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ABSTRACT

The feeding habits of brown bullhead (Ictalurus nebulosus), 20.0-23.5 cm in total length, of Kettle Island Bay in the Ottawa River were studied. They were nocturnally active and fed heavily in the early morning hours. They were omnivorous and consumed algae, benthic invertebrates, zooplankton, organic detritus and some fish. Algae were most important during mid summer and represented about 60 percent of the stomach contents. During the day algae were prominent toward the end of the feeding cycle.

Caloric values of food items were used to assess their contribution to the bullhead energy needs in terms of growth and metabolism. Benthic invertebrates proved inadequate to meet the energy requirements contrary to earlier belief, experiments on digestability of algae proved that they are an important energy source for the brown bullhead. The laboratory determined assimilation efficiencies of Spirogyra sp. and Anabaena flos-aquae were about 30 and 70 percent respectively.

Résumé

Les habitudes alimentaires de la barbotte brune (Ictalurus nébulosus), d'une longueur totale de 20.0-23.5 cm, prevenant de la baie de l'île Kettle de la rivière Ottawa furent étudiées. Elles étaient actives durant la nuit et se nourrissaient abondamment, tôt le matin. Elles étaient omnivores et consommaient des algues, des invertébrés benthiques, du zooplancton, des déchets organiques et quelques poissons. Les algues étaient les plus importantes durant le milieu de l'été et représentaient 60% des contenus d'estomac. Durant la journée, les algues étaient dominantes jusqu'à la fin du cycle d'alimentation.

Les valeurs caloriques des aliments ont été utilisées pour estimer leur contribution aux besoins énergitiques de la barbotte en fonction de la croissance et du métabolisme. Les invertébrés ont été prouvés inadéquat pour satisfaire aux besoins énergitiques contrairement aux premiers hypothèses. Des expériences concernant la digestion des algues ont prouvé qu'elles sont une source importante d'énergie pour la barbotte brune. Nous avons déterminé que les capacités d'assimilation de Spirogera sp. et Anabaena flos-aquae étaient environs 30 et 70% respectivement.

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INTRODUCTION

Energy relationships have been considered fundamental to the understanding of an organism's ecology since Lindeman's (1942) classic paper: "The trophic-dynamic aspects of ecology". Investigators have studied the fate of energy as it passes from one trophic level to another (Allen 1951; Slobodkin 1960, 1962; Gerking 1962), and the calorie has become the common denominator to describe this transfer (Slobodkin and Richman 1961; Cummins and Wuycheck 1971; Paine 1971). More recently certain energy and trophic relationships have been identified with the accumulation of contaminants in aquatic systems (Uthe and Bligh 1971; Jernelov and Lann 1971; Fagerström and Asell 1973). Pollutant accumulation is not simply a linear progression through the trophic levels but also involves a coupling of the biokinetics of the pollutant with the energetics of the organism (Fagerström *et al.* 1974; Norstrom *et al.* 1976).

The study described here was initiated to measure certain undescribed bioenergetic relationships of the brown bullhead *Ictalurus nebulosus*. Fish energetics have been studied both in the field (Gerking 1962, 1971; Mann 1965; Wissing 1974) and in the laboratory (Solomon and Braefield 1972; Fischer 1972; 1973; Nimii and Beamish 1974). Several investigators have attempted to describe in mathematical form the possible fates of energy consumed (Winberg 1956; Ivlev 1961; Warren and Davis 1967). In these balanced energy budgets the ingested ration, which is corrected for fecal and nonfecal losses to give the assimilated ration, is equal to the energy expenses (growth, metabolism, reproduction, body compositional changes). Major problems still exist in quantifying the input parameters, both the ingested ration and the assimilation efficiency. Sampling problems involving foraging activity of the population and individual fish variability has resulted in underestimation of ingested ration (Healey 1972; Jenkins and Green 1974; Rodgers 1976). Under field situations the measurement of assimilation efficiency present special problems with the result that it is often poorly defined (Brocksen and Bugge 1974).

In this study prime attention has been placed on the assimilation efficiency for ingested material formerly considered indigestible. Assimilation efficiency has been demonstrated as dependent on the type of food. Animal food is digested more effectively by carnivores than plant material is by herbivores (Welch 1968). Carnivores under lab conditions have exhibited a rather constant assimilation efficiency of 80% (Ivlev 1961; Beamish et al. 1975). Herbivores display interspecific variations and values range from 13-79% (Ivlev 1939, Fischer 1970, Moriarty 1973a).

The plant component in the diet of omnivorous fish has lacked attention and has generally been considered of little nutritional value. The ingestion of filamentous algae by the brown bullhead is a particular case in point. The opinions of investigators have varied and algae has been considered as accidentally ingested (Harlan and Speaker 1956) or as an "alternate food source" for the bullhead (Cable 1929; Karlberg and Benson 1975; Rubec 1975).

The role of algae in the bioenergetics of the brown bullhead has received special attention in this study because of its applications within the overall study of the Ottawa River Project. The Ottawa River Project is a joint undertaking of the University of Ottawa and the

National Research Council, which was initiated to examine the distribution and transport of certain trace contaminants in a four km section of the Ottawa River. In this section of the river the brown bullhead is the most abundant fish species composing 67% of the fish biomass (Rubec 1975). Filamentous algae often exceeds 60% of the bullhead stomach contents and it's uncertain digestability renders calculated energy budgets dubious at best. The objectives of this study were therefore; to determine:

(1) daily and seasonal diet of the brown bullhead

(2) seasonal growth and changes in body composition

(3) caloric content of food items common in the bullhead diet

(4) the efficiency with which bullheads assimilate Spirogyra sp. and Anabaena flos-aquae and to evaluate the importance of algae in view of the energy needs of the fish

DESCRIPTION OF STUDY AREA

The Ottawa River extends 1,113 km from Lake Temiscamingue to the St. Lawrence River and drains some 145,000 sq. km (OWRC-QWB 1971). It flows through sedimentary deposits of limestone, sandstone and shale, all of which are superimposed on Precambrian rock.

The Ottawa River Project study area is located downstream of the metropolitan areas of Ottawa and Hull (Fig. 1). The four km section under investigation, has a great diversity of habitat types, for example: deep foot water (2-4 m/sec) channels, quiet bays, clean sandy shores and areas polluted by the effluent of a pulp and paper mill. Luxurious stands of macrophytic vegetation (Polygonum amphibium, Sagittaria latifolia and Spargarium argustifolium) occur along many of the shorelines (Eriksson 1974). The depth of the river varies from a maximum of 12 m in the south channel to 1m at the entrance of Kettle Island Bay. Ice cover extends from December to mid April and temperature reaches a maximum (25C) in August (Appendix 7). The chemical characteristics of the site are not directly toxic to fish life except immediately below the paper mill at Gatineau Quebec (Stobo, 1971; Mackie1971). Additional information on the physical and chemical characteristics of the site are contained in the Ottawa River Project interim reports (1972, 1973, 1975).

Brown Bullhead (Ictalurus nebulosus) Population

The fish fauna of this section of the Ottawa River has been extensively studied since 1969. (Stobo 1971, Smith 1974, Rubec 1975, Rodgers 1976). Of the 45 species collected the dominant species included: Ictalurus nebulosus, Perca flavescens; Esox lucius, Stizostedion

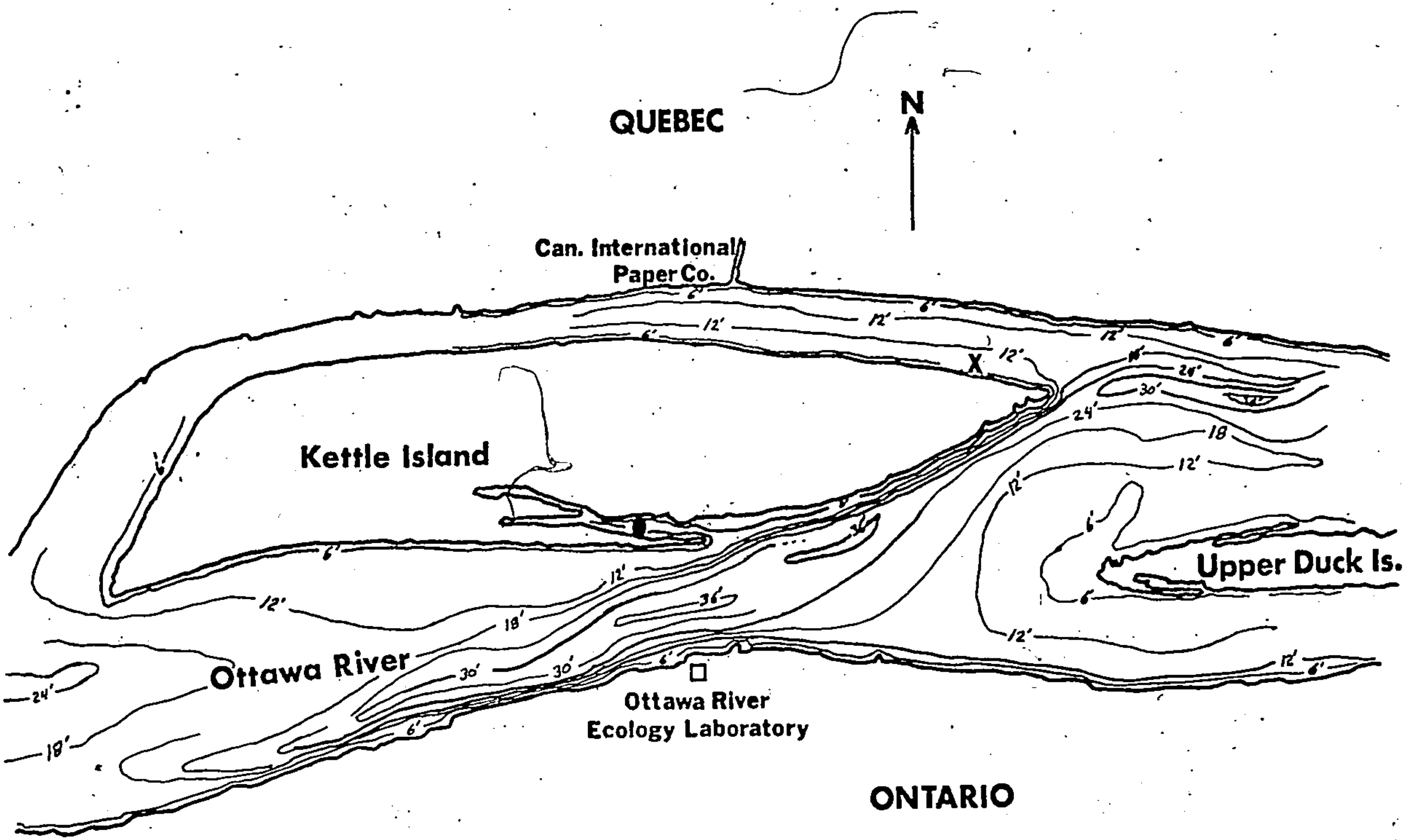

Fig. 1 Ottawa River study area, with depth contours from Clair 1976.

Collection sites: ●-Kettle Island Bay X-north channel vitrem and Lepomis gibbosus. In terms of both total biomass and individual numbers, the brown bullhead was the most abundant (Rubec 1975). The study by Rubec (1975) dealt primarily with the abundance, age, growth, mercury concentration and reproduction of bullheads in this area. Field studies by the author on feeding habits and energetics of this bottom feeding fish began in May 1974.

In this section of the river, bullheads congregate in the backwater of Kettle Island Bay (Fig. 1), an area of preferred habitat (soft oozy mud; sunken logs; 2-5 m water depth-Keast 1970). The high density population (2,600-6,400/ha) of the bay is sedentary according to the definition of Funk (1955) and Gerking (1959). Tag recapture data indicates that the "home site" of Kettle Island Bay has been maintained for several years (Gunn 1975). Seasonal changes within the population include spawning and reproductive aggression in June (Rubec 1975) and increased dispersal during warm summer months (Gunn 1975). During the spring and fall months, the population reaches a maximum in the bay, and fish regularly leave the bay to forage along the littoral zones (Gunn 1975). The author suggests that this nocturnal foraging activity is a result of the poor benthic fauna that characterizes the bay (Qadri *et al.* 1973).

MATERIALS AND METHODS

Size Class Selected for this Study

In preliminary samples the 20.0-23.5 cm (total length) bullheads represented the dominant size class and were selected for this study. This size class was chosen because of it's abundance, trophic importance and convenience of sampling.

Approximately 550 fish were collected and used in the various aspects of this study. The average length and weight of these fish were 22.5 ± 1 cm and 145.6 ± 1.4 g respectively (Appendix 1). The fish were sexually mature and females were more abundant than males (57.9% - 42.1%). Fish were aged by a method based on pectoral spine sections (Scholl 1968) and were found to be generally between 3-4 years old (Appendix 2). Ninety-one percent of the samples were of the 3-4 year class with the remaining nine percent distributed through ages 2,5,6. The aging method was verified by using vertebral sections.

Sampling Procedures

The principal sampling gear was a trap net (6 ft. long box; 2 in. diagonal mesh) with a 150 ft. lead. This net has proven effective in capturing bullheads 16-39 cm in length (Rubec 1975). In winter, bullheads were collected with hoop nets and gill nets set under the ice. Hoop nets (1 in. mesh; 20 ft. wings) were also used in the summer along the various shorelines.

All fish were collected in Kettle Island Bay with the exception of a sample of 20 fish collected in August 1974 from the north channel. This sample was used for analysis of body composition when fish were not available in the bay. These values were pooled with those from the bay after a tag recapture experiment demonstrated extensive exchange between these two sites (Appendix 3).

The natural feeding periodicity was determined for a period of 24 hours on Aug. 22 and Sept. 20, 1974. At each three hour interval 10 fish were taken from the trap net set in Kettle Island Bay. Bullheads were all from 22.0 - 23.5 cm in length and were killed and preserved (15% formalin) immediately after collection. The results of this feeding periodicity study were used to schedule the sampling program for the determination of seasonal diet.

Three hundred and twenty-six bullheads were collected in Kettle Island Bay for diet determination from August 22, 1974-July 14, 1975. Samples were collected primarily in the early morning hours (6:00-10:30) when feeding was determined to be heaviest. In winter, hoop nets were checked only every 24 hours. Fish were killed and preserved immediately after collection. A stomach pump (Seaburg 1957) was used to collect samples when fish were being tagged and released.

One hundred and five fish were collected for analyses of body composition from Kettle Island Bay August 1974- July 1975 and frozen (-20C) until analysis. The additional sample of 20 fish from the north channel was collected on August 14, 1975.

Field samples of food items (invertebrates, algae) common in the bullhead diet were collected for ash and caloric value determinations. Invertebrates (amphipods, isopods, midge larvae, damsel fly nymths) were collected with dip nets from littoral vegetation and substrate, from June-September 1974. On some of the sample date certain invertebrates were not available in sufficient numbers for the required sample size (100 mg dry wt.). On June 16, 1975 filamentous algae were collected at the top of Kettle Island where bullheads were observed feeding heavily on the abundant algae.

Stomach Analysis

The procedure used for the analysis of stomach contents was a modification of the numerical and gravimetric methods described by Windell (1968). This method was employed rather than the commonly used volumetric and points methods (Hynes 1950, Windell 1968) because of the great variety of food items involved. Bullhead stomach contents consisted of wide ranging size and numerical assortment of invertebrates, large quantities of algae and organic detritus. The following method was used to assign weights (dry) to the various food items.

Each stomach was sorted separately to demonstrate individual variability and to determine frequency of occurrence of the food items (Windell 1968). Under the stereomicroscope (X25) the invertebrates were hand sorted, counted and removed from the algae and debris. For most species the head capsule count was used to enumerate the invertebrates. Weights were determined for each of the invertebrate groups by multiplying the numerical count by a standard dry weight (Appendix 4,5,6). These standard dry weights were derived from data on invertebrates collected at different sites and throughout the season in this study area (Hamill 1975, pers. comm.; Leung et al. 1973). The sample size used for these average values generally exceeded 300; in the case of very common food items such as Chironomidae larvae, sample size was as much as 8425. The author realises that this method does not take into account seasonal size differences of invertebrates but this variation is of little importance in relation to the total weight of stomach contents.

After the invertebrates were removed from the sample the weights of algae and debris were measured directly by drying (65^{o}C) to constant weight (48 hours). The weights of these components were then added to those calculated for the invertebrates, to reconstruct the total dry weight of the stomach contents.

Growth

In order to describe seasonal growth, bullheads were tagged with dart tags (Floy FT-67) in a manner described by Keller (1971). In 1975, 3290 bullheads were tagged in Kettle Island Bay and a recapture effort maintained throughout the season. This data was used in conjunction with that of Peter Rubec (1975) who used similar methods and tagged 2800 Kettle Island Bay fish from June 26, 1972 to Sept. 26, 1973. Of the fish tagged in 1972-73 by Rubec, 447 were recaptured in Kettle Island Bay in 1974-1975.

All fish were measured in the field and total lengths were used for growth determinations. The adverse effects of tagging on growth (DeRoche 1963, Escheneyer 1959) were evaluated (Gunn et al in preparation) and on this basis only those fish recaptured at least a year after tagging were used in this study. Seasonal growth was described by the change in length between two subsequent recaptures for a fish tagged a year previous to the first recapture. Three time periods were selected for which there was sufficient data. These periods were June-July 1973; Aug.-Sept. 1973 and Aug. 1974-June 1975.

Body Composition

For analysis of body composition the fish were first thawed and the alimentary tract emptied of all contents. Each fish was cut into small chunks (~2 cm^3) and ground in a Sorvall homogenizer. Percentage moisture values were determined after freeze-drying using a

VirTis lyopholizer until constant weight (48 hrs.). The freeze dried tissue was then ground in a micro-mill (Tekman Company Model A-10), reground with a mortar and pestel and finally run through a fine screen (1 mm mesh). The screening procedure was used to eliminate pieces of skin that occasionally withstood the pulverizing procedure, and which would otherwise produce variations in pellets used for calorimetry. Presumably, the removal of this skin would not have significantly affected the chemical composition results since it represented only about 5% of the total sample. The homogenized dried tissue was stored in air tight vials and refrigerated (2C). In all subsequent analysis, samples were first equilibrated to room temperature

Percentage ash values were determined after combustion in a muffle furnace (Hotpack 7074) at 500C until constant weight (Reiners and Reiners 1972; Paine 1971). Five determinations (100mg samples) were used for each fish. Tissue energy values were determined for one gram samples using a Parr 1241 adiabatic calorimeter (Parr manual 1960). Lipid values were determined gravimetrically after extraction of the fish tissue samples (0.70-2.19 g) with chloroform-methanol-water following the procedure of Bligh and Dyer (1959). The chloroform extracts were evaporated under nitrogen and the lipid residue weighed.

