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The Biology of Juvenile Scup (*Stenotomus chrysops* (L.)) in Narragansett Bay, R.I.: Food Habits, Metabolic Rate and Growth Rate

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THE BIOLOGY OF JUVENILE SCUP

(*Stenotomus chrysops* (L.)) IN NARRAGANSETT BAY, R.I.:

FOOD HABITS, METABOLIC RATE AND GROWTH RATE

BY

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ABSTRACT

The food habits, metabolic rate and growth rate of juvenile scup (*Stenotomus chrysops* (L.)) in Narragansett Bay, R.I. were studied during the summer of 1987.

The instantaneous gastric evacuation rate of this demersal fish species was determined in the laboratory. The linear estimate of this rate was 0.17/hour and the exponential estimate was 0.34/hour.

Field studies were performed to determine the feeding periodicity of juvenile members of this species and the types of prey consumed. Scup were found to be daytime and therefore probably visual feeders. The types of prey consumed included polychaetes, mysids and other crustacea, molluscs, and fish eggs and larvae. Variation in the relative amounts of each prey type throughout a season indicated that this species is probably an opportunistic feeder.

The daily ration was determined by combining data from the gastric evacuation study with a 24 hour field study. Two estimates of daily ration were obtained depending on the type of evacuation model used. The linear estimate of daily ration was 3.99% dry weight and the exponential estimate was 3.49% dry weight. The benthic consumption rate of scup in Narragansett Bay was found to equal 0.6-1.7 g dry wt/m2 between June 1st and September 30th.

The metabolic rate of juvenile scup *Stenotomus chrysops* was measured in the laboratory. The average respiration rate (0.23 ml O_2/g wet wt) of 46 of these one year old demersal fish was used to estimate their metabolic expenditure at 1.86% dry weight/day.

Two approaches were taken to estimate the growth rate of juvenile scup: a bioenergetic approach, and a length-frequency approach. The bioenergetic approach, which used Winberg's energy budget equation, estimated growth at 0.93% dry weight/day. The length-frequency approach estimated the growth rate of juvenile scup at 0.84% dry weight/day during their summer residence in Narragansett Bay. The field estimate of the growth rate of scup agreed well with the bioenergetic estimate.

The growth rates determined in this study were used to calculate the body weight of scup that was produced in Narragansett Bay. This production was equivalent to 0.15-0.40 g dry wt/m^2.

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PREFACE

This thesis has been prepared according to the manuscript plan and contains two papers. The first paper addresses the food habits of juvenile scup in Narragansett Bay, Rhode Island. It has been prepared for submission to the " Journal of Fish Biology". The second paper addresses the metabolic and growth rates of juvenile scup in Narragansett Bay. It has been prepared for the "Fishery Bulletin".

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FOOD HABITS OF JUVENILE SCUP (*Stenotomus chrysops* (L.)) IN NARRAGANSETT BAY, RI

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ABSTRACT

A study of the food habits of juvenile scup, *Stenotomus chrysops* took place during the summer of 1987 in Narragansett Bay, Rhode Island. The instantaneous gastric evacuation rate of this demersal fish species was determined in the laboratory. The linear estimate of this rate was 0.17/hour and the exponential estimate was 0.34/hour. Field studies were performed to determine the feeding periodicity of juvenile members of this species and the types of prey consumed. Scup were found to be daytime and therefore probably visual feeders. The types of prey consumed included polychaetes, mysids and other crustacea, molluscs, and fish eggs and larvae. Variation in the relative amounts of each prey type throughout a season indicated that this species is probably an opportunistic feeder. The daily ration was determined by combining data from the gastric evacuation study with a 24 hour field study. Two estimates of daily ration were obtained depending on the type of evacuation model used. The linear estimate of daily ration was 3.99% dry weight and the exponential estimate was 3.49% dry weight. The benthic consumption rate of scup in Narragansett Bay was found to equal 0.6-1.7 g dry wt/m2 between June 1st and September 30th.

INTRODUCTION

Fish food habits data are important to bioenergetic studies, fish productivity studies, and multispecies fisheries models (Grosslein et al, 1980; Huebner and Langton, 1982; Livingston, 1985; Livingston, 1986; Mann, 1967). Daily ration data are used to trace the flow of energy within an organism and between trophic levels (Bajkov, 1935; Mann, 1978). Diet composition, along with daily ration, provides information on the impact of fish species upon benthic communities (Collie, 1987). These data allow fish species interactions, growth, and production rates to be determined (Elliott, 1975; Godin, 1981; Grosslein et al, 1980; Windell, 1978). Fishery management plans also make use of food habits data (Grosslein et al, 1980; Livingston, 1986; Mann, 1967).

The purpose of this study was to determine the food habits of juvenile members of the demersal fish species *Stenotomus chrysops*, scup, in Narragansett Bay, Rhode Island. This migratory species supports an important commercial fishery in the Middle and North Atlantic regions (Gusey, 1977; MAFMC, 1979; O'Bannon, 1988). Juvenile fish are found within bays and estuaries in southern New England and New Jersey from May until October (Appeldoorn et al, 1981; Azarovitz, 1985; Bigelow and Schroeder, 1953; Finkelstein, 1971; Gusey, 1977, Morse, 1978; Morse, 1982). Narragansett Bay serves as an important spawning, feeding and growth area for young scup during the spring and summer (Sisson, 1974). Feeding and growth in this species is at a minimum in the winter and at a maximum during the summer months (Bigelow and Schroeder, 1953; Morse, 1978; Morse, 1982; Sisson, 1974).

The instantaneous gastric evacuation rate and daily food ration of scup have not been previously determined. Feeding patterns over a twenty four hour period have also not been previously studied. Scup prey items have been described by various studies (Bigelow and Schroeder, 1953; Bowman et al, 1976; Maurer and Bowman, 1975; Morse, 1978; Morse, 1982; Oviatt and Nixon, 1973), but most of these studies were not quantitative and did not include information about the age and size structure of the population being examined.

METHODS AND MATERIALS

Gastric evacuation study

A small otter trawl, with a 5.1 cm mesh size at the cod end, was used to collect 46 scup during a five minute tow at the Fox Island station (41°34'N, 71°25'W) in Narragansett Bay (Figure 1). The fish were immediately placed in a running seawater tank on the boat. They were then transferred to the Aquarium Building at the Graduate School of Oceanography (GSO) and placed in a 185 cm diameter tank with a 52 cm high water column. This tank had a flow through system provided with ambient Narragansett Bay seawater. Water temperature and light period were kept consistent with that of the bay. The fish were allowed to acclimate for a few days and then fed chopped frozen squid daily. Acclimation was assumed because of normal eating habits. A grid made of plastic coated wire was placed on the bottom of the tank prior to the evacuation study. The tank was cleaned daily.

The fish were starved for 24 hours prior to the experiment and then fed preweighed portions of the shrimp *Crangon septemspinosa*. The fish were allowed to feed to satiation and then uneaten prey was removed and reweighed. Sampling began one half hour after feeding had ceased and continued at hourly intervals for a total of ten and a half hours. Sampling consisted of raising the grid via a pulley system so that the effective water level was lowered and four fish could be easily dip netted from the tank per time period. Fish were immediately placed on wet ice and transported to the laboratory. There they were blotted dry, and wet body weight was measured to the lowest 0.1 g. Fork length and total length were measured to the lowest 0.5 cm with a measuring board.

The ventral body wall of each fish was slit open. The stomach was closed off anteriorly at the junction with the esophagus and posteriorly at the junction with the pyloric caeca, with hemostats. The stomach contents were removed, placed onto a prewighed aluminum pan and wet weight was measured to the nearest 0.01 g. The pans were placed in a 60°C drying oven for 48 hours and then reweighed to determine dry weight of the stomach contents.

24 hour study

On July 9-10, 1987 ten trawls at the Fox Island station took place over a 25 hour period at approximately 3 hour intervals. The first two trawls were 30 minutes in length. The other eight trawls were 15 minutes each. Trawling speed was 2.5 knots over the bottom. A minimum of 100 scup were brought up in each trawl. Fifty fish were placed in individually labelled plastic bags and immediately stored in coolers of crushed dry ice. The coolers were transported to a freezer as soon as possible where the fish were held at -20°C until processing.

Processing consisted of removing 37-38 fish from the freezer and holding them in a refrigerator at 4°C overnight (approximately 18 hrs). The fish were still slightly frozen when 12-13 were removed from the refrigerator at a time and allowed to reach room temperature. Wet body weight, fork length, total length, wet stomach content weight and dry stomach content weight were determined in exactly the same manner as described in the evacuation study.

Daily food ration

Two types of models were used to determine the daily ration of scup. The linear model was:

$$Ct = St - So + Rt \qquad \text{(Eq 1)}$$

where: Ct = the amount of food consumed within each trawling period;

St = the average amount of food found within the stomach during a trawl;

So = the average amount of food found within the stomach during the previous trawl;

R = the linear estimate of the instantaneous gastric evacuation rate;

t = the amount of time elapsed between one trawl and the previous trawl.

Elliott and Persson's (1978) exponential model was also used to estimate the daily ration of scup. This model was:

$$Ct = Rt(St - So*e^{-Rt})/1 - e^{-Rt} \quad \text{(Eq 2)}$$

where: Ct = the amount of food consumed within each trawling period;

St = the average amount of food found within the stomach during a trawl;

So = the average amount of food found within the stomach during the previous trawl;

R = the exponential estimate of the instantaneous gastric evacuation rate;

t = the amount of time elapsed between one trawl and the previous trawl;

e = the base of the natural log.

Both the linear and exponential estimates of daily ration were obtained by summing the appropriate Ct values over a twenty four hour period.

Prey identification

Stomach contents of scup were preserved twice a month during June, July, and August 1987 for prey identification. Immediately following a weekly 30 minute trawl at the Fox Island station, scup were placed in a cooler containing wet ice. The fork length and total length of each fish were measured. Stomach contents were removed as described in the evacuation study. Seawater was then used to wash the stomach contents into a vial or jar that contained 20% buffered formalin. An equal volume of seawater was added to the container so that the stomach contents were held in 10% formalin for subsequent prey identification. Both individual and pooled samples were preserved.

Preserved samples were placed in a 200 micron sieve and rinsed with tapwater. They were then transferred to glass petri dishes and examined under a light microscope at 40X power. Prey items were separated into the lowest identifiable taxonomic group and then placed on preweighed aluminum pans. These pans were placed in a 60°C drying oven for 48 hours. They were then reweighed to determine the dry weight of each prey category. A minimum of 5 stomachs were processed at a time. A total of 66 stomachs were examined.

RESULTS

Gastric evacuation study

The average wet weight of the fish in this study was 67±7 g. A total of 154 g of *Crangon septemspinosa* were consumed by 3082 g of scup. Therefore, scup ate on the average 5% of their wet body weight. The % dry body weight of the stomach contents was determined individually for each fish using the equation:

Dry body wt = 5.96 + 0.29 * Wet body wt $R^2 = 0.99$ (Eq 3)

(Appendix A). Results from 43 fish were available.

Two estimates of gastric evacuation rate were obtained by this study. The stomach contents in % dry weight were plotted versus the time elapsed in hours since feeding (Figure 2, Figure 3). The slope of the straight line that was fit to these data, 0.17/hr, was the linear estimate of the instantaneous gastric evacuation rate (Figure 2). This slope was significantly different from zero ($p < .005$). An exponential curve was fit to these same data (Figure 3). The regression slope of a semilog plot of the natural log of the stomach contents versus time, 0.34/hr, was the exponential estimate of gastric evacuation rate.

24 hour study

The average amount of food found in a scup stomach increased from 6 am until noontime (Table 1, Figure 4, Appendix B). From noon until 6 pm the average amount found in a stomach remained constant at about 0.72 % dry weight. After 6 pm the stomach contents declined to a minimum at 3 am, and then gradually increased to the 7 am trawl. The average amount of food found in scup stomachs at 6 am trawls on consecutive days was practically identical at 0.17 and 0.16% dry weight. An analysis of variance of the 24 hour trawl data showed that the differences between trawls were significant when compared to the differences within trawls ($p < .005$) (Table 1).

Daily food ration

The linear model estimate of daily food ration was 3.99% dry weight/day (Table 2). The comparative estimate of daily food consumption obtained using Elliot and Persson's exponential model was 3.49% dry weight/day.

Prey identification

The identifiable fauna found in the stomachs of scup included polychaetes in the family Maldanidae, *Nepthys* sp., *Nereis* sp., *Pherusa affinis*, unidentified polychaete remains; crustacea including hermit crabs, brachyuran crabs, unidentified crustacean remains, the mysid shrimp *Neomysis americana*, the amphipods *Leptochirus* sp, and unidentified amphipods; mollusks; the coelenterate *Cerianthiopsis* sp; and fish larvae and eggs (Table 3). Polychaetes and crustacea together made up more than 50% of the scup diet by weight for each of the sampling dates and averaged 72% of the seasonal diet and 88% of the identifiable seasonal diet. Crustacea made up 41% and polychaetes accounted for 47% of the identifiable diet during the summer.

The relative importance of the individual prey types varied throughout the season (Table 3). *Nepthys* sp made up 23-33% of the diet in June, but were not found in the July and August samples. *Pherusa affinis* made up 6-12% of the scup diet in June and in August. This species was not found in stomachs in July. The mysid *Neomysis americana* was a more important prey item in late June and mid July (17-29% of the diet), than at other times during the summer (<8% of the diet). Brachyuran crabs were only present in the July samples. Fish larvae made up 6-19% of the diet in August, but were absent in the June and July samples.

DISCUSSION

Gastric evacuation study

The instantaneous gastric evacuation rate measures the disappearance of food from the stomach over time. Most of this disappearance is due to peristaltic (mechanical) movement rather than absorption (Windell, 1978). Different methods for determining evacuation rates include voluntary or force-feeding fish and measuring evacuation via x-ray, radioactive tracers, undigestible tracers or by sacrificing fish at intervals and measuring stomach contents by either weight or volume displacement (Davis and Warren, 1968; Flowerdew and Grove, 1979; Windell, 1967; Windell, 1968; Windell, 1978).

When food is fed individually to fish it is often in known quantities, usually expressed in terms of percent body weight of the fish. The amount remaining in the stomach at subsequent time periods is expressed in terms of percent of the initial meal size. Schooling fish, such as scup, will often not voluntarily feed in isolation. Various studies have either force fed these fish or fed the entire school to satiation with a known amount of food (Windell, 1968; Windell, 1978). The amount of food remaining in the stomachs of these serially sacrificed fish is expressed in terms of percent body weight rather than as a percentage of the initial meal size.

Factors that could influence the rate of evacuation include: stress from handling (including force feeding), fish size, type of food, particle size, water temperature, meal size, meal succession and previous starvation. Various studies have concluded that water temperature, food type and force feeding are important, particle size may or may not be important, but that meal size, fish size and meal succession do not effect the rate of evacuation (Durbin et al, 1983; Soofiani and Hawkins, 1985; Windell, 1967; Windell, 1978). Evacuation rates increase with increasing temperature (Durbin et al, 1983). Fish flesh and prey with high fat content tend to be evacuated more slowly than most small invertebrate prey (Durbin et al, 1983; Windell, 1978). Elliott (1972) found that previous starvation of up to 5 days did not affect evacuation rates.

In the present study the water temperature was kept consistent with that in the field and remained constant at 20°C throughout the experiment. The fish were fed a natural small invertebrate prey item, *Crangon septemspinosa* (Oviatt and Nixon, 1973). Scup were allowed to eat voluntarily and were handled as little as possible throughout their captivity. The design of the sampling system also minimized the stress on the fish being sampled as well as those remaining in the tank.

Several different mathematical models have been used to describe gastric evacuation. These have been reviewed by Durbin and Durbin (1980), and include linear, exponential, square root and Gompertz models. A linear model assumes that a constant amount of food is evacuated from the stomach per unit of time. If this model were accurate then a small meal would be evacuated more quickly than a large meal (Durbin and Durbin, 1980; Olson and Mullen, 1986). However stomach evacuation has been found to be independent of meal size (Durbin and Durbin, 1980; Durbin et al, 1983).

Exponential models with or without a time lag appear to be the most accurate models used (Cohen and Grosslein, 1981; Durbin and Durbin, 1980; Soofiani and Hawkins, 1985). These models assume that a constant proportion rather than a constant amount of food is evacuated over time. The square root model assumes that the radius of a cylindrical fish stomach decreases as the volume of the stomach decreases. This model relates evacuation to the square root of stomach volume (Jobling, 1981). Gompertz and logistic models have been used when time lags have occurred before the onset of evacuation (Medved, 1985).

There is a positive relationship between water temperature and the gastric evacuation rate of fish. Durbin et al (1983) proposed the exponential equation:

$$R = 0.0406e^{0.111T} \qquad \text{(Eq 4)}$$

to predict the instantaneous stomach evacuation rate (R) of fish consuming small invertebrate prey at a given temperature (T).

