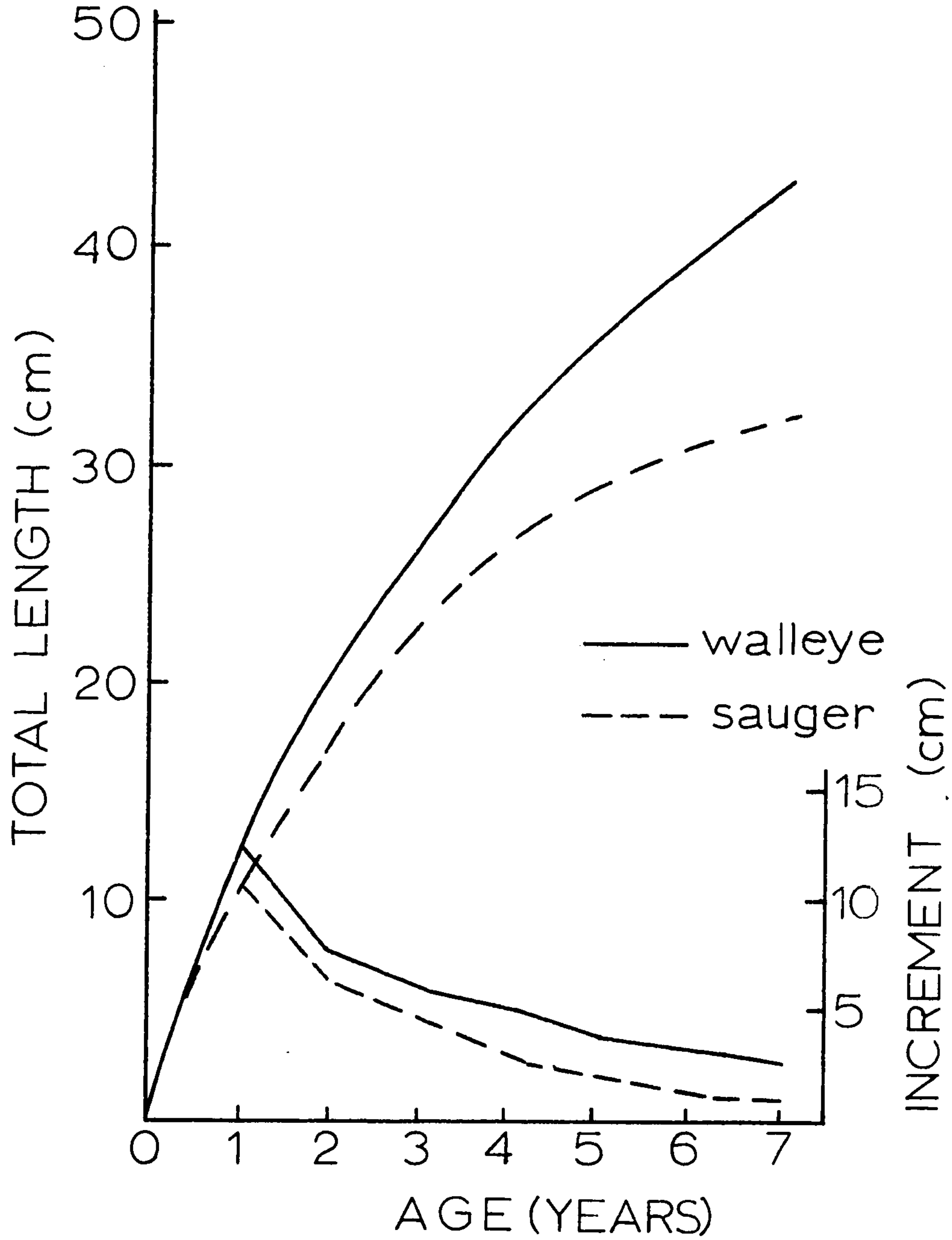


Figure 4. Mean growth in length and annual increment in length of Ottawa River walleye (solid line) and sauger (broken line).

Table 4. Mean Total Lengths and Weights of Walleye and Sauger Caught in the Upper and Lower Areas of the Ottawa River Between 1967 and 1972 (Total number of fish are indicated in parentheses)

	Age Group							
	1	2	3	4	5	6	7	8
Walleye								
Mean total length (cm) (sexes combined)								
Upper River	17.65(4)	25.61(29)	28.32(16)	32.76(24)	36.24(16)	38.44(13)	40.93(3)	43.40(4)
Lower River	18.04(16)	25.41(20)	30.97(17)	34.41(33)	37.87(27)	41.22(22)	43.47(9)	46.37(8)
Mean weight (g) (sexes combined)								
Upper River	39.30(4)	131.19(29)	190.67(16)	305.57(24)	401.37(16)	481.46(13)	600.00(3)	732.85(4)
Lower River	50.39(16)	144.05(20)	269.50(17)	381.21(33)	528.33(27)	663.82(22)	800.86(9)	1003.17(8)
Mean weights (g) (all walleye)								
Males		130.44(25)	232.06(13)	345.63(23)	466.62(22)	534.61(18)	706.75(6)	844.10(3)
Females		142.69(24)	244.27(20)	351.89(34)	496.24(21)	661.18(17)	794.53(6)	930.39(9)
Sauger								
Mean total length (cm) (sexes combined)								
Upper River	13.57(3)	18.62(8)	22.66(13)	25.74(23)	27.98(28)	28.85(41)	30.79(21)	30.83(16)
Lower River	17.30(4)	23.66(34)	26.94(62)	28.88(49)	30.40(26)	32.07(8)	36.10(5)	37.60(5)
Mean weight (g) (sexes combined)								
Upper River	19.67(3)	47.13(8)	82.94(13)	119.89(23)	154.71(28)	168.91(41)	207.25(27)	215.59(16)
Lower River	36.88(4)	98.45(34)	146.09(62)	180.96(49)	219.76(26)	253.50(8)	395.28(5)	430.42(5)
Mean weights (g) (all sauger)								
Males		90.29(15)	121.55(33)	151.72(35)	171.11(28)	167.23(28)	217.51(20)	210.12(12)
Females		87.77(27)	145.80(42)	170.65(37)	202.10(26)	203.38(21)	268.56(12)	342.23(9)

year old fish. The lower river sauger surpassed the upper river sauger in length in all age classes with a minimum difference of 2.42 cm (age 5) and a maximum difference of 6.77 cm (age 8).

Mean yearly weight gains for females of both species, and all lower river fish, were higher than the males of both species and for all the upper river fish (Table 4). Eight year old female walleye surpassed the males in weight by a maximum difference of 136.29 g. Female sauger were 132.11 g heavier than the males at age 8. The average 8 year old lower river walleye, was 270.32 g heavier than the average upper river walleye of the same age. The 8 year old lower river sauger exceeded the average upper river sauger by 214.83 g.

The condition factor or ponderal index as discussed by Hile (1936) is an indication of relative plumpness of a fish. Condition factors for walleye and sauger were derived from the formula:

$$\frac{W \cdot 10^5}{L^3} = C \text{ (condition factor)}$$

where W = weight in grams

and L = total length in centimeters.

The C values for all age groups of walleye and sauger (Table 5) of the lower river were greater than those of the upper river by a minimum of 0.46, with the exception of the one year old upper river sauger which exceeded the lower river sauger by 1.85. Walleye from the upper river had larger condition

Table 5. Mean Condition Factors ($\frac{W \cdot 10^5}{L^3} = C$) for Walleye and Sauger Caught in the Ottawa River Between 1967 and 1972. (Number of fish are in paraentheses. Significant differences occurred only between species).

	Mean Condition Factors for Age Classes							Average C Value for all Classes
	1	2	3	4	5	6	7	
Walleye								
Upper River	26.56(4)	29.03(29)	31.17(16)	31.98(24)	31.34(16)	31.51(13)	32.53(3)	30.63
Lower River	31.88(16)	32.62(20)	33.73(17)	34.77(33)	36.15(27)	36.11(22)	36.25(9)	34.37
Sauger								
Upper River	28.30(3)	27.15(8)	26.48(13)	26.13(23)	26.26(28)	26.15(41)	26.38(27)	26.83
Lower River	26.43(4)	27.61(34)	27.75(62)	27.94(49)	28.65(26)	28.55(8)	31.22(5)	28.37

factors than sauger in all categories except age 1, where sauger exceeded the walleye by 1.74. The average C for all age classes of walleye in the lower river (34.37) exceeded those of the upper river by 3.74. The lower river sauger (28.37) exceeded the upper river sauger by 1.54.

Five year old walleye (upper river only) and all 6 year old walleye decreased in condition from the previous age (Table 5). Sauger from the upper river showed less consistency in condition than walleye with a maximum factor of 29.30 at age 1 (based on three individuals) and a minimum of 26.12 at age 4. Lower river sauger followed the same pattern as their walleye counterparts with the only decrease from the previous year occurring at age 6.

Year Class Strength

Year class distribution for the walleye and sauger between 1959 and 1970 (Table 6) indicated sauger strengths in the classes of 1967 and 1969 and walleye strengths in the classes of 1965 through 1968. Walleye and sauger both showed their greatest strength in the 1967 year class. Mean ages for all walleye caught during each year between 1967 and 1972 ranged from 3.5 to 4.4 with an overall mean of 4.1. Sauger caught during the same period ranged in average age from 3.8 to 5.4 and had an overall mean of 4.4.

Annulus Formation

Annulus formation occurred earlier in walleye than sauger. All 2 year old walleye and 92% of the 3 year old

Table 6. Year Class Distribution of all Walleye and Sauger Caught in the Ottawa River Between 1967 and 1972 (Percent of year's catch appears in parentheses)

	Year Caught	Total Fish	Mean Age	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959
Walleye	1967	36	3.5						14(38.9)	6(16.7)	8(22.2)	3(8.3)	2(5.6)	3(8.3)	0(0)
	1968	13	4.2					4(30.8)	2(15.4)	3(23.1)	0(0)	1(7.7)	1(7.7)	2(15.4)	
	1969	42	3.7				16(38.1)	4(9.5)	10(23.8)	2(4.8)	8(19.0)	2(4.8)	0(0)		
	1970	27	4.4			5(18.5)	7(25.9)	4(14.8)	4(14.8)	1(3.7)	1(3.7)	5(18.5)			
	1971	67	4.3		6(9.0)	9(13.4)	17(25.4)	15(22.4)	8(11.9)	6(9.0)	6(9.0)				
	1972	57	4.4	4(7.0)	5(8.8)	15(26.3)	18(31.6)	15(26.3)	0(0)	0(0)					
	Mean Percent			7.0	8.9	19.4	30.3	20.8	17.5	9.6	10.8	9.8	4.4	11.6	0
Sauger	1967	88	4.1						9(10.2)	21(23.9)	21(23.9)	15(17.0)	10(11.4)	7(8.0)	5(5.7)
	1968	83	4.9					12(14.5)	12(14.5)	12(14.5)	10(12.0)	20(24.1)	9(10.8)	8(9.6)	
	1969	57	3.8				14(24.6)	12(21.1)	11(19.3)	11(19.3)	7(12.1)	2(3.5)	0(0)		
	1970	24	4.2			4(16.7)	9(37.5)	3(12.5)	2(8.3)	1(4.2)	3(12.5)	2(8.3)			
	1971	42	5.4		2(4.8)	4(9.5)	7(16.7)	6(14.1)	10(23.8)	10(23.8)	3(7.1)				
	1972	44	3.8	1(2.2)	17(38.6)	11(25.0)	10(22.7)	1(2.3)	1(2.3)	3(6.8)					
	Mean Percent			2.2	21.7	8.3	25.4	12.9	13.1	15.4	13.5	13.2	11.1	8.8	5.7

walleye formed an annulus by August (Table 7). In contrast, only 83% of the 2 year old sauger and 56% of the 5 year old sauger had completed an annulus by August.

Maturation

Males matured at an earlier age than females, but growth patterns between the sexes in both walleye and sauger (females grew faster than males) began to differ before maturity was reached. The growth pattern was similar in both species. One half of the three year old walleye and sauger males were found to be sexually mature and one half of the 4 year old females of both species were sexually mature. All males of both species were mature by age 6 and all females matured by age 7. Although measurements were not taken on the size and weight of ovaries, those of the walleye were notably larger and contained more eggs than those of the sauger, a factor contributing to the weight difference between the females of the two species at maturation.

Governor's Bay

Capture

A total of 798 fish representing 13 species were caught during the twenty-seven nights of fishing in Governor's Bay (Appendix A). Of these fish, 73 walleye and 105 sauger were used in this study. Mooneye, Hiodon tergisus, were most abundant, representing twenty-five percent of the total catch. The walleye and sauger represented nine and thirteen percent respectively.

Table 7. Percentages of 1967-1971 Walleye and Sauger from the Ottawa River with Annulus Formation Completed at Time of Capture (The number of fish appear in parentheses).

	Age Group	July %	August %	September %
Walleye				
	2	93(14)	100(17)	100(4)
	3	73(11)	92(12)	100(2)
	4	53(19)	75(16)	90(5)
	5	44(9)	73(11)	80(4)
Sauger				
	2	78(9)	83(12)	100(3)
	3	50(18)	81(21)	88(7)
	4	43(23)	62(16)	75(4)
	5	23(13)	56(18)	60(2)

Walleye and sauger were caught in Governor's Bay primarily between sunset and sunrise (693 net hours). In addition to the nets set during the night, 800 net hours of fishing were conducted (Figure 2) during daylight hours of the summer to determine whether walleye and sauger were active during the day. One walleye and three sauger were caught during these daylight hours shortly before sunset; all four of these fish had empty stomachs and were entering the bay. Walleye and sauger were not caught in a fourth net in the middle of the bay (two or three meters deep) during the daylight fishing periods.

One hundred and twenty-four hours of gill net fishing in the deep water of the main channel at Governor's Bay caught two lake sturgeon, *Acipenser fulvescens*, and two mooneye, but no walleye or sauger. Due to the swiftness of the river current these nets were pulled taut, more so than those set in the bay, and the greater tension may have reduced their efficiency. All nets were set close to the bottom because netting in the bay showed that 27 out of 29 walleye and sauger were caught near the bottom.

Gill nets set in Governor's Bay that were clogged with wood fiber were less effective for catching fish than were the clean nets. Although a quantitative evaluation was not made because of the variation in the amount of wood fiber in the nets, it should be noted that the clogged nets never caught more than 36% of the fish caught by the clean nets (Table 8). They averaged 31% of the clean nets. A

Table 8. Comparative Results of Three Twenty-four Hour Clean and Clogged Gill Net Catches in Governor's Bay During the Summer Months of 1972

	Clean Nets			Clogged Nets		
Species of Fish	July 2	July 23	August 6	July 2	July 23	August 6
Perch (*Perca flavescens*)	3	5	6	2	4	1
Bullhead (*Ictalurus nebulosus*)	1	5	2	1	3	2
Mooneye (*Hiodon tergisus*)	4	9			1	
Rock Bass (*Ambloplites rupestris*)	4			1		
Northern Pike (*Esox lucius*)	2		1			1
Sauger (*Stizostedion canadense*)	1	1	2			
Walleye (*Stizostedion vitreum*)		1	1			
Sturgeon (*Acipenser fulvescens*)	2					
Sucker (*Catostomus commersoni*)	—	1	—	—	—	—
Total Fish	17	22	12	4	8	4

total of nine species was caught in the clean nets, but only five of these species (two species, each represented by only one individual) were caught in the clogged nets. It should also be noted that those fish trapped by the clogged nets were not entangled to the same extent as those in the clean nets, and a few yellow perch fell free from the clogged nets when they were hauled into the boat.

Fifty-six percent of all walleye and sauger caught during the summer in Governor's Bay were caught by the net at site B in deeper water (Table 9). The net at site A was the least productive (12% of the total walleye and sauger catch) possibly because it received both the current from the main channel and the back-flow from the eddy currents that caused turbulence in that portion of the bay. The net at site C caught 32% of the fish during the summer.

Activity and Feeding Chronology

The greatest number of walleye caught during the summer were either entering (65%) or leaving (51%) the bay at site B. Net site A caught the fewest walleye with 12% entering and 15% of those leaving. Eighty-two percent of all the walleye entering the bay had empty stomachs and 85% of those leaving had at least one fish in their stomachs.

The net at site B also caught the greatest number of sauger entering (56%) and leaving (54%) the bay. The smallest number of sauger were caught at site A, 12% entering and 13% leaving the bay. Of all the sauger entering the bay,

Table 9. A Fifteen Day Summary of Walleye and Sauger With (+) or Without (0) Food in Their Stomachs Caught at Net Positions A, B, and C in Governor's Bay During the Summer of 1972

		GILL NET POSITIONS																							
		WALLEYE													SAUGER										
		Entering						Leaving							Entering						Leaving				
		A		B		C		A		B		C			A		B		C		A		B		C
First Day of Fifteen Day Period	Total Walleye	0	+	0	+	0	+	0	+	0	+	0	+	Total Sauger	0	+	0	+	0	+	0	+	0	+	0	+
May 16	3			1							2			2					1					1		
June 1	7	1		1		1					1		3	17		1	4	1	1	2				7		1
June 16	14			1	1	2	1		2		4	1	2	9	1		2	1	2					1		2
July 1	17	2		7		1				1	3		3	21			8	2	2	1		1	2	3		2
July 16	13			4	1	3			2		2		1	18	1		3	1	3	1		1		4		4
August 1	12	1		1	1				2	1	4	1	1	27	4		7	1	3			2		5	1	4
August 16	4			3							1			4					1				1	1		1
September 1	2			1						1				4			1		1		1					1
September 16	0													0												
October 1	1											1		3			1				1		1			
Total No.	73	4	0	19	3	7	1	0	6	3	17	3	10	105	6	1	26	6	14	4	2	4	4	22	1	15

81% had empty stomachs and of the total number leaving the bay, 85% had at least one fish.

The total number of walleye and sauger entering the bay with empty stomachs and leaving the bay with food, between sunset and sunrise, was similar. When this nocturnal activity is divided into three periods of three hours each (Table 10), the walleye and sauger activity shows the greatest concentration during the first period, and the least amount of activity during the last period. Twenty-three walleye (72% of those entering) entered the bay between sunset and midnight, and all had empty stomachs. Twenty-five percent of the walleye entered the bay between midnight and 3 a.m., and 60% had empty stomachs. Only one walleye with an empty stomach entered during the last period, 3 a.m. to sunrise. Of the 33 walleye caught leaving the bay, 24% left between sunset and midnight and 60% of these fish had food in their stomachs. Fifty-eight percent (19) of the walleye left the bay between midnight and 3 a.m., and all of these fish had food in their stomachs. Eighty percent of the walleye leaving during the last period had consumed at least one fish during the night.