Ash and Caloric Determination of Food Items

The analysis of ash and caloric content of field collected algae and invertebrates was used to describe the bullhead diet in energy terms. Samples were collected through the season, and values were expressed in cal/ash free dry weight to best describe intraspecific seasonal changes in the food items (Prus 1970, Paine 1971).

Field samples were carefully washed, the invertebrates were sorted to taxanomic group and the samples frozen (-20C) for further analysis.

The invertebrates were thawed and dried at 60C for 24 hours (Crisp 1971), ground to a homogenous powder with a mortar and pestal and stored in a dessicator. Pellets of the sample material were pressed, weighed (10-20 mg) and caloric content determined using a Phillipson microbomb calorimeter (Phillipson 1964). Only fuse wire heat input corrections were applied. Three to six determinations were made for each sample. Ash fraction was determined by combustion of sample material (10-20 mg) in a muffle furnace at 600C to constant weight (Crisp 1971).

The ashing procedure for filamentous algae used 170-475 mg samples and the caloric content of the sample material (840-960mg) was determined using the Parr Adiabatic Calorimeter. Both the Parr and the Phillipson calorimeters were calibrated using benzoic acid (6318 cal/g) as the calorific standard (Paine 1971).

Digestability of Algae

Three approaches were used to assess the digestability of algae. The first experiments used a radioactive label (^{14}C) to determine the assimilation efficiency of ingested algal carbon. A mass balance experiment was then used to demonstrate the assimilation efficiency in terms of mass and it's caloric equivalent. Finally morphological changes of the ingested algae were photomicrographed.

Many of the procedures used were original or modifications of earlier methods and are described here in separate sections.

Care and Training of Fish

A total of 26 bullheads (90-200 g) were used in these experiments. The fish were placed in separate aerated aquaria (30-40 liters) eight weeks prior to feeding experiments. Particular attention was paid to minimizing stress for the experimental animals, as suggested by Fish (1960) and Moriarty (1973b). The aquaria were kept clear and the water temperature maintained at 20 ± 2C. The walls of the aquaria were blackened to prevent disturbance through activity in the laboratory (people, neighbouring fish).

Bullheads were trained to feed on trout chow and minnows in gelatin capsules (#0). A water-minnow extract was introduced into the aquaria water shortly before presenting food capsules. Bullheads which depend heavily on chemoreceptors for identifying sapid food items (Biedenbach 1973) were easily trained to consume the capsules in this manner. All fish were feeding regularly and voluntarily six weeks prior to the experiments.

Growth and ^{14}C-labelling of Algae

The green algae Spirogyra sp. and the blue-green Anabaena flos-aquae were used for this study. Spirogyra was chosen because it is a dominant algae in the study area (Rosemarin 1974) and is found abundantly in bullhead stomach contents. The Cyanophyte Anabaena was used for comparison to the Chlorophyte Spirogyra. The species A. flos-aquae was chosen for the following reasons: although A. flos-aquae has not been identified in this area it does occur in bullhead stomach contents in other areas (Nurnberger 1930); other investigators have considered certain species of Anabaena inedible and indestible (Sorokin 1968; Hutchinson 1973; Rabe et al 1973); and finally A. flos-aquae is easily grown under lab conditions.

Spirogyra was collected from the Ottawa River. The algae was thoroughly washed and placed in a ^{14}C-labelled medium ($^{14}NaHCO_3$ in tap water). After photosynthesizing under strong sunlight for three hours the algae was rinsed and allowed to grow in fresh water for three additional days. This transfer and duration was used to insure that all the labelled carbon was incorporated into the algal mass rather than in the form of surface contamination. After harvesting, the algae was blotted dry, placed in gelatin capsules and fed to the fish.

Anabaena flos-aquae (no. 1444) was obtained from the Indiana University culture collection (Starr 1964). A flos-aquae was grown in a culture medium (ASM) of McLachlan and Gorham (1961). The medium was prepared in 8 liter bottles and was autoclaved before innoculation. The innoculated bottles were aerated and maintained under continuous light at 20C. A. flos-aquae grew rapidly under these conditions, filling culture bottle and requiring harvesting eight days after innoculation. Two days prior to harvesting 100µc $^{14}NaHCO_3$ was added to each bottle. The algae were harvested by centrifugation and resuspended in unlabelled medium. A sample of the original supernate was counted to determine percentage uptake (usually >90%). After the final centrifugation, four culture flasks (50 ml) of the sterilized medium were innoculated to demonstrate the viability of the algae.

Digestion of ^{14}C-labelled Algae

The intent of the initial experiment using Spirogyra was to determine the efficiency of carbon assimilation from ingested algae and to measure the C^{14} counts incorporated into various tissues. The samples of labelled Spirogyra (0.574-0.916 g wet wt.) were encapsulated as live intact algae and fed to the fish. Two fish were sacrificed at each of the 9,12 and 24 hour interval after ingestion. From each fish various tissues were removed, weighed and frozen for analysis of ^{14}C content. The alimentary tract was carefully opened and washed free of feces. All feces and washings were collected and frozen. The assimilation efficiency was expressed as the fish tissue ^{14}C counts as a percentage of the total recovered counts (A.E. = cpm ^{14}C tissue/cpm ^{14}C tissue + feces + washings). In this experiment using Spirogyra the total recovered count was used as a measure of the original ingested counts.

Modifications were used in the A. flos-aquae experiment to measure ingestion directly by carefully weighing the encapsulated algae (.2270-.3621 g wet wt.) and then calculating a weight to counts conversion factor. The conversion factor was established from the ^{14}C counts in subsamples (.6266-1.1021 g wet wt.) of the same algal mass. This procedure for quantifying ingestion was the basic premise behind using gelatin capsules in the first place. Other investigators have used free floating algae and measure ingestion indirectly as the change in the aquarium ^{14}C count after feeding (Sorokin 1968; Gulati 1974). The experimental error is high using the free floating method, because of problems associated with sampling a heterogeneous suspension of ^{14}C-labelled filamentous algae (Moriarty 1973b).

Fresh weights of encapsulated algae and subsamples (N=3) of the algal mass were recorded at the time of feeding. Four fish were fed the capsules of labelled A. flos-aquae. Aquarium water samples (50 ml) were collected after each six hour interval to determine the fate of the labelled carbon. Particulate matter (regurgitated algae, feces) was concentrated on Millipore (0.45 µm) filters and counted. Respired $^{14}CO_2$ in the filtrate was precipitated as $BaCO_3$, and counted on Millipore (0.45 µm) filters (Sorokin 1968). Samples of the second filtrate were then counted to detect soluble excretions.

Twenty-four hours after ingestion the fish were sacrificed. The 24 hour duration was selected after preliminary experiments demonstrated an evacuation rate of approximately 30 hours at the experimental temperature (20C). After 24 hours the fecal material was in the hindgut section where it could be easily collected. Relatively little absorption occurs in the hindgut (Neff and Musacchia 1967); an observation that was verified in the Spirogyra time-course experiment.

After killing the fish, the feces was washed from the alimentary tract and collected. The aquarium contents were given a brisk stirring and the final water samples (2 X 400 ml) siphoned off. The counts of particulate matter, respired $^{14}CO_2$, and soluble excretions were determined as indicated above. Totals were constructed according to the measured volume of the aquaria contents.

Tissue Preparation and Counting Procedure

Algae were dried (65C) until constant weights were reached. The dried algae was then ground in a glass homogenizer and suspended in distilled water (150 ml). The suspension was maintained by a magnetic stirrer and subsamples (1 ml) taken.

The individual tissues (eg. liver, spleen) were prepared and counted separately in the Spirogyra time-course experiment. Muscular tissues (eg. stomach, lateral muscle) were first finely sliced before homogenization. The carcass remains (74.06-137.71 g wet wt.) were first macerated (Sorvall omnimixer) and then subsamples (5.97-11.05 g wet wt.) taken for final homogenation. Tissues were homogenized in a measured volume of water at high speed (Sorvall 1500 rpm).

In the A. flos-aquae experiment the alimentary tract was the only tissue removed and counted separately. The carcass remains were subsampled as described above and the same homogenizing procedure used. Similar emulsions were prepared for the fecal samples.

Duplicate one ml samples of each tissue were counted for one minute in the Beckmann LS200 liquid assintilation counter (Amersham-Searle PSC solubilizer). The window of the counter had been narrowed to eliminate low energy phosphorescence. All samples were quench corrected using an internal standard (^{14}C-labelled toluene). Background corrections were applied to all samples in the A. flos-aquae experiment. No other corrections were used.

Mass Balance Assimilation Efficiency

The mass balance experiment was conducted as a parallel to the labelled carbon experiment. For both experiments the same feeding procedure (encapsulated algae) type of algae, (A. flos-aquae) number of fish (4) and experimental duration (24 hr) were used. The experiments differed in that the mass balance experiment used unlabelled algae and the assimilation efficiency was measured in terms of mass and caloric changes of the ingested algae.

The encapsulated algae (.5164-.5950g wet wt.) and subsamples (1.4841-3.4286g wet wt.) from the same algae mass were carefully weighed before feeding the fish. The fish were sacrificed after 24 hours and feces collected from the alimentary tract. The algae and fecal samples were dried (65C) to constant weight. Pellets of the sample material were pressed, weighed (15-22mg) and caloric value determined using the Phillipson microbomb calorimeter. No corrections for intestinal mucous or capsule remains in the feces were applied.

Morphological Changes of Digested Algae

Photomicrographs were taken of Anabaena flos-aquae (X 750) and Spirogyra sp. (X 120) under phase-contrast using a ZEISS microscope. The Spirogyra sp. (no.1343) used for these pictures was obtained from the Indiana Univ. culture collection. Photomicrographs were taken of the algae before ingestion and then again 24 hours later. The material for the post digestion pictures was obtained from the hind-gut section of the alimentary tract.

Data Presentation and Statistical Analysis

Proximate body composition which included lipid, ash and total organic matter (including lipid) were expressed as a percentage of total dry weight. Moisture was expressed as a percentage of total wet weight. Energy values were in calories/g ash free dry weight (Prus 1970, Paine 1971). There was no significant difference (t-test; $p \leq 0.05$) between male and female values on eight of the nine sample dates. Only the August 1975 sample displayed sexual differences. The values for males and females were pooled to demonstrate seasonal changes in body composition. One way analysis of variance and linear regression analysis (Steele and Torrie 1960) were used to assess the seasonal changes and proximate body composition relationships.

Growth rates (Δ total length (cm)/day) of the tagged fish were grouped for seasonal considerations and means compared for significant differences ($p \leq 0.05$). The data bank of the Biomathematic section of N.R.C. (Sussex Dr., Ottawa) contains the tag-recapture data for approximately 8,000 individually coded bullheads.

The diet was presented in terms of frequency of occurrence (%) and dry weight composition (%). Frequency of occurrence is the number of stomachs in which each item occurred expressed as a percent of the total number of stomachs (N) examined. Only stomachs containing food were used for this calculation. Dry weight composition is the total dry weight for each item expressed as a percentage of the total dry weight of stomach contents for that sample date. A one way analysis of variance was used to detect seasonal changes in caloric content of food items. The appropriate moisture values were used to express dry weight of stomach contents as a percentage of the body dry weight.

Bullhead assimilation efficiency of ingested algae was expressed in three forms. In the ^{14}C labelling experiment the assimilation efficiency was the ratio of assimilated to the ingested carbon (as cpm ^{14}C). The mass-balance experiment produced a gravimetric measure of assimilation efficiency. Finally the calorie values of the whole algae and feces was used to express assimilation efficiency in caloric terms.

RESULTS

Feeding habits

The brown bullhead is omnivorous in it's feeding habits. The frequency of occurrence and percentage composition (dry weight) of the diet items are presented in tables 1,2. The diet consisted of benthic invertebrates, zooplankton, plant material, organic detritus and occasionally fish. The invertebrate component varied throughout the year from a low of 2.8% in August to 37.2% in October (Table 2). Plant material was primarily filamentous algae with the occassional occurrence of Potamogeton and Myriophyllum. Filamentous algae was very common during the summer months, representing 63.6% of the diet on August 22, 1974. Mixed debres (detritus, silt, sand, wood fibers) was consistently a large component of the stomach contents (33.5-76.6%). The selected size class was rarely piscivorous with only three samples containing any fish remains. The only identified fish species was a Notemigonous crysoleucas.

The chironomidae larvae, isopods, Sphaeriidae clams, and the amphipods Hyalela azteca and Gammarus fasciatus were the most common invertebrates in the diet (Table 1,2), Chironomidae larvae consistently displayed high percentage occurrence (73.3-100%). On the other hand the isopods Asellus display extreme seasonal variations. Asellus was the most important food invertebrate during the fall and winter samples but represented only 0.01% (dry wt) of the diet in August. In terms of both numbers and weight Gammarus fasciatus was the most

Table 1 Stomach contents of brown bullheads taken in Kettle Island Bay at various months of 1974-1975.

Frequency of Occurrence (%)

Month	1974 Aug.	Sept.	Oct.	Nov.	Feb.& Mar.	May	1975 June	July
Nematoda	17.7	2.0	5.1	6.6	-	28.6	16.6	42.9
Mollusca								
Gastropoda	6.5	17.7	38.5	33.3	22.2	28.6	19.4	42.9
Sphaeriidae	30.6	62.8	51.3	26.6	11.1	71.4	52.8	78.6
Annelida								
Hirudinea	-	2.0	-	-	-	-	-	-
Oligochaeta	-	-	-	-	-	-	2.7	21.4
Arachnida								
Hydracarina	14.5	15.7	2.6	6.6	-	-	11.1	21.4
Crustacea								
Amphipoda-<u>Gammarus</u>	4.8	9.8	61.5	33.3	-	28.6	16.6	36.7
<u>Hyallela</u>	4.8	7.8	43.5	40.0	-	14.3	16.6	14.3
Misc.	3.2	27.4	46.1	53.3	-	14.3	27.8	28.6
Cladocera	61.3	80.4	84.6	60.0	-	57.1	52.8	78.6
Copepoda	27.4	3.9	18.0	6.6	-	42.9	5.6	28.6
Isopoda-<u>Asellus</u>	1.6	15.7	46.2	60.0	88.8	71.4	41.7	50.0
Ostracoda	17.7	43.1	28.2	13.3	-	-		57.1
Insecta								
Coleoptera adult	-	2.0	2.6	-	-	-	-	-
Coleoptera larvae	1.6	-	-	-	-	-	8.3	14.3
Diptera								
Ceratopogonidae	11.3	35.3	33.3	33.3	11.1	85.7	55.6	78.6
Chaoboridae	1.6	2.0	12.8	-	-	-	-	-
Chironomidae	88.7	86.3	94.9	73.3	77.8	100	80.6	100
pupae diptera indet.	11.3	9.8	7.8	-	-	85.7	63.9	71.4
Ephemeroptera	3.2	17.7	18.0	13.3	-	-	30.6	14.3
Hemiptera	-	-	2.6	-	-	-	5.6	7.1
Lepidoptera	-	-	2.6	-	-	-	-	-
Megaloptera	-	-	-	-	22.2	-	-	7.1
Odonata-Zygoptera	12.9	9.8	28.2	13.3	-	-	5.6	7.1
Plecoptera	-	-	-	6.6	-	-	-	-
Trichoptera adult	-	-	-	-	-	-	11.1	14.3
Trichoptera larvae	12.9	39.2	46.2	53.3	22.2	85.7	36.1	71.4
Fish remains	-	2.0	-	6.6	-	14.3	-	-
Filamentous algae	75.8	41.2	20.5	40.0	-	14.3	44.4	71
debris	93.5	96.1	79.5	93.3	88.9	100	100	100
N	62	51	39	15	9	7	36	14

Table 2 Stomach contents of brown bullheads in Kettle Is. Bay at various months of 1974-1975.

% Composition (dry wt.) of the diet

Month	1974						1975	
	Aug.	Sept.	Oct.	Nov.	Feb.& Mar.	May	June	July
Nematoda	<.01	0.01	<.01	<.01	–	<.01	<.01	0.01
Mollusca								
Gastropoda	<.01	0.12	0.82	0.92	0.06	0.87	0.06	0.08
Sphaeriidae	0.47	3.90	2.52	0.75	0.12	11.55	6.02	1.95
Annelida								
Hirudinea	–	0.01	–	–	–	–	–	–
Oligochaeta	–	–	–	–	–	–	0.02	0.18
Arachnida								
Hydracarina	0.01	0.03	<.01	0.01	–	–	0.10	0.05
Crustacea								
Amphipoda-Gammarus	0.02	0.15	5.67	1.25	–	1.11	0.13	4.11
Hyallela	0.01	0.04	0.69	0.26	–	0.72	0.08	0.21
Misc.	0.02	0.64	2.10	0.65	–	0.63	0.74	0.66
Cladocera	<.01	0.09	0.06	0.01	–	0.01	0.03	0.02
Copepoda	<.01	<.01	<.01	<.01	–	<.01	<.01	<.01
Isopoda-Asellus	0.01	0.94	15.05	19.07	22.13	1.18	1.92	2.85
Ostracoda	<.01	0.01	<.01	<.01	–	–	<.01	0.02
Insecta								
Coleoptera adult	–	0.02	0.04	–	–	–	–	–
Coleoptera larvae	0.01	–	–	–	–	0.04	0.05	0.02
Diptera								
Ceratopogonidae	0.02	0.14	0.13	0.14	0.03	0.49	0.29	0.27
Chaoboridae	<.01	0.01	1.70	–	–	–	–	–
Chironomidae	2.07	3.89	7.12	2.49	2.48	3.90	5.61	7.99
pupae diptera indet.	0.08	0.05	0.10	–	–	0.74	1.27	0.44
Ephemeroptera	<.01	0.07	0.09	0.02	–	–	–	0.02
Hemiptera	–	–	0.05	–	–	–	0.04	0.05
Lepidoptera	–	–	0.03	–	–	–	–	–
Megaloptera	–	–	–	–	1.00	–	–	0.21
Odonata-Zygoptera	.02	0.06	0.21	0.04	–	–	0.06	0.01
Plecoptera	–	–	–	0.10	–	–	–	–
Trichoptera adult	–	–	–	–	–	–	0.47	0.63
Trichoptera larvae	0.03	0.56	0.86	0.64	0.15	2.21	0.22	1.06
Invertebrate Wt.	2.77	10.74	37.24	26.35	25.97	23.45	17.08	20.88
Filamentous algae	63.67	17.24	11.88	.48	–	<.01	12.49	16.25
debris	33.57	75.02	50.88	73.17	74.03	76.55	70.43	62.86
$\bar{X}$ sample wt. (g)	.2427	.0830	.0590	.0950	.0557	.1781	.1788	.1706
N	62	51	39	15	9	7	36	14

common amphipod in the diet. Zooplankton, primarily Cladocera (Bosmina) often occurred in great numbers but represented little weight (.00009-.00382g). In one exceptional case (Oct. 22, 1975) cladoceron represented 20% of the weight of a north channel fish's stomach contents.