Various other studies have examined the effect of water temperature on gastric evacuation rate (Table 4). When evacuation rate is plotted versus temperature, the relationship between these parameters can be described by the linear equation:

$$R = -0.003 + 0.014T \qquad \text{(Eq 5)}$$

(Figure 5a), or by the exponential equation:

$$R = 0.042e^{0.101T} \qquad \text{(Eq 6)}$$

(Figure 5b). The water temperature of the current study (20°C) was used in these three equations and the three resulting literature predictions of scup gastric evacuation rate were: 0.374/hr, 0.277/hr and 0.317/hr. The mean of these three literature predictions was 0.323/hr, which was close to the exponential estimate of gastric evacuation rate (0.34/hr) obtained in this study.

The results from the scup instantaneous gastric evacuation rate study were presented in terms of % dry body weight, since the amount of water in stomach contents can vary and bias results (Steigenberger and Larkin, 1974). In this study the R^2 value for the linear estimate of the evacuation rate was higher than for the exponential estimate (Figures 2 and 3). Thus when these results were viewed in isolation the linear model appeared to better describe the gastric evacuation rate than did the exponential model. However, it has already been stated that exponential models appear to be more accurate than linear models, especially since evacuation rates have been found to be independent of meal size. The exponential estimate (0.34/hr) was in closer agreement with the literature prediction (0.322/hr), than was the linear estimate (0.17/hr). Also the exponentail model more closely predicted the initial meal size of 2.3% dry body weight than did the linear model. The linear estimate of initial meal size was 1.7% dry weight and the exponential estimate was 2.6% dry weight (Figure 2, Figure 3). In addition, the choice of model affected the predicted consumption in the field. Since the linear model assumed a constant rate of gastric evacuation it also assumed that food was being consumed at night. For example the linear estimate of consumption between midnite and 3 am was 0.36% dry body weight. The exponential estimate of food consumption for this same time period was 0.01% dry body weight (Table 2). Thus the exponential estimate of daily food ration was more consistent with the feeding periodicity of this species than was the linear estimate.

24 hour study

The results of the 24 hour study showed a nearly constant amount of food within the stomachs from noontime until 6 pm, with decreasing amounts found before and after this period. The pattern seen in the stomach content data indicated that scup are daytime and therefore probably visual feeders (Figure 4). Periodicity in the feeding habits of scup has not been previously studied.

Diurnal feeding patterns have been noted in other fish species including pink salmon fry, *Oncorhynchus gorbuscha*

(Godin, 1981), juvenile sockeye salmon *Oncorhynchus nerka* (Doble and Eggers, 1978), diamond turbot, *Hypsopsetta guttulata* (Lane et al, 1979), carp bream, *Abramis brama* (Nebol'sina, 1968) and yellow perch, *perca flavescens* (Keast and Welsh, 1968). Fish species that have largely diurnal feeding habits, but with a nocturnal component include: bluegill, *Lepomis macrochirus;* pumpkinseed, *Lepomis gibbosus;* and banded killifish *Fundulus diaphanus* (Keast and Welsh, 1968). Northern squawfish, *Ptychocheilus oregonensis* feed primarily from dusk to dawn (Steigenberger and Larkin, 1974). Rock bass, *Ambloplites rupestris* have been found to feed equally throughout the day and night (Keast and Welsh, 1968).

Daily food ration

During the past two decades a great many studies have taken place to determine the food rations of various fishes (Livingston and Goiney, 1984). Measurement of daily food ration often consists of two different phases: a laboratory determination of the instantaneous stomach evacuation rate, and a field study of stomach contents of fish collected over a 24 hour period (Bajkov, 1935; Elliott and Persson, 1978; Soofiani and Hawkins, 1985). Although this method does rely, in part, on laboratory measurements, it is the best direct method available for estimating daily rations. However, it is not used in the same manner by all investigators. Investigators have used different models, force feeding versus voluntary feeding, natural food versus pellets, different water temperatures, etc. and they have expressed their results in terms of wet weight, dry weight and have not always indicated all experimental conditions. These inconsistencies make it difficult to compare results from different investigations (Brafield, 1985; Soofiani and Hawkins, 1985).

The daily ration of scup has not been previously determined. However, a literature estimate of the daily food ration of scup was obtained by combining this study's twenty four hour data with a literature estimate of gastric evacuation (R = 0.323/hr). The Elliott-Persson model was used. The resulting literature estimate of scup daily ration was 3.30% dry weight/day.

The daily rations of other fish have been determined (Table 5). Ration estimates have ranged from a low of 0.15% body weight for perch, *Perca fluviatilis* (Craig, 1978), to a high of 6.2% body weight for yellowtail flounder, *Limanda ferruginea* (Cohen and Grosslein, 1981). Since water temperature and food type may affect daily ration estimates, these parameters should be considered when daily rations are compared (Table 5). The daily ration of scup found by this study fell within the range found in the literature.

Prey identification

The diet of scup has been qualitatively described in several studies. Prey items have included annelid worms, hydroids, crustacea, including *Crangon* shrimp and amphipods; mollusks, sand-dollars, squid, fish fry, and vegetative material (Bigelow and Schroeder, 1953; Morse, 1978; Morse, 1982; Olsen and Stevenson, 1975; Oviatt and Nixon; 1973).

Only one previous study quantitativily described the diet of *Stenotomus chrysops*. The Northeast Fisheries Center of the National Marine Fisheries Service conducted a groundfish survey from 1969 to 1972 to examine the food habits of marine fishes of the Northwest Atlantic. Two data reports that resulted from that survey included scup stomach content information (Bowman et al, 1976; Maurer and Bowman, 1975).

The results from the two NMFS reports were comparable to those of the present study (Table 6). Polychaetes and crustacea together accounted for 42-68% of the diet in the NMFS studies. In the present study 72% of the diet consisted of polychaetes and crustacea. The differences found between the two NMFS reports could be accounted for by both spacial and temporal separation. Different geographical areas may have been sampled at different times. The data from the present study were all collected from the same location, but were collected over a three month period. Bigelow and Schroeder (1956) described scup as feeding on "whatever invertebrates the particular bottom over which they live may afford". These three studies support the statement that scup are opportunistic feeders that prey primarily on benthic invertebrates, especially polychaetes and crustacea.

The presence of the mysid *Neomysis americana* accounted for the higher percentage of crustacea found by the present study. Mysids made up less than 1% of the diet of the scup examined in the NMFS study. These organisms are more prevalent in Narragansett Bay than in the offshore regions sampled by NMFS. Herman (1962) found *N. americana* to be an important epibenthic species in Narragansett Bay. Tattersall (1951) found that *N. americana* was found only in shallow water along the eastern coast of North America from the Gulf of St. Lawrence to Virginia. The NMFS studies were conducted offshore in waters that ranged in depth from 27 to 366 meters (Bowman et al, 1976; Maurer and Bowman, 1975). The scup in the bay took advantage of the mysids' presence.

The presence of fish eggs and larvae in the stomachs of scup from Narragansett Bay also supported the idea of opportunistic feeding. Fish eggs were only found in the June samples. The peak abundance of eggs in Narragansett Bay is from June to July (Herman, 1963). Fish larvae were only present in samples from August. The peak abundance of fish larvae in the bay is during July and August (Herman, 1963).

Other fish species that have been described as being opportunistic feeders include: estuarine round herring, *Gilchristella aestuarius* (Talbot and Baird, 1985); carp bream, *Abramis brama* (Nebol'sina, 1968); pink salmon fry *Oncorhynchus gorbuscha* (Godin, 1981); juvenile sockeye salmon, *Oncorhynchus nerka* (Doble and Eggers, 1978); yellow perch, *Perca flavescens* (Keast and Welsh, 1968); bluegill, *Lepomis macrochirus* (Keast and Welsh, 1968); pumpkinseed, *Lepomis gibbosus* (Keast and Welsh, 1968); banded killifish, *Fundulus diaphanus* (Keast and Welsh, 1968); Black Sea anchovy, *Engraulis encrasicholus ponticus* (Sirotenko and Danilevskiy, 1977) and rock bass, *Ambloplites rupestris* (Keast and Welsh, 1968). These species exploit different food sources that have either seasonal or diel patterns of availability.

The age and size strucure of the population of scup examined in the present study was known. The fish were 1 year old. They had been hatched during the summer of 1986 and ranged in size from an average of 10 cm in June to an average of 12.5 cm in August 1987. No previous scup study has provided both age/size information and stomach content analyses.

Impact on Narragansett Bay

The impact of the demersal fish species *Stenotomus chrysops* on the benthic invertebrate population of Narragansett Bay was determined based on the results of this study. A consumption rate of 0.6-1.7 g dry wt/m^2 was calculated (Table 7). If the diet were assumed to consist of 50% polychaetes and 50% crustacea this was equivalent to a consumption rate of 0.3-0.9 g dry wt/m^2 of each of these prey types. Rhode Island commercial catch data (Olsen and Stevenson, 1975) and Narragansett Bay fish abundance data (Jeffries, 1986), used in conjunction with the daily ration estimated by the present study, resulted in similar estimates of benthic consumption by scup (Table 7).

These rates were similar to those of other fish species. Waiwood and Majkowski (1984) found that 3 year old cod, *Gadus morhua*, consumed $3.97*10^{10}$ g between May and November 1980 in the southern Gulf of St. Lawrence. A total of 70% of the diet of these 350 g fish consisted of invertebrates. Nebol'sina (1968) found that a benthic population of 1.06 g/m^2 was limiting to the carp bream, *Abramis abrama*. Annual consumption rates of other fish species ranged from 0.8 g dry wt/m^2 to 11.2 g dry wt/m^2 (Table 8).

Table 1. Analysis of variance of the twenty four hour trawl stomach content data (% dry weight). Other statistics including mean stomach content (% dry wt), standard deviation, standard error and 95 percent confidence interval are also given for each of the trawls.

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	P
BETWEEN GROUPS	9	22.00	2.44	27.11	<0.005
WITHIN GROUPS	363	33.41	0.09		
TOTAL	372	55.42			

OTHER STATISTICS

TRAWL	N	MEAN STOMACH CONTENT (% DRY WT)	STANDARD DEVIATION	STANDARD ERROR	95 PCT CONF INT FOR MEAN
0600A	37	0.17	0.16	0.03	0.12 TO 0.22
0900	38	0.35	0.24	0.04	0.28 TO 0.43
1200	38	0.72	0.43	0.07	0.58 TO 0.86
1500	37	0.73	0.36	0.06	0.61 TO 0.85
1800	37	0.70	0.41	0.07	0.56 TO 0.84

Table 1. (continued)

TRAWL	N	MEAN STOMACH CONTENT (% DRY WT)	STANDARD DEVIATION	STANDARD ERROR	95 PCT CONF INT FOR MEAN
2100	37	0.54	0.50	0.07	0.41 TO 0.68
2400	37	0.23	0.34	0.06	0.11 TO 0.34
0300	37	0.09	0.94	0.02	0.06 TO 0.12
0600B	37	0.16	0.11	0.02	0.12 TO 0.20
0700	38	0.21	0.83	0.04	0.14 TO 0.29
TOTAL	373	0.39	0.39	0.02	0.35 TO 0.43

Table 2. Estimates of the daily ration (F) of scup *Stenotomus chrysops* using two different models. The exponential estimate was calculated using the Elliott-Persson model ($Ct = Rt(St - So\ e^{-Rt})/1-e^{-Rt}$), and the exponential estimate of gastric evacuation rate (R = 0.34/hr). The linear estimate was calculated using the linear model Ct = St - So + Rt, and the linear estimate of gastric evacuation rate (R = 0.17/hr).

HOUR (T)	% DRY WT(S)	1. Ct EXP. ESTIMATE (% DRY WT)	2. Ct LIN ESTIMATE (% DRY WT)
0600	0.17		
1000	0.35	0.56	0.85
1200	0.72	0.75	0.70
1545	0.73	0.94	0.63
1800	0.70	0.52	0.34
2100	0.54	0.46	0.34
2400	0.23	0.06	0.19
0300	0.09	0.01	0.36
0600	0.16	0.20	0.57
F =	TOTAL	3.49% DRY WT/DAY	3.99% DRY WT/DAY

Table 3. Stomach contents of juvenile scup, *Stenotomus chrysops*, from Narragansett Bay, RI. Results are expressed as % dry weight of the diet for each prey type. (*) indicates that this prey was present, but that the dry weight was less than the detection limit of 0.01 g.

DATE	6/23/87	6/30/87	7/15/87	7/28/87	8/12/87	8/25/87
N	31	5	5	10	5	10
N EMPTY	2	0	0	0	0	0
	% DRY WT	% DRY WT	% DRY WT	% DRY WT	% DRY WT	% DRY WT
POLYCHAETES	45.8	49.9	14.3	42.9	50.1	19.2
Maldanidae	2.8	8.3	14.3	14.3	31.3	7.7
Pherusa affinis	5.7	8.3	0.0	0.0	6.3	11.5
Nereis sp	5.7	0.0	0.0	14.3	0.0	0.0
Nepthys sp	23.0	33.3	0.0	0.0	0.0	0.0
Unidentified remains	8.6	*	*	14.3	12.5	*
CRUSTACEA	28.4	33.4	71.5	42.9	18.9	34.6
Leptochirus sp	2.8	0.0	0.0	*	0.0	0.0
Neomysis americana	2.8	16.7	28.6	*	6.3	7.7
Hermit crab	0.0	0.0	0.0	0.0	0.0	17.4
Brachyuran crab	*	0.0	14.3	14.3	0.0	0.0
Amphipods	2.8	*	*	0.0	6.3	*
Unidentified remains	20.0	16.7	28.6	28.6	6.3	11.5
MOLLUSKS	2.8	0.0	0.0	7.1	*	3.8
COELENTERATES	0.0	0.0	0.0	0.0	0.0	7.7
Cerianthiopsis sp	0.0	0.0	0.0	0.0	0.0	7.7
FISH	0.0	0.0	0.0	0.0	6.3	19.2
eggs	*	*	0.0	0.0	0.0	0.0
larvae	0.0	0.0	0.0	0.0	6.3	19.2
UNIDENTIFIED	23.0	16.7	14.3	7.1	25.0	15.4

Table 3. (continued)

N	66	
N EMPTY	2	
	SEASON TOTAL WT (G)	SEASON TOTAL % DRY WT
POLYCHAETES	0.42	38.2
Maldanidae	0.12	10.9
Pherusa affinis	0.07	6.4
Nereis sp	0.04	3.6
Nepthys sp	0.12	10.9
Unidentified remains	0.07	6.4
CRUSTACEA	0.37	33.6
Leptochirus sp	0.01	0.9
Neomysis americana	0.08	7.3
Hermit crab	0.04	3.6
Brachyuran crab	0.03	2.7
Amphipods	0.02	1.8
Unidentified remains	0.19	17.3
MOLLUSKS	0.03	2.7
COELENTERATES	0.02	1.8
Cerianthiopsis sp	0.02	1.8
FISH	0.06	5.5
eggs	0.00	0.0
larvae	0.06	5.5
UNIDENTIFIED	0.20	18.2
TOTAL	1.10	100.0

Table 4. Literature values for instantaneous gastric evacuation rates of marine and freshwater fish feeding on small invertebrate prey or pellets.

FISH SPS	WATER TEMPERATURE	EVACUATION RATE (R)	REFERENCE
1.ATLANTIC COD *Gadus morhua*	2°C	0.052/HR	TYLER,1970
	5°C	0.089/HR	
	10°C	0.183/HR	
	15°C	0.153/HR	
	19°C	0.159/HR	
2.BROWN TROUT *Salmo trutta*	5.2°C	0.095/HR	ELLIOTT, 1972
	5.2°C	0.085/HR	
	5.2°C	0.070/HR	
	5.2°C	0.042/HR	
	7.6°C	0.124/HR	
	7.6°C	0.109/HR	
	7.6°C	0.092/HR	
	7.6°C	0.056/HR	
	9.8°C	0.159/HR	
	9.8°C	0.138/HR	
	9.8°C	0.118/HR	
	9.8°C	0.072/HR	
	12.1°C	0.206/HR	
	12.1°C	0.178/HR	
	12.1°C	0.093/HR	
	15.0°C	0.284/HR	
	15.0°C	0.241/HR	
	15.0°C	0.209/HR	
	15.0°C	0.126/HR	

Table 4. (continued)

FISH SPS	WATER TEMPERATURE	EVACUATION RATE (R)	REFERENCE
3.DIAMOND TURBOT *Hypsopsetta guttulata*	18.5°C	0.307/HR	LANE ET AL, 1979
4.FLOUNDER *Platichthys flesus*	10°C	0.130/HR	KIORBOE, 1978
	15°C	0.190/HR	
5.PERCH *Perca fluviatilis*	7.4°C	0.21/HR	CRAIG, 1978
	11.0°C	0.18/HR	
	14.5°C	0.19/HR	
	14.7°C	0.21/HR	
	17.0°C	0.35/HR	
	19.5°C	0.32/HR	
6.PERCH *Perca fluviatilis*	4.0°C	0.032/HR	PERSSON, 1979
	8.3°C	0.058/HR	
	10.4°C	0.080/HR	
	13.5°C	0.122/HR	
	14.0°C	0.125/HR	
	16.5°C	0.182/HR	
	21.7°C	0.386/HR	
7.PINK SALMON *Oncorhynchus gorbuscha*	10°C	0.152/HR	GODIN, 1981

Table 4. (continued)

FISH SPS	WATER TEMPERATURE	EVACUATION RATE (R)	REFERENCE
8.SOCKEYE SALMON *Oncorhynchus nerka*	3.1°C	0.030/HR	BRETT AND HIGGS, 1970
	5.5°C	0.055/HR	
	9.9°C	0.127/HR	
	14.9°C	0.198/HR	
	20.1°C	0.254/HR	
	23.0°C	0.258/HR	
9.SOCKEYE SALMON *Oncorhynchus nerka*	13°C	0.345/HR	DOBLE AND EGGERS, 1978
	9°C	0.206/HR	
	11°C	0.147/HR	
	8°C	0.055/HR	
	6°C	0.057/HR	
10.WINTER FLOUNDER *Pseudopleuronectes americana*	6°C	0.079/HR	HUEBNER AND LANGTON, 1982
11.SCUP *Stenotomus chrysops*	20°C	0.17/HR	THIS STUDY
		0.34/HR	

Table 5. Literature estimates of daily food rations (% body weight/day) of various marine and freshwater fish. Wet weight (W) and Dry weight (D) estimates are indicated where appropriate.