Thirty-two sauger (65% of those entering, Table 11) entered the bay between sunset and midnight, 29% between midnight and 3 a.m., and 6% entered during the last period. Eighty-one percent of the sauger entering during the first period had empty stomachs. Seventy percent of the sauger entering during the second period had empty stomachs and all

Table 10. A Fifteen Day Summary of Walleye Caught Entering and Leaving Governor's Bay During the Night in the Summer of 1972

First Day of Fifteen Day Period	Total Net Hours (Total Nights)	ENTERING GOVERNOR'S BAY							LEAVING GOVERNOR'S BAY						
			Periods							Periods					
		Total	Sunset to Midnight		Midnight to 3 AM		3 AM to Sunrise		Total	Sunset to Midnight		Midnight to 3 AM		3 AM to Sunrise	
			0	+	0	+	0	+		0	+	0	+	0	+
May 16	81(3)	1	1						2*						
June 1	108(4)	3	3						4		1		2		1
June 16	90(4)	5	2		1	2			9		3		4	1	1
July 1	108(4)	10(1*)	6		3				7(2*)	1			3		1
July 16	99(4)	8	6		1			1	5				5		
August 1	81(3)	3	2			1			9	2	1		5		1
August 16	72(3)	3	3						1						1
September 1	27(1)	1*							1*						
September 16	0														
October 1	27(1)								1*						
Total No.		34	23	0	5	3	0	1	39	3	5	0	19	1	5

0 - fish with empty stomachs; + - fish with food in their stomachs

*time period data lacking

Table 11. A Fifteen Day Summary of Sauger Caught Entering and Leaving Governor's Bay During the Night in the Summer of 1972

First Day of Fifteen Day Period	Total Net Hours (Total Nights)	ENTERING GOVERNOR'S BAY							LEAVING GOVERNOR'S BAY						
		Total	Periods						Total	Periods					
			Sunset to Midnight		Midnight to 3 AM		3 AM to Sunrise			Sunset to Midnight		Midnight to 3 AM		3 AM to Sunrise	
			0	+	0	+	0	+		0	+	0	+	0	+
May 16	81(3)	1	1						1				1		
June 1	108(4)	9	3	3	1	1	1		8		2		6		
June 16	90(4)	6	5			1			3		1		1		1
July 1	108(4)	13(5*)	3		3	1	1		8(3*)			1	1		3
July 16	99(4)	9	4	1	3	1			9		2		5		2
August 1	81(3)	15	10	1	3		1		12	1	1		4		6
August 16	72(3)	1	1						3	1			2		
September 1	27(1)	2*							2*						
September 16	0														
October 1	27(1)	1*							2*						
Total No.		57	27	5	10	4	3	0	48	2	6	1	20	0	12

0 - fish with empty stomachs; + - fish with food in their stomachs

*time period data lacking

fish entering during the last period were empty. A total of 41 sauger were caught leaving the bay. One third of the sauger leaving during the first period had at least one fish in their stomachs, the stomachs of all but one of the 21 sauger leaving during the second period contained at least one fish,and all of the fish leaving during the last period (12 fish) had consumed a minimum of one fish during the night.

Walleye activity, as measured by catch per unit effort, peaked in late June and the first two weeks of July (Fig. 5). The sauger showed a more irregular activity pattern, with peaks during late July and the first two weeks of August (maximum c.u.e. of 0.3334) and had greater movement than the walleye in late August and September. The average catch per unit effort for the three most active months (June, July and August) for walleye was 0.1060 and for sauger was 0.1704.

Since the walleye and sauger feed primarily during darkness (Hatfield, et al., 1972; Niemuth, et al., 1972; Rawson, 1957; Regier, et al., 1969), it was assumed that walleye and sauger caught from 1967 to 1971 by 24 hour net sets in the Ottawa River were caught between sunset and sunrise. Figure 6 shows the catch per unit effort of 200 walleye and 370 sauger. This 15-day catch distribution also indicated a walleye peak during July and was similar to the 1972 data. The peak for sauger follows that for the walleye during August. Just as in 1972, the sauger movement for 1967-1971 was more irregular than that of the walleye movement.

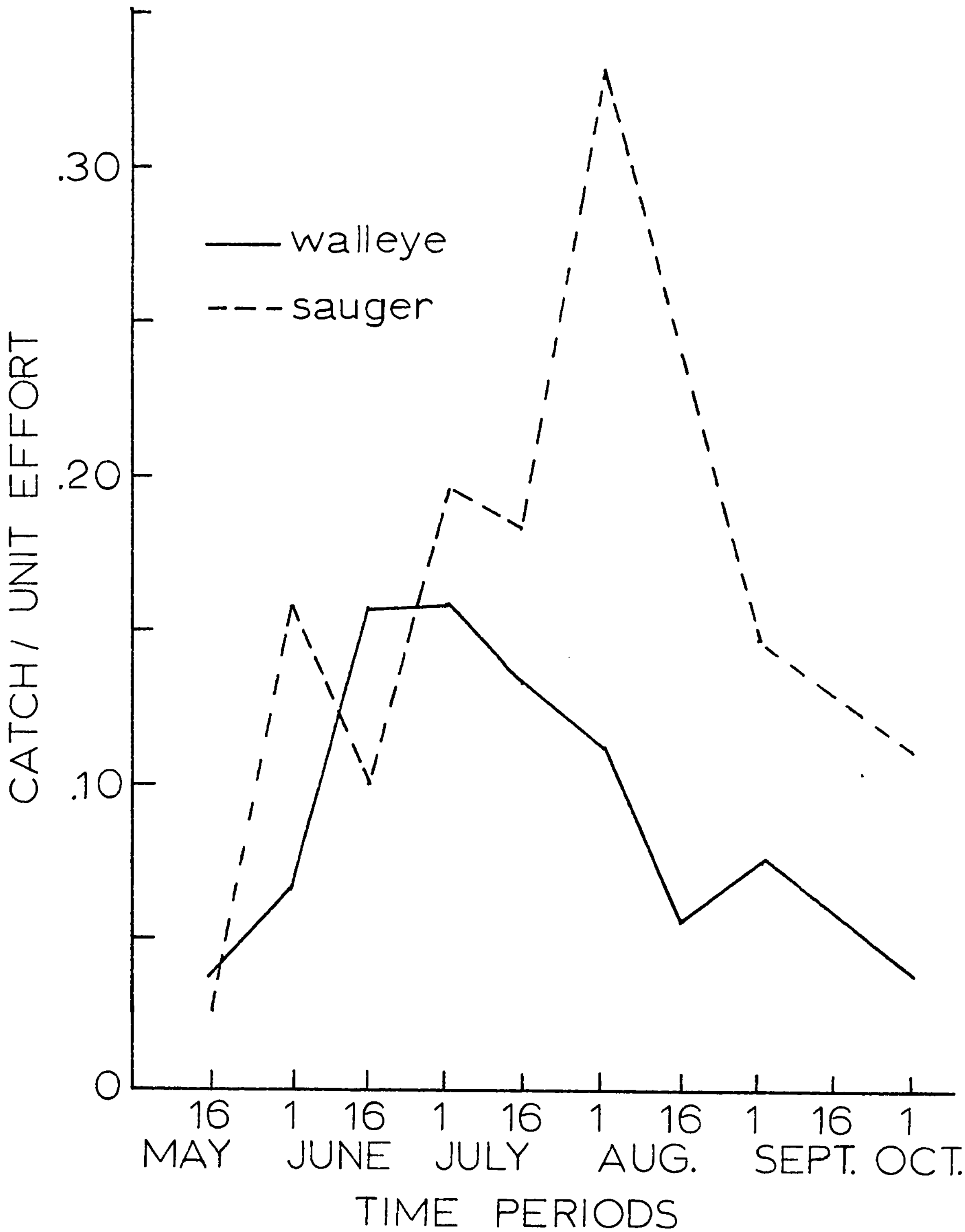


Figure 5. Overnight catch per unit effort for walleye (w) and sauger (s) in Governor's Bay during the summer of 1972.

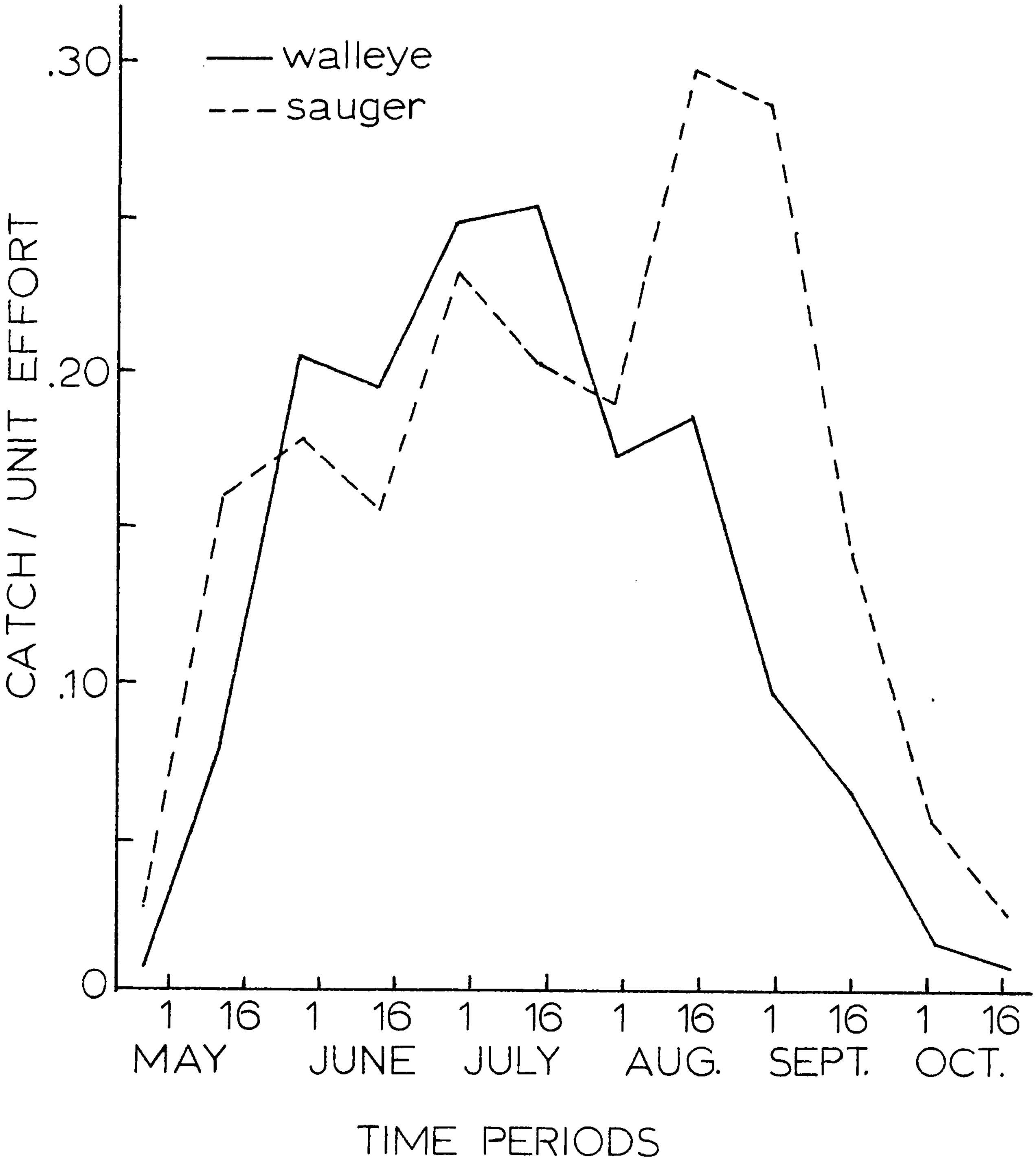


Figure 6. Overnight catch per unit effort for walleye(w) and sauger (s) in the Ottawa River at Ottawa (upper and lower river) between 1967 and 1971.

Food Consumption

To estimate the stages of digestion and time of consumption of food by walleye and sauger examined in the field during the summer months, various stages of digestion of food (emerald shiner) were determined for 6 walleye and 8 sauger in the laboratory. During the first six hours of digestion, the soft portions of the fins were lost as was most of the dermal tissue supporting the scales. During the second six hours the abdominal wall was digested and the abdominal organs were exposed. During the final six hours the brain and the vertebrae were exposed.

A conversion table (Table 12) was used to determine the live weight of emerald shiners that were pumped from the stomachs of the walleye and sauger when the standard length of the shiner could be measured. The average emerald shiner during the summer contained 4.910 kcal/g dry weight or 1.227 kcal/g wet weight. Female emerald shiners with eggs ranged from 5.210 to 5.570 kcal/g dry weight and immature fish from 4.815 to 4.840 kcal/g dry weight.

Ninety-five percent of the prey consumed by the walleye and sauger were cyprinids (primarily emerald shiners) and yellow perch. The remaining food identified in the stomachs of these fish was pumpkinseeds (Lepomis gibbosus), rock bass (Ambloplites rupestris), and fragments of arthropods. Seine catches from Governor's Bay indicated that the emerald shiners and yellow perch populations provided a food supply throughout the summer months. Although seining could not be

Table 12. Mean Weight in Grams and Average Total Caloric Content of Eight Length Classes of Emerald Shiners Caught in Governor's Bay During the Summer of 1972. (Ranges are in parentheses. Each length group represents fifteen to twenty specimens).

Fish Length (cm)	Whole Body Wet Weight (g)	Caloric Content kcal/fish
4.5	1.72(1.60-1.92)	2.12
5.0	2.31(2.04-2.39)	2.97
5.5	2.80(2.67-3.71)	3.19
6.0	3.26(3.09-3.62)	3.99
6.5	3.78(3.51-4.19)	4.46
7.0	4.35(4.15-4.66)	5.31
7.5	4.87(4.62-5.24)	5.69
8.0	5.31(4.98-5.71)	6.13

conducted in a quantitative fashion to evaluate the available prey fish, due to the presence of stumps and other debris, a six meter seine pulled through a distance of fifteen meters always captured a minimum of 20 yellow perch (age 0-2) and 50 mature emerald shiners. An average seine haul during July and August in Governor's Bay, Brewery Creek and around Kettle Island contained 63 yellow perch and 112 emerald shiners. There was a 70 percent decrease in abundance of mature emerald shiners between July and August, but the number of young-of-the-year shiners, which were large enough to be caught in a 6.5mm stretched mesh seine, increased. The yellow perch population remained relatively stable even though cannibalism is known to occur within the species (Stobo, 1971).

Stomachs and intestinal tracts of all the preserved walleye and sauger from Governor's Bay were examined. Ninety-four percent of the walleye and 87% of the sauger contained undigested fragments of food in the first one half of their intestines. It is highly possible that the walleye and sauger in this portion of the river were feeding on a regular nightly basis because stomach evacuation could be accomplished in less than twenty-four hours.

All but two walleye and six sauger caught leaving the bay with food in their stomachs had consumed emerald shiners, even though yellow perch were available. Because emerald shiners were consumed in the greatest quantity by both the walleye and sauger in the Ottawa River, only stomachs containing the shiners were used to determine the caloric value of the daily ration. Kettle Island walleye and sauger caught during 1972 utilized the greatest variety of prey fish, 64% of which were emerald shiners and the remainder of which were a combination of yellow perch, pumpkinseeds and rock bass. Ninety-one percent of the identifiable stomach contents from the upper river fish caught in 1972 were emerald shiners. Stomach contents indicated that walleye and sauger from the same area of the river never varied more than 7% from each other in their use of the emerald shiner for food.

Daily rations (as a percent of whole body wet wt) of walleye decreased with an increase in age. It was assumed that a fish leaving Governor's Bay had consumed a daily ration of food. The 2 year old walleye consumed an average daily ration of emerald shiners which was equivalent to 4.01% of their body weight or 57.9 cal/g of whole body wet weight (Table 13). Six year old walleye consumed an average of 3.64% of their body weight in food or 43.0 cal/g of whole body wet weight. The large caloric value of stomach contents/unit whole body wet weight of fish for 5 year old walleye (49.7 cal) was due to a higher than average number of emerald shiners (9-11 fish) in the stomachs of three of the walleye examined. Caloric values of stomach contents/unit whole body wet weight of fish differed significantly at the 0.01 level between 2 and 6 year old walleye but was not significantly different between each age group of fish. The average

Table 13. Average Weights and Caloric Values of Stomach Contents Taken from Walleye and Sauger in Governor's Bay and Yellow Bay During June, July and August of 1972.

	Age of Fish	Total No. of Fish	Average Weight of Predator(g)	Average Wet Weight of Stomach Contents(g)	Average Stomach Contents As % of Body Wt. (wet)	Caloric Value of Total Stomach Contents (kcal)	Caloric Value of Stomach Contents /Unit Whole Body Wet Wt Of Fish(cal)
Walleye	2	9	133 ± 9.7*	6.42 ±1.6*	4.01	6.95	57.9
	3	12	227 ±23.5	8.77 ±2.3	3.76	11.41	50.3
	4	11	353 ±20.8	12.11 ±3.6	3.21	14.59	41.3
	5	6	478 ±31.0	19.97 ±3.2	5.10	21.96	49.7
	6	4	591 ±39.3	21.41 ±3.9	3.64	25.20	43.0
Sauger	2	10	84 ±12.4	3.19 ±1.2	3.87	3.75	44.2
	3	12	127 ±17.4	2.76 ±1.1	2.24	3.24	25.4
	4	7	169 ±15.9	3.29 ±1.3	1.91	3.90	23.1
	5	8	191 ±27.0	3.94 ±1.7	2.02	4.59	24.8

*One standard deviation of the mean

walleye consumed 4.12% of its body weight in food during the month of July (Table 14) which was 7.8% higher than the month of August (3.82% body weight) and 15.7% higher than the month of June (3.56% body weight). Although there were differences in the monthly food consumption, the differences were not statistically significant.

Two year old sauger (Table 13) consumed a mean daily ration of 3.87% of body weight or 44.2 cal/g of whole body wet weight which differed significantly (0.01 level) from the 3 year old sauger which consumed 25.4 cal/g of whole body wet weight. The older sauger did not differ significantly from one another in the daily ration. Two year old sauger consumed 16% fewer calories in their daily meal than the walleye of the same age (differing significantly at the 0.05 level), and by age 3, the sauger's diet was 49% less than the walleye. Sauger consumed a greater amount of food per body weight (Table 14) during the month of July (2.70%) than during June (2.45%) or August (2.14%); however, these differences were not significant. When compared to the walleye, the sauger consumed a significantly lesser (0.05 level) amount of food during June, July and August.