Spirogyra was generally the most abundant algae in the diet. Other identified algae included: Ulothrix, Rhizoclonium, Vaucheria, Oedogonium, Fragilaria, and Oscillatoria. Generally green algae predominated with an occasional stomach containing great masses of diatoms (Fragilaria).

The feeding chronology of the Kettle Island Bay population (Aug. 22, 1974; Sept. 20, 1974) is presented in figures 2 and 3. In August, fish began feeding at dusk (21:30) and stomach content increased to a maximum of 0.8% body weight at 14:30. Stomach contents then decreased and all fish (N=12) were empty at 21:30 (Fig. 1). On September 20 the maximum stomach contents occurred in the 5:00 sample; equalled only 0.36% of body weight, which is less than half of the comparable August peak. The September stomach contents decreased from the early morning peak, and 73% of the stomachs collected shortly after dark (19:30) were empty (Fig. 2).

On the sample dates of Aug. 22, 1974 and Sept. 20, 1974 bullheads demonstrated food preference throughout the feeding cycle (Fig. 4,5). The diet consisted of invertebrates and debris at the onset of feeding and shifted dramatically to algae towards the end of the feeding cycle. In the early morning hours (5:00-9:00) of August 22, algae increased from

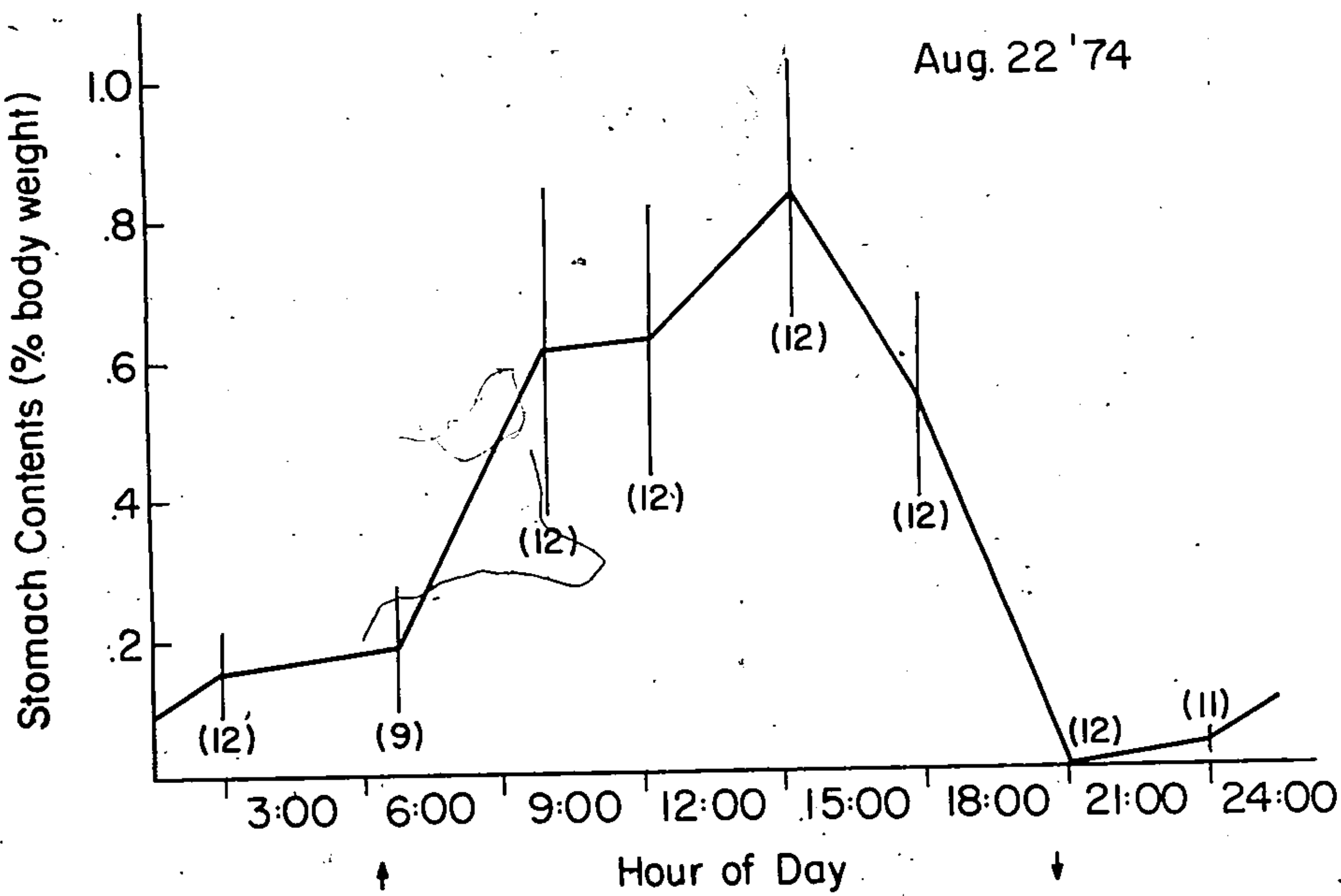

Fig. 2. Daily feeding periodicity of brown bullheads collected in Kettle Island Bay (Aug. 22 '74). Mean stomach contents (as percent body weight), standard error of the mean and sample size (n) shown. ↑ Sunrise ↓ Sunset.

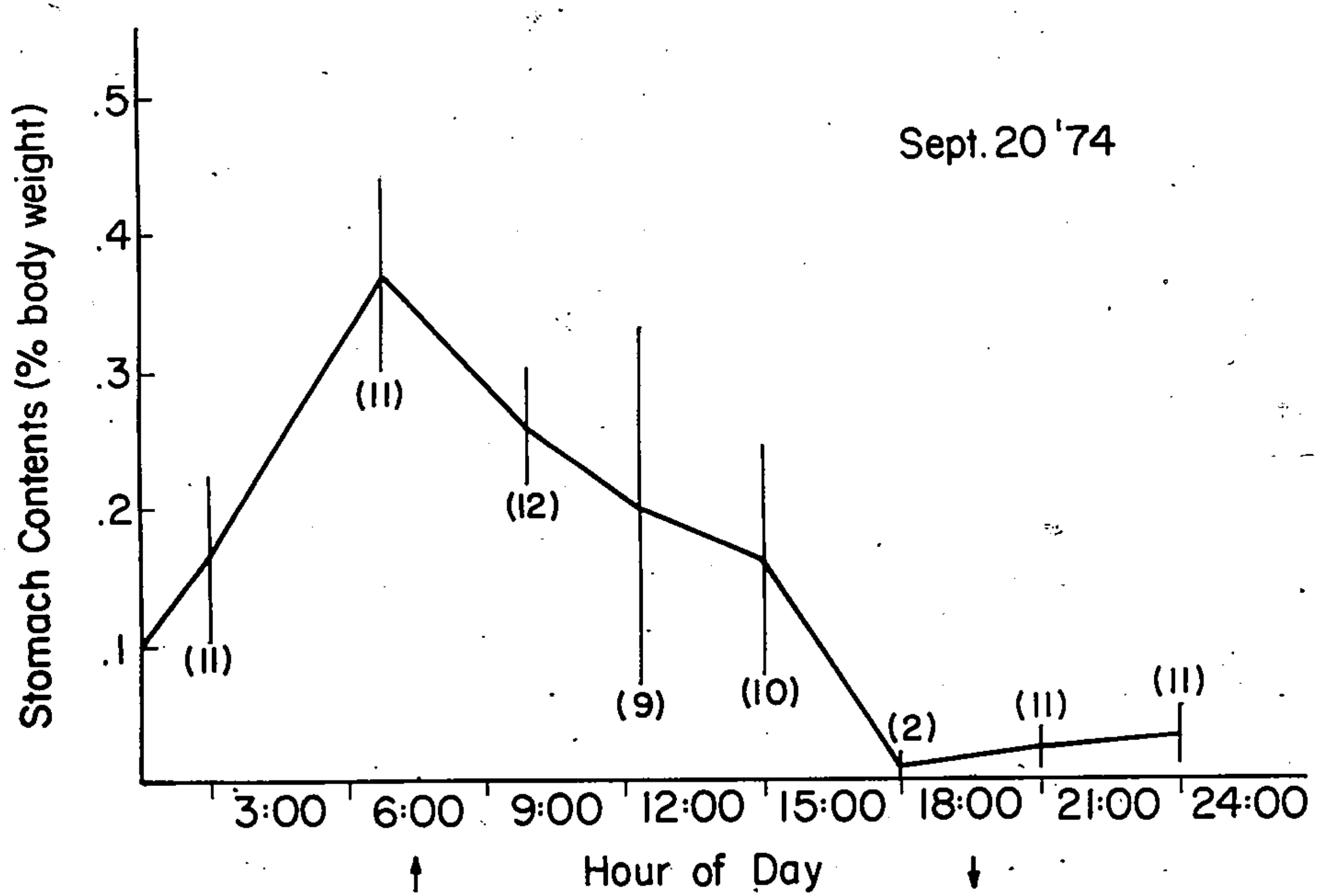

Fig. 3. Daily feeding periodicity of brown bullheads collected in Kettle Island Bay (Sept. 20 '74). Mean stomach contents (as percent body weight), standard error of the mean and sample size (n) shown. ↑ Sunrise ↓ Sunset

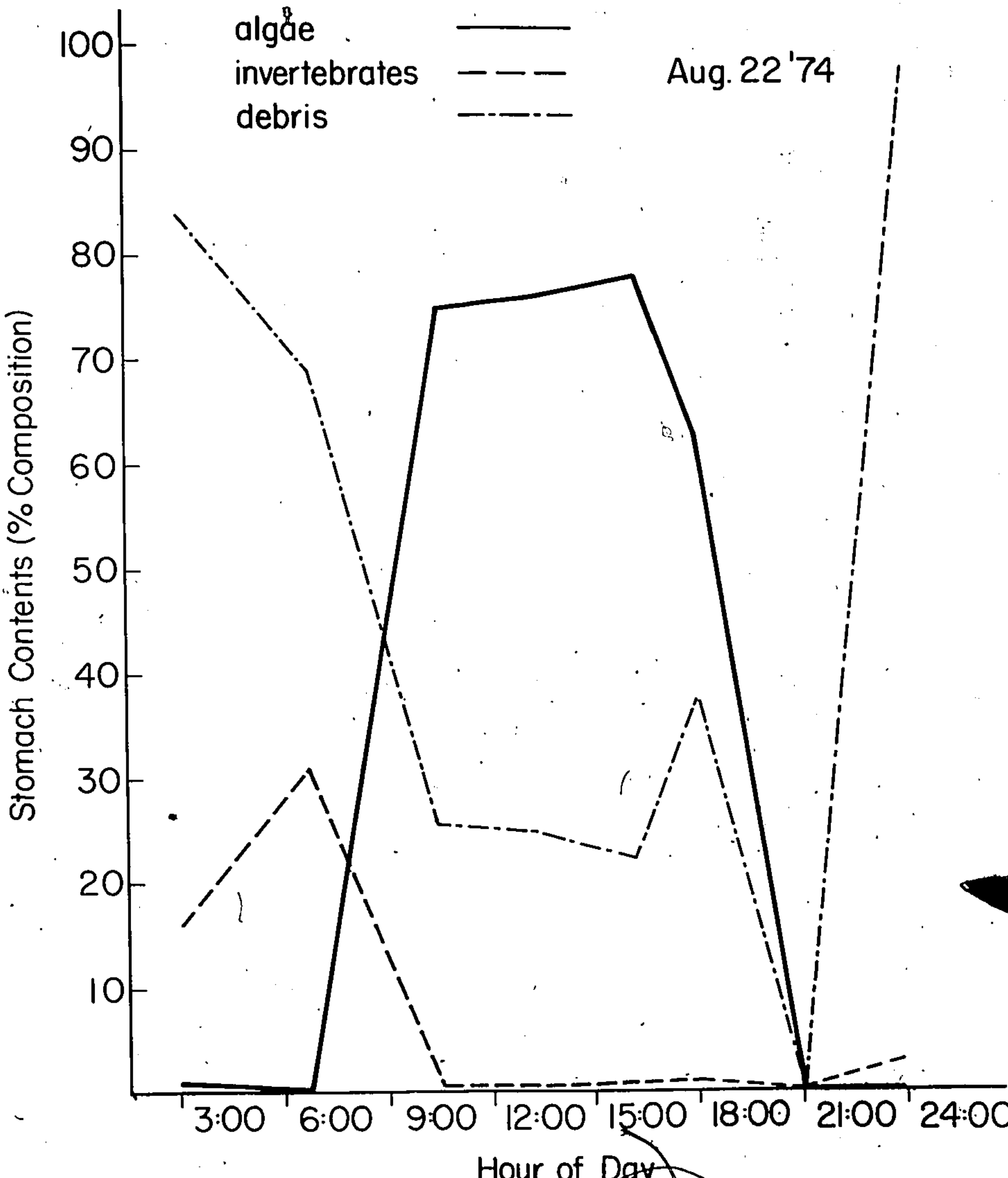

Fig. 4. Percentage composition of bullhead stomach contents, collected throughout the day in Kettle Island Bay (Aug. 22 '74).

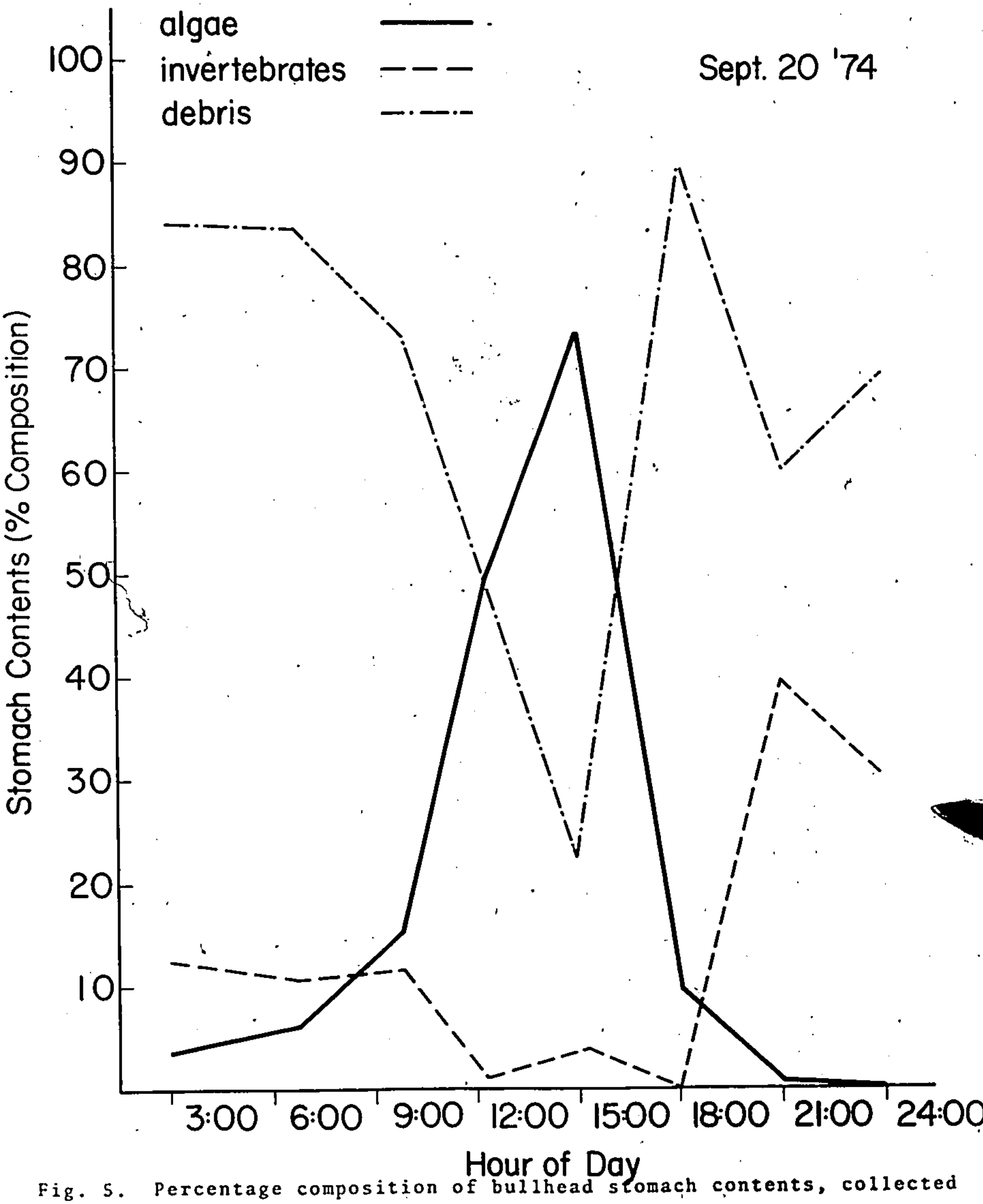

Fig. 5. Percentage composition of bullhead stomach contents, collected throughout the day in Kettle Island Bay (Sept. 20 '74).

0.5 to 73.0% of the stomach contents (Fig. 4). On September 20 the switch to algae was even further delayed and did not occur until the last few hours (9:30-13:30) of the feeding cycle (Fig. 5).

Growth and Body Composition

Only 35 of the original 5300 tagged fish (1972, 1973, 1975) had appropriate recapture data for this growth study (Table 3). The limited nature of these data was a result of the restrictions of dual recapture, size and season. There was also the basic problem of effectively recapturing tagged fish in a large system like the Ottawa River. Of the 3240 fish tagged in 1975 only 86 (2.7%) were recaptured.

The fish grew the fastest in the spring and summer months (Table 3). The mean growth rate of fish recaptured between June 1973-July 1973 (group 1) was .012 ± .003 cm/day. From August 1973 to September 1973 (group 2) fish grew on the average .009 ± .002 cm/day. In the fall and overwintering period of August 1974 to the following June 1975 (group 3) very little growth (.002 ± .001 cm/day) was detected. The growth rate of both group 1 and 2 were significantly greater ($p \leq 0.05$) than group 3 but not significantly different from each other.