FISH SPS	WATER TEMPERATURE	FOOD TYPE	DAILY FOOD RATION	REFERENCE
1. ATLANTIC COD *Gadus morhua*	15°Ç	SHRIMP TAILS	1.87% (D) 1.74% (W)	TYLER, 1970
"	19°C	"	2.34% (D) 2.18% (W)	" "
2. "	5.7-9.3°C	FISH AND OTHER	0.9-1.5%	DURBIN ET AL, 1983
3. "	GEORGES BANK	"	1.2-2.0%	COHEN AND GROSSLEIN, 1981
4. BANDED KILLIFISH *Fundulus diaphanus*	18-22°C		1.4%	KEAST AND WELSH, 1968
5. BLUEGILL *Lepomis macrochirus*	18-22°C	SMALL INVERTEBRATE	2.5%	KEAST AND WELSH, 1968

Table 5. (continued)

FISH SPS	WATER TEMPERATURE	FOOD TYPE	DAILY FOOD RATION	REFERENCE
6.CARP BREAM *Abramis brama*	18-23°C	SMALL INVERTEBRATE	1.1-2.3%	NEBOL'SINA, 1968
7.DIAMOND TURBOT *Hypsopsetta guttulata*	12.4-23.7°C	MOSTLY INVERTEBRATE	3.76%	LANE ET AL, 1979
8.HADDOCK *Melanogrammus aeglefinus*	GEORGES BANK	MOSTLY INVERTEBRATE	1.5-2.9%	COHEN AND GROSSLEIN, 1981
9.PERCH *Perca fluviatilis*	7.4-19.5°C	MOSTLY INVERTEBRATE	0.15-1.04%	CRAIG, 1978
10.POLLOCK *Pollachius virens*	GEORGES BANK	FISH AND OTHER	2.2-5.5%	COHEN AND GROSSLEIN, 1981
11.PUMPKINSEED *Lepomis gibbosus*	18-22°C	SMALL INVERTEBRATE	2.6%	KEAST AND WELSH, 1968

Table 5. (continued)

FISH SPS	WATER TEMPERATURE	FOOD TYPE	DAILY FOOD RATION	REFERENCE
12.RED HAKE *Urophycis chuss*	7-12°C	FISH AND INVERTEBRATE	3.38-5.84%	VINOGRADOV, 1977
13.ROCK BASS *Amboplites rupestris*	18-22°C	"	4%	KEAST AND WELSH, 1968
14.SILVER HAKE *Merluccius bilinearis*	7-12°C	"	3.36%	VINOGRADOV, 1977
15. "	GEORGES BANK	FISH AND OTHER	0.6-2.2%	COHEN AND GROSSLEIN, 1981
16. "	5.7-11.9°C	"	0.8-3.2%	DURBIN ET AL, 1983
17.SOCKEYE SALMON *Oncorhynchus nerka*	15-17°C	PELLETS	2.8%(D)	BRETT AND HIGGS, 1970
18. "	8.5-10.0°C	SMALL INVERTEBRATE	1.35-4.41%(D)	DOBLE AND EGGERS, 1978

Table 5. (continued)

FISH SPS	WATER TEMPERATURE	FOOD TYPE	DAILY FOOD RATION	REFERENCE
19.WINTER FLOUNDER *Pseudopleuronectes americanus*	12-16°C	BIVALVE SIPHONS	1.88-3.24%(W)	FRAME, 1973
20.WINTER FLOUNDER *Pseudopleuronectes americanus*	7°C	CLAMS AND BEEF LIVER	2%(W)	TYLER AND DUNN, 1976
21. "	6°C		1.8-2.4%(W)	HUEBNER AND LANGTON, 1982
22.YELLOW PERCH *Perca flavescens*	18-22°C	SMALL INVERTEBRATE	2.0%	KEAST AND WELSH, 1968
23.YELLOWTAIL FLOUNDER *Limanda ferruginea*	GEORGES BANK	INVERTEBRATE	1.1-6.2%	COHEN AND GROSSLEIN, 1981
24.SCUP *Stenotomus chrysops*	20°C	INVERTEBRATE	3.49-3.99%	THIS STUDY

Table 6. A comparison of the results from three studies on the stomach contents of the demersal fish *Stenotomus chrysops*. The results from the present study are expressed as % dry weight of the diet for each prey type. The results from the studies of Maurer and Bowman (1975) and Bowman et al (1976) are expressed as % wet weight of the diet.

PREY TYPE	MAURER AND BOWMAN, 1975 NORTHWEST ATLANTIC % WET WT	BOWMAN ET AL, 1976 SOUTHERN NEW ENGLAND % WET WT	PRESENT STUDY NARRAGANSETT BAY % DRY WT
COELENTERATES	20.6	0.0	1.8
POLYCHAETES	32.5	54.0	38.2
CRUSTACEA	9.3	14.4	33.6
MOLLUSKS	7.7	0.8	2.7
ECHINODERMS	1.4	3.3	0.0
TUNICATES	0.3	0.0	0.0
FISH	1.0	0.0	5.5
UNIDENTIFIED	27.2	27.5	18.2

Table 7. Estimates of the benthic consumption by scup in Narragansett Bay during a 122 day period from June 1st to September 30th. Each estimate was based on the assumptions that the daily ration of scup was between 3.5% and 4.0% dry wt/day, that there was 100% catch efficiency, and that 0.29 g dry body wt of scup was equivalent to 1.00 g wet body wt. Other assumptions are indicated.

REFERENCE	FISH POPULATION ESTIMATE	NUMBER OF FISH/M^2	G DRY WT CONSUMED/M^2
OLSEN AND STEVENSON, 1975	$(1.1\text{-}10*10^5$ lbs wet wt)[1] $1.4\text{-}13.2*10^7$ g dry wt		(0.2-1.9)[2]
JEFFRIES ET AL, 1986	33-816 fish/30 min.trawl (479-11832 g dry wt/ 30 min.trawl)[3] (0.02-0.51 g dry wt/m^2)[4]	(0.001-0.035)[4]	(0.1-2.5)[4]
THIS STUDY	232-546 fish/30 min.trawl 3341-8105 g dry wt/ 30 min.trawl (0.14-0.35 g dry wt/m^2)[4]	(0.010-0.024)[4]	(0.6-1.7)[4]

Assumptions:

1. The population of scup in Narragansett Bay is equal to 10% of Rhode Island commercial landings of scup.

2. The area of Narragansett Bay equals $3.42*10^8$ m^2 (Chinman and Nixon, 1985).

3. The average dry weight of one scup at the Fox Island station is 14.5 g.

4. Since the mouth of the bottom trawl was 10 m wide and the trawl proceeded at a speed of 2.5 knots over the bottom, each 30 minute trawl covered an area of 23150 m^2.

Table 8. Annual consumption rates (g/m^2-yr) of various fish species. (W) and (D) indicate that the rate is given in terms of wet or dry weight respectively. (*) indicates that these values were obtained from given data by assuming that 1 g carbon = 2 g dry weight.

FISH	ANNUAL CONSUMPTION RATE (g/m^2-yr)	REFERENCE
FLOUNDER	0.8* (D)	BAIRD AND MILNE, 1981
FLOUNDER	0.8* (D)	KUIPERS, 1981
GOBIES	1.0* (D)	KUIPERS, 1981
PLAICE	4.2* (D)	KUIPERS, 1981
WINTER FLOUNDER	11.18 (D)	WOROBEC, 1981
YELLOWTAIL FLOUNDER	1.2-6.3 (W)	COLLIE, 1987
SCUP	0.6-1.7 (D)	THIS STUDY

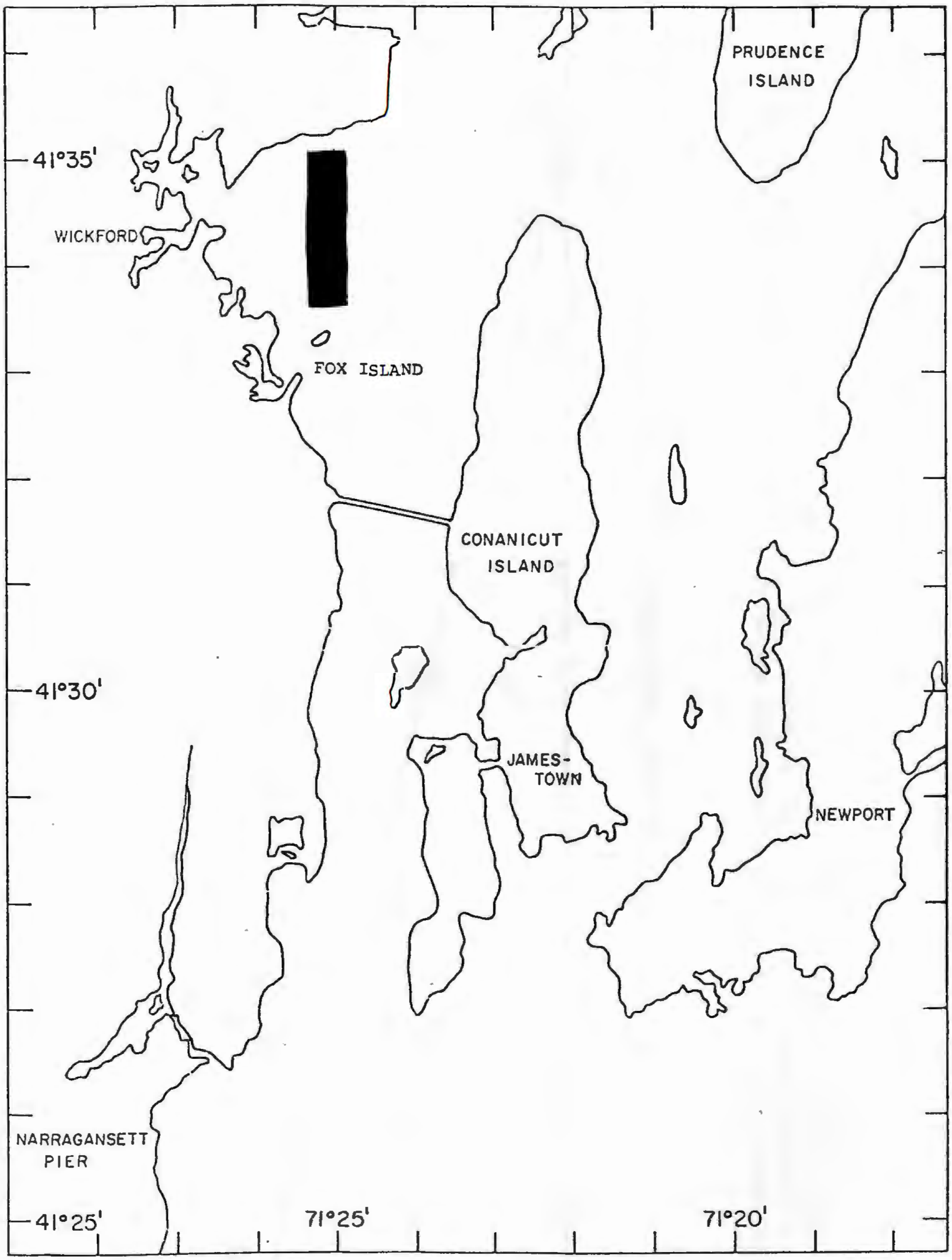

Figure 1. The Fox Island station in Narragansett Bay, RI.

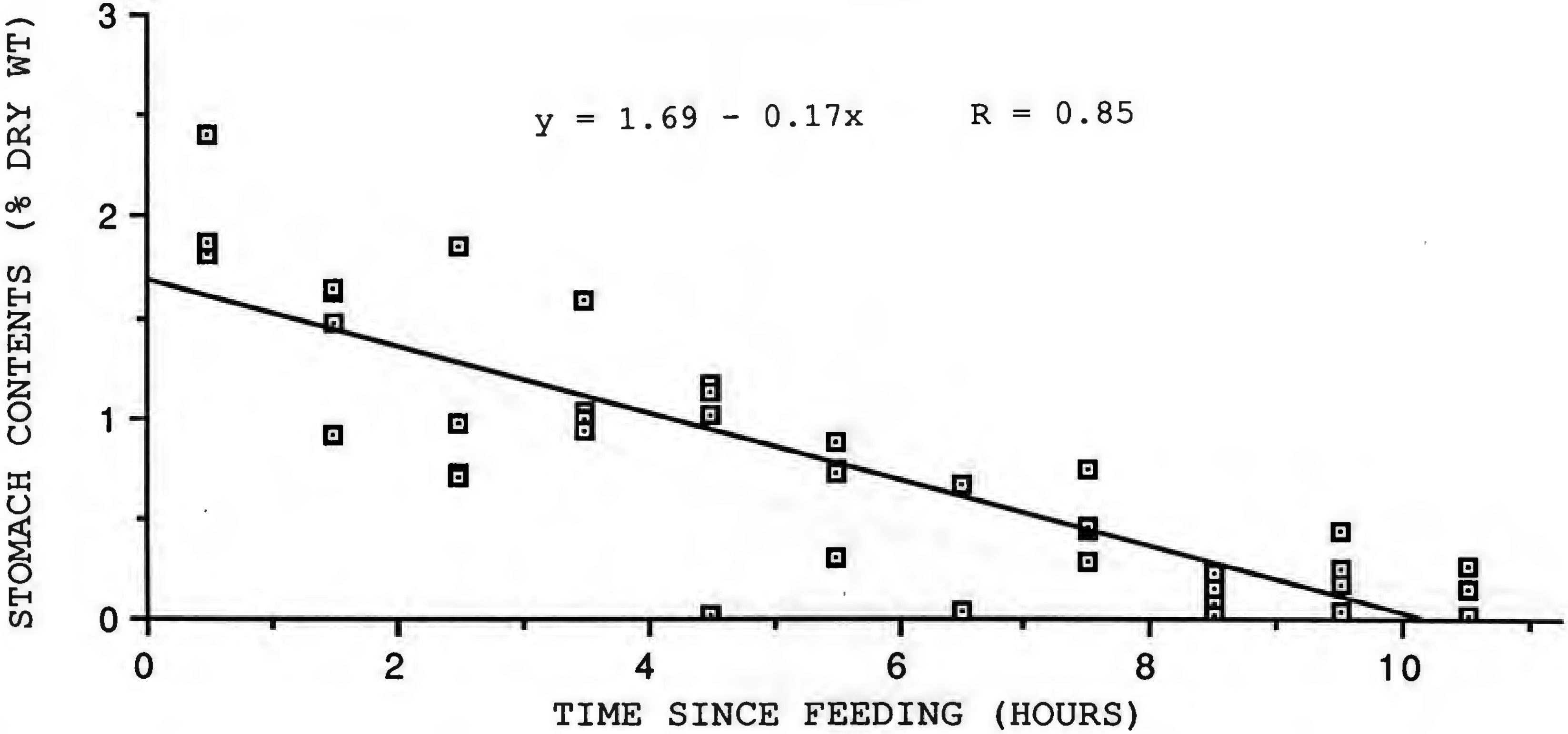

Figure 2. A linear model of gastric evacuation of scup. Stomach contents (% dry body wt) are plotted versus time since feeding (hours). A linear fit to these data resulted in an evacuation rate estimate of 0.17/hr.