Fish other than walleye and sauger were caught consistently in nets and these also fed on emerald shiners. Yellow perch of 20 cm total length and longer showed little fluctuation in catch per unit effort during the summer and were consistently twice as numerous as walleye and sauger in the catch. Pumpkinseeds, rock bass, northern pike (Esox lucius),

Table 14. Monthly Variation in Food Consumption of Walleye and Sauger Caught in Governor's Bay and Yellow Bay for the Summer of 1972.

	Month	Total No. of Fish	Average Stomach Contents As a % of Body Wt. (wet)
Walleye (ages 2-6)	June	15	3.56 ±0.9*
	July	17	4.12 ±1.1
	August	10	3.82 ±0.9
Sauger (ages 2-5)	June	10	2.45 ±0.6
	July	15	2.70 ±0.5
	August	12	2.14 ±0.8

*One standard deviation of the mean

white suckers (Catostomus commersoni), lake sturgeon, and black crappies (Pomoxis nigromaculatus) also appeared frequently in the nets during the summer. Brown bullheads (Ictalurus nebulosus) were caught on an irregular basis in the bay during the summer months. Mooneye appeared in the bay in large quantities (15-20 per net) in June and again in August at which time a few longnose gar (Lepisosteus osseus) also appeared.

The stomach contents of several representatives of all of the above mentioned species were examined. At least one emerald shiner was found in each of the species with the exception of the white suckers, lake sturgeon (difficult to pump), and mooneye.

Data on the 217 walleye and 292 sauger caught between May and October from 1967 through 1971 (during 24 hour netting periods) were treated on the same basis as the fish caught between sunset and sunrise in Governor's Bay (Table 15). The fish containing food in their stomachs (76 walleye and 73 sauger of the 519 total) were used to estimate the size of a daily meal.

Emerald shiners were the primary food source for both the walleye and sauger. The identifiable stomach contents of the fish caught in Governor's Bay between 1967 and 1971 contained 89% emerald shiners and 11% yellow perch. Walleye and sauger caught during the same period in the upper river contained 91% emerald shiners; in Brewery Creek, 82% shiners; and at Kettle Island and Upper Duck Island, 64% shiners,

Table 15. Caloric Values of Stomach Contents of Walleye and Sauger Caught in the Ottawa River Between May and October, 1967-1971.

	Age of Fish	Total No. of Fish	No. of Fish Con-taining Food	No. of Fish Con-taining Only Shiners	Average Wet Weight of Predator(g)	Average Wet Weight of Stomach Contents(g)	Average Stomach Contents As % of Body Wt. (wet)	Caloric Value of Total Stomach Contents (kcal)	Caloric Value of Stomach Contents /Unit Whole Body Wet Wt. of Fish (cal)
Walleye									
	2	49	19(39%)	16	141 ±10.1*	6.13 ±1.3*	4.28	7.42	54.1
	3	33	8(24%)	7	246 ±22.6	9.91 ±2.2	3.82	11.80	44.8
	4	57	20(35%)	14	360 ±24.9	13.8 ±3.5	3.98	16.69	46.7
	5	43	14(33%)	11	469 ±33.2	15.5 ±3.1	3.48	19.04	40.1
	6	35	15(43%)	10	592 ±49.5	17.2 ±3.7	3.01	20.82	36.4
Sauger									
	2	42	12(29%)	9	109 ±16.3	3.61 ±1.4	3.26	4.37	41.9
	3	75	16(21%)	15	150 ±15.8	4.31 ±1.8	2.95	5.01	35.1
	4	72	19(26%)	14	171 ±20.7	5.47 ±2.1	3.14	6.54	36.8
	5	54	17(32%)	15	199 ±18.2	5.19 ±2.4	2.71	6.24	31.3
	6	49	9(18%)	6	213 ±18.0	6.01 ±1.9	2.99	7.33	33.9

*One standard deviation of the mean

respectively.

Food consumptions (daily ration expressed as cal/g whole body wet weight) for the 1967-71 walleye and sauger (Table 15) were similar to the values for the 1972 Governor's Bay fish. Conversion of these stomach contents to their caloric value was made by using the caloric values for the 1972 emerald shiners. Two year old walleye consumed 54.1 cal/g whole body wet weight which was significantly different (0.05 level) from age 3 walleye, which had consumed 44.8 cal/g whole body wet weight. Six year old walleye ate significantly less/unit body wt (0.05 level) than three year old walleye, consuming 36.4 cal/g whole body wet weight. Differences in food consumption between 3, 4 and 5 year old walleye were not significant.

Two year old sauger (1967-71) consumed a significantly higher (0.05 level) daily ration/unit body wt than the older fish. But the food consumed by the 3, 4, 5 and 6 year old sauger did not differ significantly from each other (range, 33.9 to 35.1 cal/g whole body wet weight). The sauger consumed an average of 10 cal/g whole body wet weight less than the walleye in each age group.

Walleye collected in 1967-71 showed the highest mean stomach content as percent of body weight (Table 16) during the month of July (4.06%), and the lowest (3.04%) during September. The sauger reached their peak consumption in August with 3.47% of body weight and a low in October (2.87%). The sauger consumed a significantly lower amount of food

Table 16. Average Monthly Stomach Contents as Percent of Body Weight of Walleye and Sauger Caught in the Ottawa River Between 1967 and 1971 and Distributed on a Monthly Basis

	Month	Total No. of Fish	Average Stomach Contents as a % of Body Weight
Walleye (ages 2-6)	May	2	3.15
	June	19	3.62 ±0.9*
	July	22	4.06 ±1.2
	August	12	3.24 ±1.0
	September	3	3.04
Sauger (ages 2-6)	May	3	2.89
	June	13	2.92 ±0.6
	July	15	3.05 ±0.7
	August	20	3.47 ±1.0
	September	7	3.11 ±1.2
	October	1	2.87

*One standard deviation of the mean

during June and July when compared to the walleye.

Intestines of 31 walleye and 36 sauger caught between 1967 and 1971 were examined to determine their food consumption during the 24 hour period previous to the time of capture. Sixty-four percent of the walleye and 69% of the sauger contained traces of food material in the first one half of their intestines. A greater percentage of fish which were examined may have contained partially digested food fragments in their intestines, but due to the large quantity of mucus in the gut, some food was undoubtedly obscured.

Daytime Behavior

Sunlight penetrated to the bottom of the greatest portion of the bay during daylight hours. One foot-candle of light was recorded on a submerged Sea Cell at a depth of 4.7 m at noon under a sunny sky. Walleye and sauger were not caught in the bay during the mid-day hours even though nets were set on days with heavy cloud cover. Walleye and sauger remained at depths greater than 4.7 m with less than 0.5 foot-candles of light during the daylight hours.

Gill nets were unsuccessful in determining the daytime movements of the walleye and sauger, and SCUBA gear was used with moderate success to make visual surveillance. Walleye or sauger were observed during five daylight dives in June and July of 1972, conducted in the lower river and in similar habitats to the Ottawa area at Arnprior and Wendover.

The walleye and sauger were at depths of between five and thirteen meters under and around rocks and debris on the bottom and were usually suspended motionless in the water. These fish were reluctant to move even when approached by the diver with a light. Many of the fish were in groups of two or three and were often in direct contact with the bottom of the river, facing into the current. Only occasional movement of the pectoral or caudal fins of these fish was evident. Because of the turbidity of the water and the lack of sunlight, it was difficult to differentiate between the walleye and sauger in the Ottawa River but walleye were easily identified in the less turbid St. Lawrence River (at Prescott, Ontario) where they also showed a lack of activity during the daylight hours. No walleye or sauger were seen in Governor's Bay during three midday and three evening dives.

Winter and Spring Feeding

Stomachs of 8 walleye and 38 sauger caught by anglers during the daylight hours of the winter months were examined. Walleye were difficult to catch in shallow water during bright winter daylight but could be caught on heavily overcast days in these areas. Thirty-eight of the fish caught during the winter (6 walleye and 32 sauger) had at least one emerald shiner in their stomachs. No yellow perch were found. Food items in the stomachs of all the fish were in the early stage of digestion and were easily identified. Very few of the stomachs contained bait fish; the bait fish being recognized by the hole made by the hook in either the tail or the dorsal surface of the body. All of the fish examined had fragments of food in the first one half of the intestine.

Forty-four fish (31 walleye and 13 sauger) caught by anglers were examined during the spring of 1972. Of these, seven walleye had food in their stomachs which was composed of emerald shiners, yellow perch, and fragments of arthopods. In no case did the food exceed two percent of the total body weight of the fish. Four of the walleye examined had partially digested food in the intestines; however, the quantity of food in the intestine was less than one half the quantity found in the fish examined during the summer months.

Laboratory Studies

Food Consumption and Growth

Thirty-three walleye and 29 sauger, ages 2 and 3 were fed diets of yellow perch and emerald shiner for a period of five weeks at the rate of 3.7 to 4.0% (wet weight) of body weight per day. No significant difference in weight gain was found between diets of emerald shiner and yellow perch (Table 17). Two year old walleye feeding on emerald shiners had the highest gross growth efficiency[1] (K_1 =0.143); three year old walleye were slightly less at 0.132. Growth efficiency decreased slightly in walleye eating yellow perch, two year old walleye had a K_1 value of 0.140 and the three year

[1]Gross or total growth efficiency is expressed by the ratio of growth (ΔB) to the total food consumed. In terms of energy, this is Ivlev's energy coefficient of growth of the first order, represented by K_1 or simply K.

Table 17. Age 2 and 3 Walleye and Sauger Fed Emerald Shiners and Perch in the Laboratory for Five Week Periods (Ranges are in parentheses)

Predator	Total No. of Predator Fish	Age	Food	Average Predator Weight (g)	Average Predator Weight Gain in (g)	Average Weight of Food (g)	Food - Average Percent of Body Weight Per Day	Growth Efficiency; Average K_1 $(\frac{\Delta W}{R})$
Walleye	9	2	Shiner	139.2 ±0.8*	21.5(19.9-22.7)	152.0(146.2-154.8)	3.95(3.83-4.02)	.143(.135-.148)
	8	3	Shiner	216.3 ±1.4	36.2(32.8-41.9)	276.3(254.1-297.7)	3.89(3.81-3.99)	.132(.126-.141)
	8	2	Perch	147.6 ±0.9	25.8(23.1-26.9)	185.6(171.0-190.8)	3.92(3.72-4.04)	.140(.133-.143)
	8	3	Perch	241.1 ±3.7	43.7(38.4-47.1)	336.1(309.5-348.1)	3.91(3.79-4.05)	.131(.123-.137)
Sauger	8	2	Shiner	85.6 ±0.5	14.8(13.6-15.9)	107.2(100.9-113.6)	3.87(3.80-3.93)	.139(.134-.141)
	7	3	Shiner	132.5 ±1.9	23.0(21.3-24.7)	181.4(173.0-189.8)	3.81(3.76-3.85)	.127(.123-.130)
	7	2	Perch	91.4 ±0.5	16.1(14.9-16.4)	116.9(109.6-124.1)	3.88(3.81-3.94)	.134(.132-.136)
	7	3	Perch	126.6 ±2.8	21.1(19.4-22.8)	172.3(166.4-178.2)	3.76(3.70-3.82)	.123(.117-.128)

*One standard deviation of the mean

olds, a value of 0.131. The K_1 values for all sauger were lower than all walleye but not significantly different. Two year old sauger feeding on emerald shiners had a K_1 value of 0.139 and three year old sauger a value of 0.127. Three year old sauger feeding on yellow perch had the lowest K_1 value (0.123). Three year old sauger refused to feed during the last eight days of the test and had to be force fed.

Satiation Volume

The five walleye and four sauger (age 2-4) which were given an additional amount of emerald shiners (satiated) for five weeks fed only during the lowest light levels at night. As a result of this response to low light intensity, all other laboratory fish were fed during low light periods. Satiated fish consumed between 4 and 9% of their body weight per day (average 5.8%) and showed a reduction in K_1 values (walleye, 0.105 and sauger, 0.090) when compared to those fish fed on a 3.7 to 4.0% diet. Both species consumed approximately the same amount of food during these studies, varying less than ±4%/g body weight. Satiation tests were the most difficult feeding tests to quantify since the exact weight of the food fish consumed was not always known. In most cases, emerald shiners of the same weight were used for the satiation feeding, and at no time did the food fish vary more than ±0.20 g in weight within the same tank.

Stomach and Gut Evacuation

Stomach and gut clearance for seven walleye and seven sauger ages 2 through 4 was the same for both the diets of emerald shiners and yellow perch. The mean time for stomach clearance was 18.75 hours for walleye and 17.4 hours for sauger with a range of 16.2-19.9 hours for both fish. The mean clearance of the entire digestive system was 49.5 hours for walleye and 47.5 hours for sauger with a range of 45.0-51.8 hours for both fish (all times taken at 19-21°C).

Assimilation Efficiency

Assimilation efficiency derived from fecal analysis of fourteen walleye and sauger samples showed walleye assimilated an average of 93.01% (91.6-96.3%) of the caloric content of the emerald shiner ration, and sauger, not significantly different from the walleye, assimilated 91.11% (88.2-94.8%). Approximately 50% of the ash content of the ration for both the walleye and sauger was present in the feces.

Maintenance

Seven sauger and six walleye (ages 2 and 3) were held at zero weight gain for five weeks at 19-20°C on a diet of emerald shiners. Four weeks were needed prior to each test to establish the food consumption level. The walleye maintained a constant weight when fed food equivalent to 2.0 to 2.2% (2.05% average) of their body weight per day. The walleye were easily fed at this level and remained in good condition throughout the testing period. The sauger maintained a constant weight when fed 1.7 to 1.9% (mean, 1.87%) body weight per day. The two, three year old sauger refused live food after the fourth week of acclimation and were force fed until they died during the second week of the test. The remaining five 2 year old sauger fed normally during the test period.

Four and five year old walleye and sauger were not used in the laboratory testing as was originally planned since feeding could not be established and force feeding disturbed the fish to the extent of frequent regurgitation of part or all of the daily meal. In addition, the sauger ages 4 and 5 never became acclimated to the confined environment and continued to swim into the walls of the tanks and damaged their mouths. All younger fish held in the laboratory became acclimated to the tanks within one week if the light was reduced to one to two foot-candles at the surface of the water during the day and total darkness was provided at night.

Metabolism

Average "quiet" metabolism for walleye and sauger showed no significant difference between the two species (Table 18). The five walleye ranged in weight from 148 g to 258 g and ranged in metabolic rate from 1.09 to 1.49 mg O_2/hour/g of fish (at 19°C) within nine hours from the beginning of the test and remained at that level for seven hours. The five saugers tested ranged in weight from 82 g to 141 g and reached their lowest oxygen consumption at nine to fifteen hours into the tests. The lowest range for the sauger was

Table 18. Resting Metabolic Rates Recorded for Five Walleye and Five Sauger Ages 2 and 3 at 19°C.

	Age	Weight (g)	Average "Quiet" Metabolism (mg O_2/hr/g of fish)**	Total Time of Experiment in Hours
Walleye *	2	148	.149	16
	2	162	.144	16
	2	177	.139	16
	3	239	.116	17
	3	258	.109	17
Sauger *	2	82	.154	15
	2	97	.146	15
	2	107	.141	15
	3	136	.137	15
	3	141	.124	15

*Fish were preconditioned for two weeks in ten gallon aquaria (one fish per tank) at 19 C and fed emerald shiners at the rate of 4% of body weight per day.

**Mean values determined from measurements taken at hour 9 until termination of experiment.

recorded between 0.124 and 0.154 mg O_2/hr/g of fish, but at no time did the oxygen consumption decrease as steadily as that of the walleye at the beginning of the tests nor did the sauger appear as relaxed as the walleye in the chamber throughout the tests.

Movement and Spawning Behavior

Movement

A total of 153 walleye and 159 sauger were tagged during the study. Of these, 61 walleye and 57 sauger were tagged in Governor's Bay and the lower river during the summer of 1972. Five tagged sauger and four tagged walleye were recaptured in the bay during the same summer. Two walleye and one sauger tagged in the bay were recaptured within two weeks, one walleye and three sauger within one month, and one walleye and one sauger tagged in June were caught in August. In addition to those recaptured in the bay, one sauger tagged in the bay was recaptured 5 km downstream during the same summer and one walleye was reported to have been caught by an angler more than 15 km downstream from Governor's Bay, three months after tagging.

Ninety-two walleye and 102 sauger were tagged in the upper river throughout the summer of 1971. There was only one tag recovery in the upper river during 1971. One walleye tagged during July was caught in a trap net in August 3.5 km upstream from where it was tagged. Three sauger tagged in 1971 were recovered in 1972, one by an angler and two by gill nets. The tagged sauger showed no damage to the skin where the tags had been inserted for as long as 12 to 14 months.

Spawning Behavior

Spawning walleye and sauger have not been observed in the Ottawa River at Ottawa. Spawning walleye have been reported at Arnprior, 49 km west of Ottawa, where the Mississippi River enters the Ottawa River, and at Wendover, 49 km east of Ottawa, where the South Nation River enters the Ottawa River. To determine whether the walleye and sauger spawn at Ottawa, the shoreline was observed during the spawning period. Walleye spawned at the base of the Chaudière Falls from mid April to early May, 1972, beginning at sunset in water temperatures between 4 and 8°C. A few fish were still present at the base of the falls when the water temperature reached 12°C (May 19). There were an estimated 200 walleye at the base of the falls during the peak period of spawning which occurred in 5°C water during the last week of April.

Twenty-one walleye caught by anglers over a period of eight days were examined. Sixteen of these fish were males between four and seven years old. The five females were five to seven years old and contained between 24,000 and 49,000 eggs each (average - 35,000). Sauger were not observed in the spawning areas during the time of walleye spawning. Unsuccessful attempts were made to determine whether or not walleye and sauger spawned along the shoreline of the river.

Nine post-larval walleye and three of sauger were pumped from a total of 47 perch stomachs sampled from the lower river. Perch caught along the south shore of the river in Governor's Bay and Yellow Bay were the only fish which contained the post larval stages of the walleye and sauger. All post-larval stages were found between June 15 and July 15 of 1971 and 1972 even though stomach sampling of the perch continued throughout the summer. No post-larval stage of walleye or sauger was found in the 55 perch stomachs from the upper river during the same two summers. Numerous young-of-the-year walleye and sauger were seined in the lower river after dark in August and September of 1971 and 1972.

DISCUSSION

Growth

Growth of the walleye throughout North America differs with respect to geographic location (Figure 7). Southern populations of walleye grow faster than their northern counterparts because of the longer growing season, warmer temperatures and higher productivity of the habitats (Vasey, 1967). Walleye of the Ottawa River, because of latitude, might be expected to grow at a rate approximately mid-way between the most northern and southern populations

Figure 7. Age-length relationships of walleye from the Ottawa River and other bodies of water.

a - Rosebery, 1951 - Claytor Lake, Virginia (approx. 37°Lat.).

b - Stroud, 1949 - Norris Reservoir, Tennessee (approx. 36°Lat.).

c - Mayhew, 1956 - Cedar River, Iowa (approx. 42°Lat.).

d - Rose, 1951 - Spirit Lake, Iowa (approx. 43°Lat.).