Body composition values for the 125 fish are included in Appendix 8b. Males and females were pooled for determination of seasonal changes in % moisture, % organic matter, % inorganic matter and tissue energy values (Kcal/g able 3. Seasonal growth of tagged brown bullheads in the Ottawa River

	Total length on first recapture date (cm)	total length on second recapture date (cm)	duration between subsequent recaptures (day)	growth rate (cm/day)	$\overline{X}$ growth rate (±Se)
	21.1	21.4	68	.004	
	20.0	20.6	23	.026	
	21.8	21.9	68	.002	
	21.4	22.1	21	.003	
Group 1	23.8	24.1	23	.013	0.012 (0.003)cm/day
tagged 1972	21.1	21.5	65	.006	
recaptured	21.0	21.4	23	.017	
une-July 1973	22.9	30.0	34	.003	
	20.0	20.3	34	.009	
	21.1	21.5	53	.008	
	27.6	27.8	53	.004	
	25.3	25.9	55	.011	
	21.8	21.8	57	.000	
Group 2	23.5	24.2	54	.014	0.009 (0.002)cm/day
tagged 1972	22.2	23.3	54	.020	
recaptured	24.2	24.4	52	.004	
ug.-Sept. 1973	21.5	22.1	52	.012	
	20.1	20.7	52	.012	
	21.2	21.6	53	.008	
	21.1	21.7	249	.002	
	23.8	23.5	246	-.001	
	22.3	23.5	294	.004	
	24.0	24.2	276	.007	
	23.3	23.7	242	.002	
	24.0	24.2	275	.001	
	23.5	25.1	268	.006	
Group 3	23.1	23.1	249	.000	0.002 (0.001)cm/day
tagged 1973	23.1	23.6	276	.002	
recaptured	21.3	22.5	274	.004	
ug. 1974-June 1975	23.8	24.1	252	.001	
	23.2	23.6	254	.002	
	23.3	22.3	279	-.004	
	26.3	25.7	274	-.002	
	22.1	23.4	295	.004	

ash-free dry wt). Sexual differences in values ($p \leq 0.05$) were demonstrated on one of the sample dates (Appendix 8a). On August 14, 1975 females had significantly lower ($p \leq 0.05$) % moisture values and higher ash free caloric values than males (73.92 $\pm$ 68 - 75.92 $\pm$ .40%; 6177 $\pm$ 90 - 5836 $\pm$ 36 cal.). These sexual differences were probably a result of higher liquid content in females. The ash free caloric value has a positive correlation, and percentage moisture has a negative correlation with lipid content. These relationships can be described by the following linear regression equations.

$$\text{Kcal/g (a.f.d.)} = 4.86 \pm 0.08 \; (.0455 \pm .0045 \times \text{\%lipid (a.f.d.))} \quad r = .919 \; (p \leq 0.01)$$

$$\%H_2O = 79.04 \pm 0.65 \; (.9348 \pm .1695 \times \text{\%lipid (a.f.d.))} \quad r = .809 \; (p \leq 0.01)$$

An analysis of variance showed no significant difference ($p \leq 0.05$) in the pooled (male + female) seasonal % moisture values which had an annual mean value of 75.29%. Significant seasonal fluctuations ($p \leq 0.01$) occurred in % organic and the % ash (inorganic) components. Assuming that little absolute change occurs in the ash content of a mature fish (Pearse 1925), seasonal % organic matter (protein, lipid, carbohydrates) reflect the fleshiness of the fish. Percentage organic matter increased well into the winter months (Feb. & March-87.7%) and then declined until spring (Fig. 6). Percentage organic values were lowest on June 3, 1975. In June the bullheads reproduce and body constituents are mobilised for gonad development.

The organic fraction increased both in its contri-

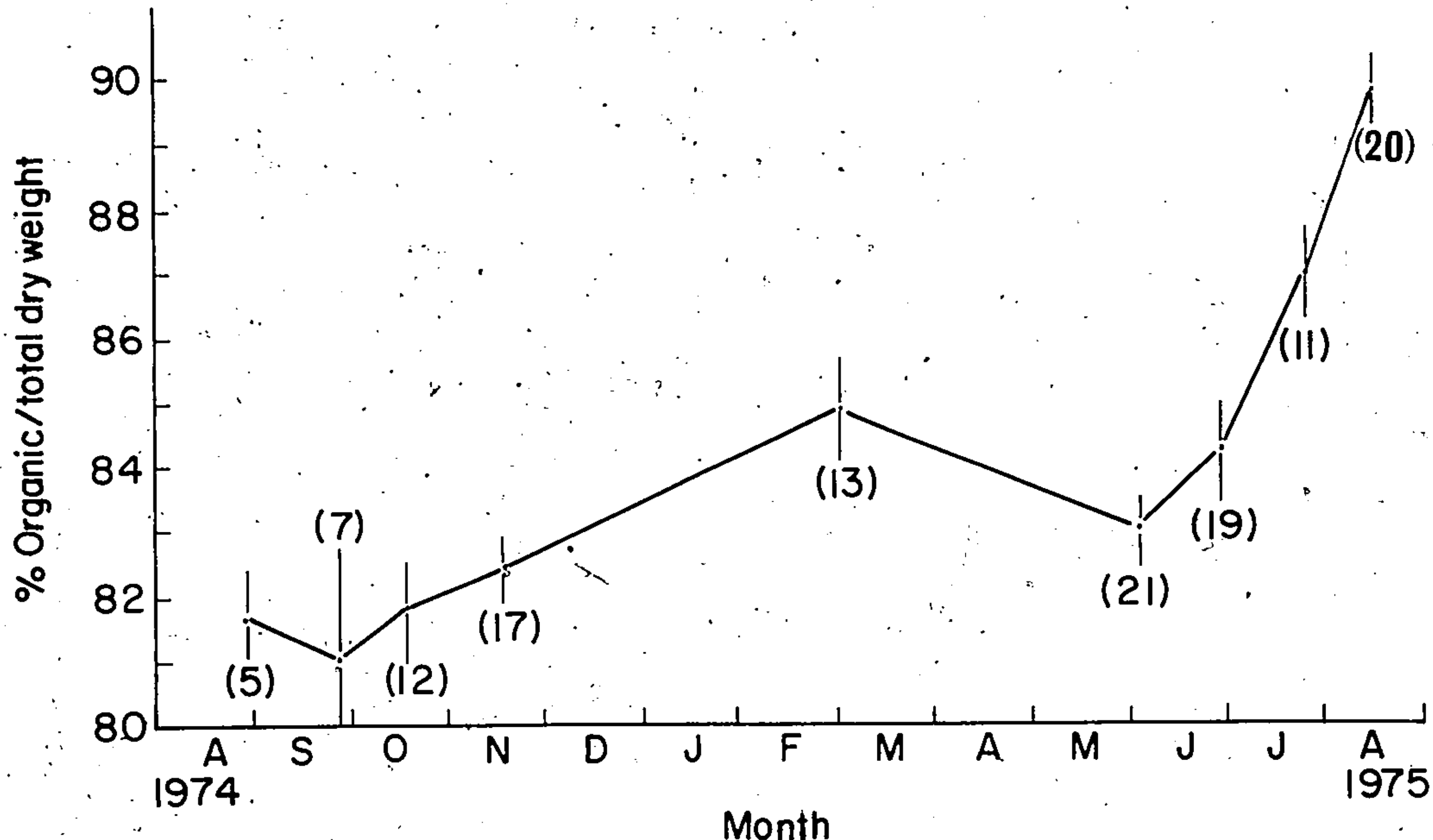

Fig. 6 Seasonal changes in percentage organic matter of brown bullheads. Mean values, standard error of the mean and sample size (n) shown.

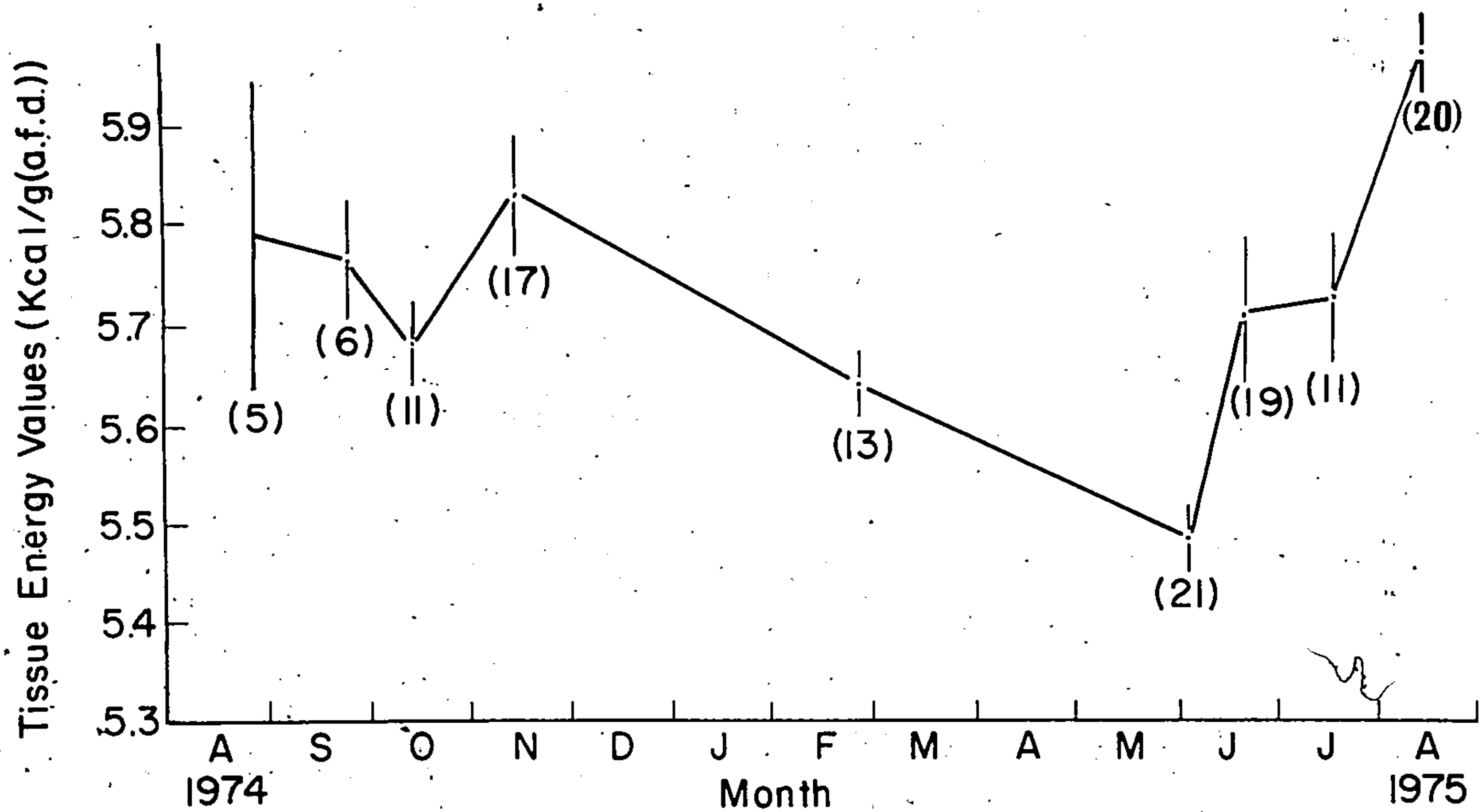

Fig. 7. Seasonal changes in brown bullhead tissue energy values. Mean caloric content (Kcal/ash free dry weight), standard error of the mean and sample size (n) shown.

bution to the total weight (dry) and also in it's caloric content in the fall of 1974 (Fig. 6,7). Tissue caloric values displayed a cyclic pattern, increasing to a maximum in the fall (Nov. 17/74, 5835 cal/g) and then a decrease to a minimum on June 3, 1975 of 5486 cal/g (Fig. 7). The ash free caloric values were lowest on June 3/75 even though high energy lipids (9.45 Kcal/g-Brody 1945) were being concentrated in gonad tissue. The caloric values increased from this low June 3 level reaching a maximum on Aug. 14, 1975 of 5970 cal/g. The ash-free caloric values and % organic matter for Aug. 1974 and 1975 were significantly different ($p \leq 0.01$). This demonstrated the year to year fluctuations in factors that produce body compositional changes.

Caloric Value of Food Items

The results of the ash and caloric content of food items are presented in Table 4.

The amphipoda Gammarus fasciatas and Hyallela azteca displayed significant seasonal variations in ash and caloric content (cal/g dry wt.). In G. fasciatus these differences were 8.0% of the minimum observed caloric content and in H. azteca, 19.5%. In G. fasciatus seasonal variations ($p \leq 0.05$) in caloric content (cal/g dry wt.) were effected by changes in the ash fraction ($p \leq 0.01$) alone, because there was little change in the caloric content of the organic fraction. H. azteca on the other hand displayed seasonal variations in both the relative ash fraction ($p \leq 0.01$) and the caloric content of the organic fraction ($p \leq 0.01$).

Table 4. Ash and caloric value of food items.[1] (mean, standard error of the mean and number (n) of samples given).

Gammarus fasciatus	June 24	July 15	Aug. 14	Sept. 23
Ash (% dry wt.)	22.99 ±.65 (5)	19.30 ±.73 (5)	22.33 ±.56 (5)	19.81** ±.25 (5)
cal/g (dry wt.)	4205 ±57 (4)	4258 ±18 (5)	3943 ±122 (5)	4125* ±53 (5)
cal/g (ash free dry wt.)	5455 ±74 (4)	5278 ±22 (5)	5077 ±144 (5)	5144 ±66 (5)

Hyalella azteca	June 24	July 15	Aug. 14	Sept. 23
Ash (% dry wt.)	23.62 ±1.25 (5)	18.91 ±.54 (5)	17.10 ±.02 (4)	22.76** ±.23 (5)
cal/g (dry wt.)	3611 ±53 (5)	3669 ±67 (6)	4301 ±45 (5)	4315** ±61 (5)
cal/g (ash free dry wt.)	4704 ±68 (5)	4510 ±79 (6)	5171 ±54 (5)	5580** ±80 (5)

Asellus sp.	July 10	Aug. 14	Sept. 23
Ash (% dry wt.)	32.71 ±1.10 (7)	19.61 ±.74 (5)	27.13** ±.25 (5)
cal/g (dry wt.)	3252 ±150 (3)	3981 ±122 (5)	3795 ** ±29 (5)
cal/g (ash free dry wt.)	4750 ±320 (3)	4952 ±152 (5)	5208 ±40 (5)

Table 4 (Cont'd). Ash and calorie value of food items.

Chironomidae sp.	July 15	Aug.14
Ash (% dry wt.)	21.44 ±.45 (2)	13.97 ±.21 (5)
cal/g (dry wt.)	4176 ±30 (3)	4737 ±47 (5)
cal/g (ash free dry wt.)	5315 ±40 (3)	5507 ±55 (5)

Enallagma signatum	July 10	Sept. 23
Ash (% dry wt.)	4.04 ±.50 (5)	25.52 ±.87 (4)
cal/g (dry wt.)	5102 ±107 (5)	5273 ±41 (5)
cal/g (ash free dry wt.)	5317 ±112 (5)	7093 ±54 (5)

filamentous algae[2]	Ash (% dry wt.)	cal/g (dry wt.)	cal/g (ash free dry wt.)
June 16, 1975	8.55 ±2.59 (10)	3882 ±25 (2)	4245 ±28 (2)

[1] collections made in 1974 unless otherwise noted
* $p \leq 0.05$ one way analysis of variance (3 or more groups)
** $p \leq 0.01$
[2] mixed species with the green algae Vaucheria in predominance

The isopod Asellus sp. displayed significant seasonal variation ($p \leq 0.01$) in the ash and caloric content (cal/g dry wt.). Seasonal variations amounted to 22.4% of the minimum observed caloric value (cal/g dry wt.). As in G. fasciatus, changes in the relative size of the ash fraction effected changes in caloric content (cal/g dry wt.) while little change was observed in the caloric content of the organic fraction.

The chironomidae larvae and damselfly nymph (Enallagma signatum) were available in sufficient amounts on only two sample dates (Table 4). The caloric content (cal/g dry wt.) of the chironomidae larvae and E. signatum varied between 4176-4736 cal/g and 5102-5273 cal/g respectively.

The mean ash and caloric content of the June 16, 1975 sample of filamentous algae were 8.55% and 3882 cal/g respectively. Vaucheria sp. was the dominant algae in this sample. Other algae included were Spirogyra sp., Oedogonium sp., Rhizoclonium hieroglyphicum and Fragilaria crontonensis.

Efficiency of Assimilating Algae

The results of the time-course Spirogyra experiment are presented for the individual fish (Tables 5,6). The tissue distribution of algal carbon (as cpm ^{14}C) was the ^{14}C counts in a tissue expressed as a percentage of the whole fish count $\left(\frac{\text{cpm } ^{14}C \text{ tissue}}{\text{cpm } ^{14}C \text{ total fish}} \%\right)$. Approximately 50% of the assimilated counts were recovered in the carcass remains (Table 5). The extremely high carcass value for fish number 2 was presumably the result of contamination of carcass tis-

Table 5. Distribution of algal carbon (as cpm ^{14}C) in the tissues of brown bullheads following ingestion of ^{14}C-labelled algae (Spirogyra). The cpm of ^{14}C in each tissue was expressed as a percentage of the total count of radioactive carbon in all the body tissues $\left(\frac{\text{cpm tissue}}{\text{cpm total fish}}\right)$.

	time after ingestion 9 hrs		12 hrs		24 hrs	
Fish #	1	2*	3	4	5	6
Tissue						
liver	9.59	4.47	7.63	7.98	9.03	13.13
spleen	.40	.22	.60	.56	.35	.63
Kidney	2.50	.88	2.50	2.42	4.77	7.08
gonads	.95	.15	.35	.38	.30	.81
stomach	2.36	1.66	2.43	1.65	6.86	3.09
foregut	31.86	15.77	31.32	24.55	18.71	19.88
midgut	2.52	1.03	1.68	7.01	1.71	5.23
hindgut	.99	.32	.77	1.31	1.24	2.70
remaining carcass	49.29	75.51	52.71	54.14	57.03	47.40

* The high carcass value for fish #2 was presumably due to contamination of body tissues by feces matter from the alimentary tract during dissection.

sue by fecal matter. Time progression changes in ^{14}C content can be noted for such tissues as the foregut and kidney (Table 5). The foregut values decrease from 31.8% after nine hours (fish #1) to 18.7% after 24 hours (fish #6). Kidney values, on the other hand, increase from 2.05 to 7.08%.