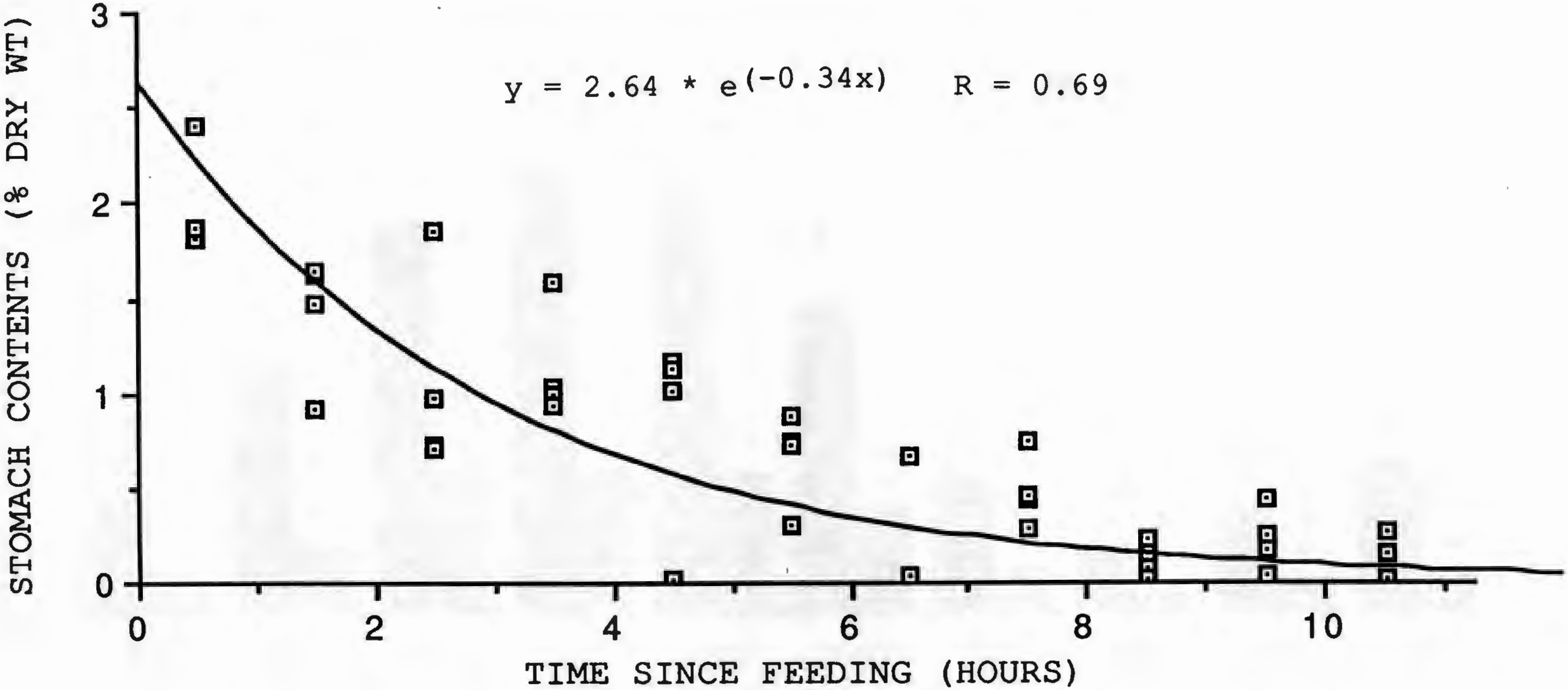

Figure 3. An exponential model of gastric evacuation of scup. Stomach contents (% dry body wt) are plotted versus time since feeding (hours). An exponential fit to these data resulted in an evacuation rate estimate of 0.34/hr.

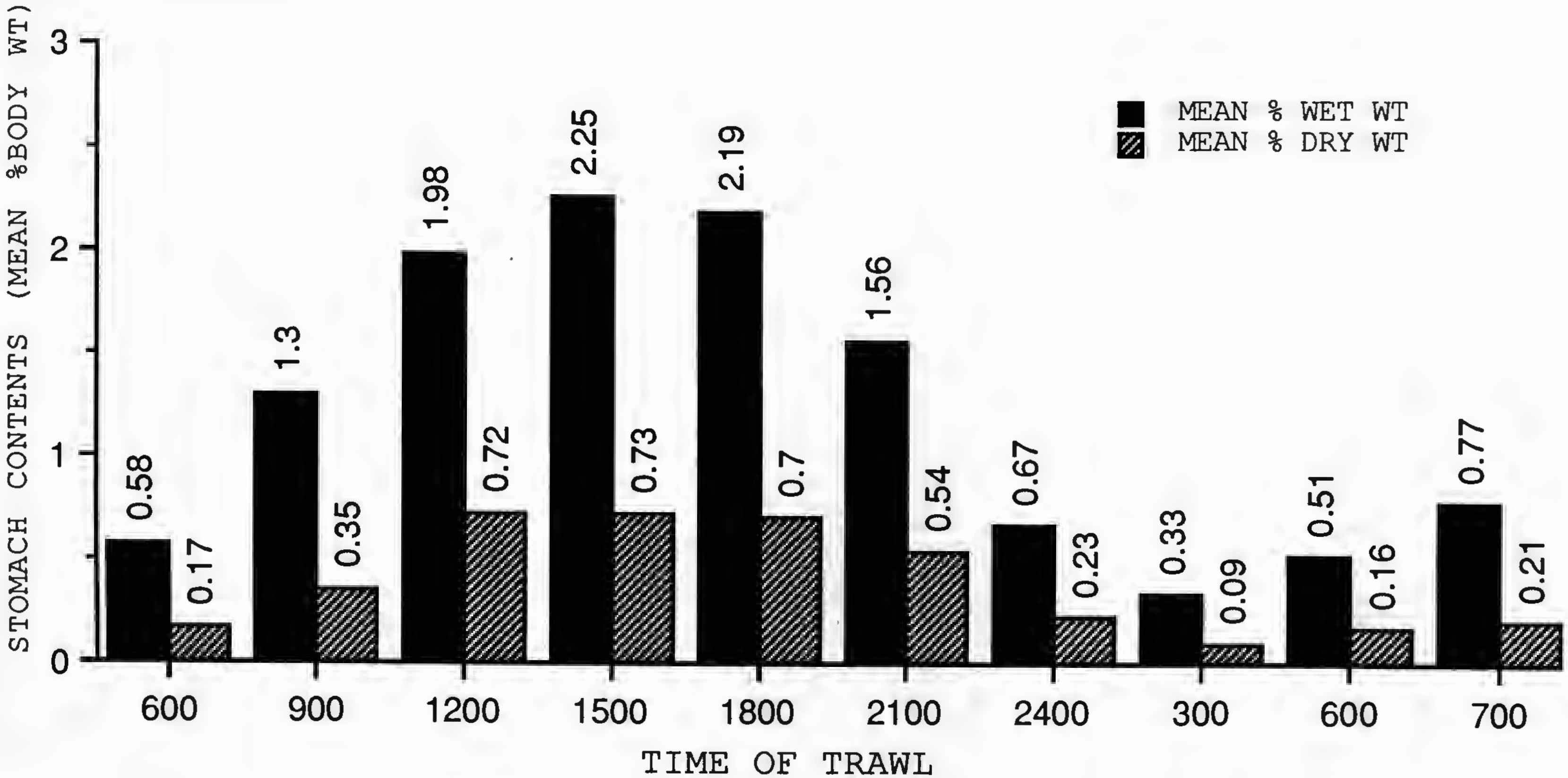

Figure 4. Stomach contents of *Stenotomus chrysops* over a twenty four hour period. The mean % body weight, both wet and dry, of stomach contents for 37 to 38 fish are given for each trawl.

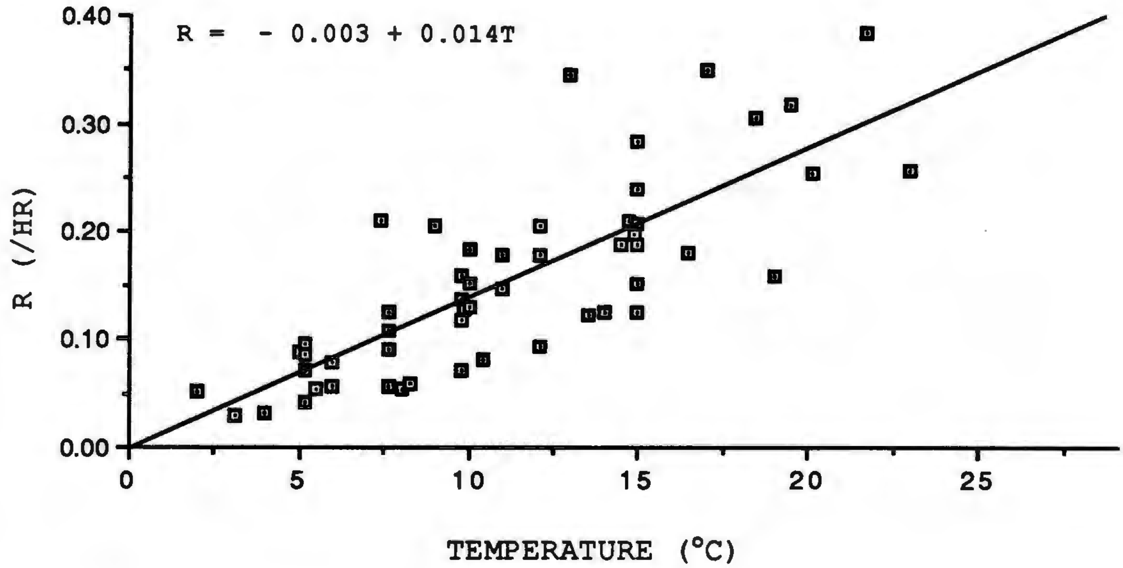

Figure 5a. Literature values for instantaneous gastric evacuation rate (R) versus water temperature. A linear curve has been fit to the data. References are listed in Table 4.

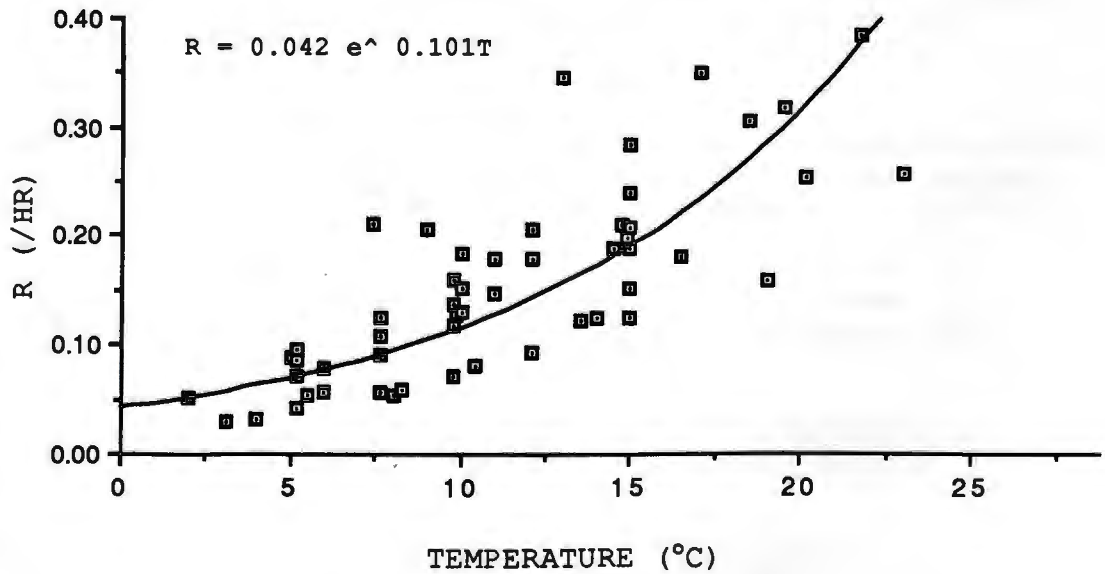

Figure 5b. Literature values for instantaneous gastric evacuation rate (R) versus water temperature. An exponential curve has been fit to the data. References are listed in Table 4.

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METABOLIC AND GROWTH RATES OF JUVENILE SCUP (*Stenotomus chrysops* (L.)) IN NARRAGANSETT BAY, RI

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ABSTRACT

The metabolic rate of juvenile scup *Stenotomus chrysops* was measured in the laboratory. The average respiration rate (0.23 ml O_2/g wet wt) of 46 one year old demersal fish was used to estimate their metabolic expenditure at 1.86% dry weight/day. The growth rate of juvenile scup in Narragansett Bay was also determined. Two approaches were taken to estimate the growth rate: a bioenergetic approach, and a length-frequency approach. The bioenergetic approach, which used Winberg's energy budget equation, estimated growth at 0.93% dry weight/day. The length-frequency approach estimated the growth rate of juvenile scup at 0.84% dry weight/day during their summer residence in Narragansett Bay. The field estimate of the growth rate of scup agreed well with the bioenergetic estimate. The growth rates determined in this study were used to calculate the body weight of scup that was produced in Narragansett Bay. This production was equivalent to 0.15-0.40 g dry wt/m^2.

INTRODUCTION

Metabolic measurements are important to both bioenergetic and fish production studies. Metabolism is one of the major uses of food energy by living organisms. It is essential to studies of the flow of energy both within an organism and between trophic levels (Durbin, et al, 1981; Solomon and Brafield, 1972). It is crucial to an understanding of biological production since it is, in part, a measure of the amount of energy expended in order to replenish an organism's energy (Beamish and Dickie, 1967). The metabolic rate of fish, together with daily ration can be used to estimate growth rates (Ivlev, 1945; Warren and Davis, 1967; Winberg, 1956).

Metabolic rates of fish are most often estimated by measuring oxygen consumption under various conditions (Brafield, 1985; Beamish and Dickie, 1967; Fry, 1957; Winberg, 1956). Three basic methods have been used to measure oxygen consumption by fish. These are the sealed chamber method, the continuous flow method, and the manometric method (Beamish and Dickie, 1967, Fry, 1957).

The growth rate of fish is an important parameter in fish productivity models, ecosystem studies and fishery management plans (Soofiani and Hawkins, 1985; Van Ooosten, 1957). Fishery management and aquacultural plans may aim to maximize growth, while minimizing the cost of raising fish (Knights, 1985). At the same time continued success of the population in terms of numbers of successful offspring must be guaranteed (Calow, 1985; Sisson, 1974).

Fish continue to grow throughout their lives. The highest growth rate is found during during larval stages. Growth then slows slightly and continues at a steady rate until it reaches an asymptote, at which time growth continues at a minimum rate (Brown, 1957).

Four main approaches have been taken to measure the growth rates in fish. These are: relating rings formed on scales and otoliths to an increase in biomass (DeBont, 1967; Soofiani and Hawkins, 1985; Van Oosten, 1957); tagging either whole fish, or certain tissues such as scales and bones and then measuring changes (DeBont, 1967; Hamer, 1979; Sisson, 1974; Soofiani and Hawkins, 1985; Weatherly, 1972); examining length frequency data and following the growth of cohorts over time (DeBont, 1967; Weatherly, 1972); and using an energy budget to determine the growth rate of fish (Ivlev, 1945; Warren and Davis, 1967; Winberg, 1956).

Growth rate in fish has been most often described using the von Bertalanffy growth curve. The general equation for this type of curve is :

$$Lt = L\,[1 - e^{-k(tn - to)}] \quad \text{(Eq 1)}$$

where:

Lt = length in centimeters at time t

L = the maximum expected length in centimeters

k = a constant which is proportional to the destruction of body materials

to = hypothetical age at 0 length

tn = age of fish in nth age group where t1 = 0.

The purpose of this study was to measure the metabolic and growth rates of juvenile members of the demersal fish species *Stenotomus chrysops*, scup, in Narragansett Bay, Rhode Island. This commercially important species is found within bays and estuaries in southern New England and New Jersey from May until October (Appeldoorn et al, 1981; Azarovitz, 1985; Bigelow and Schroeder, 1953; Finkelstein, 1971; Gusey, 1977; Morse, 1978; Morse, 1982). Narragansett Bay serves as an important spawning, feeding and growth area for young scup during the spring and summer (Sisson, 1974). Feeding and growth in this species is at a minimum in the winter and at a maximum during the summer months (Bigelow and Schroeder, 1953; Morse, 1978; Morse, 1982; Sisson, 1974).

The metabolic rate of scup has not been previously measured. There have been no bioenergetic studies of the species *Stenotomus chrysops*. Age and growth determinations have been made for this species, as a whole. It has been found that scup average 11 cm at one year, 16 cm at two years, 20 cm at three years, 23 cm at four years, and 25 cm at five years (Bigelow and Schroeder, 1953; Hamer, 1979; Hildebrand and Schroeder, 1928; Howell and Simpson, 1985; Johnson, 1978; Morse, 1982; Olsen and Stevenson, 1975;). The length-weight relationship of *S. chrysops* has been measured by various authors (Table 1). The von Bertalanffy growth curves have been generated for *S. chrysops*

(Finkelstein, 1969a; Hamer, 1979; Howell and Simpson, 1985; Sisson, 1974) (Table 2). However no growth measurements have been made within a single age class of scup. One previous study has attempted to study the growth of scup in Narragansett Bay. This study used tagged fish in order to determine migration patterns and growth rates (Sisson, 1974). Unfortunately too few tagged fish were returned for growth estimates and migration patterns to be established by this approach.