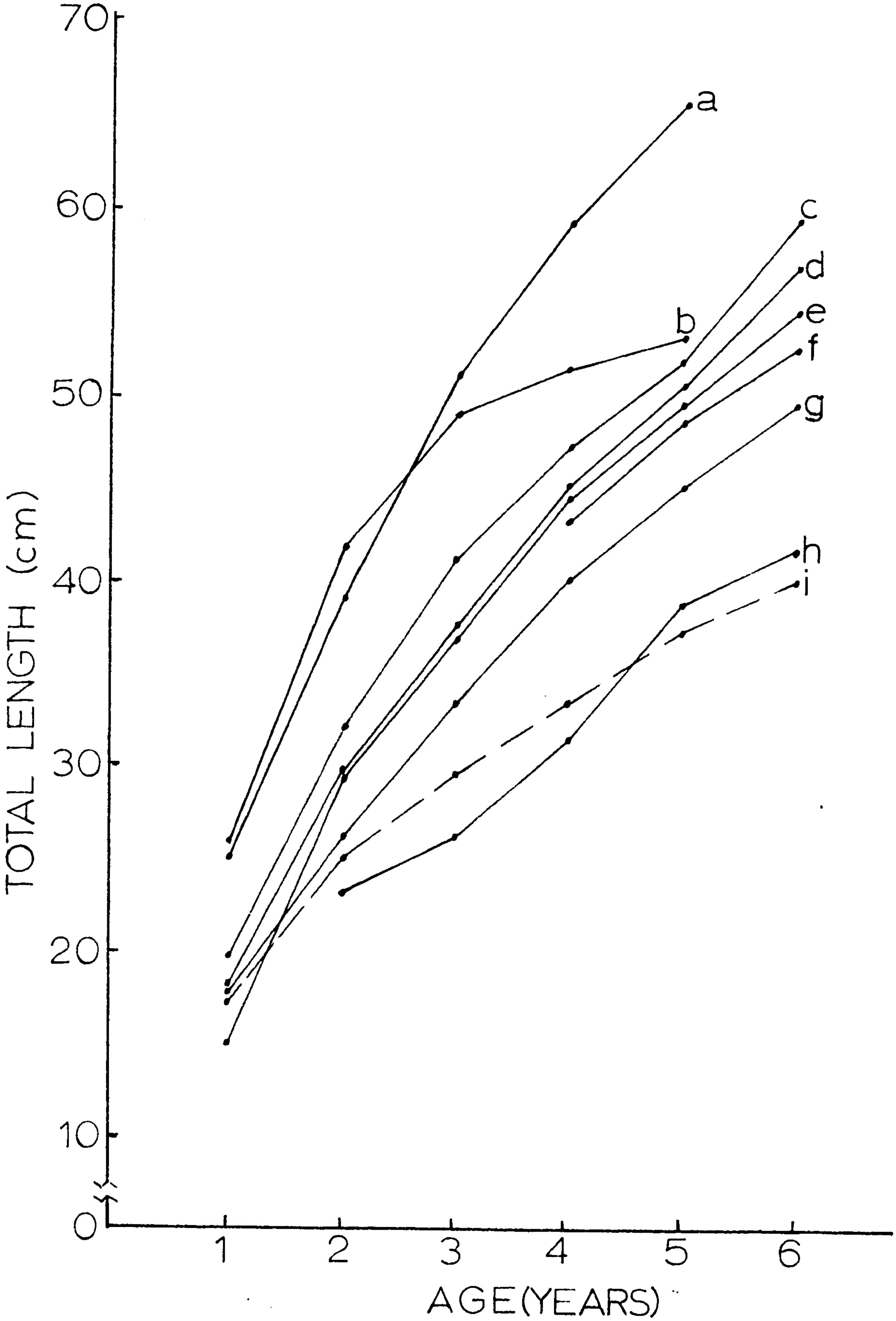
e - Cleary, 1949 - Clear Lake, Iowa (approx. 43°Lat.).

f - Raine, 1967 - St. Lawrence River, Ontario (approx. 44°Lat.).

g - Balch, 1951 - Northern Green Bay, Wisconsin (approx. 45°Lat.).

h - Rawson, 1957 - Lac LaRonge, Saskatchewan (approx. 55°Lat.).

i - Ottawa River - present study (approx. 45°Lat.).



TOTAL LENGTH (cm)
70
60
50
40
30
20
10
0
1
2
3
4
5
6
AGE(YEARS)
a
b
c
d
e
f
g
h
i

of the range. The Ottawa River walleye actually grow in length at a rate similar to the walleye from Lac La Ronge, a body of water which is located near the northern edge of the walleye range.

Yet walleye from the Ottawa River grow in length more slowly than walleye from other areas with similar climates (Figure 7). Six year old walleye from Green Bay, Wisconsin, are 20% longer than 6 year old walleye from the Ottawa River (Balch, 1951). Six year old walleye from the neighboring St. Lawrence River exceed the walleye in the Ottawa River by 30% in length (Raine, 1967).

Also, growth in weight of the Ottawa River walleye is less than the growth in weight of walleye from other bodies of water (Figure 8). Raine (1967) found that walleye of the St. Lawrence River averaged 1300 g at age 4. Ottawa River walleye are less than one quarter the weight of the St. Lawrence fish at the same age. Raine suggests that walleye of the St. Lawrence River are somewhat heavier than might be expected, and that the increase in weight is possibly a result of increased food consumption due to the lack of competition among the piscivorous fish in the river. He further notes that the size of the walleye population in the St. Lawrence River has been decreasing since 1960, while sauger are no longer found.

Figure 8. Age-weight relationships of walleye from the Ottawa River and other bodies of water.

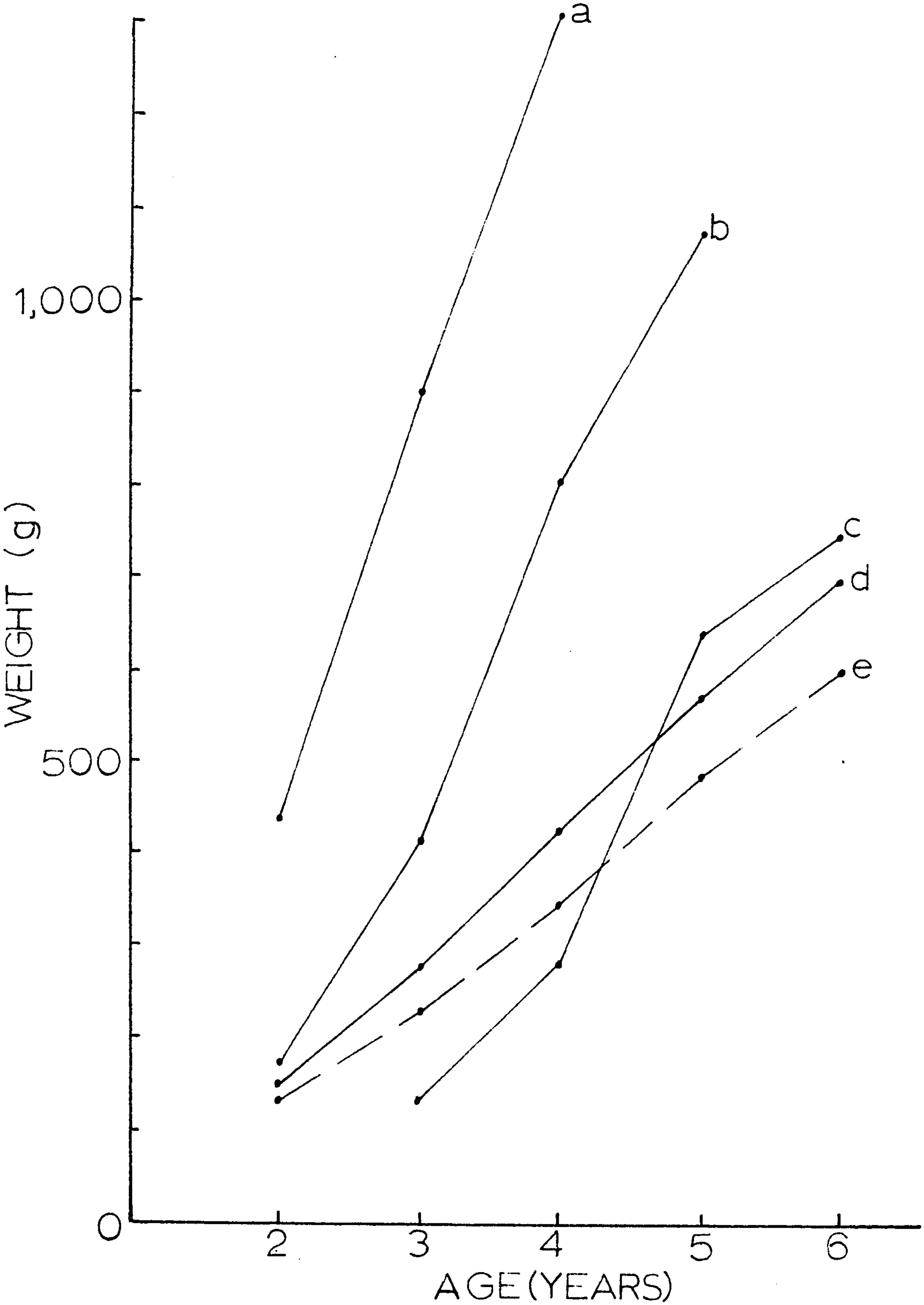
a - Rosebery, 1951 - Clator Lake, Virginia (approx. 37^{o}Lat.).

b - Rose, 1951 - Spirit Lake, Iowa (approx. 43^{o}Lat.).

c - Rawson, 1957 - Lac LaRonge, Saskatchewan (approx. 55^{o}Lat.).

d - Priegel, 1969 - Lake Winnebago, Wisconsin (approx. 44^{o}Lat.).

e - Ottawa River - present study (approx. 45^{o}Lat.).



a
b
c
d
e
1,000
500
0
WEIGHT (g)
2
3
4
5
6
AGE (YEARS)

The reason for the change in the two populations is not discussed by Raine. Both populations did coexist in the St. Lawrence River, west of Montreal, before the construction of the dams and locks in the late 1950's (Moore 1934).

Condition factors quantify relative plumpness in fish and indicate whether or not a fish is properly proportioned with respect to its length and weight. Condition factors that are below average suggest limited growth of the fish, and higher than average factors suggest excess growth. Mean condition factors for the Ottawa River walleye indicate a limited growth when compared to walleye from the Mississippi River (Figure 9). Since condition factors for all age groups of the Ottawa River walleye are relatively constant, rather than showing an increase with age, the factors which are responsible for the reduced growth of the walleye may be affecting the older fish to a greater extent than the younger fish. The difference between condition factors of the walleye and sauger in the upper and lower river (Table 5) indicate that the lower river fish are heavier for their length and suggest that either the two populations differ in their growth characteristics or more likely that the lower river habitat

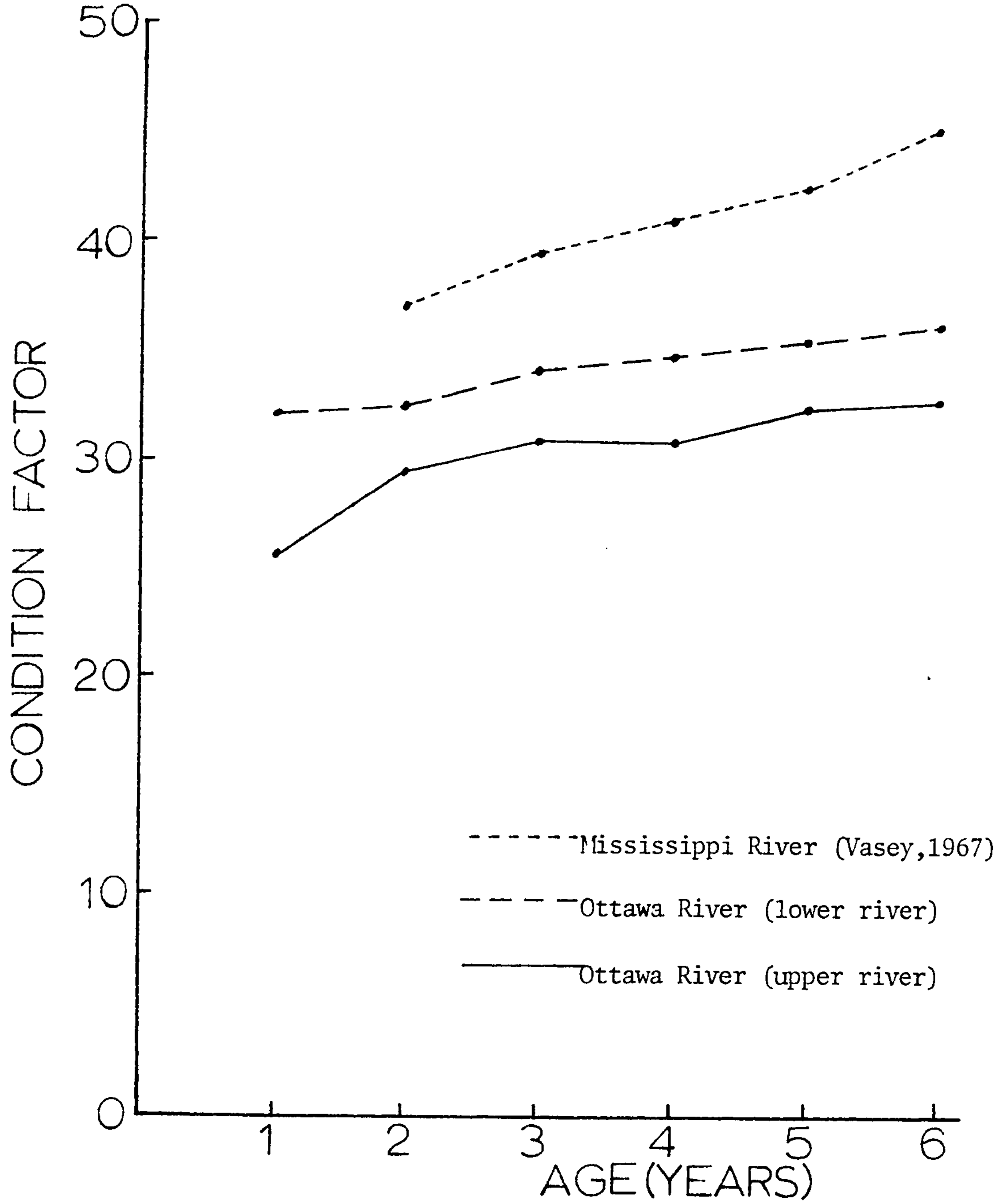


Figure 9. Relation of condition factors of walleye from the Ottawa River to walleye from the Mississippi River.

provides somewhat better growing conditions than those of the upper river.

The low growth rate of the Ottawa River walleye can be attributed to a variety of factors. The fish could be genetically different in their growth potential from other populations of the species and may not be capable of attaining the lengths of the regional norm. This is unlikely however, since walleye in our laboratory study showed that their digestive and growth characteristics were similar to those found for walleye by Kelso (1972). Also, walleye in the neighboring St. Lawrence River grow to lengths similar to the regional norm (Raine, 1967). Until recently, the Ottawa and St. Lawrence River populations have been able to mix, but man-made barriers, constructed within the past forty years, now separate the two populations. The length of time during which they have been separated, however, may not have been sufficient to allow for the genetic divergence of the two species. Therefore, local environmental factors, rather than genetic factors, are more likely to be causing these growth differences.

The sauger, although closely related to the walleye in its anatomy and certain growth related processes compared in our laboratory study, does not grow as large as the walleye. The lower condition factors of the sauger, in comparison to the walleye (Table 5), is indicative of their slender body shape. Sauger, during their first three years of growth in the Ottawa River compared favorably in growth to the same species from certain other bodies of water at the same latitude (Figure 10). However, sauger from the Ottawa River, older than age 3, showed a substantial decrease in their yearly growth rate. The decrease was greater than that found in any of the fish of the same age from the other bodies of water.

From the growth comparisons in Figures 7 and 10, it is possible that both the mature walleye and sauger in the Ottawa River lack certain necessary conditions for attaining the size reached by their counterparts elsewhere at similar latitudes. There may be no single cause for this reduction in growth. However, competition for food, and the type and abundance of food available in the common feeding sites probably have an important affect on the growth and are discussed later.

Certain growth patterns suggest that the walleye has particular advantages over the sauger. Some of these growth differences between the two species may not necessarily be adaptations to the local environmental conditions but may be characteristics of the species. As a result of these differences, the walleye may gain certain competitive advantages over the sauger.

A lag in the seasonal growth of the sauger in relation to that of the walleye is evident when annulus completion of the two fish are compared (Table 7). All of the two year old

Figure 10. Age-length relationships of sauger from the Ottawa River and other bodies of water.

a - Hassler, 1957 - Norris Reservoir, Tennessee (approx. 36°Lat.).

b - Vanicek, 1964 - Lewis and Clark Lake, Iowa (approx. 43°Lat.).