Concentration values (Table 6) are the counts per gram tissue, normalized against the average count per gram of the total fish $\left(\frac{\text{cpm } ^{14}\text{C/g tissue}}{\text{cpm } ^{14}\text{C/g total fish}}\right)$. The highest concentration of counts were in the foregut (22.51-43.22). The foregut was the most active absorbing section of the alimentary tract. The concentration values in the foregut progressively decreased (43.22-22.51) from the 9-24 hour interval. Digestive products were transported through the circulatory system and marked accumulations of labelled products were observed in the liver (3.04-4.99), spleen (1.00-2.73) and kidney (2.92-7.06). These tissues have high concentrations of blood as compared to skeletal muscle. The counts of ^{14}C in the blood ranged from 44-120 cpm/mg (absolute counts). Blood values were not included in tables (5,6) because of an incomplete sample series.

The assimilation efficiency was 19.0-27.2% using labelled Spirogyra sp. (Table 7). Digestion was essentially complete after nine hours. The percent assimilation increased only from 21.9% (fish no. 1) to 27.2% (fish no. 5) by extending the experimental duration to 24 hours. This assimilation efficiency was the ratio of the total of the fish tissue counts

Table 6. -- Relative tissue concentration $\left(\frac{\text{cpm/g tissue}}{\text{cpm/g total fish}}\right)$ of ^{14}C in brown bullheads following ingestion of a ^{14}C-labelled algae (*Spirogyra*)

	time after ingestion					
	9 hrs		12 hrs		24 hrs	
Fish #	1	2*	3	4	5	6
Tissues						
liver	3.04	1.98	3.22	3.60	3.11	4.99
spleen	1.00	1.37	2.14	1.65	2.19	2.73
kidney	2.92	1.29	2.81	2.96	6.34	7.06
gonads	1.24	.59	1.49	1.98	1.45	1.19
stomach	2.15	1.36	2.41	1.77	8.23	2.35
foregut	43.22	15.92	29.02	39.92	27.84	22.51
midgut	6.04	1.62	4.83	10.91	5.18	14.09
hindgut	1.68	.45	1.33	2.34	4.01	5.29
lat. muscle	.42	.22	.32	.61	.53	.42
remaining carcass	.54	.82	.56	.57	.61	.51

* Values for fish #2 were presumably affected through contamination of body tissues by feces matter from the alimentary tract.

Table 7. Total recovery of ^{14}C and percent recovered in brown bullhead tissues following ingestion of a ^{14}C-labelled algae (Spirogyra)

	time after ingestion					
	9 hrs		12 hrs		24 hrs	
Fish #	1	2*	3	4	5	6
^{14}C cpm recovered in: (x 10^6)						
Fish tissue	4.4	4.7	4.7	5.0	5.5	4.1
Feces & washings	15.6	8.2	20.2	13.7	14.7	(egested)
Total	20.0	12.9	24.9	18.7	20.2	-
% of total ^{14}C recovered in tissues	21.9%	36.6%	19.0%	26.7%	27.2%	

* Values for fish #2 were presumably affected through contamination of body tissues by feces matter from the alimentary tract.

as a percentage of the total recovered counts. The recovered counts were the sum of the counts in fish tissue, contents of the gastrointestinal tract and washings.

$$\therefore \text{Assimilation efficiency (}\underline{\text{Spirogyra}}\text{)} = \frac{\text{cpm } ^{14}\text{C tissues}}{\text{cpm } ^{14}\text{C tissues + G. I. tract contents \& washings}}$$

In this initial experiment the respiratory and excretory losses were considered minimal (except fish no. 6). The tissue counts and recovered counts were used as a measure of the assimilated and the ingested counts respectively. The accuracy of these assumptions was determined in the subsequent experiment with A. flosaquae. In the A. flos-aquae experiment the ^{14}C content of the encapsulated algae was measured at the time of feeding, and then the fate of the ingested carbon determined. Such a procedure could not be used for the Spirogyra because of variations in algae moisture content (i.e. inconsistent weight determination).

The results of the algal carbon assimilation experiment using ^{14}C A. flos-aquae are presented in Table 8. In this experiment assimilation efficiency was properly measured as the ratio of assimilated counts to ingested counts (%).

$$\therefore \text{Assimilation efficiency (}\underline{\text{A. flos-aquae}}\text{)} = \frac{\text{cpm}^{14}\text{C assimilated}}{\text{cpm}^{14}\text{C ingested}}$$

The total ingested counts of labelled A. flos-aquae was determined from the weight of the encapsulated algae. The percentage water and counts per gram of the algae samples were 81.25 $\pm$ 2.5% and 2.74 $\pm$ .05 X 10^7 cpm/g (wet wt.) respectively. The ratio of 2.74 $\pm$ .05 X 10^7 cpm/g was used to

Table 8. Brown bullhead assimilation of algal carbon (as cpm ^{14}C) 24 hours after ingesting ^{14}C-labelled <u>Anabaena</u> <u>flos-aquae</u>. The assimilation efficiency was the total of the assimilated counts expressed as a percentage of total ingested counts $\left(\frac{\text{cpm}\ ^{14}C\ \text{assimilated}}{\text{cpm}\ ^{14}C\ \text{ingested}}\right)$.

Fish number		1		2		3		4	
		cpm X10^6	% of total	cpm x10^6	% of total	cpm x10^6	% of total	cpm x10^6	% of total
Assimilated ^{14}C (recovered)	Carcass	2.22	78.9	2.56	74.6	4.55	77.0	2.63	76.6
	Gut	.51	18.2	.79	23.2	1.21	20.5	.76	22.0
	$^{14}CO_2$ (in aquarium water)	.08	2.9	.07	2.2	.15	2.5	.05	1.5
	Total cpm	2.82		3.43		5.91		3.44	
Unassimilated ^{14}C	Feces (from G.I. tract)	1.77	70.0	1.62	78.6	1.95	77.0	1.80	90.9
	Water particulate matter	.38[1]	15.0	.02	.8	.05	1.9	.005	.3
	Excretions (soluable)	.38	15.1	.42	20.6	.53	21.1	.17	8.9
	Total cpm	2.53		2.07		2.53		1.98	
Total ingested counts		7.52 X 10^6		7.02 X 10^6		9,91 X 10^6		6.21 X 10^6	
Total recovered counts (tissue, feces, water)		5.34 X 10^6		5.46 X 10^6		8.45 X 10^6		5.42 X 10^6	
[2]Assimilated counts lost as $^{14}CO_2$ from open aquaria		2.18 X 10^6		1.56 X 10^6		1.46 X 10^6		.79 X 10^6	
Assimilation efficiency		69.5%		71.1%		74.4%		68.1%	

[1]High particulate count presumably due to regurgitation. The ingested counts for fish #1 were corrected for this regurgitation before calculating assimilation efficiency.

[2]The counts of $^{14}CO_2$ lost from open aquaria were added to the other assimilated counts for calculation of assimilation efficiency.

determine the total ingested counts. For the fish used in this experiment, the ingested counts ranged from 6.21-9.91 X 10^6 cpm.

The assimilation efficiency from the blue-green A. flos-aquae ranged from 67-74% (Table 8). The great majority (74.66-78.87%) of the recovered assimilated counts (fish tissue; respired $^{14}CO_2$ in water) occurred in the carcass. The $^{14}CO_2$ precipitated as $^{14}BaCO_3$ represented only 1.48-2.94% of the recovered assimilated counts. These unusually low $^{14}CO_2$ values measured from the final water samples were probably the result of loss of $^{14}CO_2$ through gas exchange from the open aerated aquaria. This loss can be calculated as the difference between the total ingested and the total recovered counts (Table 8). The total for respired $^{14}CO_2$ calculated in this manner represented from 19.0-45.2% ($\overline{X}$ = 28.0%) of the assimilated carbon.

The recovered $^{14}CO_2$ counts were determined from the final water samples (2 X 400 ml) collected after 24 hours. The fish began respiring $^{14}CO_2$ within 6 hours after ingestion.

The feces collected from the hindgut of the alimentary tract contained the majority of the unassimilated counts (89.94-90.86%). The water particulate matter (feces, regurgitated algae) was relatively low with the exception of fish number one (Table 8). The high count in fish number one was presumably a result of gill excretions or regurgitations, since all water samples from the aquarium produced high water particulate counts (eg. 12 hr; 50 ml; 1266 cpm).

In retrospect to the Spirogyra experiment, the distribution of the recovered counts in the A. flos-aquae experiment suggested that the carbon assimilation efficiency values from Spirogyra (19.0-27.2%) were minimal. The carbon assimilation efficiency from Spirogyra was based solely on recovered counts in body tissues and fecal matter from the alimentary tract. The unmeasured components were the respiratory and the excretory losses. In the A. flos-aquae experiment the mean respiratory loss in 24 hours was 28.0% of the assimilated counts and the excretory losses, 18.3% of the unassimilated counts. Assuming that these corrections can be applied to the Spirogyra results, the assimilation efficiency after 24 hours increased by 2.4%. Although this increase results in little change (a fact that supports the methods used in the Spirogyra experiment) it does allow a direct comparison of the carbon assimilation results for the two classes of algae.

From these experiments the carbon assimilation efficiency from Spirogyra and A. flos-aquae were approximately 30% and 70% respectively.

Mass Balance Assimilation Efficiency

The mean gravimetric and carbon efficiency was assimilating ingested A. flos-aquae were 45.3 ± 2.1% and 58.0 ± 4.4% respectively (Table 9). The ingested encapsulated algae (.5164-.5960 wet wt. samples) were 78.14% moisture, with a mean caloric content of 4327 cal/g (dry wt.). Twenty-four hours after ingestion the mean algae weight or gravimetric assimilation efficiency was 42.3%. The caloric content of

Table 9. Brown bullhead assimilation of *Anabaena flos-aquae* 24 hours after ingestion, determined by caloric and gravimetric methods.

Fish	Ingested algae			Feces[1]			Assimilation Efficiency[2]	
	caloric value (cal/g)	dry weight (g)	caloric content (cal)	caloric value (cal/g)	dry weight (g)	caloric content (cal)	gravimetric	caloric
1	4327	.1147	496	3118	.0651	203	43.2%	59.1%
2	4327	.1313	568	3075	.0683	210	48.0%	63.0%
3	4327	.1228	531	3697	.0685	252	44.2%	52.5%
4	4327	.1140	493	3401	.0620	211	45.7%	57.3%

[1]Feces collected from the hindgut

[2]Assimilation efficiency was the weight loss after ingestion (gravimetric) expressed in caloric terms. No corrections were applied for intestinal mucous in feces samples or for losses through respiration or into aquarium water.

feces varied from 3075-3697 cal/g dry wt.

The following are the results of the chemical analysis of the A. flos-aquae used in this experiment. Values are expressed as a percentage of the total dry weight.

Chemical analysis of A. flos-aquae:

% carbon	% hydrogen	% ash	% nitrogen	% crude protein
42.1	6.1	14.9	7.6	47.6

cal/g	
dry wt.	ash free dry wt.
4327 ± 34	5083 ± 39

The chemical composition of the algae affected it's digestability. The mean ash free dry weight of the ingested algae and resulting feces was .1040 ± .0093 and .0481 ± .0022, with a caloric content of 5083 ± 39 cal/g (a.f.d.) and 4556 ± 370 cal/g (a.f.d.) respectively. The declining caloric content of the organic fraction indicated that high energy compounds were used in preference to lower low energy compounds (lipid-9450 cal/g; protein-5650 cal/g; carbohydrates -4100 cal/g).

Morphological Changes of Ingested Algae

Spirogyra maintained it's filamentous form 24 hours after ingestion, although most cells were fractured and were void of much of their protoplasm (Fig. 8a,b). Some of the cells were completely empty and only the cellulous walls remained, whereas other cells were intact. (Fig. 10). The intact cells were green in colour and grew when placed in fresh water.

In A. flos-aquae the colour and morphological changes were very striking. The algae remains were dark brown as compared to the blue-green of the original ingested algae. This colour change was the result of chlorophyll decreasing in proportion to phaeophytin. Filaments were disintegrated and large masses of heterocysts remained (Fig. 9a,b). The heterocysts are the specialised cells (nitrogen fixing) that can be identified through their relatively large size and the clefts in the cell envelope. Some filaments of A. flos-aquae remained but all cells were plasmolyzed (Fig. 11).

Fig. 8a. Spirogyra sp., before ingestion by brown bullhead.

Fig. 8b. Spirogyra sp. 24 hours after ingestion by brown bullhead.
CW -cell wall

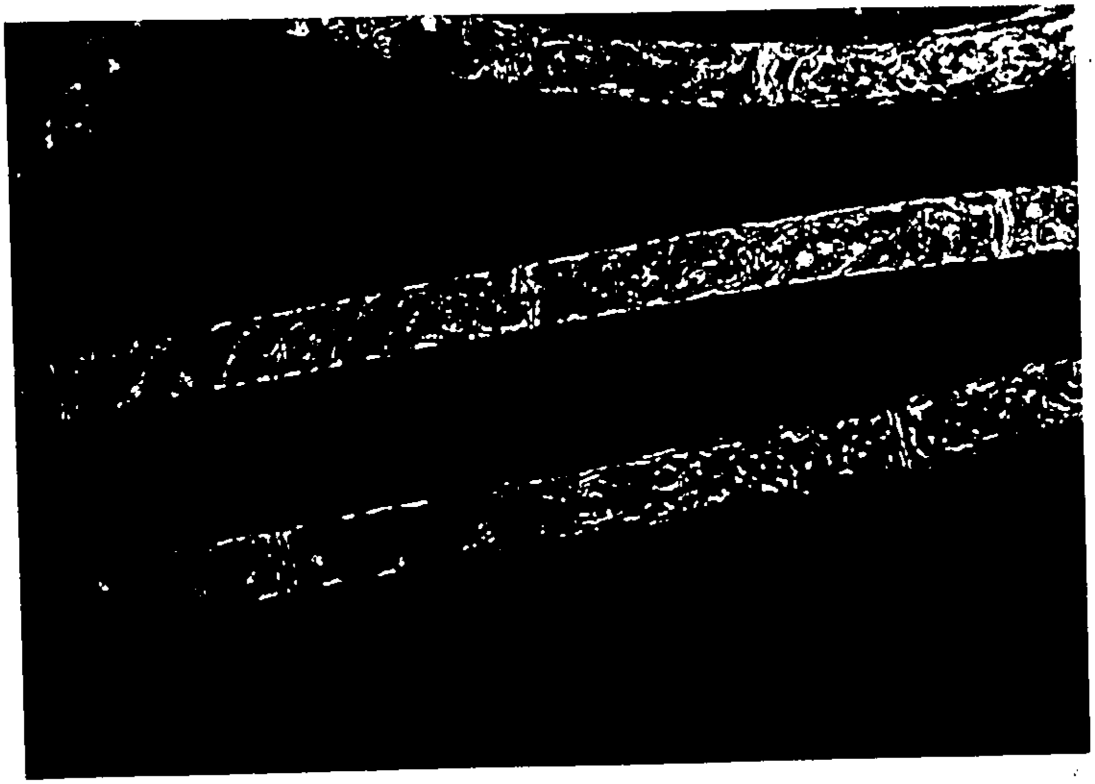

FIG. 8a. 200 μ

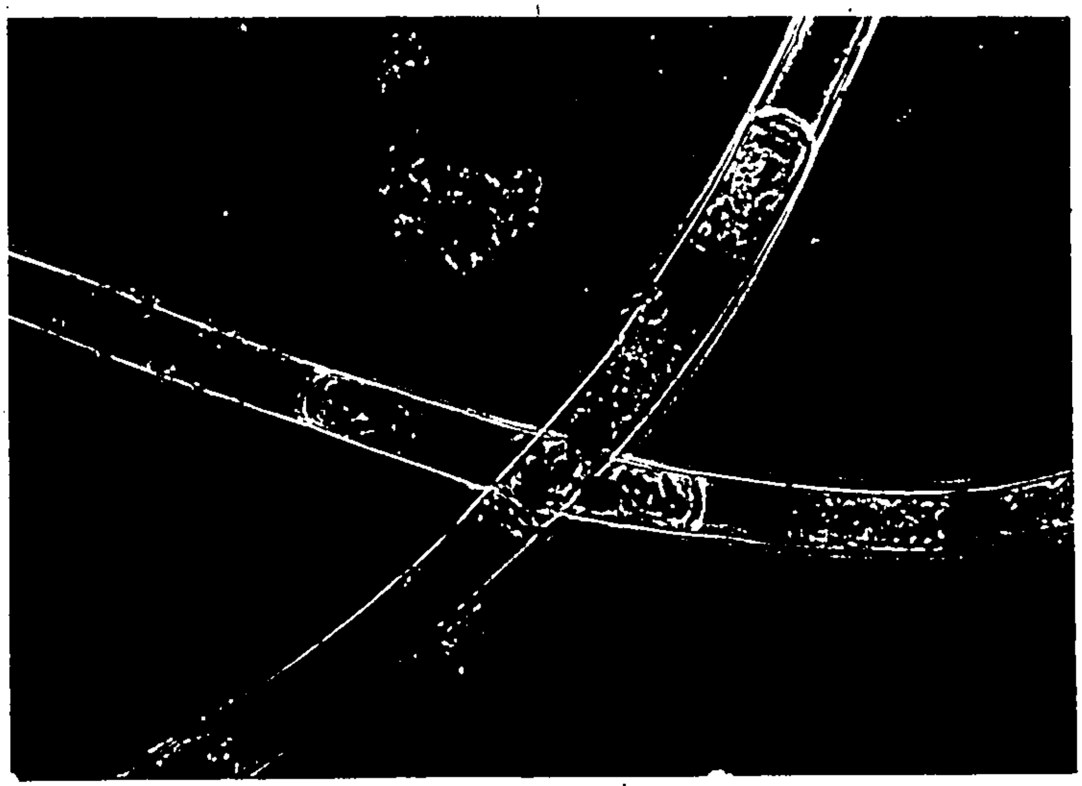

FIG. 8b. 200 μ

Fig. 9a. Anabaena flos-aquae, before ingestion by brown bullhead.

Fig. 9b. Anabaena flos-aquae, 24 hours after ingestion by brown bullhead. H.-heterocyst.