Previous scup studies have used only one method to determine growth rates: scale and fish length data. Two methods such as a bioenergetic approach and a length-frequency approach have not been used simultaneously to determine growth rates in this species. There have been no previous studies that had this kind of internal check on their results.

METHODS AND MATERIALS

Metabolic Study

A small otter trawl, with a 5.1 cm mesh size at the cod end, was used to collect 46 scup during a five minute tow at the Fox Island station (41°34'N, 71°25'W) in Narragansett Bay (Figure 1). The fish were immediately placed in a running seawater tank on the boat. They were then transferred to the Aquarium Building at the University of Rhode Island's Graduate School of Oceanography and placed in a 185 cm diameter tank with a 52 cm high water column. This tank had a flow through system provided with ambient Narragansett Bay seawater.

The water temperature in the tank was kept the same (20-21°C) as in the field and did not vary throughout the experiments. The volume of the water in the tank was held constant at approximately 1400 liters. The scup were not kept under low food conditions, or stressed in other ways. The fish were fed squid, a normal prey item of scup (Bigelow and Schroeder, 1953; Morse, 1978; Morse, 1982; Oviatt and Nixon, 1973). They were fed to satiation daily. Acclimation was assumed because of normal eating habits. The fish were handled as little as possible, and they experienced light, temperature, salinity etc. conditions similar to those in the field. Movement was neither restricted, nor enforced. The tank was cleaned daily.

Closed system respirometry was the method used to measure metabolic rate in this study. A plexiglass lid that was 185 cm in diameter and had a neoprene edge was suspended above the fish tank. The water supply and drain from the tank were closed off. The lid was lowered onto the water surface so that an airtight seal was formed. All air was forced from beneath the lid through sampling ports which were subsequently plugged. A thermometer was placed in one sampling port and a siphon was established in another.

Triplicate water samples for oxygen were removed from the tank at 10 minute intervals for approximately two hours. The Winkler method (Lambert and Oviatt, 1986) was used to measure the oxygen content of each of the water samples. This procedure was carried out twice, on consecutive days, while the fish were in the tank. Two control measurements were also made. These were carried out in an identical manner except that the the tank did not contain fish. One control experiment took place before the fish were added to the tank, and the second, after the fish were removed. The average wet weight of the fish was 67±7 g.

Growth Rate study:

Bioenergetic approach

Winberg's energy equation was used to determine the growth rate of scup from daily food ration and metabolic rate data. This equation was:

$$G = 0.8F - M \qquad \text{(Eq 2)}$$

where, G = the amount of energy expended in growth;

F = the amount of energy taken in, in the form of food;

0.8 = the amount of energy lost via egestion and excretion;

M = the amount of energy used in normal activities such as normal body maintenance, swimming, foraging for food, etc.

Each of the parameters was expressed in the same units of % dry body weight/day.

Length-frequency approach

The Fox Island station in the west passage of Narragansett Bay (41°34'N, 71°24W), was sampled weekly using a small otter trawl. The otter trawl was towed for thirty minutes so that the average speed over the bottom was 2.5

knots. Wet weight, total length and fork length were measured for a minimum of 100 scup in each trawl. Every scup caught was counted so that length frequency could be followed throughout the season. A total of 32 fish of known fork length and wet body weight were dried to a constant weight in a 60°C oven.

RESULTS

Metabolic study

During the metabolic study the amount of oxygen in the water decreased at a rate of 0.70 mg O_2/liter-hour (Figure 2). This was equivalent to a respiration rate of 0.32 mg O_2/g wet wt - hr or 0.23 ml O_2/g wet wt - hr. This result when expressed in terms of dry weight, (by using an oxycalorific equivalent of 5 cal/ml and assuming that 5 kcal = 1 g dry weight (Winberg, 1956)) was equal to a metabolic expenditure of 1.86 % dry body wt/day. There was no change in oxygen concentration of the water in the control experiments.

Growth rate study:

The following length:weight relationships were obtained:

Dry body wt = 5.96 + 0.29*Wet body wt $R^2 = 0.99$ (Eq 3)

Log dry wt = -0.84 + 1.92*Log fork length $R^2 = 0.94$ (Eq 4)

Log wet wt = -1.91 + 3.23*Log fork length $R^2 = 0.96$ (Eq 5)

(Appendix A)

Bioenergetic approach

A growth rate of 0.93% dry weight/day was determined by the bioenergetic study. This result was obtained from Winberg's equation, (Eq 2) by using an estimate of scup daily food ration of 3.49% dry weight/day (Michelman, 1988) along with the metabolic rate measured by the current study (1.86% dry weight/day). Both of the 'known' parameters (F, M) were measured using one population of juvenile fish in Narragansett Bay.

Length-frequency approach

Scup first appeared at the Fox Island station in late May. Throughout most of the summer only one cohort was present at this station. These were the fish that had been spawned during the summer of 1986. The average size of the fish, as determined by the progression of the modes, increased from 10.0 cm in June to 11.0 cm in July, to 12.5 cm in August, to 15.0 cm in September 1987 (Figure 3). During September the young of year were also caught by the trawl. In October the 1 year old scup were no longer caught at this station, but the young of year were present and had almost reached the size of the 1 year old fish in June.

The growth rate of the 1 year old scup was calculated from the length-frequency data. The fork length:dry weight conversion was used to express each of the modes in terms of dry weight (Eq 4). The dry weight equivalents of the modes were plotted at the appropriate 30 to 31 day intervals (Figure 4). An exponential curve was fit to these data, and the calculated field growth rate was found to equal an increase of 0.84% dry wt/day.

Comparison of the two approaches

The two methods used to determine the growth rate of juvenile scup in Narragansett Bay resulted in very similar estimates (Figure 5). A curve representing the bioenergetic growth rate was generated by starting with the dry weight corresponding to June (12.0 g) and then increasing by 0.93% dry wt/day. Dry weight (in g) was plotted versus time (in days) for both the field and bioenergetic data (Figure 5).

DISCUSSION

Metabolic study

Several factors may affect the metabolic and therefore respiration rate of fish. These include activity level, body weight of the fish, temperature, oxygen concentration and CO_2 concentration of the water, feeding conditions (including diet composition), stress, and season of the year (Beamish and Dickie, 1967; Davis and Warren, 1968; Fry, 1957).

Fish that are actively swimming consume oxygen at a higher rate than do those that are stationary (Brett, 1964). Increased water temperature will also increase oxygen consumption (Beamish and Dickie, 1967; Fry, 1957; Knights, 1985). Increased CO_2 concentration may decrease oxygen consumption rates (Beamish and Dickie, 1967; Fry, 1957). Under conditions of low oxygen concentration respiration rates are decreased (Beamish and Dickie, 1967; Fry, 1957).

Changes in the O_2 and CO_2 concentrations did not effect the respiration rate of scup in this study. A comparatively large tank (holding approximately 1400 liters) and a relatively short sampling time (2 hours) were used. These factors minimized both the buildup of CO_2 and the O_2 depletion rate within the tank. The respiration rate remained constant throughout each experiment. It was also consistent between experiments.

Fish seem to be able to adjust metabolic demands to the environmental situation. Under low food conditions fish appear to be able to decrease their oxygen demand as well as to increase their efficiency of food conversion (Brown, 1957; Fry, 1957; Jobling, 1985; Palheimo and Dickie, 1966; Soofiani and Hawkins, 1985). The biochemical composition of the food influences metabolic rate. Metabolic rate increases with increasing protein content in the diet (Jobling, 1985; Soofiani and Hawkins, 1985). The size of the experimental chamber and the amount of handling may lead to stress and therefore to increased respiration rates (Fry, 1957; Knights,1985). The time of day and time of season may affect metabolic rates also (Fry, 1957; Soofiani and Hawkins, 1985). The conditions in this experiment duplicated, as far as possible, those in the field. Therefore the metabolic rate obtained was a reliable estimate of field metabolism (Davis and Warren, 1968; Priede, 1985; Soofiani and Hawkins, 1985).

Smaller, younger fish consume oxygen at relatively higher rates than do larger, older fish (Soofiani and Hawkins, 1985). The relationship between body weight and metabolism has been described by the equation:

$$Q = 0.3W^{0.8} \qquad \text{(Eq 6)}$$

where Q = resting metabolism and W = the wet body weight of the fish (Winberg, 1956). The resting metabolic rate (Q/W) has thus been estimated by the equation:

$$Q/W = 0.3W^{-0.2} \qquad \text{(Eq 7)}$$

(Winberg, 1956). Winberg suggested that a value of two times the resting metabolic rate be used to estimate fish metabolic rates under field conditions (Winberg, 1956). Mann (1967) examined various metabolic studies and concluded that Winberg's estimation of field metabolic rates:

$$M = 2 * 0.3W^{-0.2} \qquad \text{(Eq 8)}$$

was accurate to within 25%. The results of the present study (M = 0.23 ml O_2/g wet wt-hr) were very close to the value predicted by Winberg's equation (0.26 ml O_2/g wet wt-hr, when W = 67.0 g).

It may be argued that the metabolic rate obtained in this study would have been slightly higher if the experiment had been performed earlier in the season, when the fish of this cohort weighed less. If Winberg's equation had been used to predict the metabolic rate of fish weighing 29 g (the average wet body weight in July), the result would have been a metabolic rate of 0.31 ml O_2/g wet wt-hr. The actual metabolic rate, as measured during the first week in September, was within 25% of this theoretical metabolic rate. Since Winberg's prediction may have a 25% error associated with it, a literature estimation of metabolic rate, based on a smaller fish size, would not have been any more accurate than the measured metabolic rate. Therefore the laboratory results were considered correct for this cohort throughout the season.

Metabolic rates of other marine fish species have been measured (Table 3). Since fish size and water temperature influence metabolic level these parameters were included when results of various metabolic rate studies were compared. The diamond turbot, *Hypsopsetta guttulata;* silver hake, *Merluccius bilinearis;* winter flounder, *Pseudopleuronectes americanus;* and red porgy *Pagrus major* in the size range 28-801g, and the temperature range 7-21.5°C had metabolic rates from 0.7 to 2.65% body weight (Apostolopoulos and Ishiwata, 1986; Lane et al, 1979; Tyler and Dunn, 1976; Vinogradov, 1977) (Table 3). The results of the current study, a metabolic rate of 1.86% body weight for scup, *Stenotomus chrysops*, fell within this range.

Growth rate study

The growth rates for juvenile scup obtained in this study were considered reliable since two different methods provided such close results. The accuracy of these results also were confirmed by a comparison with other scup growth studies. The length frequency data in the current study that found the June mode equal to 10.0 cm and the September mode equal to 15.0 cm, agreed well with the literature averages of 11 cm at one year and 16 cm at two years. The fact that Narragansett Bay is at the northern edge of this fish's range may account for the slightly smaller length at age found here.

Growth rates also have been determined for other marine fish (Table 4). These rates have ranged from a low of 0.07%

body weight/day for haddock, *Melanogrammus aeglefinus* (Jones, 1978) and silver hake *Merluccius bilinearis* (Vinogradov, 1977) to a high of 2.1% body weight/day for winter flounder, *Pseudopleuronectes americanus* (Chesney and Estevez, 1976). The growth rate measured in the current study was within this range.

Impact of Narragansett Bay

The increase in scup weight during their seasonal residence in Narragansett Bay was determined based on the results of this study. A production rate of 0.15-0.40 g dry wt/m^2 was calculated (Table 5). Rhode Island commercial catch data (Olsen and Stevenson, 1975) and Narragansett Bay fish abundance data (Jeffries, 1986), used in conjunction with the growth rates estimated by the present study, resulted in similar estimates of scup production (Table 5). Since food consumption by scup has previously been found to be 0.6-1.7 g dry wt/m^2 (Michelman, 1988) this means that the growth efficiency of these juvenile fish was approximately 24%. Steele (1974) found that transfer efficiencies between the benthos and primary carnivores, or demersal fish, ranged from 8 to 29%. Also Jones and Henderson (1980) found that growth efficiencies of juvenile fish may be as high as 30%. Therefore the production estimate obtained by this study was reasonable.

Table 1. The length-weight relationship of *Stenotomus chrysops* as determined by various authors; where W is wet weight in grams and L is fork length in centimeters.

REFERENCE	LENGTH-WEIGHT EQUATION
BRIGGS, 1968	LOG W = 2.8491 * LOG L - 4.3944
HAMER, 1970	LOG W = 2.72 * LOG L - 1.254
HOWELL AND SIMPSON, 1985	LOG W = 3.05 * LOG L - 1.69
SMITH AND NORCROSS, 1968	LOG W = 3.0391 * LOG L - 4.7249
THIS STUDY	LOG W = 3.23 * LOG L - 1.91

Table 2. von Bertalanffy growth curves for *Stenotomus chrysops* as estimated by various authors; where Lt = length in centimeters at age t and tn = age of fish in nth age group where t1 = 0.

<u>REFERENCE</u>	<u>VON BERTALANFFY GROWTH CURVE</u>
HAMER, 1979	$Lt = 34.10\ [\ 1 - e^{-0.2945\ (tn\ +\ 0.7964)}]$
HOWELL AND SIMPSON, 1985	$Lt = 38.93\ [\ 1 - e^{-0.22\ (tn\ +\ 0.35)}]$
FINKELSTEIN, 1969	MALES:
	$Lt = 34.25\ [\ 1 - e^{-0.2688\ (tn\ +\ 0.4053)}]$
	FEMALES:
	$Lt = 37.41\ [\ 1 - e^{-0.2247\ (tn\ +\ 0.4705)}]$
SISSON, 1974	$Lt = 32.38\ [\ 1 - e^{-0.3365\ (tn\ +\ 0.3119)}]$

Table 3. Literature values for metabolic rates (% body wt) of various marine fish. (*) indicates that this rate was calculated from given data, assuming that 20% of the daily food ration is not utilized by the fish.

FISH SPS	WATER TEMPERATURE	SIZE RANGE	METABOLIC RATE % BODY WT	REFERENCE
1.DIAMOND TURBOT *Hypsopsetta guttulata*	18.5°C	95 g	2.65*	LANE ET AL, 1979
2.RED PORGY *Pagrus major*	17.0-21.5	28 g	0.86*	APOSTOLOPOULOS AND ISHIWATA, 1986
3.SILVER HAKE *Merluccius bilinearis*	7-12°C	169 g	1.03	VINOGRADOV, 1977
4.WINTER FLOUNDER *Pseudopleuronectes americanus*	7.5°C	590-801 g	0.7*	TYLER AND DUNN, 1976
5.SCUP *Stenotomus chrysops*	20-21°C	67 g	1.86	THIS STUDY

Table 4. Literature values for growth rates (% body wt) of various marine fish. (*) indicates that this rate was calculated from given data.

FISH SPS	SIZE RANGE	GROWTH RATE % BODY WT/DAY	REFERENCE
1.ATLANTIC COD *Gadus morhua*	2650 g	<0.20	JONES, 1978
2.DIAMOND TURBOT *Hypsopsetta guttulata*	>25g AVG=95 g	0.36	LANE ET AL, 1976
3.HADDOCK *Melanogrammus aeglefinus*	500-1750 g	0.07-0.13	JONES, 1978
4.MENHADEN *Brevoortia tyrannus*	241-260 g	0.93-1.03	DURBIN ET AL, 1983
5.SILVER HAKE *Merluccius bilinearis*	68-1267 g	0.07-0.28	VINOGRADOV, 1977
6.WINTER FLOUNDER *Pseudopleuronectes americanus*	18-34 g	1.7-2.1*	CHESNEY AND ESTEVEZ, 1976

Table 4. (continued)

FISH SPS	SIZE RANGE	GROWTH RATE % BODY WT/DAY	REFERENCE
7.WINTER FLOUNDER *Pseudopleuronectes americanus*	590-801 g	0.1-0.3	TYLER AND DUNN, 1976
8. " "	15-18 cm	0.33-0.38	WOROBEC, 1981
9.SCUP *Stenotomus chrysops*	21-77 g	0.84-0.93	THIS STUDY

Table 5. Estimates of the production of scup in Narragansett Bay during a 122 day period from June 1st to September 30th. Each estimate was based on the assumptions that the growth rate of scup was between 0.84% and 0.93% dry wt/day, that there was 100% catch efficiency, and that 0.29 g dry body wt of scup was equivalent to 1.00 g wet body wt. Other assumptions are indicated.

REFERENCE	FISH POPULATION ESTIMATE	NUMBER OF FISH/M^2	G DRY WT PRODUCED/M^2
OLSEN AND STEVENSON, 1975	($1.1-10*10^5$ lbs wet wt)[1] $1.4-13.2*10^7$ g dry wt		(0.04-0.44)[2]
JEFFRIES ET AL, 1986	33-816 fish/30 min.trawl (479-11832 g dry wt/ 30 min.trawl)[3] (0.02-0.51 g dry wt/m^2)[4]	(0.001-0.035)[4]	(0.02-0.58)[4]
THIS STUDY	232-546 fish/30 min.trawl 3341-8105 g dry wt/ 30 min.trawl (0.14-0.35 g dry wt/m^2)[4]	(0.010-0.024)[4]	(0.15-0.40)[4]

Assumptions:

1. The population of scup in Narragansett Bay is equal to 10% of Rhode Island commercial landings of scup.

2. The area of Narragansett Bay equals $3.42*10^8$ m^2 (Chinman and Nixon, 1985).

3. The average dry weight of one scup at the Fox Island station is 14.5 g.

4. Since the mouth of the bottom trawl was 10 m wide and the trawl proceeded at a speed of 2.5 knots over the bottom, each 30 minute trawl covered an area of 23150 m^2.