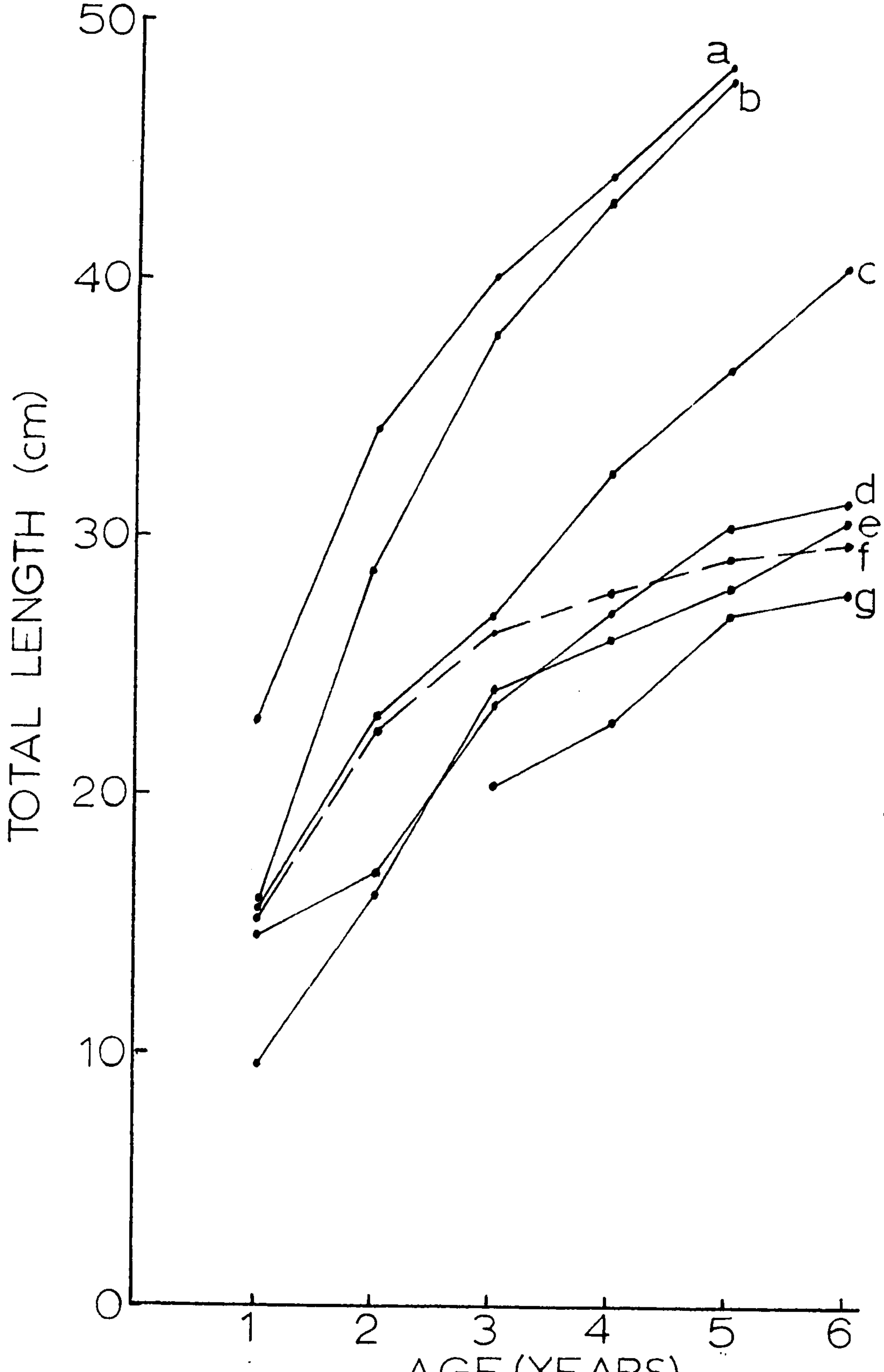
c - Van Oosten, 1948 - Lake Erie (approx. 42°Lat.).

d - Carlander, 1950 - Lake-of-the-Woods, Minnesota (approx. 49°Lat.).

e - Bajkov, 1930 - Lake Winnepeg, Manitoba (approx. 51°Lat.).

f - Ottawa River - present study (approx. 45°Lat.).

g - Hart, 1928 - Lake Nipigon, Ontario (approx. 46°Lat.).



TOTAL LENGTH (cm)
50
40
30
20
10
0
1
2
3
4
5
6
AGE (YEARS)
a
b
c
d
e
f
g

walleye caught in the Ottawa River had completed their annulus by August following their peak feeding activity during the month of July. Annulus completion of the Ottawa River walleye was similar to the two year old walleye from Oneida Lake (Forney, 1965) which also completed their annulus formation by late August.

However, sauger in the Ottawa River were slower than the walleye in completing their annulus. Only 83% of the two year old sauger had completed an annulus by August (Table 7). The slower annulus formation of the sauger suggests that certain growth conditions of the habitat are less favorable for the sauger than for the walleye. Latitude location may be such a condition. Deason (1933) found that walleye and sauger from Lake Erie (≃42° lat.) grew at the same seasonal rate when food was abundant for both species. But when the food supply declined, the sauger were more seriously affected than the walleye. The food supply in the Ottawa River was limited during portions of the growing season and our study showed that the sauger consumed less food per body weight and grew at a slower seasonal rate than the walleye.

Young-of-the-year walleye provided an early indication that the species is a more rapidly growing fish than the sauger. Walleye exceeded the sauger in length by approximately 7% at the end of their first year of growth. Although stomach contents for young-of-the-year fish were not analyzed, it has been reported by Swenson and Smith (1976) that young walleye in Minnesota consume a substantially larger daily ration of food per gram of body weight than do sauger of the same age and from the same body of water. This difference is partly the result of the early spawning of the walleye and may afford the young-of-the-year certain advantages in foraging over their competitors.

Older walleye in the Ottawa River continued to surpass the sauger in length, and had a more constant increase with age. The sauger increased in length to a lesser extent than the walleye, with the exception of age 6 sauger. The apparent lack of growth between the age 5 and age 6 sauger (Table 1) could not be the result of incorrectly determining the age of the fish. More than likely, the reason for this irregularity was that a large number of age 6 sauger were caught early in the growing season. As a result, the average length and weight for the age 6 sauger does not accurately represent the growth of the population from midsummer age 5 to midsummer age 6. No reason other than chance can be given for this sampling error and the difference did not appear in any of the other data. Errors of this type can be avoided if back calculations based on scale annuli are used rather than direct measurements.

The back calculated average lengths and annual increments (Tables 2 and 3) of Ottawa River fish indicate that the walleye and sauger grew the fastest during their first two years of life. This was followed by a greater than usual decline in growth for each succeeding year of life.

Summation of annual increments were found to be, in most age classes, representative of the actual growth conditions as was the grand average of the calculated lengths at the time of annulus formation. Priegel (1969) cautions against the use of the grand averages in describing growth of a population where there is a possibility of selective mortality of individuals with more rapid growth. This may be the cause for the few disagreements in the data of our study. Fish of the Ottawa River are no longer gill netted commercially, and it is hard to rationalize why angling would necessarily select for rapid growing individuals or exploit the walleye more than the sauger.

Lee's phenomenon is evident in some of the back calculated growth data for both walleye and sauger. That is, the younger fish appear to be growing more rapidly than did the older fish when they were young. Explanations for Lee's phenomenon have been discussed by several authors (Van Oosten, 1929; Hile, 1936). Vasey (1967) noted that selective sampling could have been the explanation for Lee's phenomenon in both walleye and sauger from the Mississippi River (U.S.A.), since an effort was made to collect only fish larger than 11 inches for tagging. In the present Ottawa River study, nonselective or random sampling of at least age 2 through 6 fish could be assumed, since a variety of net sizes were used for capture.

Pronounced differences in growth between sexes in both species did not appear during their first few years of growth

(Table 2 and 3). Many females were longer and heavier than the males at age three and the differences in growth between the sexes became significant at maturity. However, the difference in weight between the sexes never reached the proportions reported for the fish from lake habitats (Eschmeyer, 1950; Regier et al., 1969). Although the lake fish may grow larger because of a greater abundance of food, gonad development and egg size also adds to the weight difference, especially in the females of both species. Gamete production in Ottawa River walleye and sauger females was less than 50% of the production from other bodies of water. For example, a 900 g female walleye from Lake Erie was reported to produce an average of 90,000 eggs or 10,000 eggs/ 100 g of fish (Regier et al., 1969). Walleye females from the Ottawa River averaged 4-5,000 eggs/100 g of fish and the sauger were between 20 and 30% less in egg production than the walleye. Although it was not the purpose of this study to measure egg size and compare fecundity of the fish, the larger egg production of the Ottawa River walleye would appear to provide some competitive advantage over the sauger by producing a greater number of young fish.

Walleye and sauger from the Ottawa River did not differ with respect to the time of maturation. This characteristic is very constant in both species throughout their North American range. Maturation, as discussed by Eschmeyer (1950), occurs in males between the ages of 3 and 5 and is a year or two later in the females.

Influence of Impoundments on Growth

Because detailed pre-impoundment studies dealing with fish growth are lacking for the Ottawa River, it is difficult to determine how long the growth of the Ottawa River walleye has been below normal, and how long the dams constructed in the late 1950's at Hawksbury, Arnprior and on the tributaries of the Ottawa River have affected the fish. Dymond (1939) reported that a considerable commercial fishery for walleye existed in the Ottawa River in the early 1900's, and that large specimens reached weights of 3.5 to 4.5 kg. The largest fish caught during our study weighed less than 1.5 kg.

Sauger were once present in the entire St. Lawrence River system, but now the Ottawa River is the only river in the system west of Montreal in which the sauger still exists (personal communication--Ontario Ministry of Natural Resources, Ottawa). Detailed documentation of the decline and extinction of the sauger in these rivers is lacking. Comments from the local residents, however, indicate that a reduction in the size of the sauger as well as walleye caught by angling followed the completion of the impoundments.

Considerable evidence from other rivers supports the hypothesis that impoundments in the Ottawa River have contributed to reduced growth in the walleye and sauger. When barriers are constructed in a river system, movement of the fish is restricted, physical characteristics of the habitat change (e.g. current velocity and water depth), and accessibility to foraging and spawning areas frequently become limited (Nelson and Walburg, 1977). Changes in growth of walleye and sauger as a result of impoundments affecting their feeding behavior and movement are not uncommon and have been reported by Elrod and Hassler (1969) and Nelson (1969).

Before the construction of dams in the Ottawa River, the river was confined to the original channel and traversed many rapids and falls (Piché, 1954). Impoundments slowed water currents, increased the depth of the water, flooded the low-lying shoreline creating numerous shallow bays, increased sedimentation, and flooded most of the rapids. Demersal fish, commonly fed upon by walleye and especially sauger, such as the logperch, Percina caprodes, and the Johnny darter, Etheostoma nigrum, were described by Dymond (1939) as being abundant in the rapids and sublittoral zone of the Ottawa River, but are now scarce in the river. Neither species were found in the stomachs of the walleye and sauger examined during this study nor was either observed during the SCUBA dives in the river.

Natural and cultural eutrophication has increased in the river, especially in the lower river as a result of the impoundments and the effluent wastes from human waste disposal plants and wastes from a meat processing plant near Brewery Creek (Piché, 1954). Early stages of eutrophication can be beneficial to the growth and production of walleye and sauger populations; however, progressive eutrophication is usually not tolerated by either species and is somewhat more detrimental to the feeding behavior of the walleye than the sauger (Leach *et al.*, 1977). Growth data from our study confirm the response of walleye and sauger to different stages of eutrophication. Growth rates of both the walleye and sauger were greater in the lower river where eutrophication was greater than in the upper river. Very few sauger and no walleye were caught during the study in the highly eutrophic Brewery Creek tributary of the lower river.

Influence of Competition on Growth

Physical conditions of the environment are not the only factors which may affect the growth of a fish population. Competition also plays an important regulatory role in the growth of a biotic community. When food is limited and two or more species depend on the same food source, the success of a species in foraging determines its food consumption and growth. The greater the similarity these species have in their feeding behavior, the greater the effect competition will have on their food consumption and growth.

Walleye, sauger, and yellow perch were the closest competitors for the limited prey in the Ottawa River. Competitive interactions for food between walleye, sauger, and other species are common and have been described by Carlander (1942), Forney (1974), Swenson (1977) and Swenson and Smith (1976). Many of these studies deal with large lake habitats in which the *Stizostedion* spp. and their competitors were found to occupy either different portions of the habitat or to consume different food fish. Walleye in these lakes forage primarily in the littoral zone for pelagic food while the sauger are restricted more to the sublittoral zone and feed on the demersal species. In such habitats, interspecific competition for food may cause only a slight stress on the two predator populations, especially if they feed on different food species. In rivers, however, the diversification of feeding sites is frequently not as extensive as in lakes. In the Ottawa River, the demersal species are no longer an abundant source of food in the sublittoral zone because of the effects of the impoundments and also the wood fiber from the paper mills which covers most of the river bottom. The sauger, therefore, have been forced to feed with the walleye on the same food species in the littoral zone.

Food Consumption

Certain aspects of food consumption of walleye and sauger in the Ottawa River did not differ greatly from those reported for the two species from other bodies of water by Dobie (1966), and Swenson and Smith (1976). Both species fed during periods of darkness, consumed a diet of fish, and rarely exceeded a daily ration of 5% of body weight. However, the Ottawa River fish were different from the above fish and consumed the same species of food fish in the littoral zone of the river.

Our results indicate that the walleye and sauger caught in the Ottawa River between 1967 and 1972 fed mostly on the emerald shiner (Table 15) and that yellow perch composed an important secondary food source. Yellow perch and the cyprinids were the most abundant prey in the river, and comprised approximately three quarters of the available food.

The number of prey species in the stomachs of walleye and sauger in different areas of the Ottawa River varied with the abundance of available prey fish (Figure 11). Stomachs of walleye and sauger from Governor's Bay, Brewery Creek and Yellow Bay in July and August contained an average of 88% emerald shiners (the remaining contents were mostly yellow perch). Seining in the same areas during July and August produced an average emerald shiner/yellow perch ratio of 2.1 in both day and night hauls. More than 70% of the fish in all seine hauls were emerald shiners and yellow perch. Further downstream at Kettle Island, the stomachs contained an average of 64% emerald shiners and a seine ratio of 1.7. In no area of the river did the yellow perch exceed the emerald shiners as a percentage of stomach contents or seine counts during July and August. However, during June, September and October the abundance of emerald shiners decreased and was only slightly higher than the perch in the seine counts. It was difficult to determine the emerald shiner/yellow perch ratio of the upper river since the quantity of prey fish retrieved by seining was extremely variable (at times, less than 70% of the total for the lower

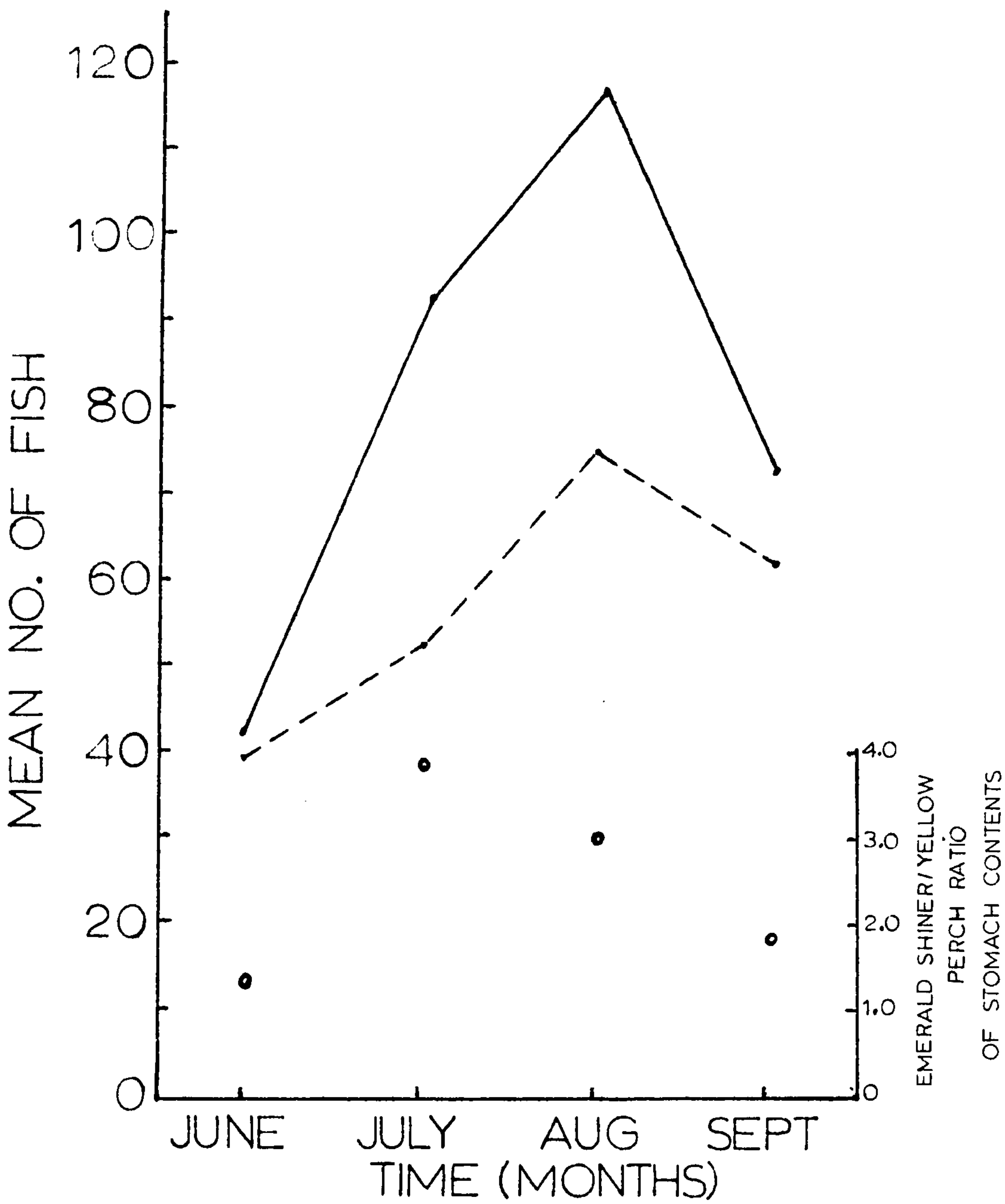


Figure 11. Relation of mean number of emerald shiners (solid line) and yellow perch (dotted line) caught in seine hauls to emerald shiner/yellow perch ratios (0) in stomach contents of the walleye and sauger caught in Governor's Bay during 1972.

river). Because cyprinids composed 91% of the stomach contents of the upper river fish, it is believed that either they were being selected for, or more likely, they were the most abundant food source. Another factor contributing to the high percentage of cyprinids may be their schooling nature which allows them to be located visually with greater ease by the predator than the less gregarious perch.

Although the emerald shiner was the primary source of food for walleye and sauger, the yellow perch served as an important food source as well in all areas of the river. Yellow perch were found to be more numerous in the stomach contents of the walleye and sauger in early summer and in early fall. Seine hauls were lowest in emerald shiner concentration during these periods. The new recruitment of the emerald shiner for the 1970-1972 growing seasons did not appear in stomach contents until July of each season. Food consumption of the walleye and sauger peaked during July and August (Figures 5 and 6) when the emerald shiner was most abundant, indicating the importance of prey density in food selection discussed by Swenson (1977). It appears that the yellow perch serves as a supplementary or "back-up" food source and is consumed during periods of low population density of the emerald shiner. A reduction in the abundance of either of these two food species in the Ottawa River would seriously affect the feeding habits and food consumption of the *Stizostedion spp.*.

Size of the prey fish consumed by the different ages of walleye and sauger seldom exceeded 10 cm in length. Large prey fish, such as yellow perch, were not common in the stomach contents of the larger predators. It would seem to be a more efficient use of energy if the larger walleye and sauger preyed upon the larger food fish. Perhaps the larger prey fish were more difficult to capture and were less abundant than the smaller fish.