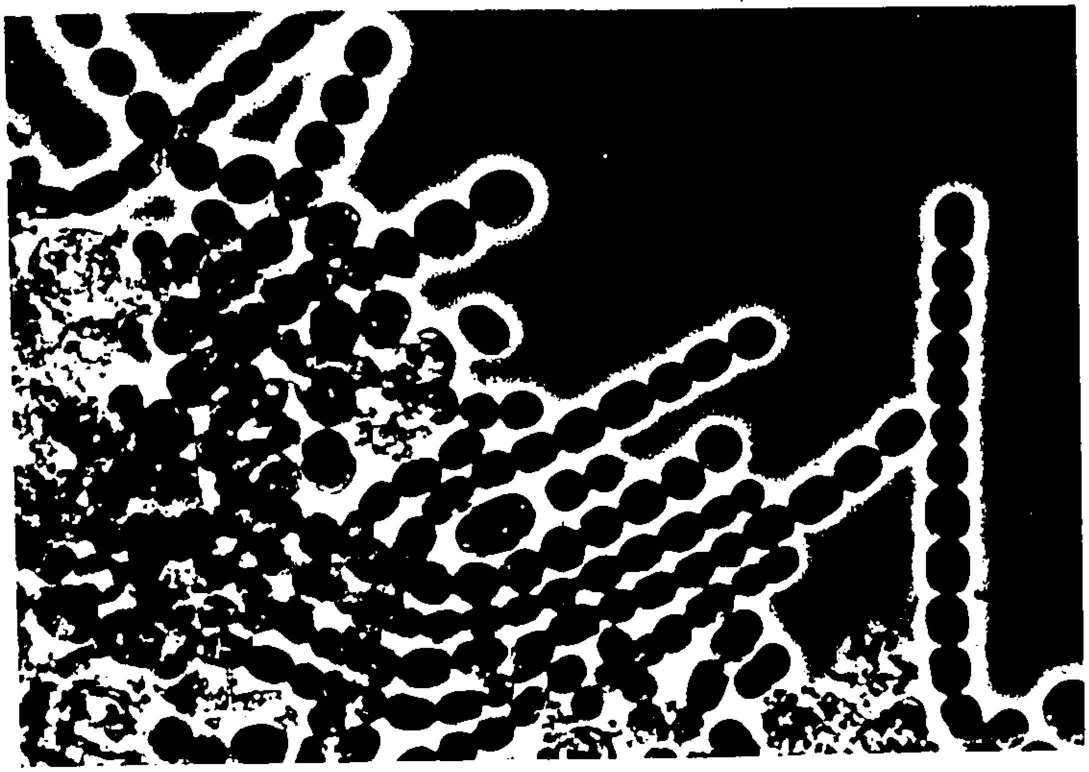

FIG. 9a. 20 μ

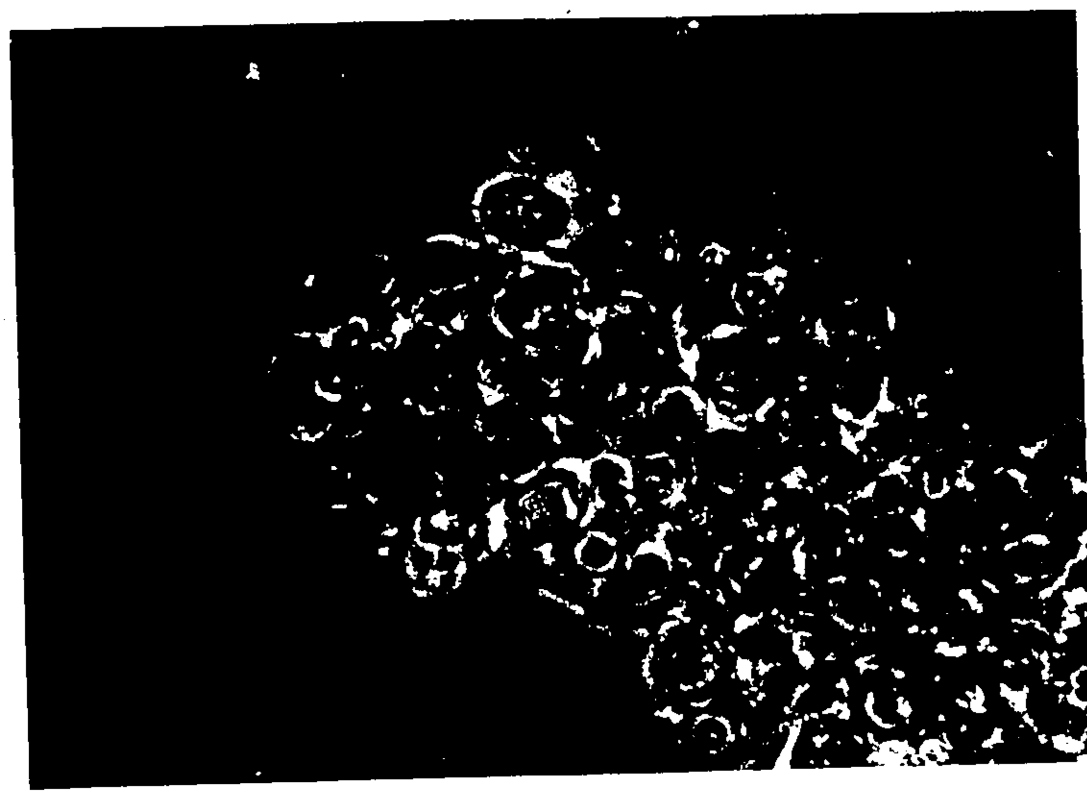

FIG. 9b. 20 μ

Fig. 10. Filaments of Spirogyra sp. collected from the bullhead hindgut, with cells in various stages of digestion. CW -cell wall.

Fig. 11. Plasmolysed filament of Anabaena flos-aquae collected from the bullhead hindgut, 24 hours after ingestion.

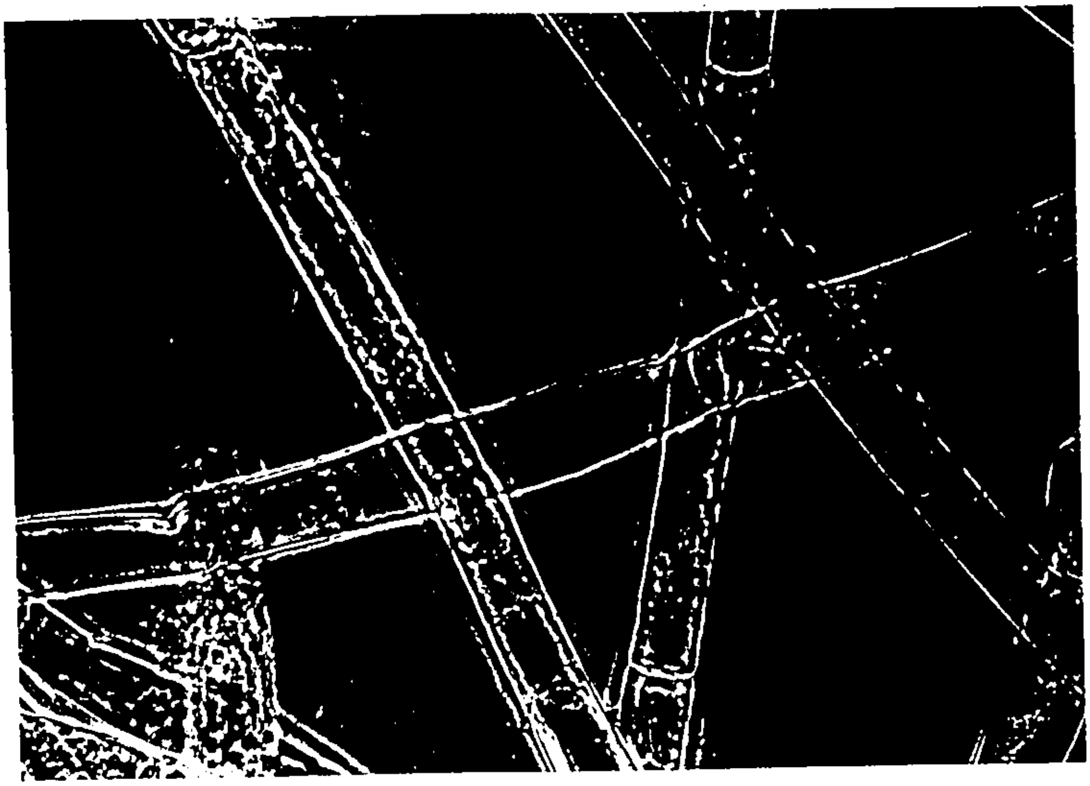

FIG. 10. 200

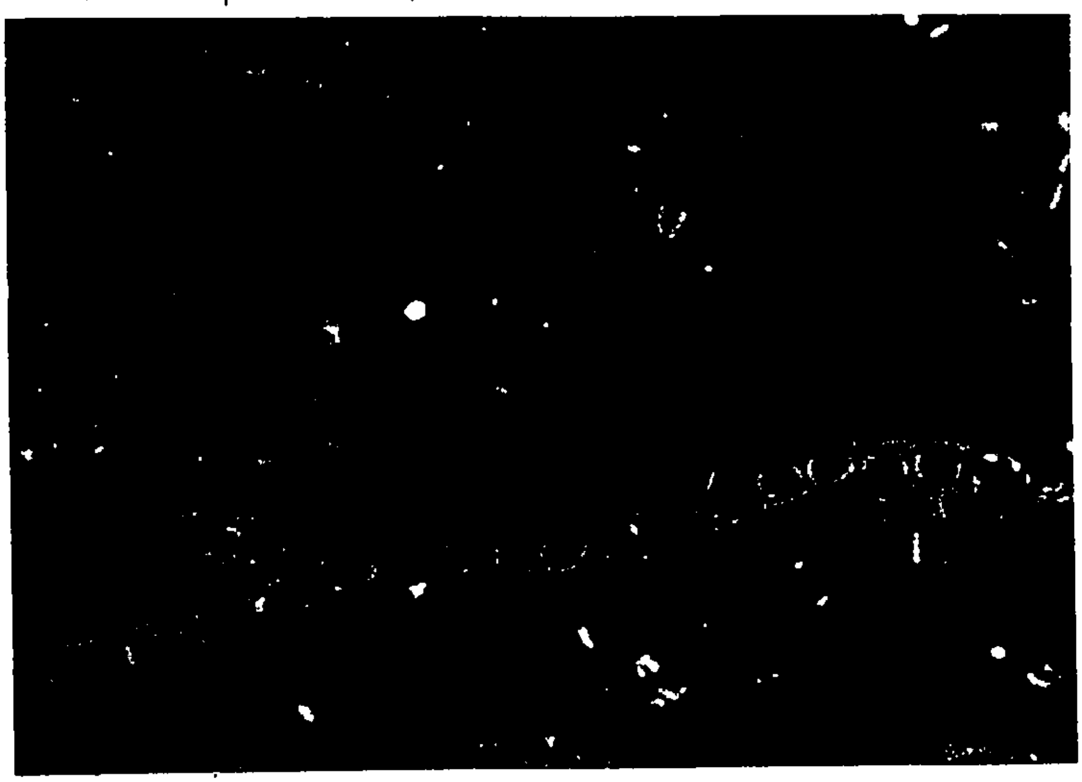

FIG. 11. 20

DISCUSSION

Feeding Habits

Bullheads are opportunistic in their feeding habits and depended heavily on benthic invertebrates in the spring and fall (Tables 1,2), when the benthos is abundant in this area (Mackie 1971). Chironomidae larvae were the most regularly consumed invertebrates, occurring in 73.3-100% of the stomach samples. Chironomids were very abundant in the substrate and at some sites were the only invertebrates present (Mackie 1971; Hamill 1975; Clair 1976). In summer, bullheads compensated for the reduced benthos by consuming filamentous algae. On August 22, filamentous algae increased to 63.7% of the diet (Table 2). Also some bullheads altered their diet and occasionally consumed fish. On August 20, 1974 bullheads (>25.0 cm T.L.) fed heavily on Hybognathus nuchalis at the top of Kettle Island. On this sampling night, schools of spawning minnows congregated in the shallows where they were preyed on by bullheads, as well as pike, walleye and other species. Stomach samples from Kettle Island Bay (Oct. 1974) even contained kernels of corn and peas.

The nocturnal activity of the bullhead minimizes direct competition with the abundant perch (Perca flavescens). The young perch have been shown to feed heavily on chironomidae larvae and other benthic invertebrates but foraged diurnally in this area (Rodgers 1976).

The temporal nature of bullhead feeding has also demonstrated diet changes throughout the day. On August 22 and September 20 the percentage composition of algae in the diet rose rapidly at the end of the feeding cycle (Fig. 4,5). This change in the percentage composition of the diet could have resulted from differential gastric evacuation rates or delayed ingestion of algae. Differential evacuation rates have been demonstrated by other investigators (Kionka and Windell 1972) but this does not provide the complete answer. On September 20 the percentage algae increased (Fig. 5) while the total weight of stomach contents decreased (Fig. 3). If the steady decrease in the feeding periodicity (stomach contents) curve (Fig. 3) means that only digestion is occurring (Tarverchyeva 1972), then the increasing percentage algae (Fig. 5) suggests that algae takes longer than invertebrates and debris to leave the stomach. However, this does not appear to be the case because the actual mean weight of algae increased from .0135g at 9:00 to .0407g at 13:00 (Fig. 3). The laboratory determined gastric evacuation rate also suggested that food consumption continued even though the stomach contents steadily decreased from 4:30-16:30 (Fig. 3). At 20 ± 2C the gastric evacuation rate was approximately six hours (from Spirogyra exp.) and therefore stomach contents would have been empty if algae had not been consumed at the end of the feeding cycle. Similar arguments and conclusions can be drawn from the August 22 results (Fig. 2,4).

The gastric accumulation of algae at the end of the feeding cycle presents interesting possibilities for increased digestability. Moriarty (1973b) has shown that minimal digestion of algae occurred at the onset of feeding but increased when stomach acid concentrations increased. In bullheads, stomach acid secretion is under nervous and possibly hormonal control, and is initiated at the onset of feeding (Ashir 1966). The quiescent stomach has a high pH (5-7) whereas the actively secreting stomach has mean pH of 2.72 (Ashir 1966). The quantity of gastric acid available for the lysing of algae cells increased dramatically after ingestion (30 min. - .002 m. equiv.; 2 hr. -.523 m. equiv.; 4.5 hr. - 2.333 m. equiv.: Smit 1967). Algae consumed at the end of the feeding cycle when acid concentrations were highest would therefore be more effectively digested.

Another apparent optimizing factor for algae digestion was the temperature at which consumption occurred. Algae was consumed in greatest quantities on August 22 (Table 2), when the Kettle Island Bay surface water temperature was 25C. This was also the temperature at which bullheads secreted the greatest quantities of gastric acid and pepsin (Smit 1967). In laboratory studies the gastric acid concentration was three times greater at 25C than either 20 or 30C (Smit 1967). It could therefore be assumed that 25C would be the nutritionally optimal temperature for algal consumption.

Temperature also has an effect on food consumption. Bullhead food consumption increases with increasing temperature (Underhill 1952, Keast 1970). Underhill (1952) found that under lab conditions bullheads increased their consumption rate to a maximum at 25C. In the field situation a similar occurrence was observed for Kettle Island Bay bullheads. On August 22 with a water temperature 25C the daily ration was 1.58% of dry body weight as compared to .60% on September 20 at 18C. The daily rations were estimated from the feeding periodicity curves (Fig. 2,3) using the methods of Noble (1972). These field results do support the laboratory determined relationship of temperature and consumption rate but the added complexity of food availability must also be considered. To make any direct extrapolation from the lab to the field presents such difficulties. In a system like the Ottawa River even the easily measured physical parameters such as temperature displayed extreme variation. Depending on site and depth, Kettle Island Bay August water temperature varied by as much as 15C.

Seasonal Changes in Growth and Body Composition

Bullheads exibited seasonal changes in growth and body composition (Table 3; Fig. 6,7). These changes demonstrated the populations reaction to the food intake and the energy expenses (eg. reproduction, temperature-dependent metabolism) of the season.

The mid-winter to early June period was a particularly stressful time of the year. The bullhead percentage organic matter decreased from 84.9 to 83.0% (Fig. 6) and the caloric content of the organic fraction decreased from 5642 to 5481 cal/g (Fig. 7). Two events occurred at this time of year, namely, food deprivation and reproduction, which can be used to explain these results.

The majority of fish species experience depletion of energy reserves through food deprivation during a part of every year of their lives (Love 1970). Fish are therefore unusually well adapted with large reserves of autolytic enzymes to mobilize their body constituents as food for survival (Siebert et al 1964). Both lipids and proteins are used to meet these energy needs but lipids are the principal source of fuel (Wilkins 1967; Nimi 1973). For bullheads in Kettle Island Bay, mid winter to early June was the period of depletion (Fig. 6, 7). Bullheads were feeding during the winter (Tables 1,2) but at an insufficient level to meet the energy needs at this time of the year. The decrease in percentage organic matter demonstrated that body tissues were depleted (Fig. 6), and the decrease in caloric content of the organic fraction (Fig. 7) indicated that high energy tissue lipids (9450 Kcal/g) were the principal energy source.

June is the bullhead breeding month in this area (Rubec 1975). Spawning occurred between June 3 and June 25/75. The females had ripe gonads in the early June sample but were spent on the later sample date. During reproduction, the lipid content of gonads has been shown to increase markedly as energy from ingested food and body tissues were directed into gonad development (Jafri 1969; Love 1970). The energy expense of mobilizing tissue reserves can further explain the percentage organic matter decrease (Fig. 6). The decrease in the caloric content of the dry weight organic fraction indicates that gonad development occurred only at the energy expense of the total fish.

The relative importance of the overwinter feeding habits or the excessive springtime energy expenses (eg. gonad development; reproductive aggression; increasing temperature) remains uncertain and deserves much further research. The factors of course are not mutally exclusive, for example during spawing bullheads were highly territorial and aggressive, remaining close to the nest site rather than foraging for food (Gill 1905; Todd 1968; Rubec 1975).

During spring and summer the percentage organic matter and caloric content increased rapidly (Fig. 6,7). These were the growth months when growth rates of .012 and .009 cm/day were recorded (Table 3). Spawning was complete on June 25 and the tissue condition (% organic matter; caloric content) increased to a maximum on August 14, 1975. The percentage organic matter and caloric content (cal/g a.f.d.) were significantly higher on Aug. 14, 1975 than Aug. 28, 1974. This demonstrated the annual fluctuations that can occur in this system. These differences were presumably a result of flooding and colder temperatures in 1974. The severe spring flood of 1974 resulted in abnormal water depths and turbidity that lasted until late June. This year also had lower water temperatures fine for comparable dates of 1975 (Appendix 7). These factors and possibly several others, affected the bullhead feeding habits and energetics to produce the observed compositional differences.