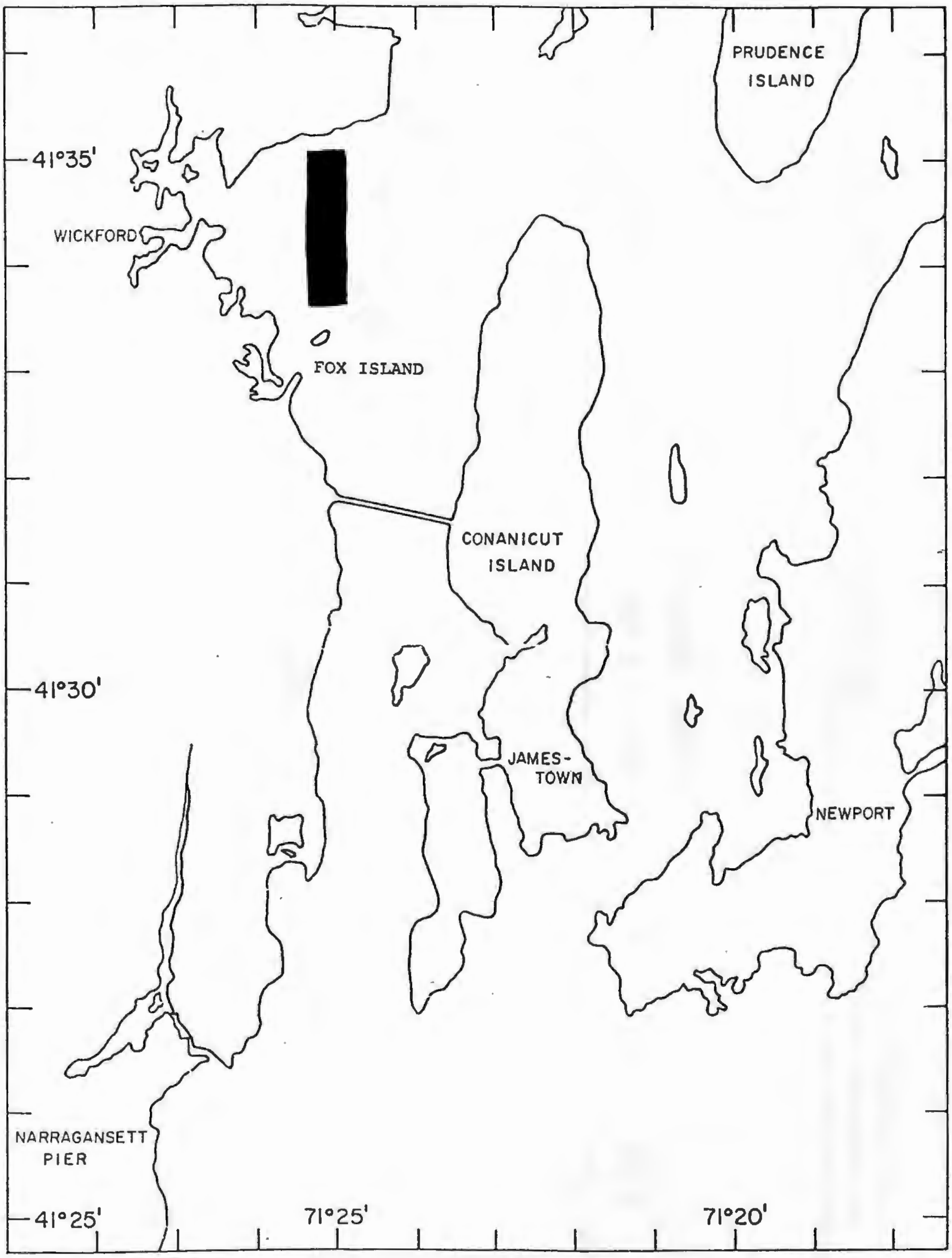

Figure 1. The Fox Island station in Narragansett Bay, RI.

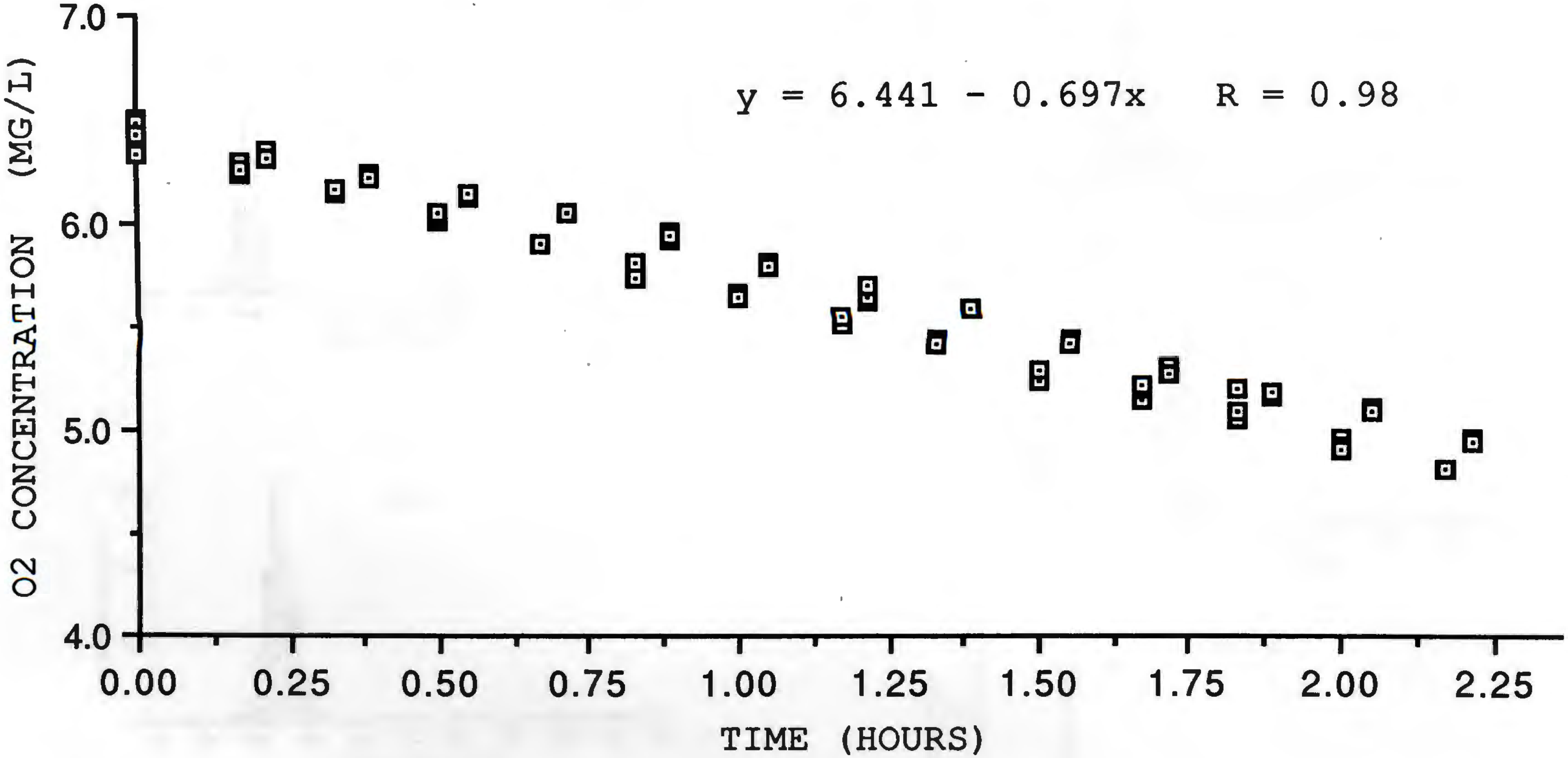

Figure 2. Respiration of 46 scup in 1400 liters of water. The O_2 concentration of the water (mg/l) is plotted versus time (hours). The results of two experiments are presented in this figure.

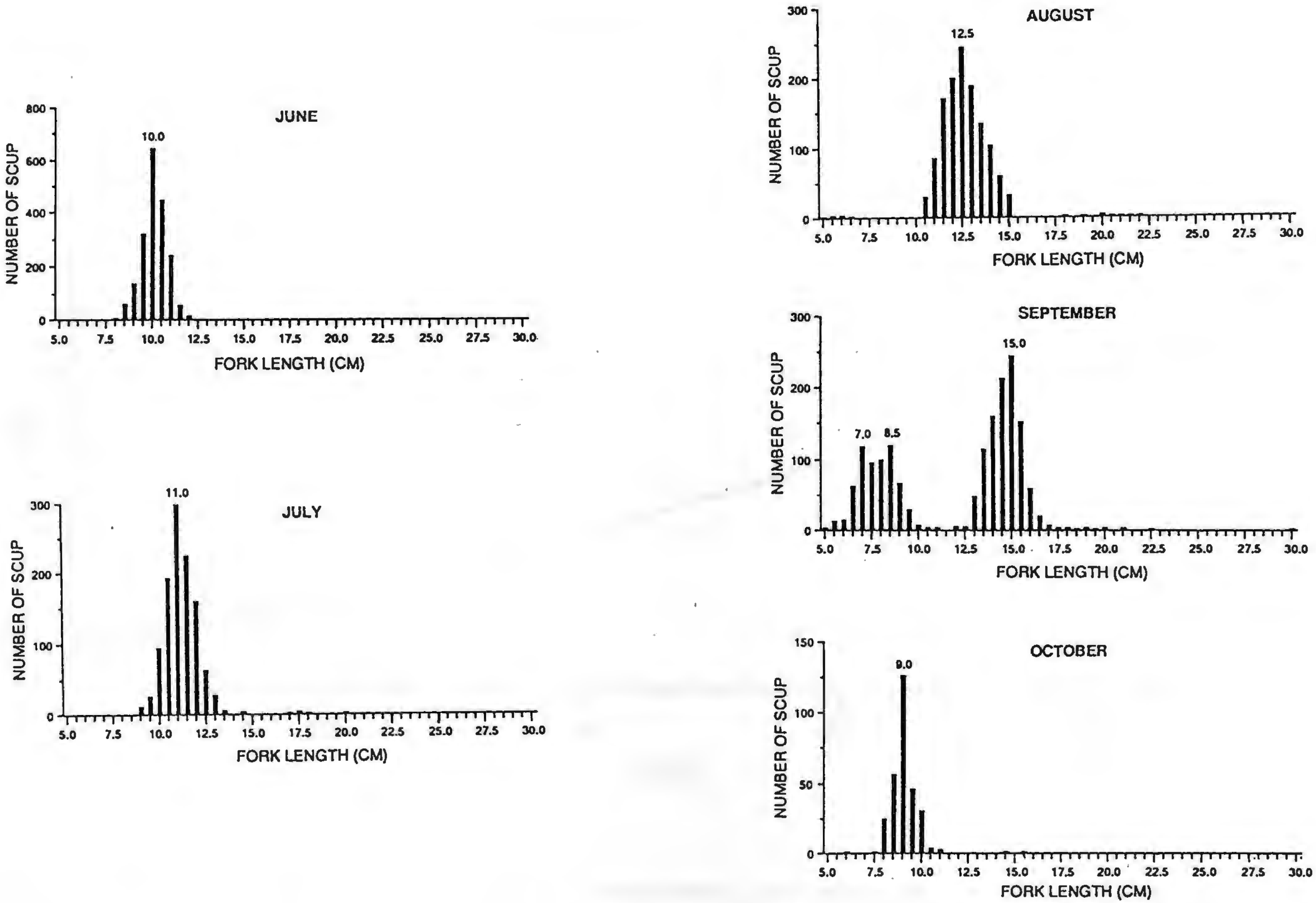

Figure 3. Length frequency of juvenile *Stenotomus chrysops* at the Fox Island station in Narragansett Bay during 1987. Number of scup is plotted versus fork length (cm). The data was summed on a monthly basis and standardized to 5 trawls per month. Note that the scales vary.

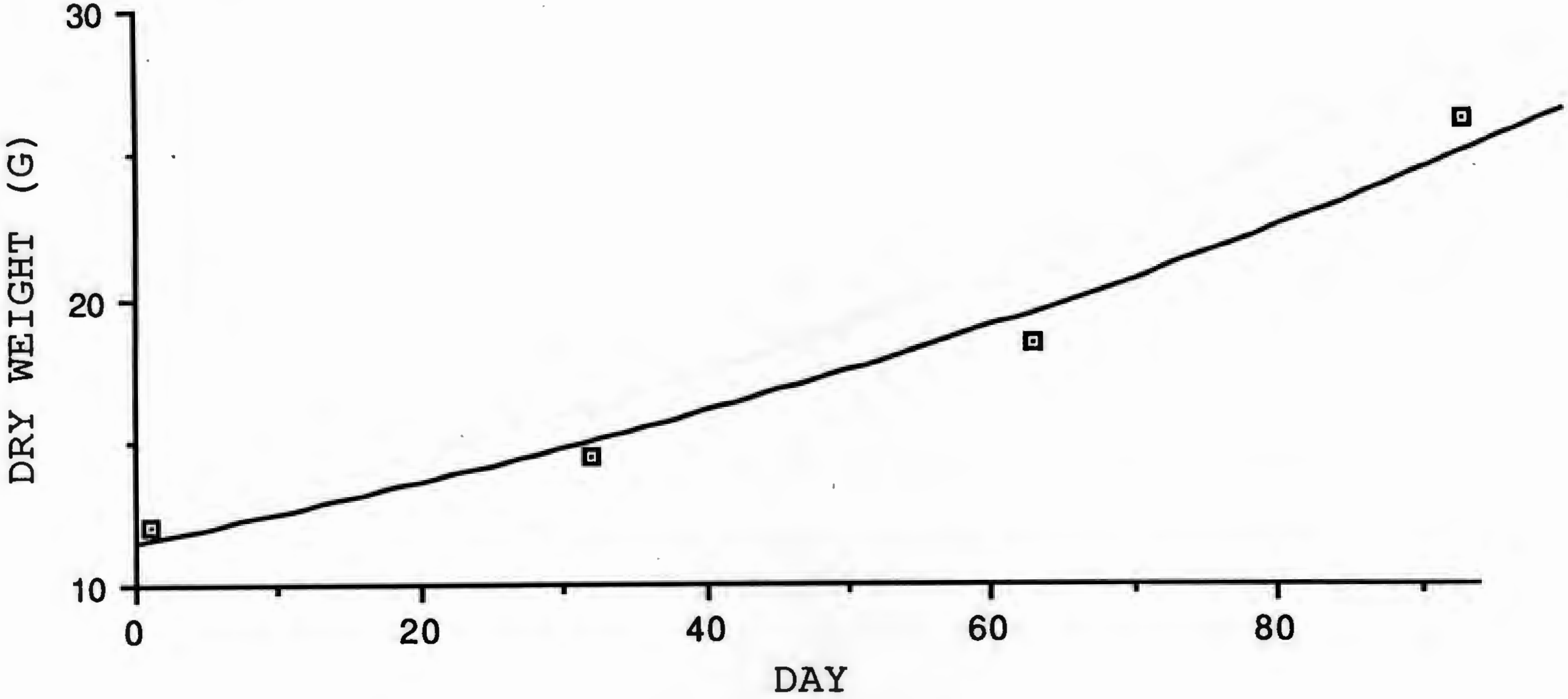

Figure 4. Length frequency of juvenile *Stenotomus chrysops* at the Fox Island station in Narragansett Bay between June 1 and September 30, 1987. Dry weight (g) is plotted versus day. The growth rate was 0.84% dry wt/day.