Food palatability may influence the food selection of the walleye and sauger in areas where there is an abundance of food types. In a study of the food habits of young-of-the-year walleye in Lake Erie, Wolfert (1966), found that they selected a higher proportion of small, pelagic, schooling cyprinids than of the equally abundant yellow perch of the same size. Forney (1965) noted that the emerald shiner, which was frequently observed in the stomachs of walleye from Oneida Lake in 1941 and 1952, has been very scarce since 1956, and is now replaced by yellow perch. Our results are in general agreement with these observations and confirm that spiny-rayed food fish are generally selected by both walleye and sauger when soft-rayed fish are lacking or are limited in the habitat.

Piscivorous fish frequently resort to cannibalism when the normal food supply is not available. Cannibalism is not uncommon among the Stizostedion spp. (Swenson and Smith, 1976). Stomach contents of the fish from the Ottawa River indicated that cannibalism was not prevalent during the study period, but did occur in June and September when the prey were least abundant.

The quantity of food consumed by the walleye and sauger in the Ottawa River provides strong evidence that the sauger are subordinate to the walleye with respect to their ability to forage. Food consumption by the two species in the laboratory established that both fish will consume a daily ration of at least 4%/g wet body weight. However, our field data indicated that the 2-5 year old sauger consumed approximately 25% less food in their daily rations (% of body wt/day) than the walleye (Figure 12). Both the walleye and sauger showed a decrease in food consumption for increasing age. The rate of this decrease for the sauger was slightly less than the walleye and was likely due to the difference in growth of the two species.

It was not possible to determine in the field whether or not the walleye and sauger consumed a meal every night. However, a few individuals of both species were caught leaving Governor's Bay with empty stomachs. Because approximately 30% of the 1967-71 fish had empty stomachs as well as empty intestines when caught, a feeding frequency greater than every 24 hours for both fish appeared to be possible. Since the clearance of food from the stomach occurs in less than 24 hours at temperatures of 19-21°C (Figure 17), a daily feeding pattern during the summer appears to be more likely. It is also possible that those fish leaving the bay with empty stomachs may re-enter the bay

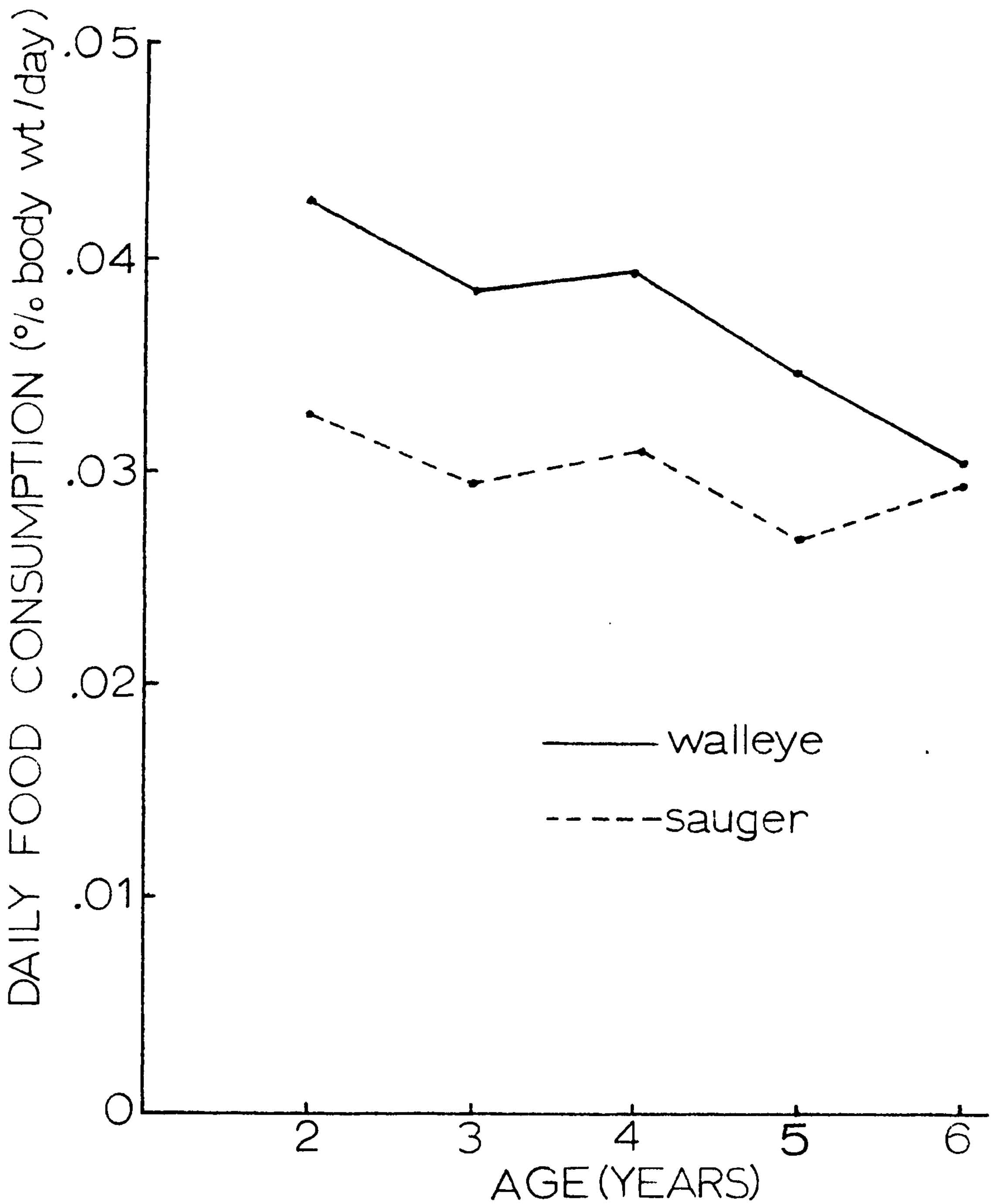


Figure 12. Average daily food consumption of walleye and sauger caught in the Ottawa River between May and October, 1967-1971.

later the same night and forage successfully. Frequency of feeding is a factor which could be affecting the growth of the fish in the Ottawa River. It can be estimated by means of determining the daily ration and growth of the fish. These estimates are discussed later.

The stomach contents of walleye and sauger in the Ottawa River during the winter months showed little deviation from the emerald shiner diet of the summer, and both consumed a smaller quantity of food. The decrease in winter feeding was probably a result of lower temperatures, a decrease in available food, lower energy requirements, lower satiation volume, and longer voidance times.

Influence of Light on Feeding Behavior

Similarity in certain aspects of the feeding behavior and movement of the walleye and sauger was evident in their time and place of capture. Both fish foraged in the shallow bays and were caught in the bays only during periods of darkness. A negative response to light intensity by both species was apparent and they remained in the deep water until sunset. Numerous authors have described this negative response to light intensity in the Stizostedion spp. (Ali et al., 1977; Eschmeyer, 1950; Regier et al., 1969; Ryder, 1977). In clear water, Bensley (1915) noted that walleye avoided light and fed only between sunset and sunrise. In more turbid inland waters, he reported walleye fed before sunset.

Ali et al. (1977) and Ryder (1971) found that walleye and sauger differed with respect to their tolerance to light because of structural differences in their eyes. The sauger, having a greater sensitivity to light than the walleye, usually remain in the deeper water where the light is less intense. It is understandable that in habitats where the distribution of food is not a limiting factor in the choice of a feeding site, the sauger will feed in the darker sub-littoral zone and the walleye will utilize the food in the littoral zone.

Also, according to Ryder (1971), sauger would have a visual advantage over the walleye in turbid water while walleye would have the advantage in relatively clear water (Secchi reading of 1.5 or greater). Secchi readings in the upper and lower river, excluding the north channel, were never less than 1.7 m and, therefore, the turbidity of the water could be considered advantageous to the foraging of the walleye rather than the sauger. Water downstream of the north channel effluents had Secchi readings ranging between 0.2 to 1.0 m; the catch per unit effort in this area, however, never reflected a predominance of sauger when, according to Ryder, it should be sauger dominated water. Because of the chemical effluents in the water of the channel and the lack of food, it is possible that the fish caught there were transients that spent most of their time in the deeper and less turbid water of the river.

Distinctive feeding behavior of walleye and sauger with relation to light was evident during 1972 in Governor's

Bay. Because the greatest movement of the fish was at net site B (Table 9), the shortest distance from the deep river channel to the feeding area, it is likely that the walleye and sauger awaiting darkness, moved as close as possible to the bay. They remained in the darkness of the deeper water until they were stimulated by a sufficient decrease in light and then moved into the bay to feed.

Light intensity affected the feeding behavior of the walleye and sauger kept in laboratory tanks. Young walleye (age 1-3) voluntarily fed on a regular basis in daylight. The older walleye only fed during the day when light was decreased to less than 1 foot-candle at the water surface. Young sauger (age 1 and 2) appeared uneasy and often refused food or regurgitated the food when light was more than 1 foot-candle at the water surface. Older sauger only fed during periods of total darkness.

The difference between the walleye and sauger with respect to their tolerance to light must have a substantial effect on their feeding behavior and growth. Although the lateral line system has been shown to aid many deep water fish in their feeding behavior, it does not replace the need for good vision in the <u>Stizostedion</u> spp. (Disler and Smirnov, 1977). It is understandable that the walleye and sauger have adapted to different intensities of light in the habitat, and have thereby lessened their interspecific competition for food when a variety of prey are available. However, the limited number of prey species available in the Ottawa River has caused the Stizostedion spp. to feed in the littoral zone where light intensity favors the vision of the walleye.

Dr. M. A. Ali (personal communication) has noted from his studies on the affects of light intensity on vision of the walleye and sauger, that the older fish suffer a greater loss of vision in intense light than the younger individuals and that the difference in light sensitivity between the two species becomes greater with age. An increase in sensitivity to light with age in the Stizostedion spp. in the Ottawa River would explain the greater than average decrease in prey caught and consumed by the older individuals (Table 13 and 15). The older walleye and sauger may be best adapted in their vision for feeding in the deepest areas of the littoral zone and in the sublittoral zone; but, because of the lack of prey in the sublittoral zone of the Ottawa River, the older fish must feed in the littoral zone and compete for food with the younger Stizostedion spp. and non-Stizostedion predators.

Feeding Behavior and Movement

Because the nets in Governor's Bay were checked during regular intervals each night, it was possible to describe certain aspects of the foraging behavior of the walleye and sauger (Figure 13). Both species consumed food during their visit to the bay. Very few fish left the feeding area after consuming only one fish or returned to the area after having consumed food. Neither species remained in the foraging

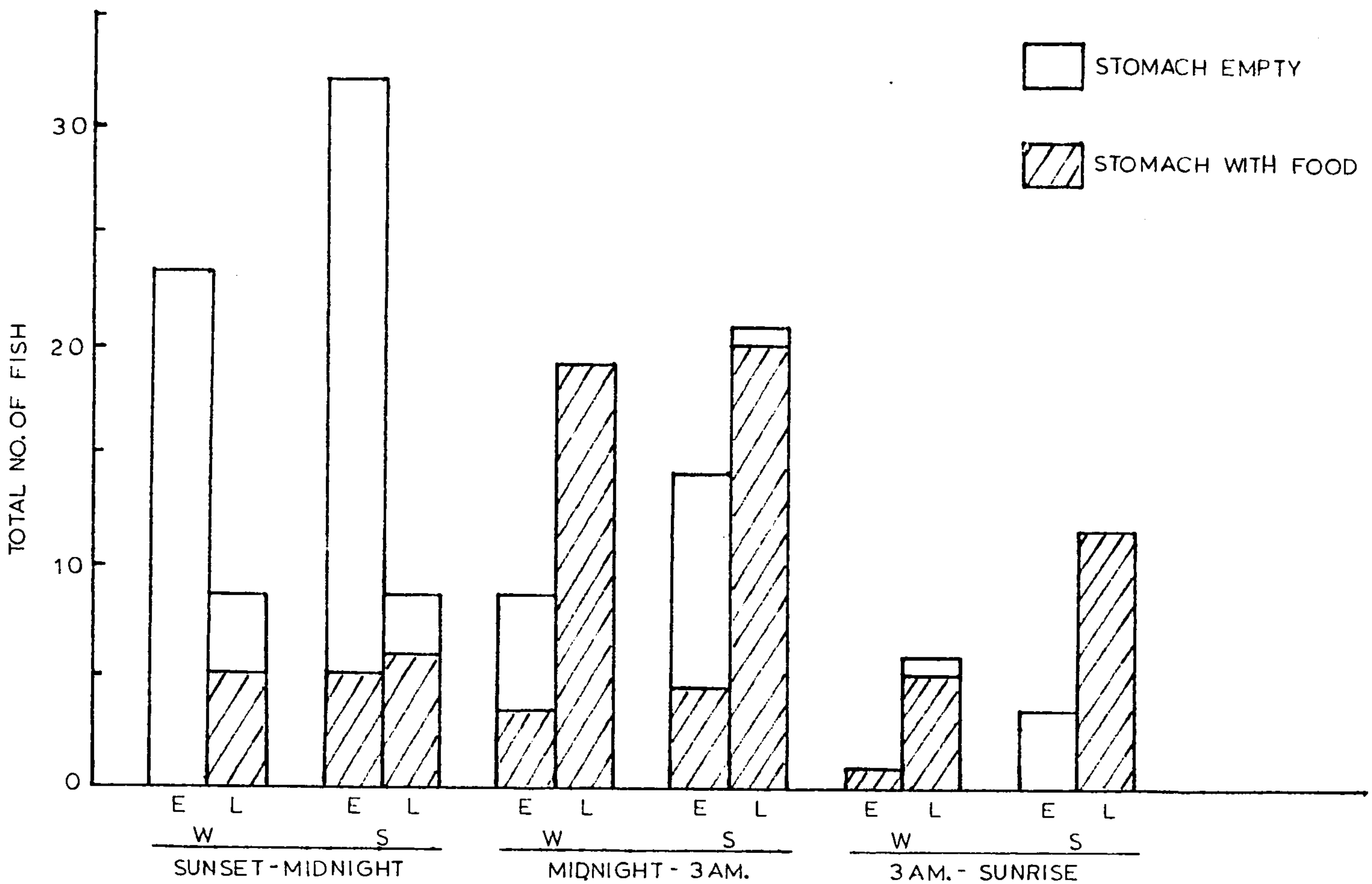


Figure 13. Relation of the total number of walleye (W) and sauger (S) caught entering (E) and leaving (L) Governor's Bay to their food intake during the summer of 1972.

area during the entire night but left for the deeper water after having foraged a daily meal. As a result, movement was the lowest between 3 a.m. and sunrise. Since the walleye and sauger feed only at night, the food consumed during their brief period in the feeding area must represent at least the minimum energy requirement for a 24 hour period.

Our results also show that the proportion of walleye and sauger in Governor's Bay during each time period was similar. Neither species dominated one period. Because the tolerance level of the sauger to light intensity was lower than the walleye, the sauger may have moved into the bay somewhat later than the walleye during the first time period.

A definite similarity between the availability of food, movement, and the food consumption by walleye and sauger was evident in the Ottawa River study (Figure 14). The peak periods of movement into Governor's Bay during July for walleye and August for sauger (Figure 5 and 6), as determined by capture, appears to be related to the number of the young-of-the-year emerald shiners and yellow perch. A greater percentage of the stomach content of the walleye and sauger after the first of July was found to consist of sub-adult prey. The peak periods of walleye movement in July and sauger in August as indicated by the catch per unit effort during 1967 to 1971, coincided with the increased number of sub-adult prey in July. The increase in movement was apparently the result of the increase in food supply

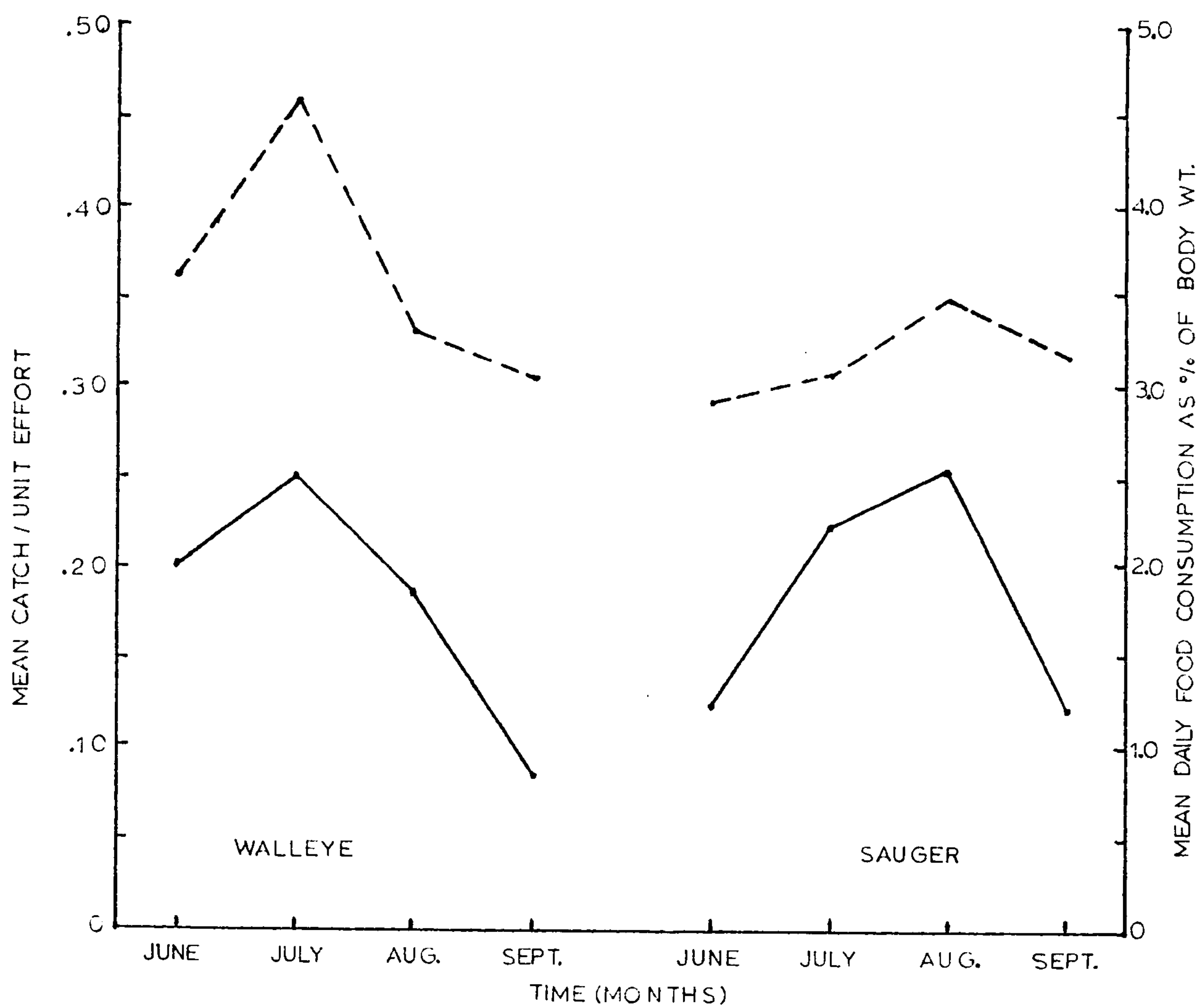


Figure 14. Catch/unit effort (solid line) and daily food consumption (broken line)of walleye and sauger caught in the Ottawa River between June and September, 1967-1971.

which provided easier foraging. The peak food consumption of the walleye in the bay preceded the sauger and explains the earlier seasonal growth of the walleye as indicated by annulus completion.