The importance that quality of diet played in the seasonal changes in growth and body composition is of course an interesting and important consideration. For many species the function served by various food constituents has been described (Phillips et al 1966; Smith 1971; Fischer 1972; Jezieroka 1974) but for the brown bullhead little is known of the fate of digestive products from plant and animal sources. This work is presently being conducted by another student, Adebayo A. Oladimeji.

Invertebrate Contribution to Energy Needs

Energy budgets have been constructed for August 22 and September 20 to evaluate the caloric importance of invertebrates in the diet of the brown bullhead (Table 10). This exercise has been performed to determine whether invertebrates alone can meet the energy needs of the fish.

Daily rations have been estimated from the feeding periodicity graphs (Fig. 2,3) using the method described by Noble (1972). The mean weight (Appendix 1) and the percentage moisture (Appendix 8a) of bullheads from these sample dates were used to express daily ration in gravimetric terms (dry wt.) On August 22 and September 20 the mean daily rations were .6510g and .2130g respectively. The percentage composition of the diet (Table 2) and the caloric content of the food items (Table 4) were used to express the ration in energy terms. Food items displayed seasonal variation in caloric content (Table 4) and therefore the appropriate monthly values were used when available. For miscellaneous invertebrates the mean caloric content of 4368 cal/g was used. The caloric content of 3882 cal/g was used for algae but no value was available for the organic debris. The

Table 10 Invertebrate contributions to the energy budget of the brown bullhead (*Ictalurus nebulosus*).

	Aug. 22 1974		Sept. 20 1974	
$\overline{X}$ body wt. (wet wt.)	157.5 ± 1.3g		146.5 ± 1.7g	
N	95		77	
daily ration (% dry body wt.)	1.58%		.60%	
daily ration (dry wt)	.6510g		.2130g	
water temperature	25C		18C	
	dry weight(g)	caloric content(cal)	dry weight(g)	caloric content(cal)
Chironomidae larvae	.0135	63	.0083	37
Gammarus fasciatus	.0001	1	.0003	1
Hyallela azteca	.0001	<1	.0001	<1
Isopod (*Asellus* sp.)	.0001	<1	.0020	8
Odonata-Zygoptera	.0001	1	.0013	7
misc. invertebrates	.0041	18	.0121	53
Invertebrate total	.0185	83	.0241	106
Algae	.4145	2472	.0367	142
Debris	.2185	-	.1598	-
Scope for activity[1,2] (Q_{max}-Q_s)	(2068-3103 cal.)		(1017-1562 cal.)	
Metabolism	2580 cal.		1290 cal.	
Growth	420 cal.		382 cal.	
Total expenses	3000 cal.		1672 cal.	

[1]Active metabolism- (Q_{max})-bullhead-Basu 1959

[2]Standard metabolism- (Q_s)-bullhead-Fry 1947

daily energy expenses are two fold, namely, metabolism and growth.

Metabolic expenses are temperature and body weight dependent and fall with a range of values that Fry (1957) referred to as the "scope for activity" (Q_{max}-Q_s). This was the range between standard (Q_s) and active metabolism (Q_{max}). In a natural situation the actual daily metabolic expense, depended on the endogenous activity of the species. For the brown bullheads of Kettle Island Bay, the daily metabolic expenses can be assumed to be 12 hours at the active rate (nocturnal foraging) and 12 hours at the standard rate (laying in the mud). Standard and active metabolism have been measured for thermally acclimated bullheads in laboratory conditions (Fry 1947; Basu 1959). These experiments measured oxygen consumption (mg O_2/Kg/hr.) which can be converted to it's caloric equivalent with the oxycaloric coefficient: 3.42 calories released per mg. oxygen consumed (Brody 1945; Winberg 1956). For the two sample dates the field measured temperatures (Table 10) and the mean body weight (Appendix 1) were used for these calculations.

Growth expenses involved both the energy incorporated into tissue and the energy expense for producing the mass increase. The daily growth rate for tagged fish recaptured between August and September was .009 cm/day (Table 3). This length increase was converted to weight using the length, weight regression equation:

$$\text{Log W (fresh wt.)} = 10.10 \pm 1.26 + 2.90 \pm .23 \text{ Log L(mm)}$$

The weight increase was converted to it's caloric equivalent using the bullhead body compositional results (Fig. 7; Appendix 8a). The daily growth for August 22 (.0444g) and September 20 (.0399g) was equivalent to 210 and 191 cal. respectively. Assuming that the energy cost of deposition of tissue was equivalent to the energy content of the tissue (Norstrom et al 1976), the total energy expenses for growth was therefore 420 (Aug.) and 382 (Sept.) cal.

Whether these calculations accurately described the natural situation is of course highly questionable, but they do provide a reasonable measure for assessing invertebrate importance. On Aug. 22 and Sept. 20 the caloric content of the ingested invertebrates were 83 and 143 cal. respectively. These ingested calories can be converted to assimilated calories using the generally accepted assimilation efficiency of 80% for animal matter (Winberg 1956; Beamish et al 1975). The final result is that invertebrates contributed only 66 cal. and 114 cal. or 2.2% and 7.6% of the daily energy needs of August 22 and September 20 respectively. This extreme insufficiency of dietary invertebrates demonstrated that indeed algae, and possibly, organic detritus were of essential nutritional importance.

Algae as a Food Source

In the algal assimilation experiment special attention was paid to the maintaining of optimal lab conditions. Bullheads were healthy and fed actively. Although consumption rates were reduced by being kept separate (Ivlev 1961), bullheads were fed an algae ration similar to that observed in the field (Table 2, 9). Algae were actively growing and were not damaged by the harvesting procedure. All culture flasks innoculated with the centrifugate (A. flos-aquae) produced good growth. The photomicrographs further verified that the centrifugation procedure did not alter the structural form of the algae nor was it responsible for the resulting digestability.

If anything, the procedure used reduced the digestability of algae. The capsules prevented the mechanical breakdown of cell walls through the grinding action of pharyngeal teeth. Mechanical breakdown could also have been reduced by the absence of sand particles in the diet. In the field, some samples contained as much as 1.4g of sand, which may enhance the breakdown of cell walls through the action of the muscular stomach. Digestion of algae was delayed because the gelatin capsules required approximately one hour to disintegrate in the stomach. The termination of the experiment at 24 hours while food was still in the alimentary tract could have minimized assimilation. Finally the author did not take advantage of higher temperatures (25C) or increased stomach acid concentrations (pre-feeding); factors which could have further increased assimilation.

In the mass-balance experiment, the caloric assimilation efficiency was minimal because of the presence of intestinal mucous in the dried feces samples. The results were otherwise in high agreement with the carbon assimilation results (Table 8,9).

An important feature of the procedures was that

A. flos-aquae was grown for several generations in the ^{14}C-bicarbonate medium to produce a homogeneously labelled algal mass. This fact, combined with the centrifuging procedure that produced an algal paste with a consistent percentage moisture value, allowed for the calculation of total ingested counts directly from the weight of the encapsulated alage. This quantification of ingestion was essential in order to accurately describe the fate of the ingested carbon.

The loss of $^{14}CO_2$ from the open aquaria reduced the recovery of respired carbon in the water sample. This loss was measured indirectly as the difference between the total ingested and total recovered counts. Twenty four hours after ingestion the corrected value for respired $^{14}CO_2$ was on the average 28% of the assimilated counts. In other studies using Tilapia nilotica in sealed aquaria, the respired $^{14}CO_2$ was 10% of the assimilated ^{14}C counts four hours after ingestion (Moriarty 1973b)

Marked differences occurred in the digestability of the two species of algae. The carbon assimilation efficiency for Spirogyra sp. and A. flos-aquae were approximately 30% and 70% respectively. The photomicrographs further demonstrated these differences. Filaments of A. flos-aquae were almost completely disintegrated (Fig. 9b, 11) whereas Spirogyra maintained it's structured form and some of the cells were still intact (Fig. 8b, 10). In other studies the presence of intact and viable cells in feces samples has unjustifiably been used to suggest that algae was indigestable (Rabe et al

1973, Karlberg and Benson 1975).

The digestability depended on the chemical and structural composition of the species (Ifante 1973, Moriarty 1973a, Gunnison and Alexander 1975b). The high cellulose content of green algae was responsible for it's low digestability (Windell 1966, Infante 1973). Spirogyra has a cellulose content equal to 10 percent of the dry weight. Although some digestion of cellulose has been observed in other species (Buhler and Halver 1961; Smith 1971), there appeared little digestion of the cellulose walls of Spirogyra in this study (Fig. 8b, 10).

The Cyanophytae characteristically have high protein content (Boyd 1968, 1973). The crude protein content of A. flos-aquae was 47.6%. Proteins vary in biological value depending on their digestability and amino acid composition (Dupree 1969). The deficiency of certain amino acids in plant protein is probably responsible for the severe growth reduction observed when fish were fed only plant material (Menzel 1959, Kitchell and Windell 1970, Fischer 1972, Stanley 1974). Growth has been shown to resume when plant protein was supplemented with certain amino acid (Rumsey and Ketsla 1975). Investigators have considered high protein algae as a valuable ingredient in formulated feeds for even direct human consumption (Cook et al 1962, Reed et al 1973, Jones 1974).

The actual mechanism used in the digestion of algal cells remains uncertian. Fish (1960) and Moriarty

(1973a) have proposed that acid autolysis is the first step in algae digestion rather than the action of specific enzymes. Cellulose produced by symbiotic intestinal bacterial flora, has been demonstrated for several fish including channel catfish (Ictalurus punctatus) and bullheads (Stickney, pers. comm. 1975), but no correlation to feeding habits was established (Stickney and Shumway 1974). In my study, cellulase was apparently of little importance in the bullhead utilization of algae because of the rapid digestion, the low pH of the stomach and reduced intestinal flora (Margolis 1953, Hofsten 1972). For blue-green algae, lysozyme of bacterial origin has been shown to lyse the cell envelope (Gunninson and Alexander 1975 a,b). Anabaena flos-aquae was particularly susceptible but still required 3-5 days for decomposition. Lysis of A. flos-aquae has also been produced byhypertonic solutions (Walsby and Buckland 1969). Under natural conditions the relative importance of acid antolysis, specific enzymes, hypertonic lysis, or mechanical breakdown has yet to be investigated.

What the present study has proven is that digestion of algae does occur. The assimilation efficiency for ingested A. flos-aquae and Spirogyra sp. was about 70% and 30% respectively. The importance of these results is that even at the lower efficiency level of Spirogyra, the assimilated ration from algae on August 22 (Table 10) is 10 times greater than that of the traditional food source (benthic invertebrates). The nutritional importance of organic detritus, which is used as a food source by some species (Odum 1970), remains to be investigated for the brown bullhead.

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Appendix 1

Size range of brown bullheads collected in Kettle Island Bay for stomach analysis in 1974-75.

Date	N	% males	% females	Total length(cm) X	± Se	Total weight(g) X	± Se
Aug. '74	105	45.2	54.8	22.8	.1	157.5	1.3
Sept. '74	77	35.6	64.4	22.5	.1	146.4	1.7
Oct. '74	55	40.0	60.0	22.6	.1	152.7	1.8
Nov. '74	20	60.0	40.0	22.5	.2	137.4	4.2
ΔFeb.&March '75	13	37.5	62.5	22.5	.3	111.6	5.1
May '75	7	--	--	19.0	.3	88.0	4.4
*June '75	40	--	--	22.5	.2	131.2	4.4
*July '75	19	40.0	60.0	22.8	.3	128.3	6.5
Total	336	42.1	57.9	22.5	.1	145.6	1.4

- Length and weights were recorded one week after preservation in 15% formalin.

Δ Fish were fresh frozen and measurements recorded after thawing.

* Fresh weights and lengths were recorded.

Appendix 2

Age distribution of bullheads collected in Kettle Island Bay Aug. 22/74-Oct. 10/74.

Age	% Occurrence	N	% males	% females	Total length(cm) $\bar{X}$	± Se	Total weight(g) $\bar{X}$	± Se
II	1.1	1	-	100	22.2	-	127.3	-
III	35.1	33	39.4	61.6	22.6	.1	151.1	2.7
IV	56.4	53	37.8	62.2	22.8	.1	153.7	1.9
V	6.4	6	83.3	16.7	22.8	.2	151.8	5.6
VI	1.1	1	100	-	22.7	-	160.5	-

- all samples from selected size class (22.0 - 23.5 cm total length)
- pectoral spine sections used for aging

Appendix 3

Recapture data from tagging operation designed to demonstrate bullhead movement between Kettle Island Bay and a site in the North Channel (Oct. 28-Nov.7 1975).

Recapture Loc.	Date	Fish tagged in N. channel[1]		Fish tagged in K.I.B.[2]	
		number recaptured	% of total available tagged fish	number recaptured	% of total available tagged fish
North channel	Oct. 29	-	-	1	.49
	30	5	1.67	5	2.45
	31	0	-	1	.44
	Nov. 6	1	.13	1	.14
	7	2	.26	9	1.22 *
Kettle Island Bay (K.I.B.)	Oct. 29	-	-	2	.98
	30	0	-	1	.49
	31	1	.18	0	-
	Nov. 4	3	.39	0	-
	5	8	1.04	9	1.53
	6	6	.78	2	.27
	7	0	-	1	.14

[1] A total of 772 bullheads were tagged and released in the north channel from Oct. 29 to Oct. 31. These fish were then recaptured either at the original tagging site or at Kettle Island Bay. For example on Nov. 5, 8 fish tagged in the north channel were recaptured in Kettle Island Bay.

[2] A total of 740 bullheads were tagged and released in Kettle Island Bay from Oct. 28 to Nov. 5.

*On all dates it was easier to recapture a Kettle Island Bay tagged fish while fishing in the N. channel, than fish that were originally tagged at this location.

Appendix 4

Standard invertebrate dry weights used in brown bullhead stomach content weight determinations (1974-1975).

Food item	Individual weight(g)	Reference
Nematoda	1.8×10^{-5}	G
Mollusca		
Gastropoda	1.62×10^{-4}	H
Sphaeriidae	5.90×10^{-4}	H
Annelida		
Hirudinea	3.66×10^{-4}	L
Oligochaeta	3.10×10^{-4}	H
Arachnida		
Hydracarina	1.14×10^{-4}	H
Crustacea		
Amphipoda-Gammarus	8.11×10^{-4}	H
Hyallela	2.30×10^{-4}	H
Misc.	7.15×10^{-4}	H,L
Cladocera	2.0×10^{-6}	Hall
Copepoda	3.0×10^{-6}	Hall
Isopoda-Asellus	9.21×10^{-4}	H,L,G
Ostracoda	3.0×10^{-6}	G
Insecta		
Coleoptera adult	8.85×10^{-4}	L
Coleoptera larvae	5.60×10^{-4}	G
Diptera		
Ceratopogonidae	1.44×10^{-4}	H
Chaoboridae	4.30×10^{-4}	H
Chironomidae	1.31×10^{-4}	H
pupae diptera indet.	4.40×10^{-4}	H
Ephemeroptera	2.50×10^{-4}	H,L
Hemiptera	1.13×10^{-3}	L
Lepidoptera	7.20×10^{-4}	L
Megaloptera	2.50×10^{-3}	G
Odonata-Zygoptera	3.00×10^{-4}	G
Plecoptera	1.40×10^{-3}	G
Trichoptera adult	7.57×10^{-3}	G
Trichoptera larvae	3.67×10^{-4}	H,L

Reference: G-author; L-Leung 1973; Hall et al 1970; H-Hamill (1975 unpublished).

Appendix 5

Numerical totals of food items from Kettle Island Bay brown bullheads stomach contents (1974-1975).

Month	1974 Aug.	Sept.	Oct.	Nov.	Feb.& Mar.	May	1975 June	July
Nematoda	13	17	3	1	-	3	7	11
Mollusca								
Gastropoda	4	32	117	81	2	67	24	12
Sphaeriidae	119	280	98	18	1	244	657	79
Annelida								
Hirudinea	-	1	-	-	-	-	-	
Oligochaeta	-		-	-	-	-	5	14
Arachnida								
Hydracarina	12	11	1	1	-	-	4	11
Crustacea								
Amphipoda-Gammarus	4	8	161	22	-	17	10	121
Hyallela	4	8	69	16	-	39	21	22
Misc.	5	38	67	13	-	11	67	22
Cladocera	216	1908	644	46	-	72	894	253
Copepoda	37	2	10	2	-	4	2	9
Isopoda-Asellus	1	43	376	302	118	16	134	74
Ostracoda	26	74	15	3	-	-	37	123
Insecta								
Coleoptera adult	-	1	1	-	-	-	-	-
Coleoptera larvae	1	-	-	-	-	1	6	2
Diptera								
Ceratopogonidae	18	41	22	14	1	42	128	145
Chaoboridae	1	1	91	-	-	-		-
Chironomidae	2379	1256	1250	271	95	371	2756	1457
pupae diptera indet.	26	5	5	-	-	21	190	24
Ephemeroptera	2	12	8	1	-	-	21	2
Hemiptera	-	-	1	-	-	-	2	1
Lepidoptera	-	-	1	-	-	-	-	-
Megaloptera	-	-	-	-	2	-	-	2
Odonata-Zygoptera	8	9	16	2	-	-	12	1
Plecoptera	-	-	-	1	-	-	-	
Trichoptera adult	-	-	-	-	-	-	4	2
Trichoptera larvae	13	64	54	25	2	75	38	69
Fish remains	-	1	-	-	-	1	-	-
N	62	51	39	15	9	7	36	14

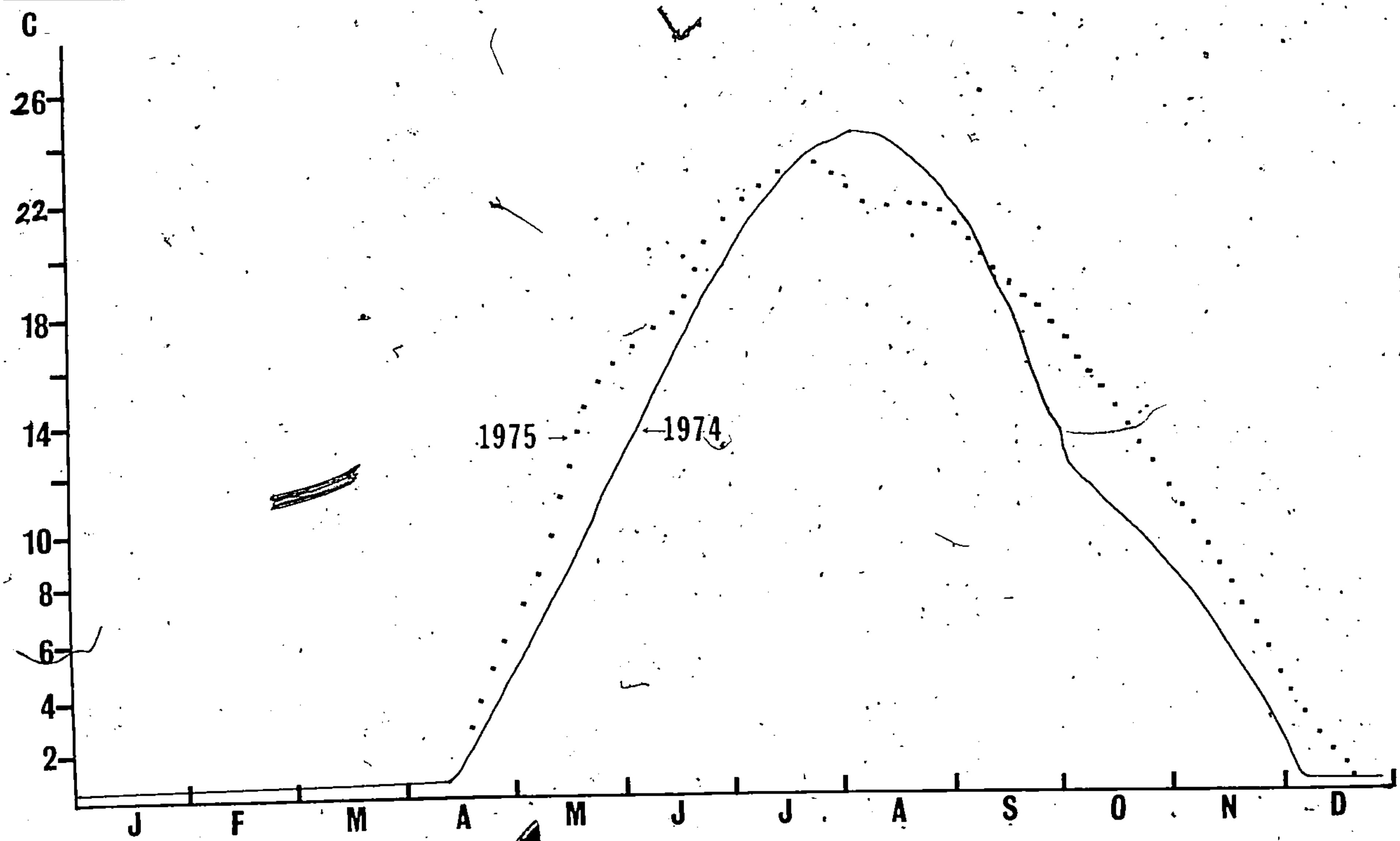
Appendix 6

Dry weight of food items from Kettle Island Bay brown bullhead stomach contents (1974-1975).