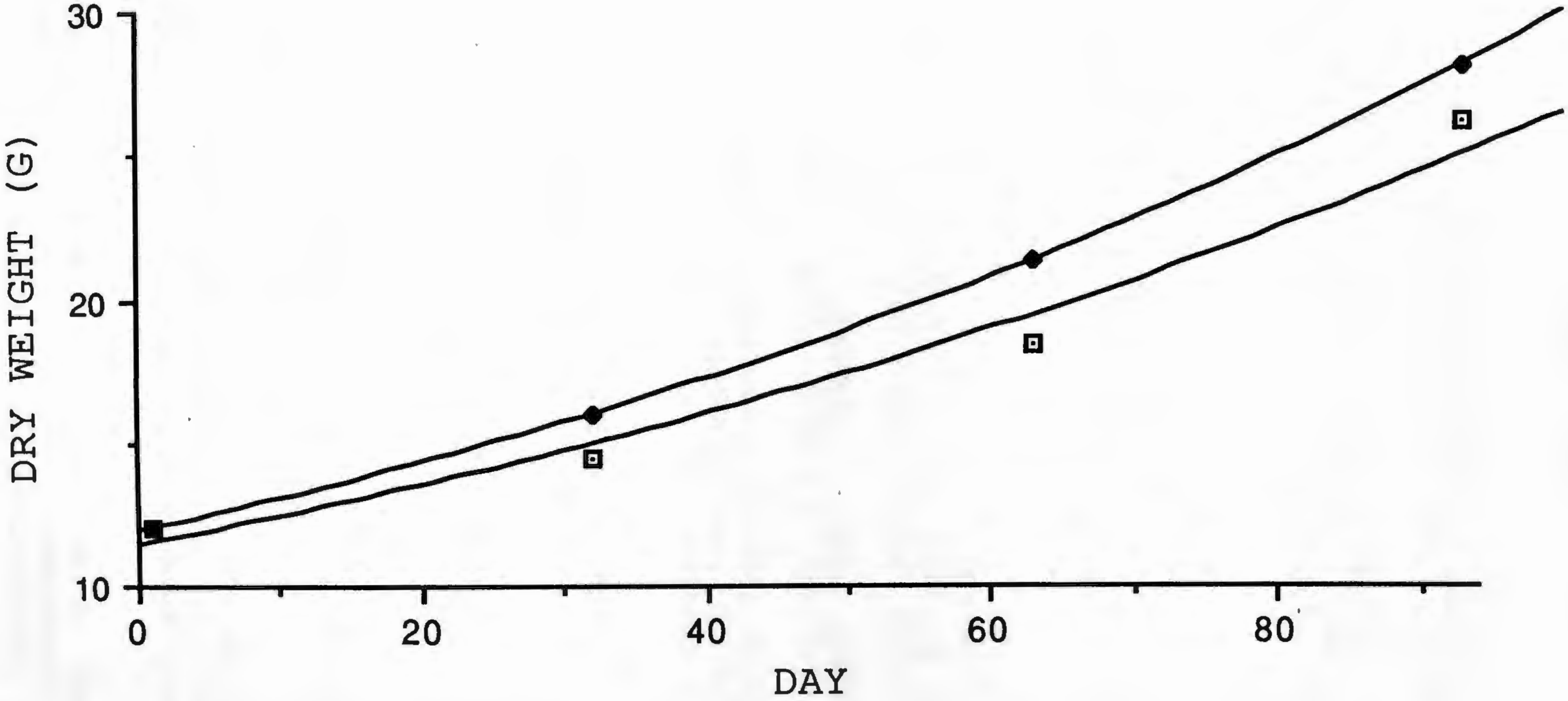

Figure 5. A comparison of juvenile scup growth rates obtained by different methods. Dry weight (g) is plotted versus day. The length frequency method estimated growth at 0.84% dry wt/day (◘). The energy budget method estimated growth at 0.93% dry wt/day (◆).

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APPENDIX A: The raw data used to determine the relationships between fork length, wet weight and dry weight in juvenile members of the fish *Stenotomus chrysops* are provided here. The fish were caught at the Fox Island station in Narragansett Bay on July 21, 1987.

WET WT (G)	DRY WT (G)	FL (CM)	LOG FL	LOG DRY WT	LOG WET WT
15.8	11.0	9.5	0.98	1.04	1.20
65.8	25.6	14.5	1.16	1.41	1.82
55.1	22.2	13.5	1.13	1.35	1.74
22.5	12.6	10.5	1.02	1.10	1.35
27.4	13.7	11.0	1.04	1.14	1.44
29.9	14.1	11.0	1.04	1.15	1.48
42.8	18.9	12.5	1.10	1.28	1.63
26.4	14.0	10.5	1.02	1.15	1.42
23.4	12.7	10.5	1.02	1.10	1.37
18.2	11.6	9.5	0.98	1.06	1.26
38.8	16.4	12.5	1.10	1.21	1.59
37.9	17.1	12.0	1.08	1.23	1.58
26.1	13.4	10.5	1.02	1.13	1.42
39.1	17.4	12.5	1.10	1.24	1.59
35.0	16.4	12.0	1.08	1.21	1.54
36.4	16.3	11.5	1.06	1.21	1.56
34.7	16.2	11.5	1.06	1.21	1.54
26.5	13.8	10.5	1.02	1.14	1.42
24.9	13.0	10.5	1.02	1.11	1.40
46.6	19.9	12.5	1.10	1.30	1.67
38.3	17.1	12.0	1.08	1.23	1.58
20.4	12.1	10.0	1.00	1.08	1.31
37.5	16.4	11.5	1.06	1.21	1.57
30.0	14.5	11.0	1.04	1.16	1.48
26.9	14.0	11.0	1.04	1.15	1.43
35.0	15.7	11.5	1.06	1.20	1.54
21.8	12.2	10.5	1.02	1.09	1.34
38.9	16.8	12.0	1.08	1.23	1.59
32.6	15.0	11.5	1.06	1.18	1.51
27.9	14.6	11.0	1.04	1.16	1.45
28.1	14.9	11.0	1.04	1.17	1.45
28.2	14.2	11.0	1.04	1.15	1.45

Appendix B. Raw data from 24 hour trawl.

Time of Trawl	Fish#	Body Wet Wt	Stomach Wet wt	Stomach Dry wt	Body Dry Wt	Stomach % wet wt	Stomach % dry wt
0600 A	1	18.1	0.08	0.01	11.2	0.44	0.09
0600 A	2	23.5	0.28	0.05	12.8	1.19	0.39
0600 A	3	21.8	0.19	0.03	12.3	0.87	0.24
0600 A	5	32.3	0.07	0.01	15.4	0.22	0.07
0600 A	6	29.3	0.10	0.01	14.5	0.34	0.07
0600 A	7	20.5	0.06	0.01	11.9	0.29	0.08
0600 A	8	27.0	0.31	0.05	13.8	1.15	0.36
0600 A	11	24.7	0.11	0.02	13.2	0.45	0.15
0600 A	13	16.7	0.05	0.00	10.8	0.30	0.00
0600 A	14	32.6	0.29	0.04	15.5	0.89	0.26
0600 A	15	24.0	0.15	0.03	13.0	0.63	0.23
0600 A	17	35.2	0.14	0.02	16.2	0.40	0.12
0600 A	19	23.8	0.27	0.04	12.9	1.13	0.31
0600 A	21	31.0	0.14	0.01	15.0	0.45	0.07
0600 A	22	25.8	0.12	0.01	13.5	0.47	0.07
0600 A	23	26.4	0.16	0.02	13.7	0.61	0.15
0600 A	25	31.7	0.11	0.02	15.2	0.35	0.13
0600 A	26	25.8	0.68	0.13	13.5	2.64	0.96
0600 A	27	28.9	0.15	0.02	14.4	0.52	0.14
0600 A	29	31.0	0.13	0.02	15.0	0.42	0.13
0600 A	30	24.3	0.10	0.01	13.0	0.41	0.08
0600 A	32	20.2	0.14	0.01	11.9	0.69	0.08
0600 A	33	22.3	0.11	0.02	12.5	0.49	0.16
0600 A	34	27.1	0.16	0.02	13.9	0.59	0.14
0600 A	35	23.4	0.14	0.02	12.8	0.60	0.16
0600 A	38	24.3	0.16	0.03	13.0	0.66	0.23
0600 A	39	28.2	0.16	0.03	14.2	0.57	0.21
0600 A	40	21.6	0.09	0.02	12.3	0.42	0.16
0600 A	41	23.2	0.06	0.01	12.7	0.26	0.08
0600 A	42	19.5	0.10	0.01	11.7	0.51	0.09
0600 A	43	23.2	0.14	0.03	12.7	0.60	0.24

Time of Trawl	Fish#	Body Wet Wt	Stomach Wet wt	Stomach Dry wt	Body Dry Wt	Stomach % wet wt	Stomach % dry wt
0600 A	44	36.0	0.12	0.01	16.5	0.33	0.06
0600 A	45	26.4	0.08	0.02	13.7	0.30	0.15
0600 A	46	30.0	0.16	0.02	14.7	0.53	0.14
0600 A	47	24.6	0.10	0.02	13.1	0.41	0.15
0600 A	49	31.8	0.05	0.01	15.2	0.16	0.07
0600 A	50	34.1	0.09	0.01	15.9	0.26	0.06
0900	1	29.1	0.60	0.09	14.4	2.06	0.62
0900	2	22.6	0.35	0.03	12.6	1.55	0.24
0900	4	17.7	0.19	0.03	11.1	1.07	0.27
0900	5	27.7	0.33	0.05	14.0	1.19	0.36
0900	6	27.4	0.42	0.07	14.0	1.53	0.50
0900	8	17.2	0.27	0.04	11.0	1.57	0.36
0900	11	26.3	0.30	0.03	13.6	1.14	0.22
0900	14	22.5	0.17	0.02	12.5	0.76	0.16
0900	15	20.7	0.35	0.06	12.0	1.69	0.50
0900	17	26.0	0.31	0.04	13.5	1.19	0.30
0900	18	20.7	0.36	0.05	12.0	1.74	0.42
0900	19	24.0	0.23	0.02	13.0	0.96	0.15
0900	20	23.9	0.19	0.02	12.9	0.79	0.15
0900	21	28.7	0.89	0.14	14.3	3.10	0.98
0900	22	35.8	0.15	0.01	16.4	0.42	0.06
0900	23	32.4	0.39	0.06	15.4	1.20	0.39
0900	25	28.2	0.35	0.05	14.2	1.24	0.35
0900	26	31.5	0.21	0.04	15.1	0.67	0.26
0900	27	26.9	0.26	0.05	13.8	0.97	0.36
0900	29	24.3	0.87	0.15	13.0	3.58	1.15
0900	30	27.4	0.29	0.04	14.0	1.06	0.29
0900	31	23.0	0.24	0.04	12.7	1.04	0.32
0900	32	23.1	0.50	0.09	12.7	2.16	0.71
0900	33	25.1	0.38	0.05	13.3	1.51	0.38
0900	34	15.5	0.09	0.02	10.5	0.58	0.19
0900	35	23.4	0.17	0.03	12.8	0.73	0.23

Time of Trawl	Fish#	Body Wet Wt	Stomach Wet wt	Stomach Dry wt	Body Dry Wt	Stomach % wet wt	Stomach % dry wt
0900	36	32.6	0.22	0.02	15.5	0.67	0.13
0900	39	31.9	0.50	0.08	15.3	1.57	0.52
0900	40	30.6	0.14	0.01	14.9	0.46	0.07
0900	42	27.6	0.63	0.10	14.0	2.28	0.71
0900	43	24.4	0.24	0.03	13.1	0.98	0.23
0900	44	22.7	0.37	0.05	12.6	1.63	0.40
0900	45	23.3	0.14	0.00	12.8	0.60	0.00
0900	46	28.9	0.29	0.04	14.4	1.00	0.28
0900	47	26.3	0.15	0.01	13.6	0.57	0.07
0900	48	21.3	0.24	0.04	12.2	1.13	0.33
0900	49	21.7	0.40	0.04	12.3	1.84	0.33
0900	50	30.5	0.40	0.07	14.9	1.31	0.47
1200	3	24.1	0.16	0.02	13.0	0.66	0.15
1200	4	24.2	0.55	0.11	13.0	2.27	0.84
1200	5	31.4	0.57	0.10	15.1	1.82	0.66
1200	6	29.4	0.81	0.17	14.5	2.76	1.17
1200	7	24.9	0.54	0.10	13.2	2.17	0.76
1200	8	32.4	0.66	0.13	15.4	2.04	0.84
1200	9	25.0	1.26	0.25	13.3	5.04	1.89
1200	11	30.9	0.28	0.03	15.0	0.91	0.20
1200	13	30.1	0.86	0.15	14.7	2.86	1.02
1200	14	25.5	0.88	0.18	13.4	3.45	1.34
1200	15	29.4	0.46	0.07	14.5	1.56	0.48
1200	16	31.2	0.41	0.07	15.1	1.31	0.46
1200	17	28.1	0.94	0.19	14.2	3.35	1.34
1200	18	24.0	0.37	0.06	13.0	1.54	0.46
1200	20	24.6	0.23	0.03	13.1	0.93	0.23
1200	21	25.8	0.69	0.14	13.5	2.67	1.04
1200	22	21.1	0.75	0.14	12.1	3.55	1.16
1200	23	25.5	0.59	0.12	13.4	2.31	0.90
1200	25	30.6	0.52	0.12	14.9	1.70	0.81
1200	27	22.3	0.10	0.02	12.5	0.45	0.16
1200	29	34.6	0.31	0.05	16.1	0.90	0.31

Time of Trawl	Fish#	Body Wet Wt	Stomach Wet wt	Stomach Dry wt	Body Dry Wt	Stomach % wet wt	Stomach % dry wt
1200	30	29.3	0.70	0.12	14.5	2.39	0.83
1200	31	21.5	0.70	0.14	12.2	3.26	1.14
1200	34	29.2	0.53	0.10	14.5	1.82	0.69
1200	35	25.1	0.25	0.04	13.3	1.00	0.30
1200	36	26.7	0.89	0.17	13.7	3.33	1.24
1200	37	28.4	1.13	0.23	14.2	3.98	1.61
1200	38	23.4	0.41	0.08	12.8	1.75	0.63
1200	40	22.3	0.26	0.05	12.5	1.17	0.40
1200	41	20.2	0.49	0.10	11.9	2.43	0.84
1200	42	27.5	0.31	0.04	14.0	1.13	0.29
1200	43	31.9	0.42	0.07	15.3	1.32	0.46
1200	44	22.7	0.47	0.08	12.6	2.07	0.64
1200	45	24.7	0.06	0.01	13.2	0.24	0.08
1200	46	20.5	0.13	0.03	11.9	0.63	0.25
1200	47	33.4	0.36	0.09	15.7	1.08	0.57
1200	48	23.1	0.30	0.04	12.7	1.30	0.31
1200	50	23.3	0.48	0.10	12.8	2.06	0.78
1500	1	24.6	0.72	0.14	13.1	2.93	1.07
1500	2	25.0	0.36	0.05	13.3	1.44	0.38
1500	3	21.2	0.97	0.17	12.1	4.58	1.40
1500	4	30.8	0.83	0.11	14.9	2.69	0.74
1500	6	23.5	0.46	0.06	12.8	1.96	0.47
1500	7	21.8	0.38	0.05	12.3	1.74	0.41
1500	8	17.4	0.38	0.06	11.0	2.18	0.54
1500	11	24.9	0.38	0.07	13.2	1.53	0.53
1500	12	28.7	0.67	0.15	14.3	2.33	1.05
1500	13	24.6	0.31	0.04	13.1	1.26	0.30
1500	14	23.0	0.46	0.06	12.7	2.00	0.47
1500	15	24.0	0.66	0.13	13.0	2.75	1.00
1500	16	22.3	0.46	0.09	12.5	2.06	0.72
1500	18	23.9	0.31	0.06	12.9	1.30	0.46
1500	20	21.5	0.30	0.05	12.2	1.40	0.41
1500	22	18.9	0.65	0.09	11.5	3.44	0.78

Time of Trawl	Fish#	Body Wet Wt	Stomach Wet wt	Stomach Dry wt	Body Dry Wt	Stomach % wet wt	Stomach % dry wt
1500	23	16.1	0.21	0.04	10.7	1.30	0.38
1500	24	25.4	0.74	0.13	13.4	2.91	0.97
1500	25	25.2	0.52	0.09	13.3	2.06	0.68
1500	26	23.0	0.80	0.15	12.7	3.48	1.18
1500	27	27.4	0.48	0.08	14.0	1.75	0.57
1500	30	25.5	0.63	0.11	13.4	2.47	0.82
1500	31	32.1	1.16	0.20	15.3	3.61	1.31
1500	32	23.2	0.96	0.19	12.7	4.14	1.49
1500	33	23.9	0.89	0.18	12.9	3.72	1.39
1500	35	21.5	0.37	0.07	12.2	1.72	0.57
1500	36	20.5	0.09	0.01	11.9	0.44	0.08
1500	37	24.4	0.50	0.10	13.1	2.05	0.76
1500	38	20.3	0.48	0.10	11.9	2.36	0.84
1500	39	19.8	0.29	0.04	11.7	1.46	0.34
1500	41	23.4	0.36	0.06	12.8	1.54	0.47
1500	43	27.2	0.78	0.11	13.9	2.87	0.79
1500	44	29.0	0.83	0.17	14.4	2.86	1.18
1500	45	33.8	0.73	0.15	15.8	2.16	0.95
1500	46	22.7	0.19	0.03	12.6	0.84	0.24
1500	48	28.6	0.49	0.07	14.3	1.71	0.49
1500	50	30.8	0.67	0.10	14.9	2.18	0.67
1800	2	33.2	0.22	0.03	15.6	0.66	0.19
1800	3	22.2	0.23	0.03	12.4	1.04	0.24
1800	5	27.8	0.47	0.08	14.1	1.69	0.57
1800	6	21.2	0.33	0.05	12.1	1.56	0.41
1800	7	30.1	0.57	0.11	14.7	1.89	0.75
1800	8	16.9	0.51	0.08	10.9	3.02	0.73
1800	9	20.4	0.19	0.01	11.9	0.93	0.08
1800	10	28.2	1.07	0.12	14.2	3.79	0.85
1800	11	25.2	0.35	0.05	13.3	1.39	0.38
1800	12	26.5	0.62	0.11	13.7	2.34	0.80
1800	13	26.5	0.36	0.07	13.7	1.36	0.51
1800	14	22.4	0.39	0.06	12.5	1.74	0.48