Laboratory Studies

Our laboratory results for the walleye were similar to those reported by Kelso (1972) and also indicated only slight differences between the walleye and sauger in food consumption, assimilation, and metabolism (Figure 15-19). Satiation in the laboratory allowed neither species the advantage of greater food consumption (Figure 16). Food consumption of the walleye and sauger was similar when the need for locating the prey was removed. Both species showed the same reduction in efficiency of food conversion when the food supply was unlimited. Walleye and sauger were also similar in the optimum levels of gross conversion efficiency (K_1) if they were fed the same daily rations (Figure 15). Kelso (1972) found that a daily ration of approximately 4% of body weight was optimum for walleye and that a slight reduction in gross conversion efficiency occurred in older fish or when the daily rations were either increased or decreased.

Clearance times of food from the stomachs of the walleye and sauger were determined because frequency of feeding is influenced by the completion of digestion in the stomach (Swenson and Smith, 1973). Because both species cleared their stomachs within 24 hours following the consumption of a

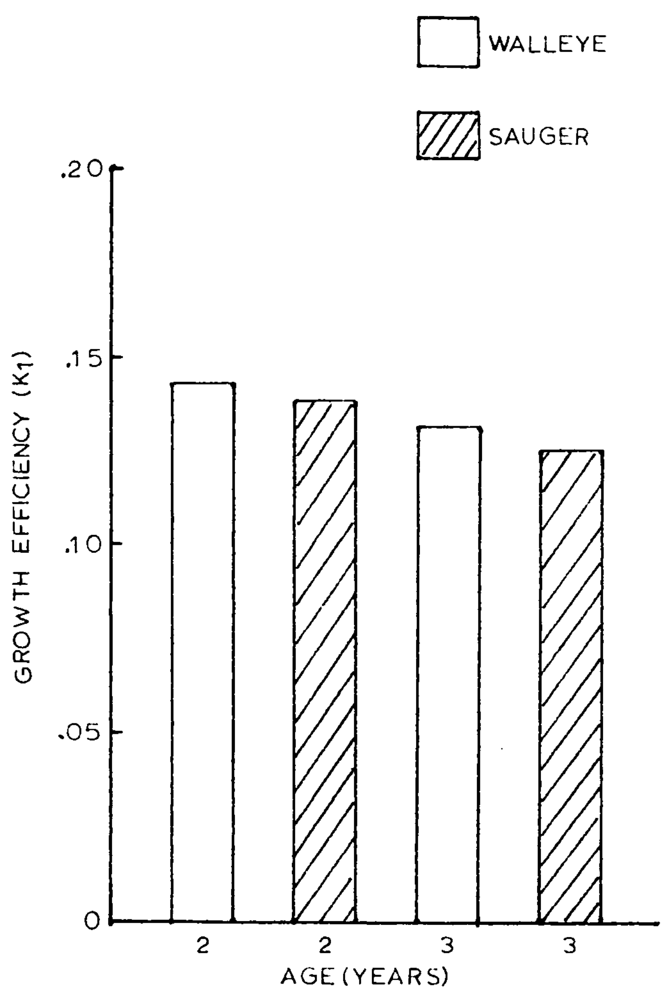


Figure 15. Mean growth efficiency (K_1) of 6 walleye and 6 sauger fed in the laboratory at the rate of 3.8-4.0 % of body weight.

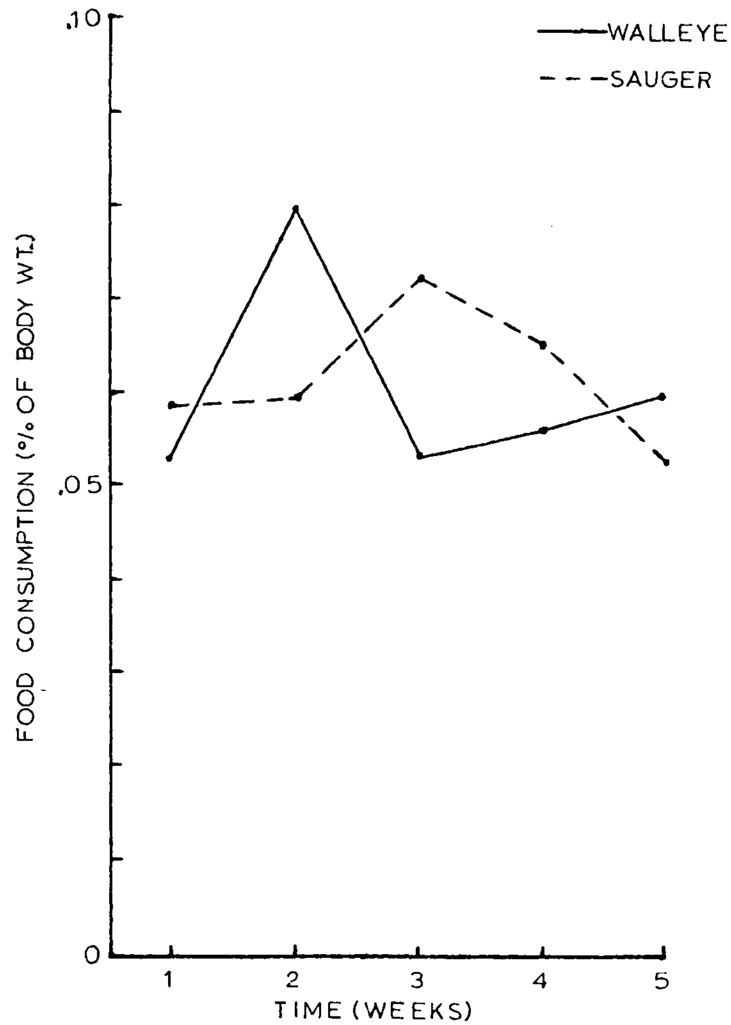


Figure 16. Relation of mean daily food consumption (% of body wt.) of walleye (ages 2&3) to sauger (ages 2 &3) satiated in the laboratory for 5 weeks.

daily meal, and the time for clearance did not differ significantly between the species (Figure 17), both fish would be stimulated to feed during each 24 hour period. The nocturnal feeding behavior of the walleye and sauger, influenced primarily by their negative response to high intensities of light, necessitates completion of their gastric digestion in less than 24 hours if they are to feed every night.

Walleye and sauger held in the laboratory were fed on the basis of the size and quantity of the prey found in the fish caught from 1967 to 1971 in the Ottawa River. Hofmann (1972) recognized that when fish were held in the laboratory for food consumption studies, the rates of digestion and evacuation time varied with the type of food. Since consistency in food type was maintained between the walleye and sauger feeding in the laboratory, it was assumed that digestion and evacuation times as well as other growth related processes could be compared. The slightly higher growth of the two and three year old fish held in the laboratory, when compared to the same fish in the field with similar food consumption, was most likely due to the limited movement of the laboratory fish, allowing the excess energy to be used for growth.

The importance of having walleye and sauger feed naturally during growth and food consumption studies conducted in the laboratory cannot be over emphasized. Food consumption and growth data from force-fed fish in this

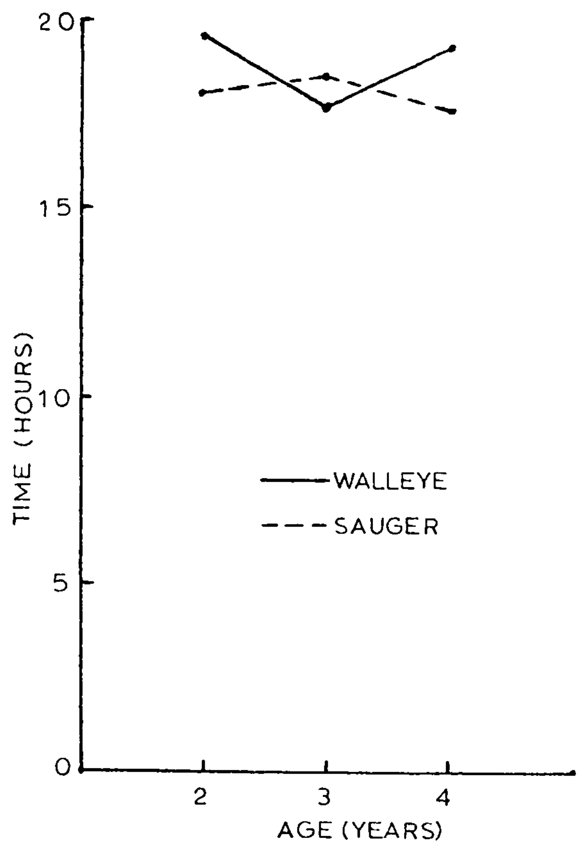


Figure 17. Mean time required for stomach evacuation of 7 walleye and 7 sauger (ages 2 and 3) fed in the laboratory of 5 weeks.

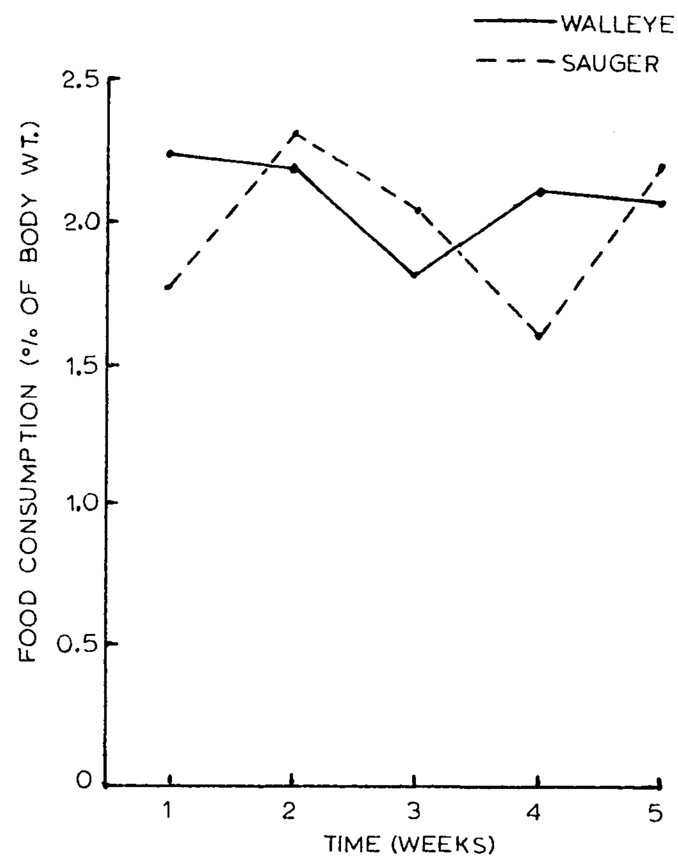


Figure 18. Maintenance requirements (food as % of body wt.) for 6 walleye and 7 sauger ages 2 and 3, fed in the laboratory for 5 weeks.

study were significantly lower than data from the laboratory fish which fed naturally. Food consumption in most of the older force-fed fish was so variable that the data were excluded from analyses. Hoffman (1972) found that walleye in the laboratory would not voluntarily consume perch. Windell (1967) stated that force feeding increased the variability in the digestive rates and Swenson and Smith (1973) noted that force-feeding is suspected to produce unreliable and variable results. Studies requiring the feeding of walleye and sauger in the laboratory should, if possible, use younger members of the species which are more tolerant to light and will feed naturally.

Maintenance levels for food (Figure 18) and quiet metabolism (Figure 19) for the walleye and sauger also showed similarities between the two species. Maintenance values for the sauger averaged slightly lower than walleye values but were not significantly different at the 0.05 level. The irregularity in the metabolism data for the sauger in comparison to the walleye may have been due to what appeared to be stress or hypertension in the older sauger. This stress was not observed in the sauger during the SCUBA dives in the river and again is probably caused by either confinement in the laboratory or more likely to the light intensity in the tanks. Since the older sauger were affected by the laboratory conditions more than the other fish, the data from the older fish could not be used for comparisons with younger fish.

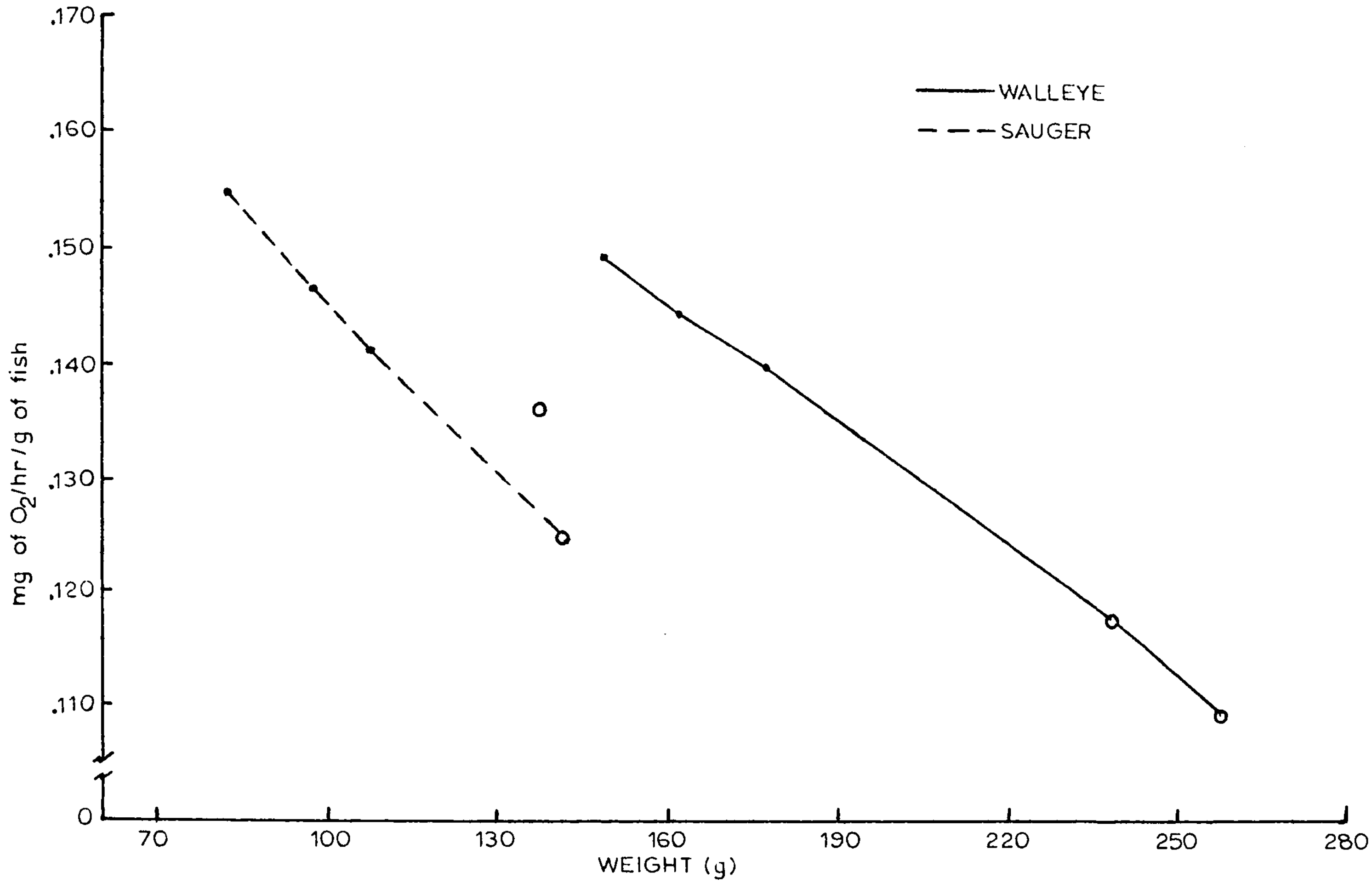


Figure 19. "Quiet" metabolism of walleye and sauger, ages 2(·) and 3 (o), as recorded by the gravity fed respirometer.

Laboratory comparisons of the walleye and sauger in this study detected no significant differences in digestion, evacuation, etc. that would give one species a competitive feeding advantage over the other. The lack of variation in the physiological processes of the two species was not totally unexpected since they showed little variation in most of their anatomical and behavioral characteristics. Although the light intensity had a definite effect on the feeding behavior of both the walleye and sauger in the laboratory and in the field, it was not possible in this study to determine whether or not light also affected the digestive phsiology of the fish.

Rate of Feeding

It was necessary to determine whether or not both the walleye and sauger fed on a daily basis throughout the growing season since their feeding frequency probably affects their rate of growth. Energy budgets were developed to estimate the total food consumed during the growing season and calculate a growth rate for both fish based on the estimated food consumption. A bioenergetic scheme similar to that of Norstrom *et al.*, 1976, was used to describe the energy relationships of the two species of fish. In this model the total assimilated ration is equal to the sum of the daily metabolism and the growth of the fish. Two energy budgets were developed for each species. One budget assumed that the fish fed every night during the growing season (approximately 120 days) while the other assumed that the fish fed every other night (approximately 60 days). The actual number of days that food is consumed probably lies somewhere between 60 and 120 days.

A daily ration of food for both the walleye and sauger was assumed to be the amount of food found in the stomach of the fish when they were caught leaving the feeding area. Gross food energy of the ration was accepted as the mean energy content (kcal/g wet weight) of the emerald shiners and was determined each month during the summer. Energy of the ingested ration had to be corrected for fecal and non-fecal losses. Fecal loss represented the energy content of the fecal products. This was estimated to be between 5 and 10% of the total ingested calories in fish (Beamish, 1972), and was found to be an accurate value for fecal loss in this study. Non-fecal loss represented the portion of the assimilated energy excreted in urine and through the gills and accounted for not more than 15% of the total ingested calories (Krueger et al., 1968). Winberg (1956) found that a 3% error in consumed calories would result if the value for non-fecal loss was disregarded. An overall assimilation efficiency coefficient of 0.82 as suggested by Norstrom et al., 1976, was used to represent the available food energy for metabolism and growth in the walleye and sauger in this study. Estimates of the caloric value of tissues of both species of fish were determined from average energy content of 2 and 3 year old individuals at the beginning and end of the growing season. The energy content of the growth tissue was determined from the energy equivalent of the growth in weight for each age and growing season (Table 19).