Month	1974 Aug.	Sept.	Oct.	Nov.	Feb.& Mar.	May	June	1975 July
Nematoda	.00023	.00030	.00005	.00002	-	.00005	.00002	.00020
Mollusca								
Gastropoda	.00065	.00518	.01895	.01312	.00032	.01085	.00389	.00194
Sphaeriidae	.07021	.16520	.05782	.01062	.00059	.14396	.38763	.04661
Annelida								
Hirudinea	-	.00037	-	-	-	-	-	-
Oligochaeta	-	-	-	-	-	-	.00155	.00434
Arachnida								
Hydracarina	.00137	.00120	.00011	.00011	-	-	.00046	.00125
Crustacea								
Amphipoda-Gammarus	.00324	.00649	.13040	.01784	-	.01379	.00811	.09813
Hyallela	.00092	.00184	.01587	.00368	-	.00897	.00483	.00506
Misc.	.00358	.02717	.04824	.00930	-	.00787	.04791	.01573
Cladocera	.00042	.00382	.00129	.00009	-	.00014	.00179	.00051
Copepoda	.00011	.00001	.00003	.00001	-	.00001	.00001	.00003
Isopoda-Asellus	.00092	.03960	.34592	.27180	.11104	.01474	.12341	.06815
Ostracoda	.00008	.00022	.00005	.00001	-	-	.00011	.00037
Insecta								
Coleoptera adult	-	.00089	.00089	-	-	-	-	-
Coleoptera larvae	.00056	-	-	-	-	.00056	.00336	.00112
Diptera								
Ceratopogonidae	.00259	.00590	.00317	.00202	.00014	.00605	.01843	.00648
Chaoboridae	.00043	.00043	.03913	-	-	-	-	-
Chironomidae	.31165	.18454	.16375	.03550	.01245	.04860	.36104	.19087
pupae diptera indet.	.01144	.00220	.00220	-	-	.00924	.08170	.01056
Ephimeroptera	.00050	.00300	.00200	.00025	-	-	.00525	.00050
Hemiptera	-	-	.00113	-	-	-	.00226	.00113
Lepidoptera	-	-	.00072	-	-	-	-	-
Megaloptera	-	-	-	-	.00500	-	-	.00500
Odonata-Zygoptera	.00240	.00270	.00480	.00060	-	-	.00360	.00030
Plecoptera	-	-	-	.00140	-	-		-
Trichoptera adult	-	-	-	-	-	-	103028	.01514
Trichoptera larvae	.00477	.02349	.01982	.00918	.00074	.02753	.01395	.02532
Invertebrate total	.41607	.45455	.85632	.37555	.13028	.29236	1.09959	.49874
Filamentous algae	9.57954	.73005	.27312	.00685	-	.00002	.80367	.38841
debris	5.05068	3.04897	1.16987	1.04296	.37144	.95432	4.53310	1.50171
Total contents wt.	15.64620	4.23357	2.29933	1.42536	.50172	1.24670	6.43636	2.38886
N	62	51	39	15	9	7	36	14

Appendix 7

Ottawa River temperature from continuous recording at C.R.E.L. pumphouse 1974-1975.



Appendix 8a

Body composition of the brown bullhead (<u>Ictalurus</u> <u>nebulosus</u>)

collected in the Ottawa River 1974-1975.

		% moisture			% ash			cal/g (ash free dry wt.)		
		male	female	M+F	male	female	M+F	male	female	M+F
Aug. 28 1974	$\overline{X}$	-	73.85	-	-	18.30	-	-	5798	-
	SD		1.09			1.66			316	
	N		5			5			5	
Sept. 26 1974	$\overline{X}$	76.54	75.08	75.91	17.30	21.10	18.93	5772	5789	5777
	SD	1.26	1.64	1.52	2.58	6.33	4.57	162	71	128
	N	4	3	7	4	3	7	4	2	6
Oct. 17 1974	$\overline{X}$	73.94	75.39	75.02	19.01	17.96	18.22	5985	5610	5678
	SD	2.71	1.56	1.88	2.23	2.63	2.47	44	273	288
	N	3	9	12	3	9	12	2	9	11
Nov. 15,17 1974	$\overline{X}$	74.41	74.37	74.40	17.32	18.17	17.59	5852	5804	5835
	SD	1.50	2.30	1.70	2.01	2.25	2.47	177	247	198
	N	11	5	16	11	6	17	11	6	17
Feb. & March 1975	$\overline{X}$	76.17	75.96	75.88	15.52	14.84	15.09	5632	5628	5642
	SD	.79	1.46	1.26	3.89	2.33	2.97	180	220	189
	N	6	6	13	6	6	13	6	6	13
June 3 1975	$\overline{X}$	-	-	-	17.35	15.75	16.96	5492	5489	5480
	SD				1.76	2.92	2.30	307	223	263
	N				12	7	21	12	7	21
June 25 1975	$\overline{X}$	75.99	75.21	75.45	15.11	15.44	15.72	5752	5721	5719
	SD	1.23	1.58	1.49	1.88	3.68	3.83	156	357	313
	N	4	14	19	4	14	19	4	14	19
July 22 1975	$\overline{X}$	75.02	76.77	76.14	14.64	12.11	13.03	5634	5777	5725
	SD	1.02	1.93	1.83	2.23	1.59	2.16	110	201	182
	N	4	7	11	4	7	11	4	7	11
Aug. 14 1975	$\overline{X}$	75.92*	73.92	74.92	10.90	9.59	10.25	5836*	6176	6006
	SD	1.27	2.17	2.01	2.03	2.15	2.15	200	286	297
	N	10	10	20	10	10	20	10	10	20

* $p \leq 0.05$

Appendix 8b

Body composition: Brown Bullhead from the Ottawa River. (1974-1975).

Capture date	Loc.	Total Weight	Total length	Sex	%H_2O	%Ash	%Lipid	cal/g (dry)	cal/g (a.f.d.)
28/8/74	KIB	148.5	23.0	F	74.58	20.37	--	4300	5400
"	"	124.5	21.1	F	72.13	16.71	--	5020	6028
"	"	127.5	21.3	F	73.62	19.04	--	4643	5736
"	"	120.0	22.0	F	74.03	16.47	--	5173	6194
"	"	120.0	21.7	F	74.88	18.93	--	4568	5634
26/9/74	KIB	120.8	--	M	74.70	18.44	--	4840	5932
"	"	146.0	23.3	M	77.13	20.01	--	4532	5665
"	"	153.3	23.3	M	76.84	13.96	--	5062	5884
"	"	154.0	23.5	M	77.50	16.83	--	4664	5607
"	"	144.0	22.1	F	74.93	17.12	--	4757	5739
"	"	117.3	23.0	F	76.79	28.41	--	--	--
"	"	125.3	21.9	F	73.51	17.79	--	4800	5839
17/10/74	KIB	129.0	22.3	M	76.91	21.35	--	--	--
"	"	123.0	22.0	M	71.62	18.77	--	4886	6016
"	"	120.5	22.3	M	73.25	16.90	--	4948	5954
"	"	131.0	22.2	F	74.93	13.71	--	5003	5798
"	"	154.0	23.7	F	75.88	17.61	--	4678	5678
"	"	114.0	21.8	F	75.30	18.33	--	4649	5693
"	"	150.0	22.8	F	75.35	14.40	--	5006	5848
"	"	129.0	22.2	F	74.39	21.03	--	4030	5104
"	"	147.0	23.1	F	74.72	18.03	--	4738	5781
"	"	125.5	22.4	F	78.48	21.71	--	4057	5181
"	"	143.0	23.0	F	76.62	18.78	--	4593	5855
"	"	139.8	22.1	F	72.82	17.99	--	4717	5752
19/11/74	KIB	128.0	22.0	M	74.81	20.53	--	4404	5541
"	"	128.0	22.0	M	75.70	16.16	--	4810	5737
"	"	152.0	22.8	M	74.49	14.65	--	5066	5936
"	"	120.0	21.8	M	75.50	16.24	--	4768	5693
"	"	157.8	23.1	M	76.89	15.05	--	4823	5677
"	"	129.3	22.2	M	71.89	17.24	--	4941	5970
"	"	115.5	21.6	M	72.57	17.26	--	4912	5937
"	"	136.3	23.0	M	72.64	17.61	--	4789	5813
"	"	166.5	23.9	M	75.07	20.74	--	4709	5941
"	"	143.5	23.0	M	74.44	16.25	--	5002	5972
"	"	162.5	22.5	M	74.55	18.81	--	4999	6158
"	"	115.0	22.0	F	73.59	20.69	--	4262	5375
"	"	125.0	21.5	F	--	16.79	--	4810	5781
"	"	115.0	22.1	F	71.05	19.06	--	4922	6081
"	"	134.3	22.3	F	74.78	15.98	--	4871	5798
"	"	148.5	23.0	F	77.31	15.83	--	4858	5773
"	"	109.3	20.9	F	75.13	20.64	--	4659	6016
-/2/75	KIB	122.5	23.0	M	76.49	15.12	15.66	4756	5602
5/3/75	"	96.5	21.5	M	77.28	13.13	11.43	4821	5547

Appendix 8b (cont'd)

Body composition: Brown bullhead from the Ottawa River. (1974-1975).

Capture date	Loc.	Total Weight	Total length	Sex	%H_2O	%Ash	%Lipid	cal/g (dry)	cal/g (a.f.d.)
-/2-/75	KIB	111.0	23.0	M	77.75	14.92	15.66	4660	5476
14/2/75	"	74.5	20.0	M	74.12	19.42	14.14	4486	5566
11/3/75	"	123.5	22.7	M	75.48	10.06	20.86	5379	5986
5/3/75	"	130.0	23:1	M	74.62	20.48	13.47	4464	5615
21/2/75	KIB	140.5	23.6	F	75.36	14.23	18.58	5051	5887
14/2/75	"	91.5	21.1	F	75.43	14.54	15.02	4842	5663
-/2/75	"	126.0	22.9	F	76.16	18.07	11.98	4591	5605
27/2/75	"	95.5	21.8	F	77.39	16.77	7.61	4367	5249
14/2/75	"	118.0	22.0	F	75.91	11.39	17.84	5131	5791
14/2/75	"	119.5	22.5	F	76.77	14.03	12.34	4794	5574
6/3/75	"	102.0	21.7	-	73.68	13.99	18.33	4980	5790
3/6/75	KIB	115.0	21.9	M	--	17.47	--	4580	5552
"	"	95.0	21.1	M	--	19.00	--	3849	4752
"	"	113.0	21.8	M	--	18.00	--	4498	5486
"	"	93.5	20.4	M	--	13.73	--	4633	5369
"	"	96.0	20.6	M	--	18.50	--	4609	5656
"	"	109.5	21.5	M	--	17.01	--	4839	5830
"	"	95.0	20.1	M	--	16.44	--	4435	5305
"	"	100.0	21.2	M	--	14.72	--	5025	5891
"	"	94.5	20.5	M	--	17.12	--	4803	5794
"	"	102.0	20.7	M	--	18.05	--	4559	5567
"	"	74.5	19.7	M	--	20.11	--	4295	5376
"	"	77.0	19.0	M	--	18.10	--	4370	5336
"	"	106.5	21.4	F	--	15.72	--	4658	5526
"	"	86.0	19.7	F	--	16.77	--	4657	5598
"	"	123.5	21.3	F	--	12.67	--	4412	5346
"	"	93.0	20.5	F	--	17.56	--	4460	5413
"	"	94.5	19.8	F	--	13.14	--	4698	5407
"	"	70.0	19.7	F	--	20.81	--	4136	5222
"	"	91.0	19.4	F	--	13.55	--	4842	5913
"	"	102.5	20.7	-	--	19.48	--	4415	5485
"	"	74.5	19.8	-	--	18.26	--	4297	5260
25/6/75	KIB	135.0	23.3	M	77.02	17.52	--	4620	5600
"	"	134.0	22.1	M	74.37	12.92	--	5147	5855
"	"	128.0	22.5	M	76.86	14.93	--	4799	5639
"	"	135.5	23.2	M	75.70	15.08	--	5023	5916
"	"	111.5	21.3	F	74.31	11.58	21.54	5251	5940
"	"	90.0	20.9	F	72.42	16.47	21.20	4975	5958
"	"	99.0	22.5	F	76.69	20.27	8.46	4328	5430
"	"	123.5	22.1	F	74.80	12.48	--	5438	6215
"	"	100.0	21.6	F	77.11	18.66	7.69	4105	4977
"	"	96.5	23.0	F	77.86	20.55	4.19	4021	5064
"	"	102.0	21.0	F	73.79	15.88	20.55	4984	5926

Appendix 8b (cont'd)

Body composition: Brown Bullhead from the Ottawa River (1974-1975).

Capture date	Loc.	Total weight	Total length	Sex	%H_2O	%Ash	%Lipid	cal/g (dry)	cal/g (a.f.d.)
"	KIB	132.0	22.3	F	74.47	12.12	18.50	5183	5897
"	"	115.0	22.4	F	74.31	18.80	--	4493	5533
"	"	96.0	21.4	F	76.81	18.32	--	4783	5854
"	"	98.5	21.3	F	76.64	16.55	--	4703	5633
"	"	126.5	22.5	F	75.08	13.31	--	5070	5848
25/6/75	KIB	129.0	22.4	F	75.07	8.65	--	4286	5559
		133.0	22.2	F	73.57	12.49	--	5501	6019
		94.0	21.0	-	76.62	22.92	9.75	5076	5801
22/7/75	KIB	119.0	22.2	M	73.91	12.41	--	4966	5669
"	"	105.0	22.4	M	74.57	16.46	--	4814	5762
"	"	93.0	20.6	M	75.30	16.66	--	4674	5609
"	"	102.0	21.6	M	76.29	13.03	--	4782	5499
"	"	146.5	24.3	F	77.10	14.19	--	4744	5528
22/7/75	KIB	139.5	23.4	F	78.30	10.37	--	5075	5662
"	"	152.0	23.5	F	77.63	11.26	--	5044	5685
"	"	143.5	23.5	F	78.02	10.71	--	5042	5646
"	"	113.0	22.4	F	73.71	13.64	--	5232	6059
"	"	140.0	23.7	F	74.35	11.14	--	5348	6019
"	"	129.0	23.2	F	78.31	13.50	--	5054	5843
14/8/75	N.CH	* 72.0	18.5	M	77.36	14.23	--	4590	5352
"	"	*113.5	20.8	M	74.63	12.64	--	5162	5909
"	"	* 97.0	20.2	M	74.90	11.49	--	5142	5809
"	"	* 93.0	19.6	M	75.07	10.53	--	5378	6011
"	"	*107.5	20.8	M	74.78	9.22	--	5547	6110
"	"	* 99.0	20.2	M	75.28	9.39	--	5215	5756
"	"	*111.5	21.3	M	76.12	12.15	--	5139	5850
"	"	*116.0	21.3	M	75.60	10.56	--	5294	5919
"	"	* 84.5	19.5	M	77.16	11.77	--	5113	5795
"	"	*109.0	20.6	M	78.28	7.02	--	5438	5849
"	"	*112.5	21.0	F	72.62	9.94	--	5683	6310
"	"	*119.5	21.5	F	72.92	9.36	--	5638	6220
"	"	*115.5	21.3	F	77.88	15.22	--	4698	5542
"	"	*120.5	21.5	F	74.55	10.09	--	5389	5994
"	"	* 94.0	19.5	F	71.42	8.43	--	6089	6649
"	"	*124.5	21.6	F	72.95	8.59	--	5731	6269
"	"	*126.0	21.7	F	72.91	8.11	--	5638	6135
"	"	*113.5	21.7	F	72.68	7.87	--	5873	6375
"	"	*114.5	20.5	F	77.60	10.05	--	5467	6078
"	"	* 99.5	20.0	F	73.60	8.25	--	5685	6196

Comment: - weights (g) and lengths (cm) are post thawing weights
* 14/8/75 sample, fresh weights and lengths.