Time of Trawl	Fish#	Body Wet Wt	Stomach Wet wt	Stomach Dry wt	Body Dry Wt	Stomach % wet wt	Stomach % dry wt
1800	15	31.7	0.57	0.11	15.2	1.80	0.72
1800	16	18.5	0.20	0.04	11.4	1.08	0.35
1800	17	31.1	0.61	0.12	15.0	1.96	0.80
1800	19	31.5	0.27	0.05	15.1	0.86	0.33
1800	20	35.5	0.81	0.15	16.3	2.28	0.92
1800	22	30.7	0.76	0.13	14.9	2.48	0.87
1800	24	21.6	0.42	0.07	12.3	1.94	0.57
1800	25	20.2	0.40	0.08	11.9	1.98	0.67
1800	27	23.6	0.47	0.08	12.8	1.99	0.62
1800	28	23.1	0.43	0.06	12.7	1.86	0.47
1800	30	19.9	0.32	0.05	11.8	1.61	0.42
1800	31	24.1	0.77	0.13	13.0	3.20	1.00
1800	33	18.7	0.76	0.13	11.4	4.06	1.14
1800	35	19.6	0.70	0.14	11.7	3.57	1.20
1800	37	32.2	1.18	0.20	15.4	3.66	1.30
1800	40	19.2	0.14	0.01	11.6	0.73	0.09
1800	41	32.6	0.54	0.08	15.5	1.66	0.52
1800	42	26.0	0.83	0.13	13.5	3.19	0.96
1800	43	28.6	1.06	0.22	14.3	3.71	1.54
1800	44	29.7	0.43	0.08	14.6	1.45	0.55
1800	45	24.4	0.72	0.14	13.1	2.95	1.07
1800	47	22.7	0.28	0.05	12.6	1.23	0.40
1800	48	27.9	0.51	0.10	14.1	1.83	0.71
1800	49	21.8	1.41	0.26	12.3	6.47	2.11
1800	50	20.6	0.44	0.07	12.0	2.14	0.58
2100	1	22.9	0.46	0.08	12.6	2.01	0.63
2100	2	23.1	0.14	0.03	12.7	0.61	0.24
2100	3	21.2	0.24	0.04	12.1	1.13	0.33
2100	4	28.2	0.71	0.14	14.2	2.52	0.99
2100	5	30.7	1.38	0.28	14.9	4.50	1.88
2100	6	29.7	0.17	0.03	14.6	0.57	0.21
2100	7	22.8	0.28	0.05	12.6	1.23	0.40
2100	8	21.7	0.22	0.03	12.3	1.01	0.24

Time of Trawl	Fish#	Body Wet Wt	Stomach Wet wt	Stomach Dry wt	Body Dry Wt	Stomach % wet wt	Stomach % dry wt
2100	10	24.1	0.36	0.06	13.0	1.49	0.46
2100	11	28.5	0.51	0.09	14.3	1.79	0.63
2100	13	15.6	0.51	0.10	10.5	3.27	0.95
2100	14	23.4	0.46	0.09	12.8	1.97	0.70
2100	15	23.4	0.06	0.01	12.8	0.26	0.08
2100	16	19.1	0.26	0.05	11.5	1.36	0.43
2100	18	26.4	0.23	0.04	13.7	0.87	0.29
2100	19	16.8	0.06	0.01	10.9	0.36	0.09
2100	20	20.7	0.34	0.06	12.0	1.64	0.50
2100	21	23.2	0.69	0.15	12.7	2.97	1.18
2100	22	19.0	0.45	0.09	11.5	2.37	0.78
2100	23	22.6	0.42	0.08	12.6	1.86	0.64
2100	25	27.6	0.04	0.00	14.0	0.14	0.00
2100	26	20.9	0.05	0.00	12.1	0.24	0.00
2100	30	34.0	0.84	0.20	15.9	2.47	1.26
2100	31	24.4	0.06	0.00	13.1	0.25	0.00
2100	32	29.2	0.40	0.07	14.5	1.37	0.48
2100	33	21.5	0.31	0.05	12.2	1.44	0.41
2100	35	15.4	0.30	0.06	10.5	1.95	0.57
2100	36	22.5	0.58	0.11	12.5	2.58	0.88
2100	37	26.0	0.77	0.14	13.5	2.96	1.03
2100	38	32.1	0.37	0.06	15.3	1.15	0.39
2100	40	30.4	0.56	0.11	14.8	1.84	0.74
2100	42	27.0	0.24	0.04	13.8	0.89	0.29
2100	43	29.2	0.07	0.01	14.5	0.24	0.07
2100	44	19.2	0.20	0.04	11.6	1.04	0.35
2100	46	21.0	0.64	0.13	12.1	3.05	1.08
2100	48	24.7	0.33	0.07	13.2	1.34	0.53
2100	50	26.7	0.25	0.04	13.7	0.94	0.29
2400	1	17.1	0.00	0.00	11.0	0.00	0.00
2400	3	22.4	0.05	0.00	12.5	0.22	0.00
2400	4	21.1	0.02	0.00	12.1	0.09	0.00
2400	5	26.0	0.04	0.01	13.5	0.15	0.07

Time of Trawl	Fish#	Body Wet Wt	Stomach Wet wt	Stomach Dry wt	Body Dry Wt	Stomach % wet wt	Stomach % dry wt
2400	7	24.9	0.04	0.00	13.2	0.16	0.00
2400	10	24.9	0.35	0.06	13.2	1.41	0.45
2400	12	23.0	0.19	0.04	12.7	0.83	0.32
2400	15	33.2	0.18	0.02	15.6	0.54	0.13
2400	16	25.1	0.21	0.04	13.3	0.84	0.30
2400	17	30.1	0.69	0.14	14.7	2.29	0.95
2400	18	32.5	0.13	0.02	15.4	0.41	0.13
2400	19	36.7	0.06	0.01	16.7	0.16	0.06
2400	23	36.5	0.03	0.00	16.6	0.08	0.00
2400	24	28.8	0.05	0.00	14.4	0.17	0.00
2400	25	28.2	0.05	0.01	14.2	0.18	0.07
2400	27	24.5	0.38	0.07	13.1	1.55	0.53
2400	28	25.6	0.15	0.03	13.4	0.59	0.22
2400	29	21.2	0.17	0.03	12.1	0.80	0.25
2400	30	20.0	0.11	0.02	11.8	0.55	0.17
2400	31	16.0	0.03	0.01	10.6	0.19	0.09
2400	32	26.0	1.08	0.21	13.5	4.15	1.55
2400	34	22.3	0.04	0.01	12.5	0.18	0.08
2400	35	22.6	0.22	0.05	12.6	0.97	0.40
2400	36	25.5	0.20	0.03	13.4	0.78	0.22
2400	37	25.4	0.11	0.01	13.4	0.43	0.07
2400	38	25.2	0.04	0.00	13.3	0.16	0.00
2400	40	20.5	0.03	0.01	11.9	0.15	0.08
2400	41	26.8	0.78	0.16	13.8	2.91	1.16
2400	42	22.3	0.26	0.05	12.5	1.17	0.40
2400	43	27.3	0.10	0.01	13.9	0.37	0.07
2400	44	18.4	0.03	0.00	11.3	0.16	0.00
2400	45	25.4	0.11	0.02	13.4	0.43	0.15
2400	46	20.8	0.04	0.00	12.0	0.19	0.00
2400	47	22.2	0.06	0.01	12.4	0.27	0.08
2400	48	22.4	0.04	0.01	12.5	0.18	0.08
2400	49	22.0	0.04	0.00	12.4	0.18	0.00
2400	50	23.8	0.22	0.04	12.9	0.92	0.31

Time of Trawl	Fish#	Body Wet Wt	Stomach Wet wt	Stomach Dry wt	Body Dry Wt	Stomach % wet wt	Stomach % dry wt
0300	1	18.4	0.04	0.01	11.3	0.22	0.09
0300	2	30.1	0.25	0.04	14.7	0.83	0.27
0300	5	27.1	0.25	0.04	13.9	0.92	0.29
0300	6	26.4	0.03	0.00	13.7	0.11	0.00
0300	12	23.3	0.02	0.00	12.8	0.09	0.00
0300	13	22.0	0.03	0.01	12.4	0.14	0.08
0300	14	21.1	0.03	0.00	12.1	0.14	0.00
0300	15	22.8	0.05	0.01	12.6	0.22	0.08
0300	16	17.7	0.02	0.01	11.1	0.11	0.09
0300	18	23.2	0.31	0.01	12.7	1.34	0.08
0300	19	21.2	0.04	0.01	12.1	0.19	0.08
0300	20	27.5	0.03	0.00	14.0	0.11	0.00
0300	21	24.0	0.05	0.01	13.0	0.21	0.08
0300	22	22.4	0.04	0.00	12.5	0.18	0.00
0300	23	21.8	0.05	0.01	12.3	0.23	0.08
0300	24	21.8	0.04	0.00	12.3	0.18	0.00
0300	25	18.1	0.05	0.01	11.2	0.28	0.09
0300	26	22.8	0.06	0.01	12.6	0.26	0.08
0300	27	27.3	0.19	0.02	13.9	0.70	0.14
0300	28	21.3	0.02	0.00	12.2	0.09	0.00
0300	29	25.3	0.03	0.00	13.3	0.12	0.00
0300	30	33.1	0.06	0.02	15.6	0.18	0.13
0300	31	26.2	0.27	0.03	13.6	1.03	0.22
0300	33	17.0	0.03	0.01	10.9	0.18	0.09
0300	34	23.8	0.04	0.01	12.9	0.17	0.08
0300	35	16.8	0.06	0.02	10.9	0.36	0.18
0300	38	26.7	0.32	0.06	13.7	1.20	0.44
0300	39	20.3	0.04	0.00	11.9	0.20	0.00
0300	40	25.0	0.07	0.01	13.3	0.28	0.08
0300	41	33.5	0.05	0.00	15.7	0.15	0.00
0300	43	29.2	0.06	0.01	14.5	0.21	0.07
0300	44	19.8	0.04	0.01	11.7	0.20	0.09
0300	45	32.0	0.05	0.00	15.3	0.16	0.00

Time of Trawl	Fish#	Body Wet Wt	Stomach Wet wt	Stomach Dry wt	Body Dry Wt	Stomach % wet wt	Stomach % dry wt
0300	46	18.5	0.07	0.01	11.4	0.38	0.09
0300	47	25.5	0.06	0.02	13.4	0.24	0.15
0300	48	29.0	0.07	0.01	14.4	0.24	0.07
0300	51	27.9	0.07	0.01	14.1	0.25	0.07
0600 B	1	25.0	0.21	0.05	13.3	0.84	0.38
0600 B	3	26.5	0.13	0.03	13.7	0.49	0.22
0600 B	4	21.6	0.16	0.04	12.3	0.74	0.33
0600 B	5	22.0	0.06	0.01	12.4	0.27	0.08
0600 B	6	21.4	0.06	0.01	12.2	0.28	0.08
0600 B	7	22.3	0.08	0.01	12.5	0.36	0.08
0600 B	10	22.5	0.08	0.01	12.5	0.36	0.08
0600 B	11	23.8	0.41	0.07	12.9	1.72	0.54
0600 B	12	24.3	0.07	0.01	13.0	0.29	0.08
0600 B	14	24.1	0.13	0.02	13.0	0.54	0.15
0600 B	15	19.2	0.07	0.00	11.6	0.36	0.00
0600 B	16	23.4	0.12	0.02	12.8	0.51	0.16
0600 B	18	19.0	0.06	0.01	11.5	0.32	0.09
0600 B	19	26.3	0.10	0.02	13.6	0.38	0.15
0600 B	20	29.2	0.23	0.03	14.5	0.79	0.21
0600 B	21	23.6	0.13	0.02	12.8	0.55	0.16
0600 B	22	24.3	0.05	0.01	13.0	0.21	0.08
0600 B	23	27.6	0.24	0.04	14.0	0.87	0.29
0600 B	24	23.1	0.06	0.01	12.7	0.26	0.08
0600 B	26	26.0	0.21	0.03	13.5	0.81	0.22
0600 B	27	22.0	0.06	0.01	12.4	0.27	0.08
0600 B	28	18.8	0.06	0.01	11.4	0.32	0.09
0600 B	29	20.1	0.08	0.01	11.8	0.40	0.08
0600 B	31	24.3	0.17	0.03	13.0	0.70	0.23
0600 B	32	33.0	0.30	0.06	15.6	0.91	0.38
0600 B	33	22.5	0.09	0.02	12.5	0.40	0.16
0600 B	34	30.9	0.17	0.02	15.0	0.55	0.13
0600 B	36	23.2	0.09	0.01	12.7	0.39	0.08
0600 B	39	26.5	0.07	0.01	13.7	0.26	0.07

Time of Trawl	Fish#	Body Wet Wt	Stomach Wet wt	Stomach Dry wt	Body Dry Wt	Stomach % wet wt	Stomach % dry wt
0600 B	41	27.7	0.10	0.02	14.0	0.36	0.14
0600 B	42	33.2	0.20	0.02	15.6	0.60	0.13
0600 B	44	20.7	0.12	0.02	12.0	0.58	0.17
0600 B	45	21.6	0.09	0.02	12.3	0.42	0.16
0600 B	46	23.7	0.11	0.01	12.9	0.46	0.08
0600 B	48	24.9	0.10	0.03	13.2	0.40	0.23
0600 B	49	25.3	0.14	0.02	13.3	0.55	0.15
0600 B	50	25.3	0.12	0.02	13.3	0.47	0.15
0700	2	22.8	0.21	0.03	12.6	0.92	0.24
0700	3	20.8	0.03	0.00	12.0	0.14	0.00
0700	4	20.5	0.15	0.02	11.9	0.73	0.17
0700	5	16.1	0.08	0.01	10.7	0.50	0.09
0700	6	23.8	0.08	0.01	12.9	0.34	0.08
0700	7	20.6	0.07	0.00	12.0	0.34	0.00
0700	8	22.2	0.39	0.07	12.4	1.76	0.56
0700	10	24.1	0.18	0.03	13.0	0.75	0.23
0700	13	29.8	0.15	0.01	14.7	0.50	0.07
0700	14	35.6	0.17	0.03	16.3	0.48	0.18
0700	17	17.0	0.08	0.01	10.9	0.47	0.09
0700	19	31.0	0.11	0.00	15.0	0.35	0.00
0700	20	17.2	0.13	0.02	11.0	0.76	0.18
0700	21	16.0	0.27	0.05	10.6	1.69	0.47
0700	24	21.0	0.07	0.02	12.1	0.33	0.17
0700	25	22.9	0.49	0.11	12.6	2.14	0.87
0700	26	19.3	0.14	0.03	11.6	0.73	0.26
0700	27	26.2	0.16	0.03	13.6	0.61	0.22
0700	28	27.8	0.10	0.00	14.1	0.36	0.00
0700	29	27.0	0.17	0.02	13.8	0.63	0.14
0700	31	21.3	0.14	0.02	12.2	0.66	0.16
0700	32	25.5	0.09	0.01	13.4	0.35	0.07
0700	33	23.9	0.21	0.03	12.9	0.88	0.23
0700	35	24.5	0.05	0.00	13.1	0.20	0.00
0700	37	19.5	0.65	0.13	11.7	3.33	1.12

Time of Trawl	Fish#	Body Wet Wt	Stomach Wet wt	Stomach Dry wt	Body Dry Wt	Stomach % wet wt	Stomach % dry wt
0700	38	19.1	0.25	0.04	11.5	1.31	0.35
0700	39	27.6	0.14	0.02	14.0	0.51	0.14
0700	40	24.6	0.21	0.04	13.1	0.85	0.30
0700	41	21.6	0.21	0.03	12.3	0.97	0.24
0700	42	21.5	0.05	0.00	12.2	0.23	0.00
0700	43	25.4	0.38	0.07	13.4	1.50	0.52
0700	44	18.1	0.10	0.01	11.2	0.55	0.09
0700	45	14.0	0.02	0.01	10.0	0.14	0.10
0700	46	27.2	0.14	0.01	13.9	0.51	0.07
0700	47	19.9	0.14	0.02	11.8	0.70	0.17
0700	48	21.4	0.10	0.02	12.2	0.47	0.16
0700	49	21.8	0.21	0.02	12.3	0.96	0.16
0700	50	24.1	0.17	0.03	13.0	0.71	0.23

Appendix C. Bibliography

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