The bioenergetics model assembled by Norstrom *et al.*, 1976, in its entirety is written:

$$R = \frac{1}{e_f} [\alpha_{\ell r} W^{\gamma} + (\beta+1)(dw/dt)] \qquad (1)$$

where R is equal to the ingested ration in calories, e_f is the assimilation efficiency coefficient, γ represents the exponent for routine metabolism, $\alpha_{\ell r}$ equals the low routine metabolic level corrected to temperature, W is the wet weight of the fish in g, β is a constant relating growth to the energy associated with growth (G), and dw/dt equals the growth rate. For this study, e_f is equal to 0.82, γ is given the value of 0.81 (Norstrom *et al.*, 1976, value for perch), $\alpha_{\ell r}$ corrected to 18-21°C is equal to $(0.24 \text{ kcal/wk} \cdot g^{0.81})$, and β is equal to 1.0 (Norstrom *et al.*, 1976). The equation for the estimation of the ration can now be written:

$$R = \frac{1}{.82} (0.24w^{.81} + 2G) \qquad (2)$$

or:

$$R = 1.23(0.24w^{.81} + 2G) \qquad (3)$$

Because food consumption based on stomach contents from walleye and sauger differed in percent body weight each month during the growing season, the daily rations were figured separately for each month with the total of 120 days

Table 19. Average Seasonal Weight and Growth and Their Caloric Equivalents for 2 and 3 Year Old Walleye and Sauger from the Ottawa River

	Total No. of Fish	Age	Mean Wet Wt. (g)	Growth For Season (g) wet wt.	Kcal/g Dry Weight of Tissue*	Total Tissue Growth for Growing Season (17^+ wks) (kcal)	Average weekly Tissue Growth (kcal)
Walleye							
	28	2	130	88.3	4.790	106.0	6.2
	20	3	240	94.9	4.888	113.9	6.7
Sauger							
	22	2	80	59.2	4.699	71.0	4.2
	28	3	140	46.4	4.701	55.7	3.3

*Kcal/g wet wt. ≈ 1.2

representing a four month growing season (Table 20). Since it was not known whether the fish were feeding every night, the total ration was based on both 60 and 120 units of feeding (daily ration). It should be noted that catch per unit effort varied in the same proportion as the daily ration for each month (Table 20), and that the highest food consumption months corresponded to the peak months in catch rate (Figures 5 and 6).

Comparisons can be made at this point between food intake (Table 20) and growth (Table 19) for both species of fish. The values for walleye food consumption and growth are approximately twice those for the sauger. With the exception of age 3 walleye, calculated rations (R) for a season of 120 days (Table 21) more closely approximated the observed rations for 120 days of feeding (R'_{120}) than 60 days of feeding (R'_{60}). This similarity suggests that both species consumed a daily ration almost every night during the growing season.

The energy budget based on observed rations of feeding (R'_{60}) in Table 22 for 60 nights allows no energy for foraging activity. However, when 120 nights of feeding are used (R'_{120}) in the same budget, an adequate energy value for activity is provided and the energy distribution appears reasonable. Because of the lack of activity energy for the 60 day feeding period (R'_{60}) and the available activity energy in the 120 day feeding period (R'_{120}), it could be assumed from the energy budget, that the walleye and sauger were feeding more

Table 20. Energy Equivalents of Food Consumption (Based on Stomach Contents) for Walleye and Sauger Age 2 and 3 from the Ottawa River*

Fish	Days	Catch/ Unit Effort	Average Daily Ration As % Body Wt. (Age 2 and 3 Combined)	Energy Equivalent of Food Consumed (kcal) Age 2	Age 3
Walleye					
	30 days (June)	.19	3.9	158.9	293.3
	31 days (July)	.28	5.2	211.9	391.1
	31 days (Aug.)	.19	3.7	150.7	278.3
	30 days (Sept.)	.09	2.7	110.0	203.1
Total energy consumed if feeding occurred 120 days out of 120 days				631.5	1165.9
Total energy consumed if feeding occurred 60 days out of 120 days (fed every other night)				315.8	582.9
Sauger					
	30 days (June)	.17	3.0	75.2	131.6
	31 days (July)	.20	3.3	82.7	144.8
	31 days (Aug.)	.27	3.8	95.3	166.7
	30 days (Sept.)	.14	2.9	72.7	127.2
Total energy consumed if feeding occurred 120 days out of 120 days				325.9	570.4
Total energy consumed if feeding occurred 60 days out of 120 days (fed every other night)				162.9	285.2

*Total no. of fish and average wet weights are listed in Table 19.

Table 21. Comparison of Calculated and Observed Daily Rations for Walleye and Sauger Age 2 and 3 from the Ottawa River. Calculated rations (R_7=weekly ration, R_1=daily ration) as derived from Equation (3). Observed rations (R') are from Table 20.

		Calculated (R)				Observed (R')		
Fish	Age	Av Wt. (g)	R_7 (kcal)	R_1 (kcal)	R Total Caloric Intake For Season (kcal)	Daily Ration R'_1 Based on 120 Days of Feeding (kcal)	R'_{120} Total Intake For 120 Days of Feeding (kcal)	R'_{60} Total Intake For 60 Days Of Feeding (kcal)
Walleye	2	130	30.5	4.4	528	5.3	631.5	315.8
	3	240	41.5	5.9	708	9.7	1165.9	582.9
Sauger	2	80	20.6	2.9	348	2.7	325.9	162.9
	3	140	24.3	3.5	420	4.8	570.4	285.2

Table 22. Energy Budgets Developed From Observed Rations and Measured Metabolism For 2 and 3 Year Old Walleye and Sauger From the Ottawa River

Fish	Age	Av. Wt. (g)	Days Of Feeding	(A) In-gested Energy (kcal)	(B) Assim-ilated Energy (.82A)	(C) Tissue Growth (kcal)	(D) Estimated Energy For Tissue Deposition (kcal)	(E) Quiet Metabolism (Measured) (kcal)	Energy Available For Activity B-(C+D+E)	Net Conversion Efficiency C/B
Walleye	2	130	60	315.8	259.0	106.0	106.0	167.7	-120.7	.41
	2	130	120	631.5	517.8	106.0	106.0	167.7	138.1	.20
	3	240	60	582.9	478.0	113.9	113.9	309.7	-59.5	.24
	3	240	120	1165.9	956.0	113.9	113.9	309.7	418.5	.12
Sauger	2	80	60	162.9	133.6	71.0	71.0	110.3	-118.7	.53
	2	80	120	325.9	267.2	71.0	71.0	110.3	14.9	.27
	3	140	60	285.2	233.9	55.7	55.7	193.1	-70.6	.24
	3	140	120	570.4	467.7	55.7	55.7	193.1	163.2	.12

frequently than every other night and more likely fed almost every night during the 120 days of the growth season.

The energy budget based on the calculated rations in Table 23, (R), is similar to the budget based on R' for 60 days and also fails to allot a sufficient amount of energy for activity. The high net conversion efficiency for age 2 walleye (Table 22) suggests that the estimation of the ingested energy is too low, or that the average weights used for the age class have over estimated the actual growth.

Based on the conversion efficiencies from our energy budgets, the feeding rates and food consumption values are reasonable approximations of the walleye and sauger. Our values were similar to those of Hofmann (1972) who found age 1 walleye had gross conversion efficiencies of 0.36 to 0.40. Steffens (1960) reported gross efficiencies of 0.25 to 0.30 for age 1 European pike-perch. Fortunatova (1961) and Ivanova (1968) report gross efficiencies for older pike-perch of 0.20 and Hofmann (1972) found gross efficiencies of 0.20 (average) for age 3 and older walleye. Kelso (1972) reported net conversion efficiencies as low as 0.12 and 0.15 for walleye age 1 and 2 held in the laboratory at 16°C. The energy distribution in our budgets is a valid approximation for the walleye and sauger and confirms the suspected daily feeding during the growing season (approximately 120 days) for both species.

Table 23. Energy Budgets Developed From Calculated Rations and Metabolism For 2 and 3 Year Old Walleye and Sauger From the Ottawa River

Fish	Age	Av. Wt. (g)	Days Of Feeding	(A) In-gested Energy (kcal)	(B) Assim-ilated Energy (.82A)	(C) Tissue Growth (kcal)	(D) Estimated Energy For Tissue Deposition (kcal)	(E) Routine Metabolism (Calculated) (kcal) (Winberg, 1956)	Energy Available For Activity B-(C+D+E)	Net Conversion Efficiency C/B
Walleye	2	130	120	528	433.0	106.0	106.0	213.1	7.9	.24
	3	240	120	708	580.6	113.9	113.9	346.5	6.3	.20
Sauger	2	80	120	348	285.4	71.0	71.0	143.9	-0.5	.25
	3	140	120	420	344.4	55.7	55.7	225.1	7.9	.16

SUMMARY AND CONCLUSIONS

The Ottawa River, once a mesotrophic habitat, is rapidly becoming eutrophic. Within the past 50 years, human activities have altered many of the physical and biological characteristics of the river. As a result, the river is now a marginal habitat for the Stizostedion spp.. Growth of the walleye and sauger is below the regional norm. Competition between the walleye, sauger, and the non-Stizostedion predators for the limited prey species has reduced food consumption of the Stizostedion spp..

Unfavorable responses of the Stizostedion spp. to the impoundments and the ensuing eutrophic conditions in the Ottawa River habitat were evident in our study and were responsible for the slow growth of the fish. A suggested order of events that changed the habitat, forage base, and feeding behavior of the Stizostedion spp. in this altered environment, and resulted in the competitive interaction of the walleye and sauger in the Ottawa River can best be summarized by the following statements.

1. Impoundments widened and deepened the river, slowed the velocity of water currents and increased the mean summer water temperature. Flooded shorelines expanded the littoral zone of the river. Silt and wood pulp, no longer carried by the swift currents, settled to the bottom of the river and covered the rocky substrate.

2. Demersal prey species became excluded from the sublittoral zone because of the warmer mean summer temperatures and the silt deposits which covered their feeding areas on the substrate.
3. Productivity of the littoral zone supported prey fish populations typical of a eutrophic habitat, but these prey did not necessarily become part of the forage base of the *Stizostedion* spp..
4. The sauger, because of their sensitivity to intense light, were best adapted to feeding on the demersal prey. The decrease in the number of demersal prey forced the sauger to feed in the littoral zone where food was available. Because light was more intense in the littoral zone in comparison to the sublittoral zone, foraging activities of the sauger were limited to periods of darkness.
5. Food consumption by the walleye and sauger became dependent on the density of a relatively few prey species in the littoral zone instead of including all of the species available in the eutrophic habitat.
6. Intra- and interspecific competion for food increased among the walleye and sauger and non-*Stizostedion* predators. Competition for food prevented the walleye and sauger from reaching

their full growth potential.

7. Since the older walleye and sauger showed the greatest reduction in growth rates, it is likely that their increased sensitivity to light with age had a substantial effect on lowering their ability to see and consume the prey.

This study has made available basic data on growth, food consumption, feeding behavior and movement of the Stizostedion spp. in the Ottawa River in anticipation of further studies of the fish. This study poses more questions than answers. Foremost is the question of the ability of the walleye and sauger to adapt to changes in the habitat, not only in the Ottawa-Hull portion of the river but throughout the entire river system. Knowledge of the habits of the fish in the Ottawa River is particularly important at this time since new impoundments may soon be constructed on the river. It is not uncommon for aquatic habitats to be severely altered by human activities with the detriment to the biotic community passing unnoticed until the condition is irreversible. The Ottawa River is a productive, viable habitat and with proper planning and management it can remain so, in spite of the intense urbanization along its shoreline.

Nelson and Walburg (1977) report that walleye and sauger in certain impoundments of the Missouri River have adapted to the altered environment and have increased in numbers relative to other groups of fish. Although increases in the populations of the Stizostedion spp. were not evident in our study, neither were decreases. Year class strengths suggest stabilization in the populations. The lack of pre-impoundment data for catch efficiencies makes it impossible to determine whether or not changes have occurred in the density of the populations as a result of the impoundments. A decline in size in one or both populations would reduce the competition between the walleye and sauger. It is unlikely that pre-impoundment growth in the walleye will ever be regained under the present conditions. However, with increased productivity and availability of food in the river, it is possible that growth rates of the fish may increase.

Interspecific stress in the walleye and sauger, as a result of the similarity of their niche requirements as defined by our study, provide the necessary conditions for the exclusion of one or both of the populations. The present characteristics of the river appear to give the walleye certain advantages in foraging over the sauger. However, it is not likely that the exclusion of the *Stizostedion* spp. will be the result of a single condition of the population or adaptation to the environment. Other conditions suggested by Leach *et al*. (1977), i.e., disease, distribution, spawning, and species dominance, contribute to the decline of the percids in a eutrophic habitat. Until these characteristics can be determined for the Ottawa River populations, it would be difficult to estimate the extent to which the *Stizostedion* spp. are at the threshold of extinction.

If the *Stizostedion* spp. in the Ottawa River respond to the alteration of the habitat by the impoundments, in the same manner as those of the St. Lawrence River, the extinction of the populations in the Ottawa River is likely. However, there is a major difference between the two habitats. Fast water and rock covered spawning sites were not available to the impounded species of the St. Lawrence River. Reproductive success is critical to the continuation of any populations. Successful spawning by the *Stizostedion* spp. is dependent on certain physical conditions of the river. The fast water produced by a limited number of falls in the Ottawa River is apparently sufficient to maintain an adequate year class strength for both the walleye and sauger populations.

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APPENDIX A

Distribution of the 798 fish (representing 13 species) caught in Governor's Bay during the 27 nights of gill netting, May-October, 1972. (NR = no record)

Species	Month - May Day -		
	15-16	23-24	30-31
Stizostedion vitreum	0	2	1
Stizostedion canadense	0	0	2
Hiodon tergisus	NR	0	57
Perca flavescens	NR	2	12
Ictalurus nebulosus	NR	0	4
Lepisosteus osseus	NR	0	0
Catostomus commersoni	NR	0	0
Acipenser fulvescens	NR	2	1
Esox lucius	NR	1	2
Ambloplites rupestris	NR	0	4
Lepomis gibbosus	NR	0	0
Pomoxis nigromaculatus	NR	0	1
Cyprinus carpio	NR	0	1

Distribution of the 798 fish (representing 13 species) caught in Governor's Bay during the 27 nights of gill netting, May-October, 1972. (NR = no record)

Species	Month - June Day -	5-6	7-8	13-14	14-15	19-20	22-23	26-27*	28-29*
Stizostedion vitreum		0	4	0	3	4	5	5	0
Stizostedion canadense		5	4	4	4	3	0	5	1
Hiodon tergisus		3	5	0	19	NR	36	16	8
Perca flavescens		5	0	4	5	NR	8	17	9
Ictalurus nebulosus		5	1	2	2	NR	10	8	3
Lepisosteus osseus		0	0	0	0	NR	0	1	0
Catostomus commersoni		2	2	1	1	NR	1	4	1
Acipenser fulvescens		0	1	3	0	NR	1	2	2
Esox lucius		1	3	1	0	NR	0	7	7
Ambloplites rupestris		2	4	3	0	NR	0	4	1
Lepomis gibbosus		0	1	0	0	NR	4	9	0
Pomoxis nigromaculatus		0	0	0	1	NR	0	0	0
Cyprinus carpio		0	0	0	0	NR	1	0	0

*Totals for 24 hour net set

Distribution of the 798 fish (representing 13 species) caught in Governor's Bay during the 27 nights of gill netting, May-October, 1972. (NR = no record)

Species	Month - July Day -	3-4	6-7	11-12	12-13	17-18	20-21	24-25	27-28
Stizostedion vitreum		5	5	4	3	4	3	2	5
Stizostedion canadense		4	2	7	8	3	3	8	4
Hiodon tergisus		6	7	0	0	NR	NR	2	2
Perca flavescens		6	4	9	35	NR	NR	2	5
Ictalurus nebulosus		1	0	2	5	NR	NR	2	0
Lepisosteus osseus		0	0	0	0	NR	NR	5	3
Catostomus commersoni		2	0	2	5	NR	NR	2	0
Acipenser fulvescens		2	1	5	8	NR	NR	2	1
Esox lucius		0	0	2	0	NR	NR	0	0
Ambloplites rupestris		0	1	1	2	NR	NR	0	0
Lepomis gibbosus		0	1	0	0	NR	NR	0	0
Pomoxis nigromaculatus		0	0	0	0	NR	NR	0	0
Cyprinus carpio		0	0	0	0	NR	NR	0	0

Distribution of the 798 fish (representing 13 species) caught in Governor's Bay during the 27 nights of gill netting, May-October, 1972. (NR = no record)

Species	Month - August / Day - 2-3	7-8	10-11	16-17	21-22	22-23
Stizostedion vitreum	2	7	3	2	0	2
Stizostedion canadense	14	7	6	3	0	1
Hiodon tergisus	4	1	22	NR	NR	0
Perca flavescens	6	4	11	NR	NR	9
Ictalurus nebulosus	6	1	2	NR	NR	4
Lepisosteus osseus	9	0	0	NR	NR	9
Catostomus commersoni	2	5	2	NR	NR	2
Acipenser fulvescens	0	0	1	NR	NR	0
Esox lucius	3	0	1	NR	NR	0
Ambloplites rupestris	1	1	1	NR	NR	2
Lepomis gibbosus	1	2	0	NR	NR	0
Pomoxis nigromaculatus	2	0	0	NR	NR	0
Cyprinus carpio	0	0	0	NR	NR	0

Distribution of the 798 fish (representing 13 species) caught in Governor's Bay during the 27 nights of gill netting, May-October, 1972. (NR = no record)

Species	Month - / Day -	September 7-8	October 5-6
Stizostedion vitreum		2	1
Stizostedion canadense		4	3
Hiodon tergisus		2	NR
Perca flavescens		0	NR
Ictalurus nebulosus		0	NR
Lepisosteus osseus		15	NR
Catostomus commersoni		0	NR
Acipenser fulvescens		0	NR
Esox lucius		0	NR
Ambloplites rupestris		0	NR
Lepomis gibbosus		0	NR
Pomoxis nigromaculatus		0	NR
Cyprinus carpio		0	NR